

**“You miss 100% of the shots you never take.” Wayne Gretzky**

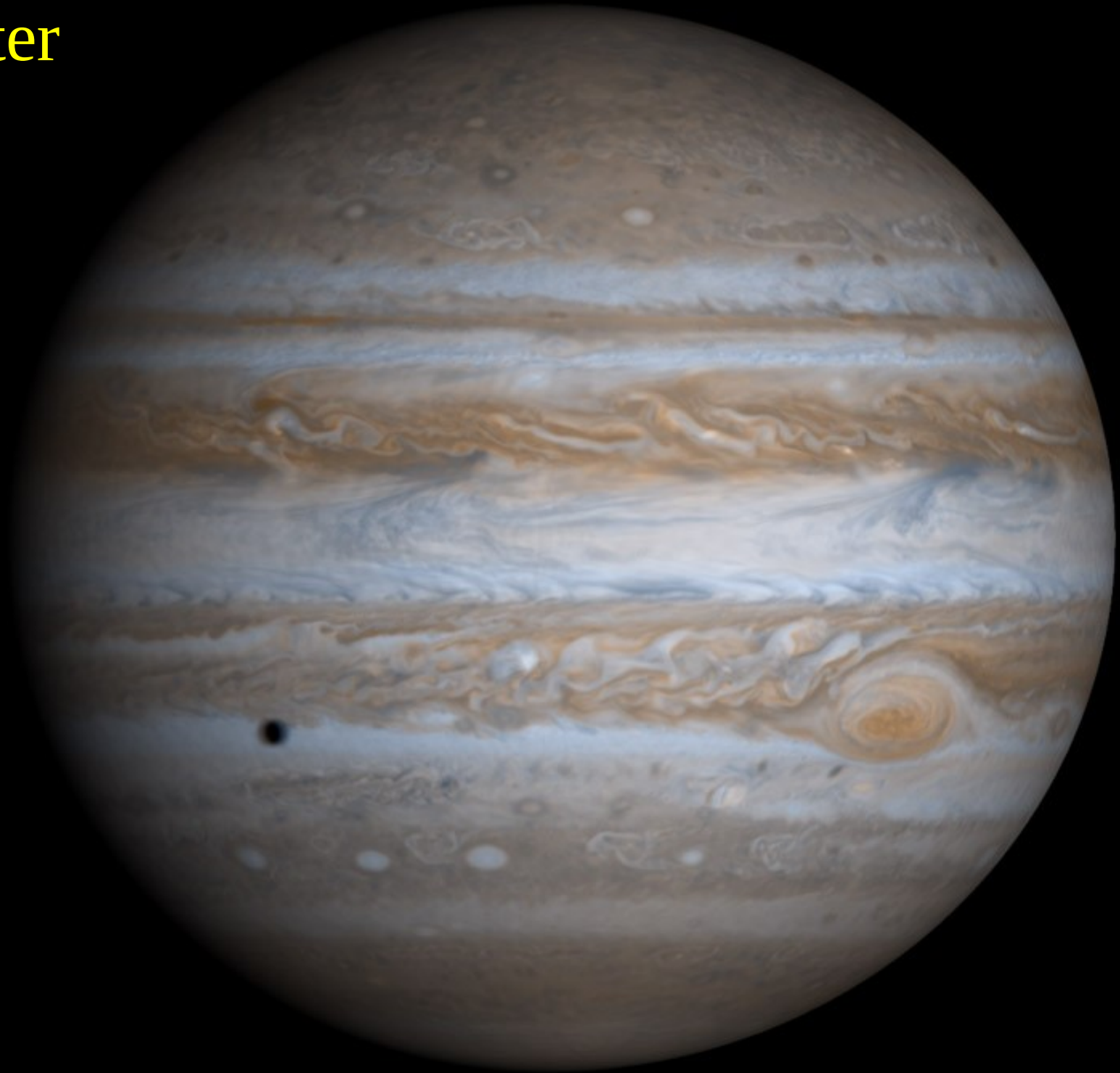
## **Notices**

**HW2 is due Friday.**

**Late HW1 papers?**

**HW1 passed back on Wednesday, be sure to sit in the row you put on your HW. HW1 solutions posted after class on Wednesday.**

# Jupiter



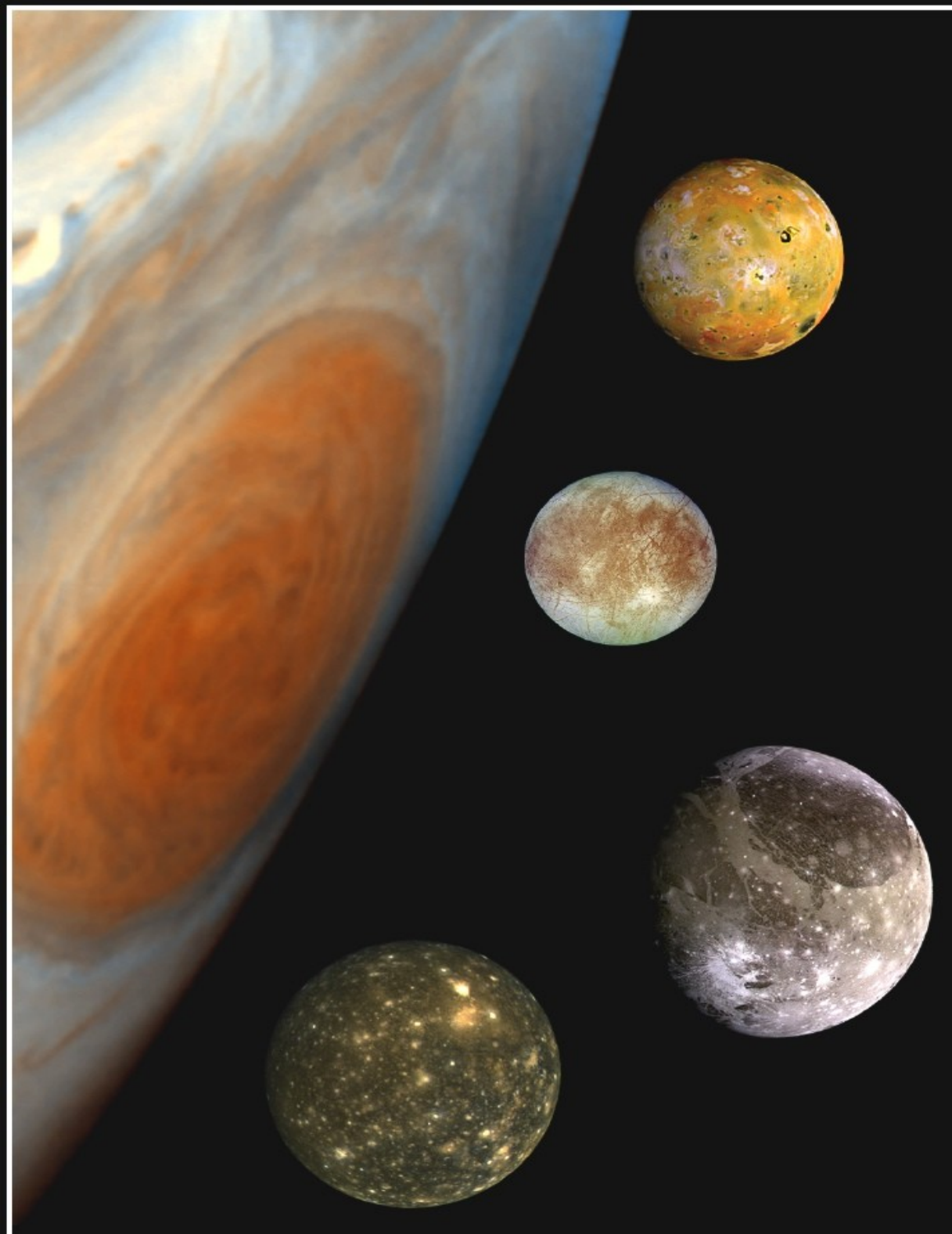
# Jupiter's Structure

- Top: H clouds over
- Liquid H over
- Liquid metallic H over
- Core Rocky, metallic core.

**Jovian Planet Structure (our 2<sup>nd</sup> of 5!)**

# Jupiter's moons

Jupiter has at least 63 moons.  
The 4 largest are known as the  
Galilean moons,



# (Warm interior) Icy moon structure

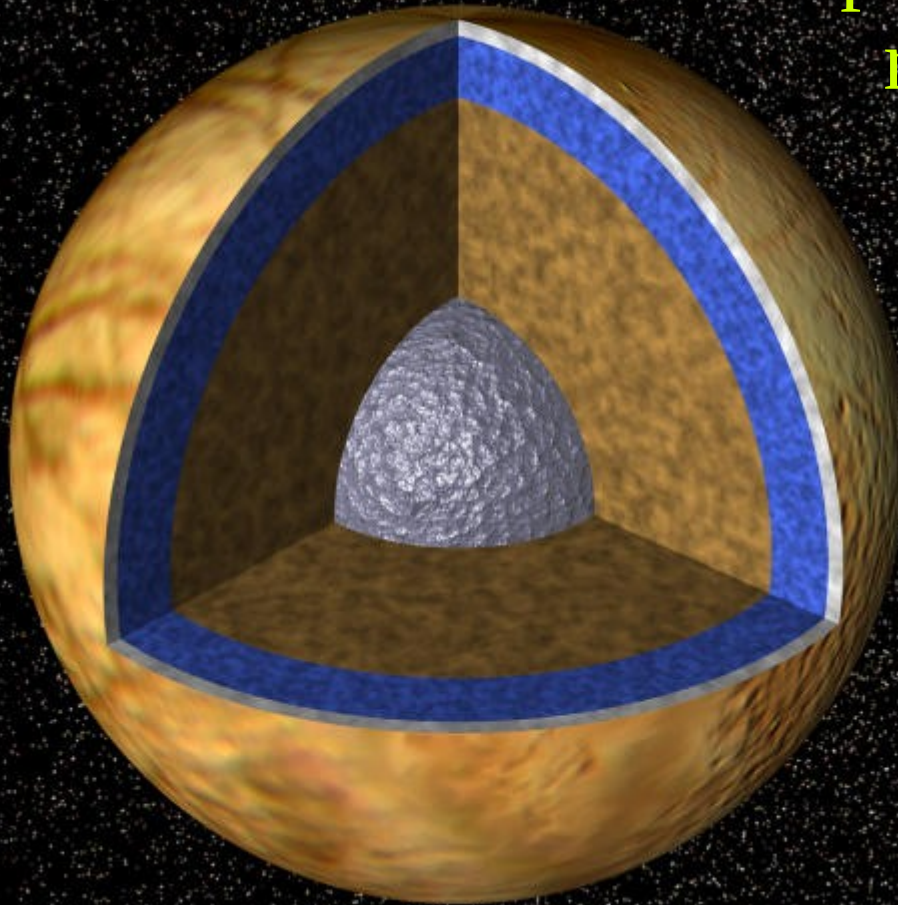
Crust made mostly of water-ice.

Underneath lies a vast liquid layer of water

Rocky mantle.

Rocky (iron) core.

Densities  $\sim 2$  g/cc  
depending on how much  
rock to water/ice.



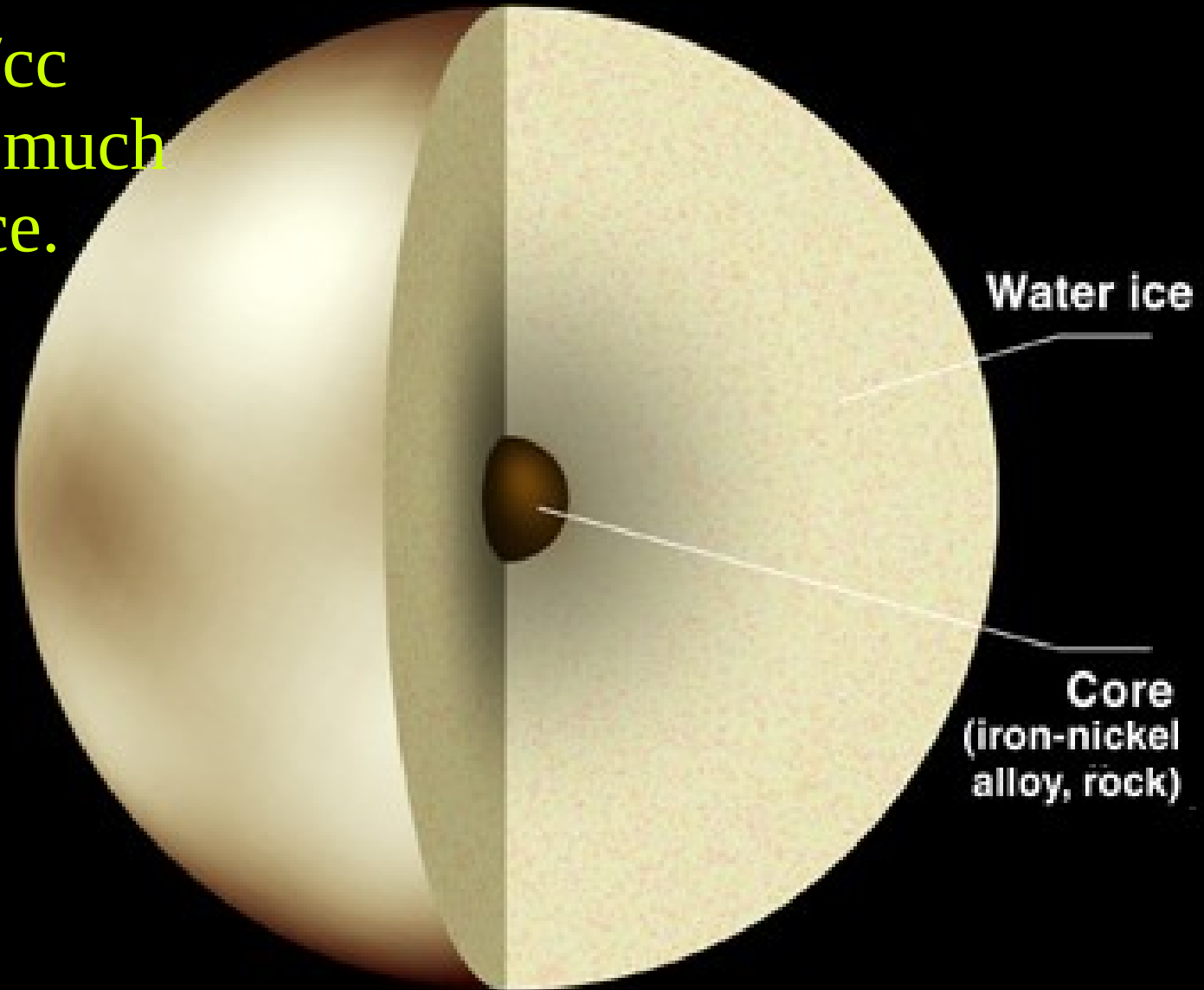
**Structure #3**

# (Cold interior) Icy moon structure

Rock/ice mixture surface/mantle

Rocky (iron-mix) core.

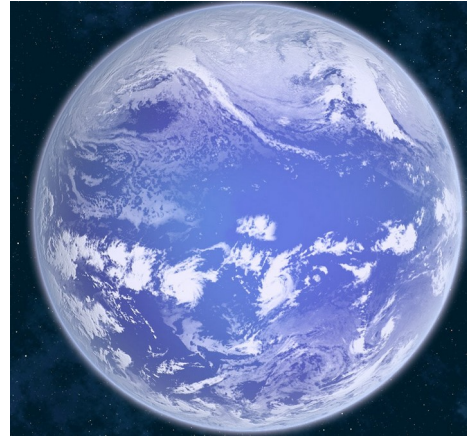
Densities  $\sim 2$  g/cc  
depending on how much  
rock to water/ice.



Structure #4

# Densities (in g/cc):

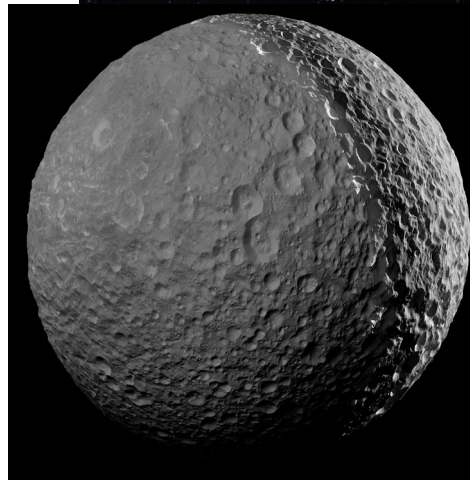
Rocky worlds: 3.5 – 5.5  
(Terrestrial planets ~5)



Gas Giants: 0.7 – 1.5



Icy moons: ~2-3



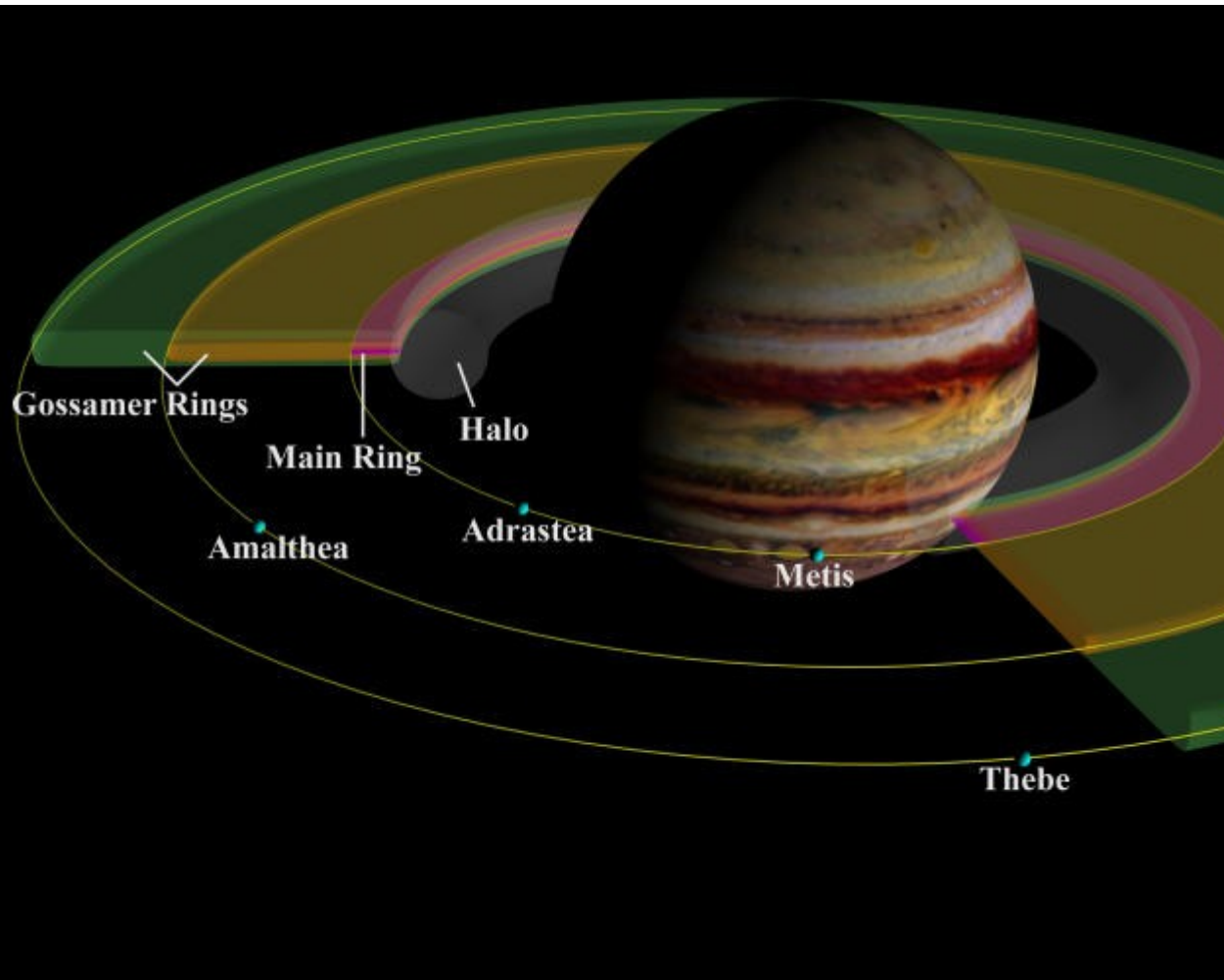
**Jupiter has rings!**





# Jupiter's Rings

The shape of the rings is determined by small (shepherd) moons, Jupiter's strong magnetic field, and of course Jupiter's gravity.



The particles are extremely small-micrometer sized!

The particles in the rings only last for about 1,000 years before falling into Jupiter. But they are continually replenished by impacts on Jupiter's moons.

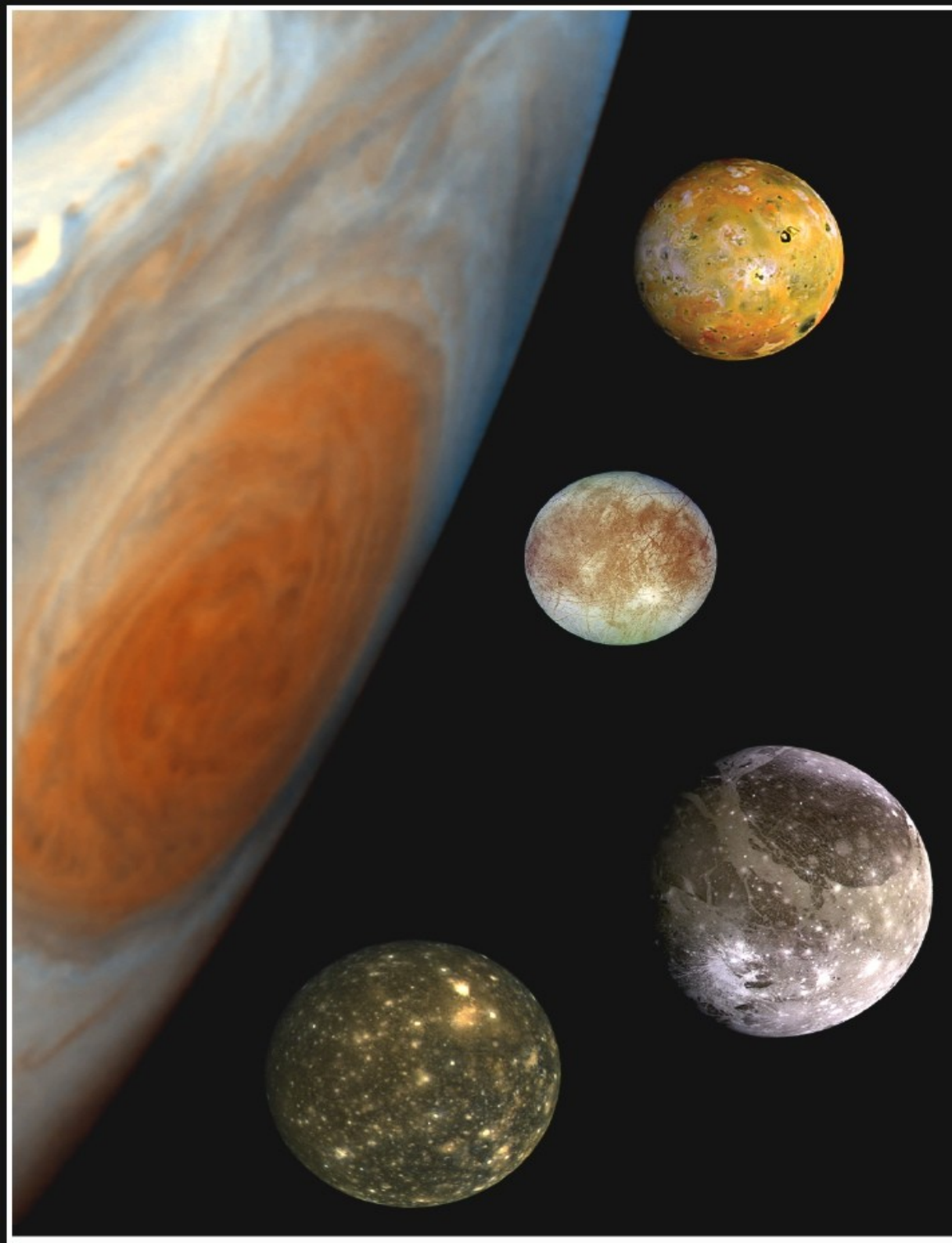


# Jupiter's moons

Jupiter has at least 63 moons. The 4 largest are known as the Galilean moons, named after their discoverer.

Io is slightly larger than our Moon while Callisto is about the same size as Mercury. Ganymede is 10% larger than Mercury!

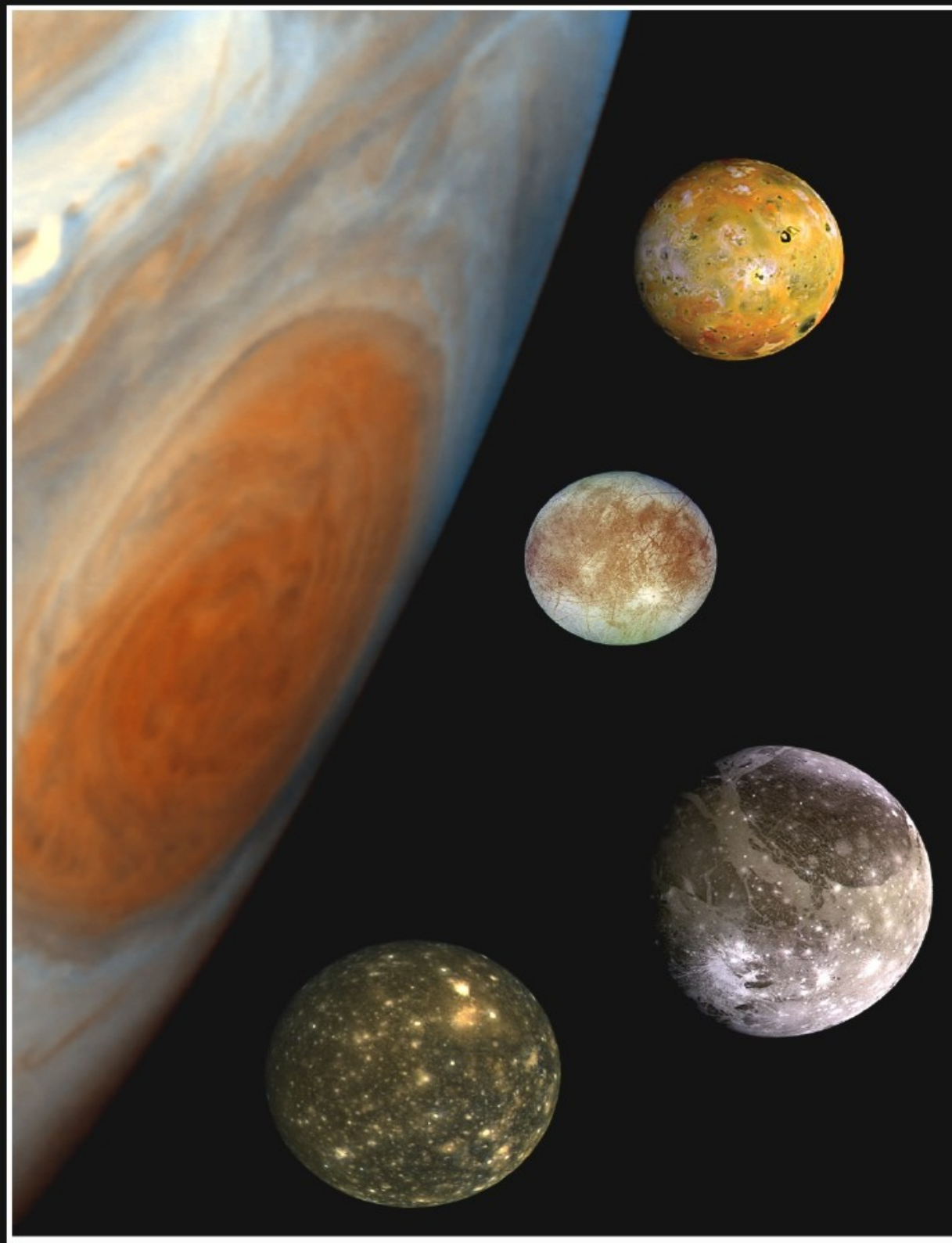
All of these moons are locked in synchronous rotation. Only one side ever faces Jupiter.



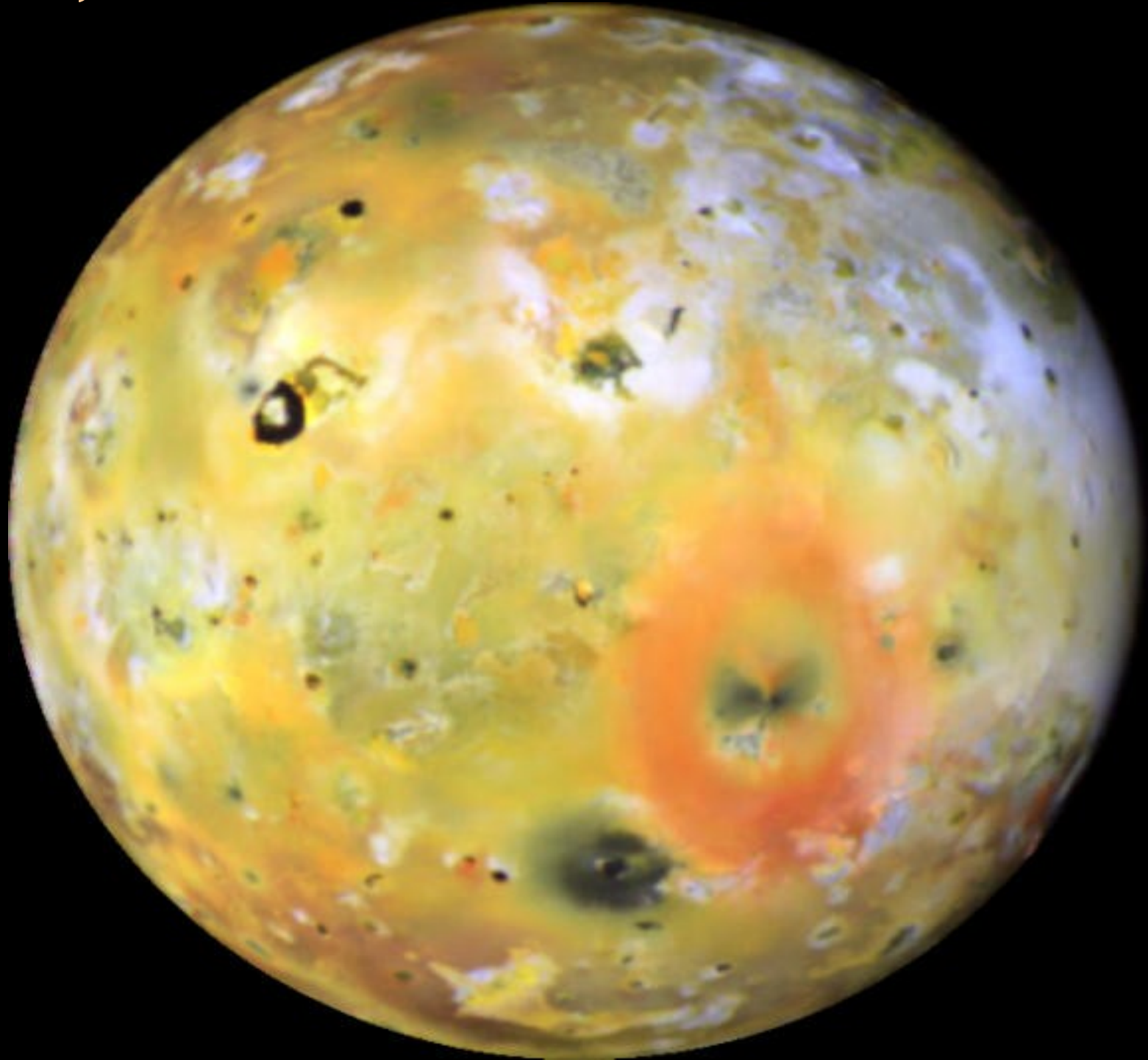
# Jupiter's moons

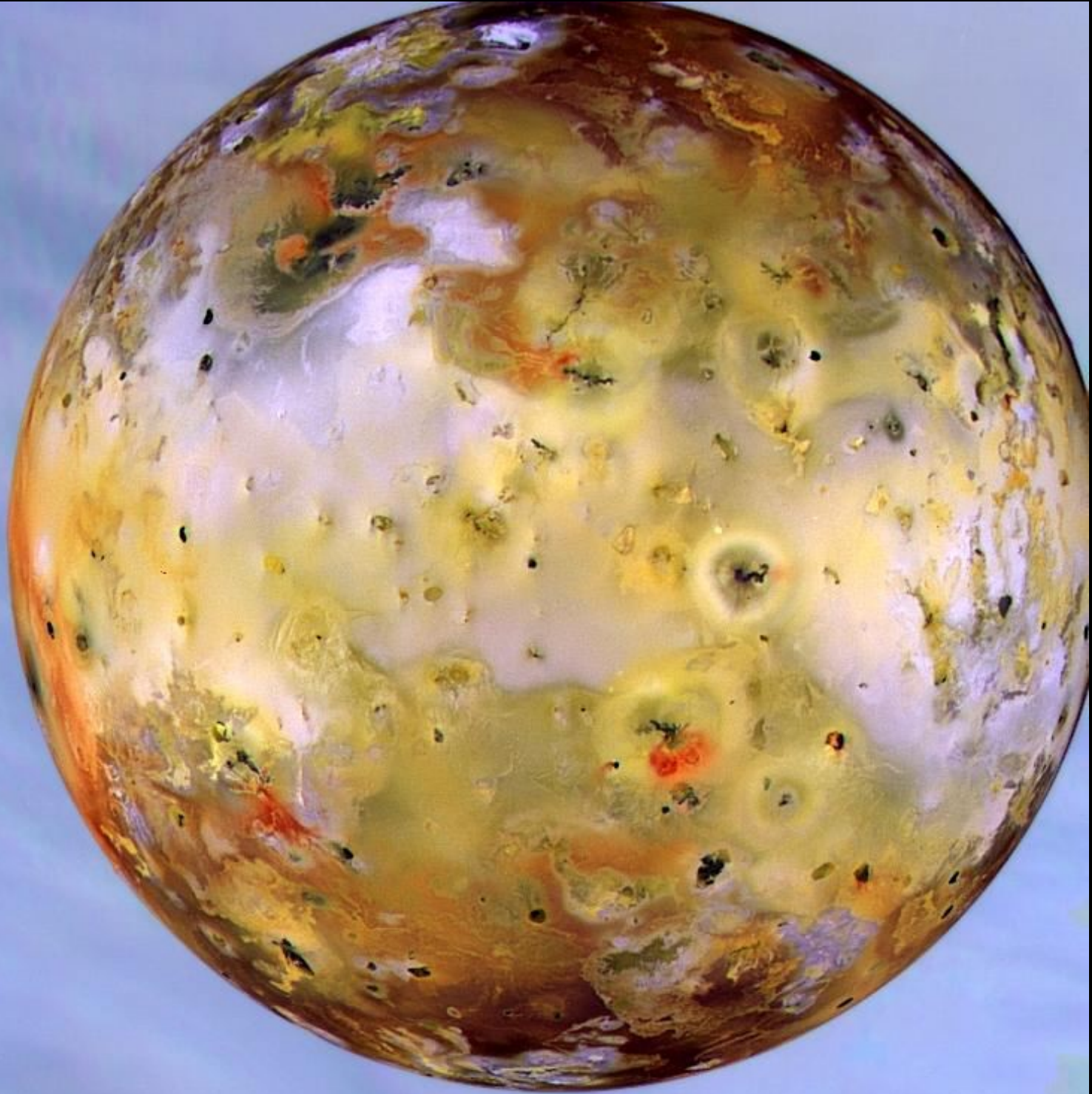
The orbital resonance ratios are **8:4:2** for Io, Europa, and Ganymede (and nearly 1 for Callisto).

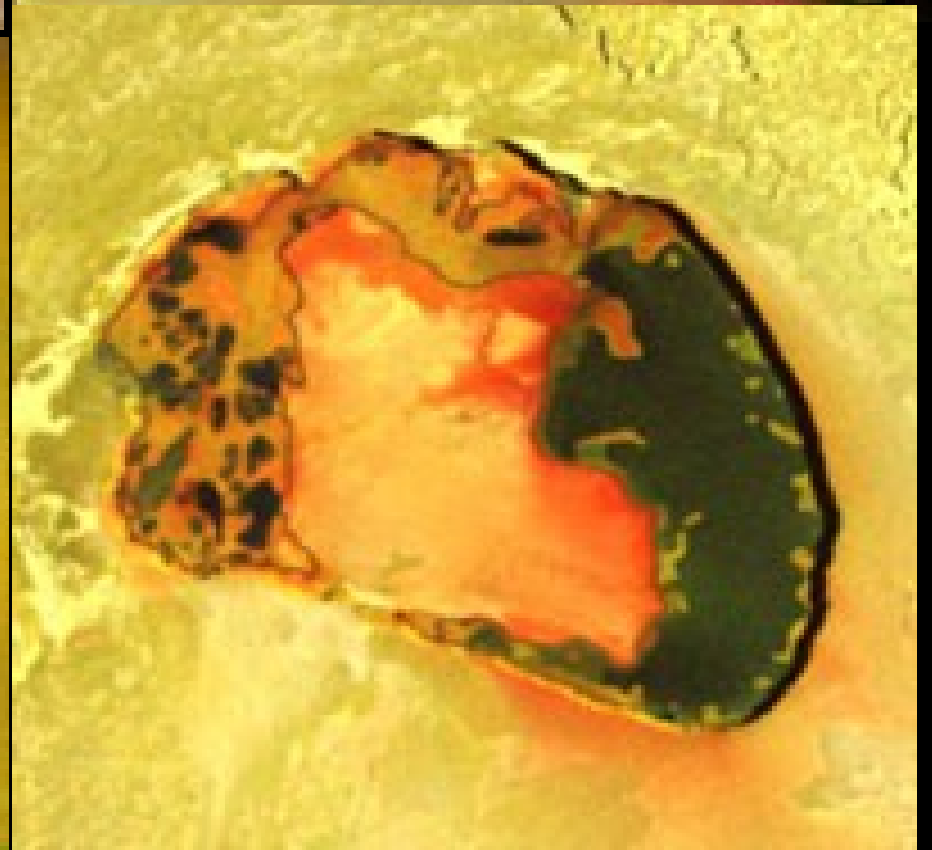
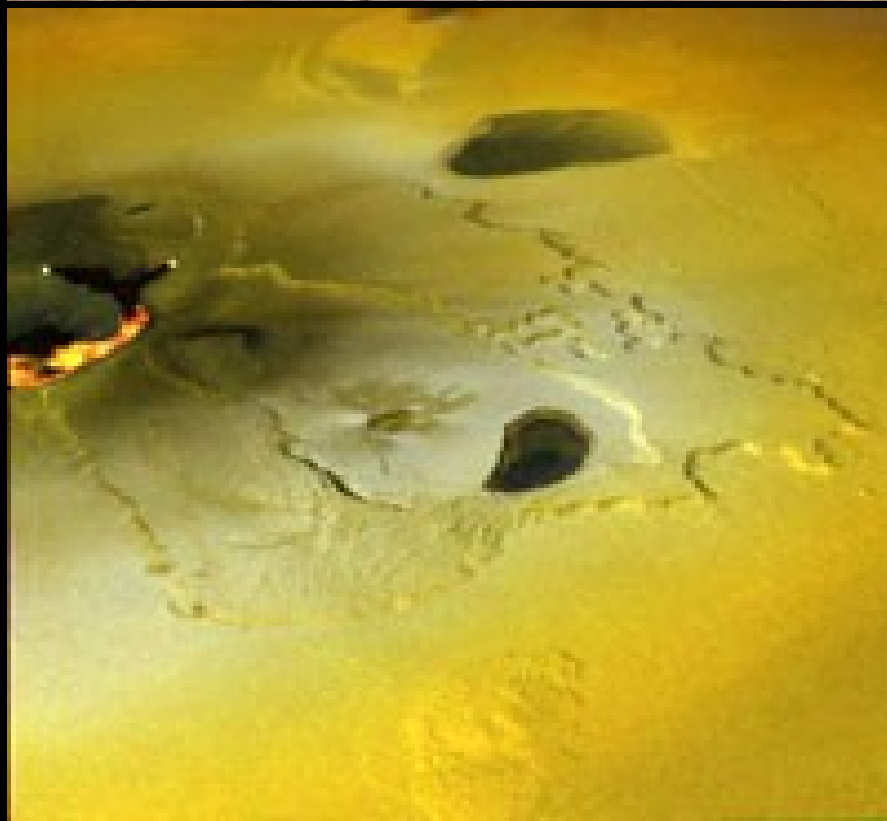
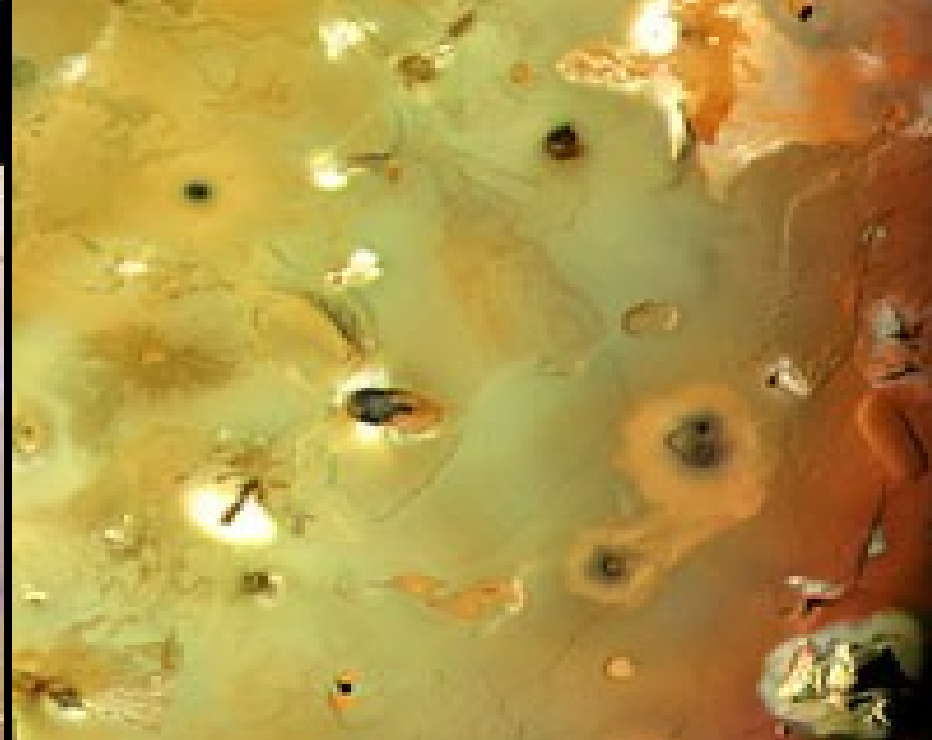
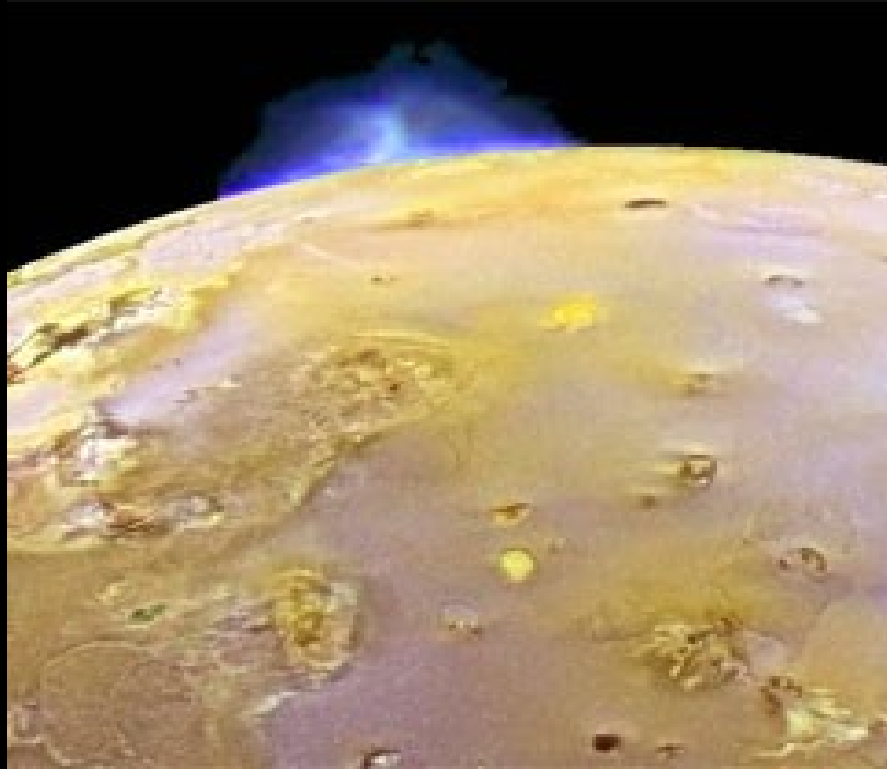
Orbital periods are 1.77, 3.55, 7.13, and 17 days.



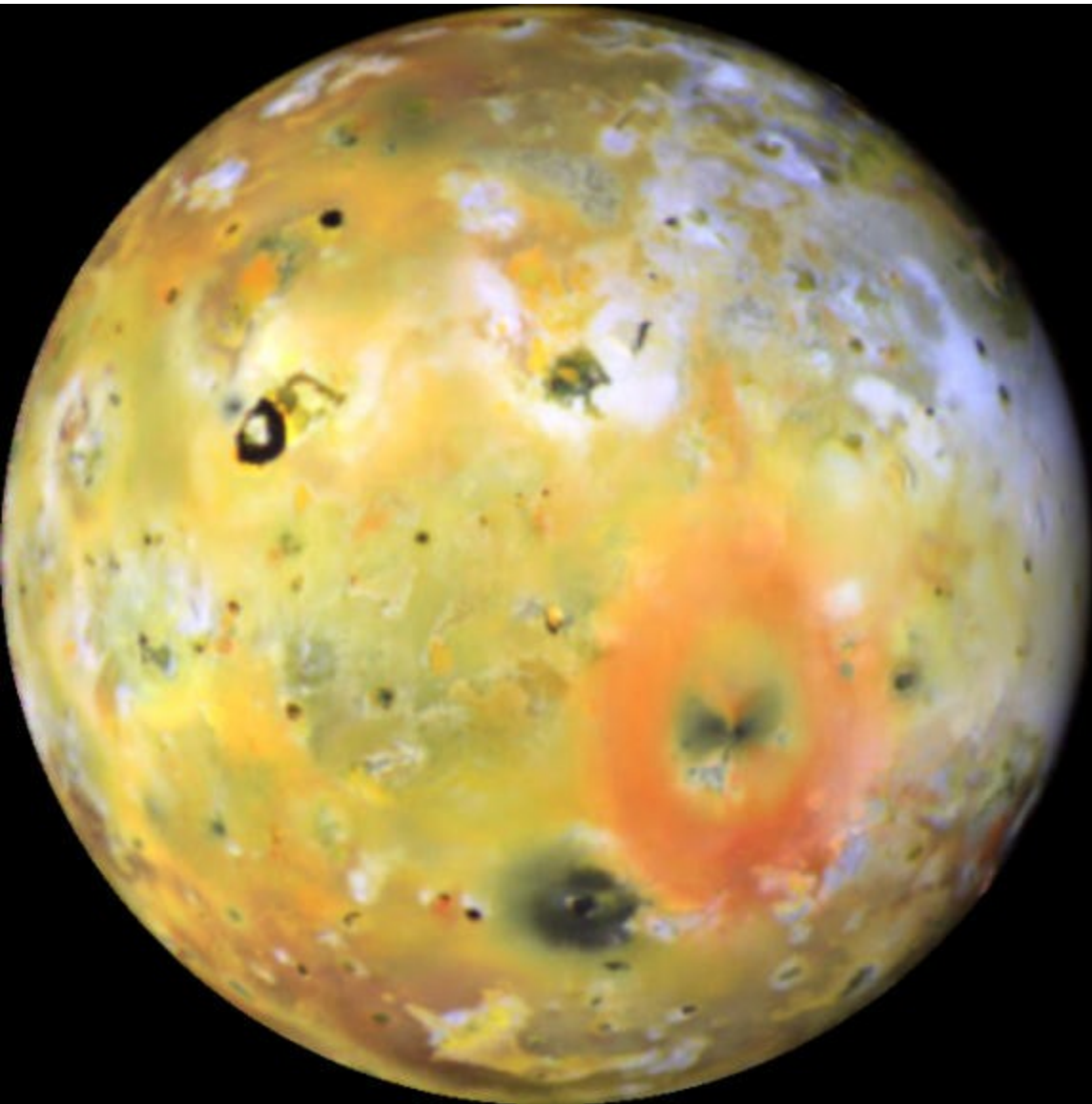
Io, the innermost Galilean moon







# Io, the innermost Galilean moon



\*Io is the most volcanically active body in the solar system!

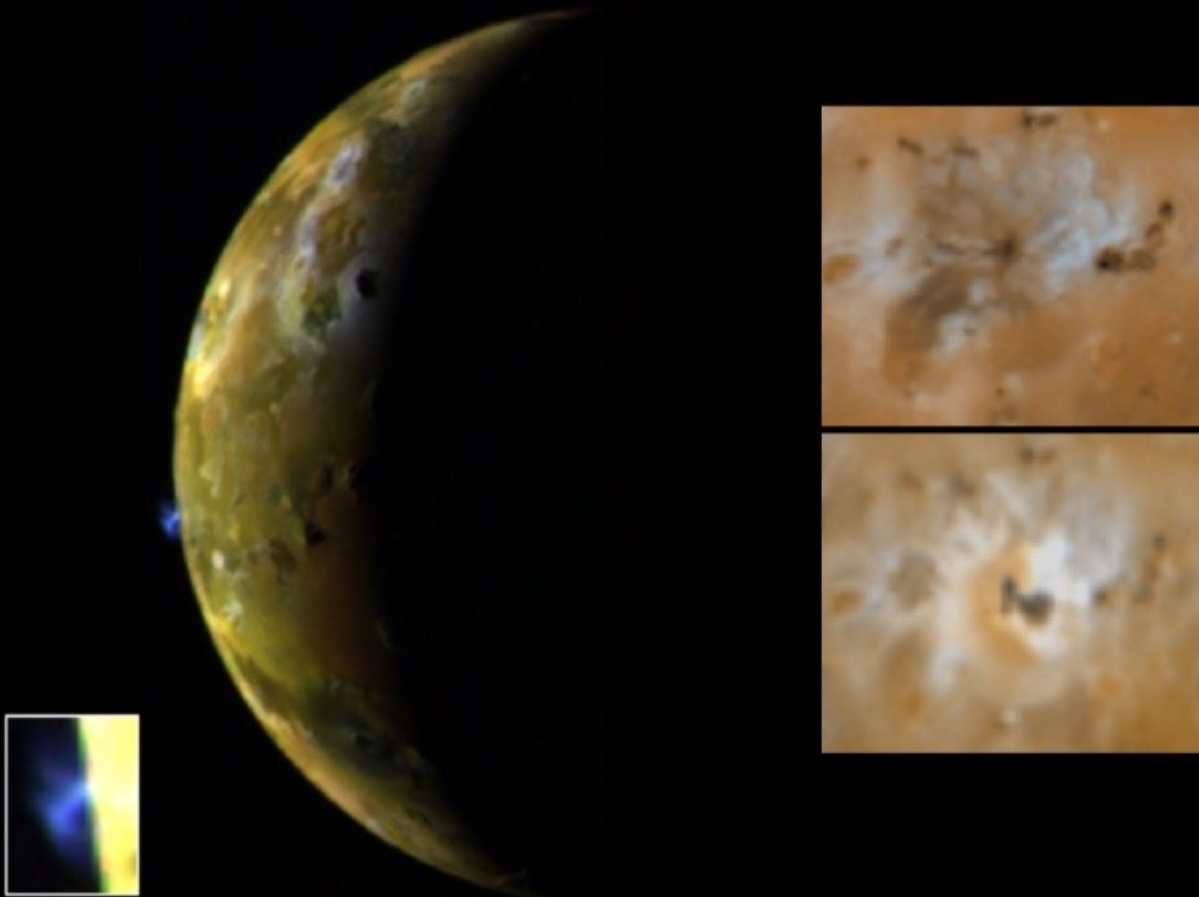
\* There are *no* noticeable impact craters on Io.

\*The heating is generated by tidal forces. Io's orbit is elliptical because of a gravitational tug-of-war between Jupiter and Europa, the next large moon.

This stretching and pulling heats Io's interior.

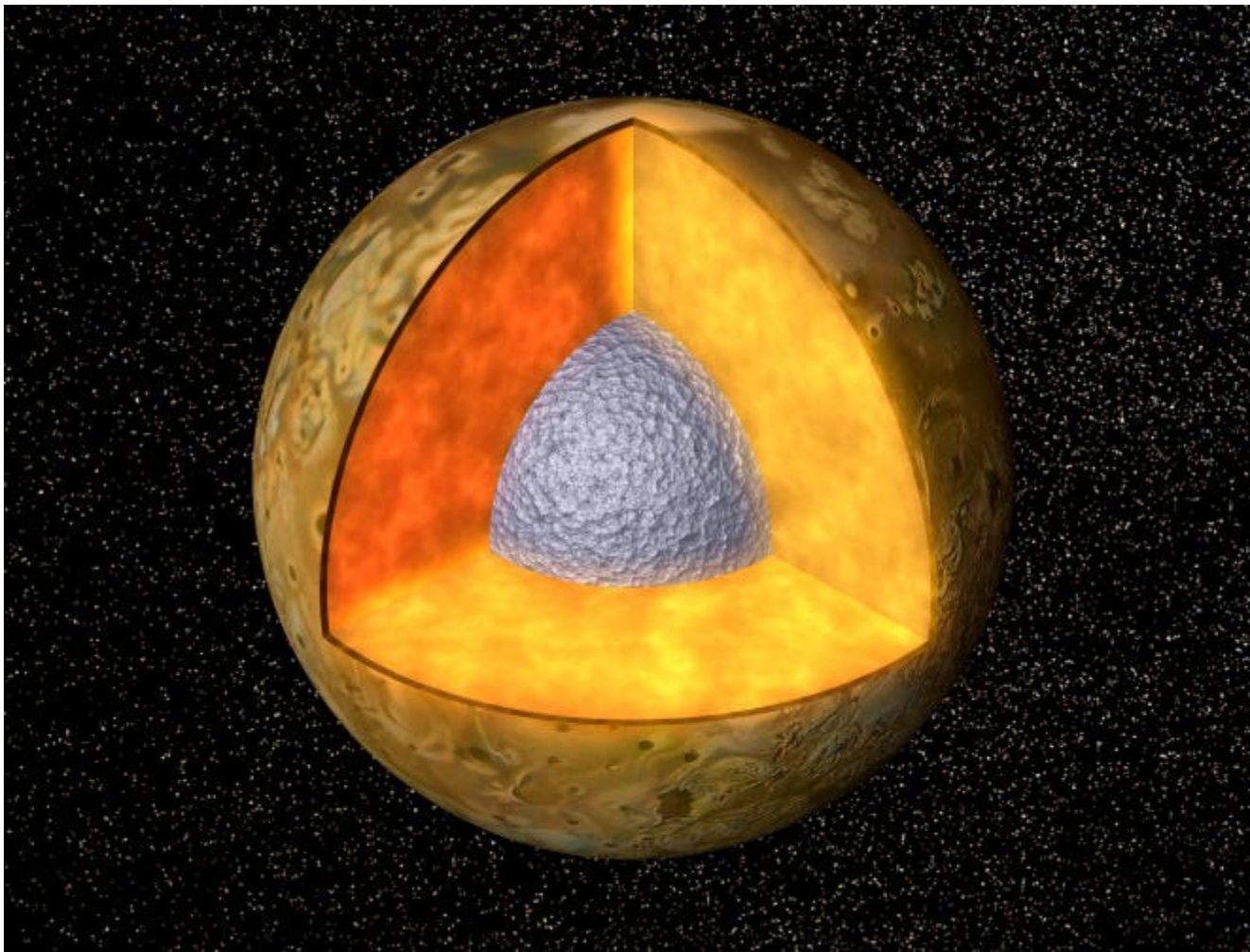


Io is covered with active volcanoes!



# Io's structure: Terrestrial

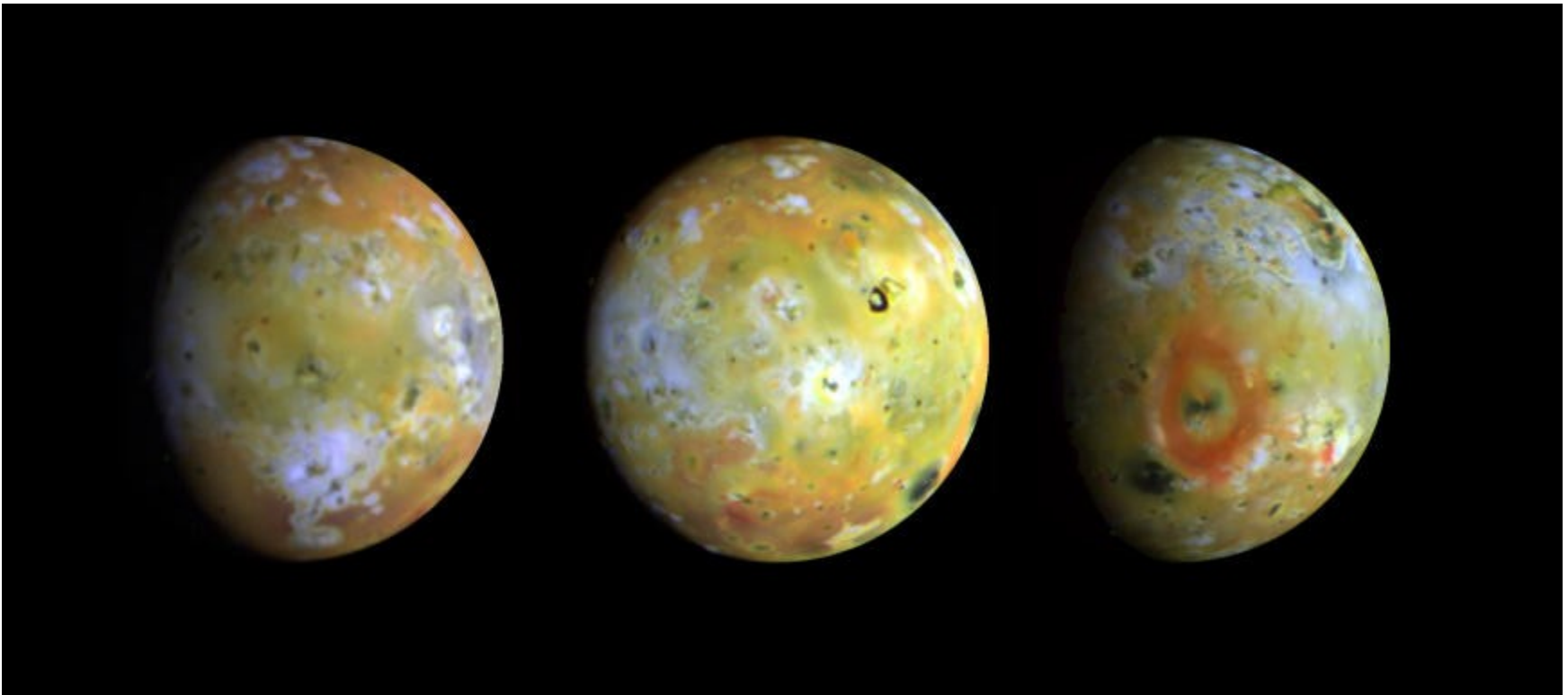
Io has 3 layers: a thin, brittle rocky crust, a thick, molten-rock mantle, and a solid, core made mostly of iron.



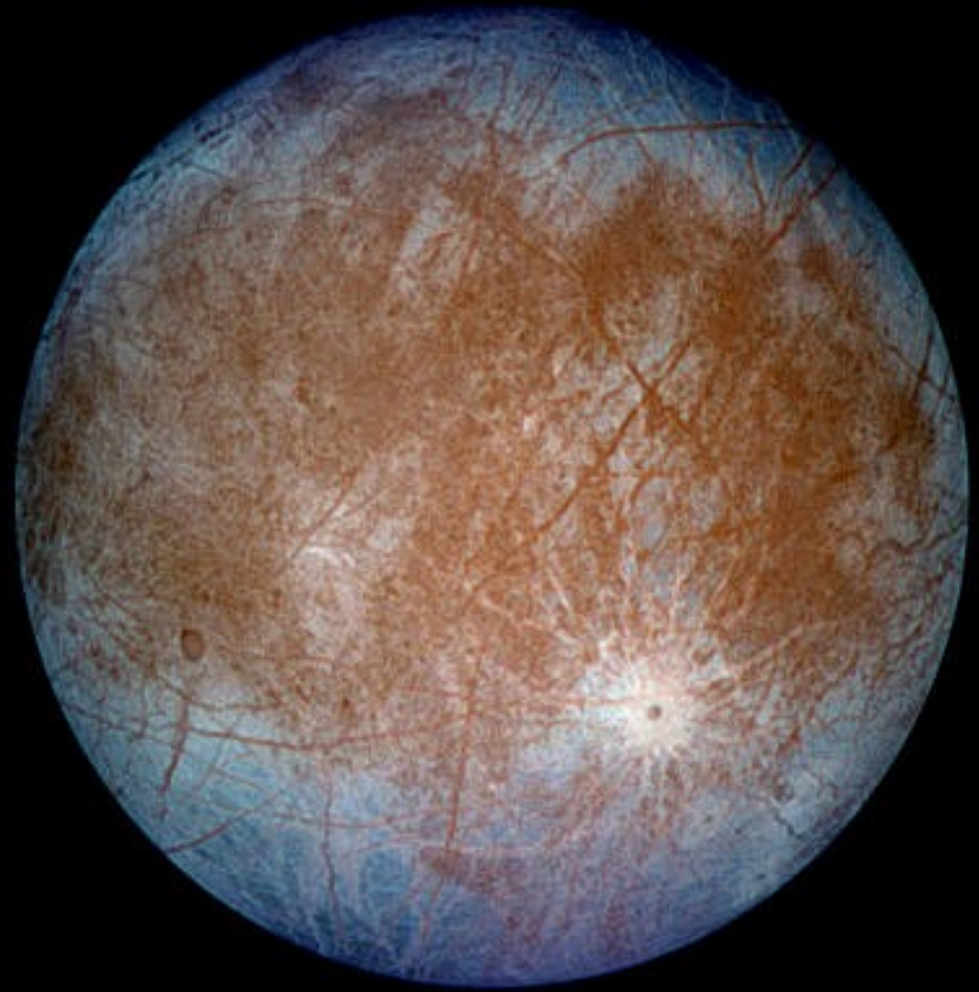
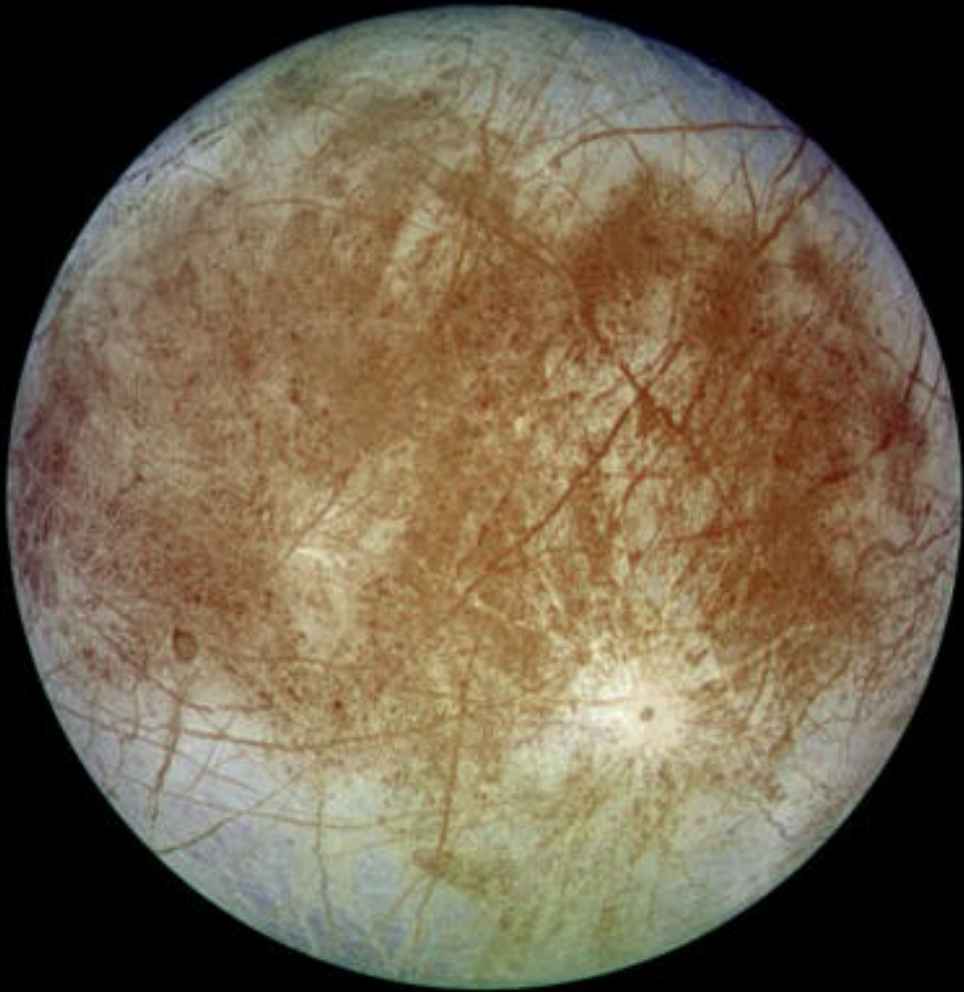
Density=  
3.5 g/cc

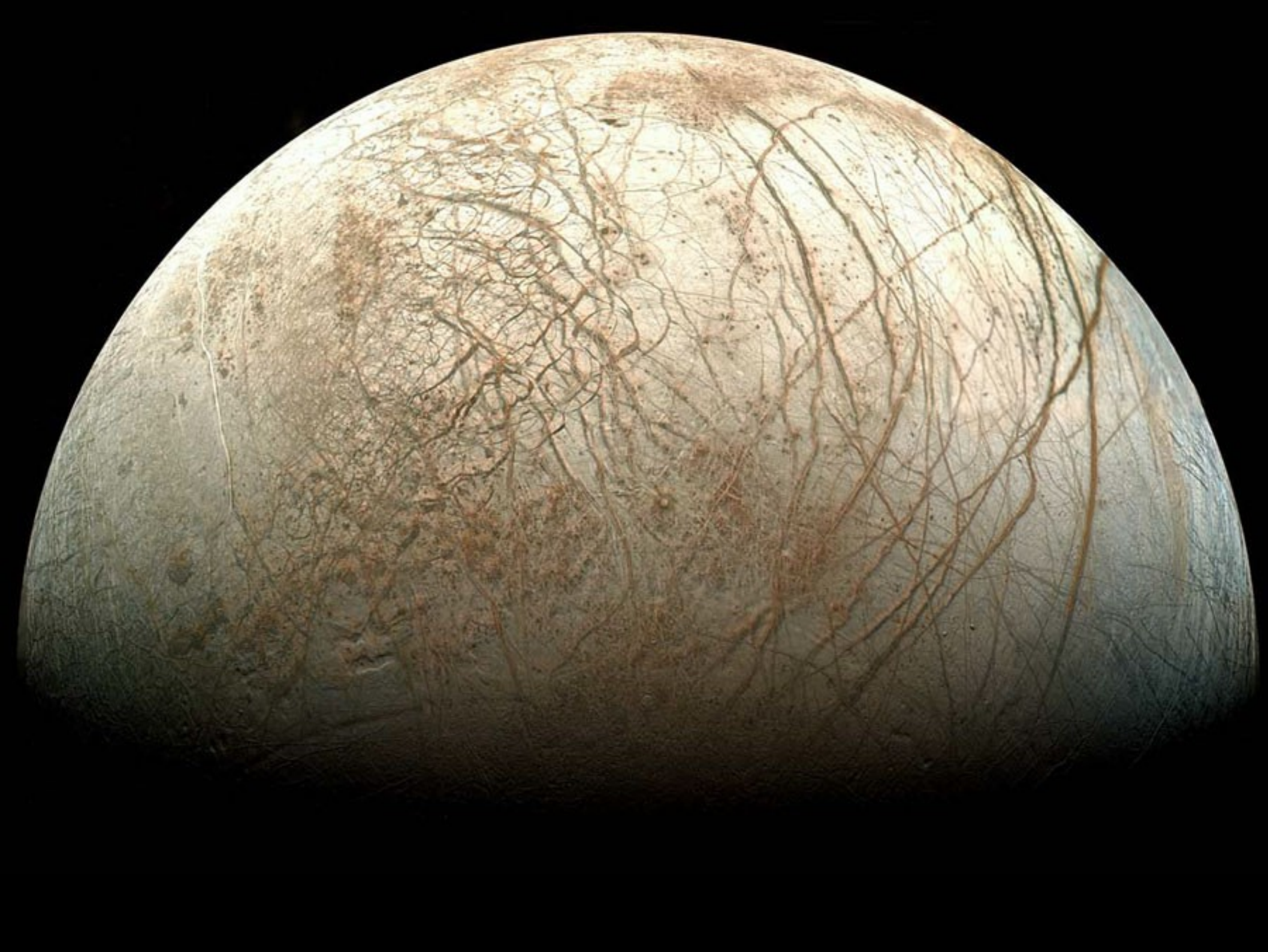
# Io's atmosphere

Io has a thin,  $\text{SO}_2$  atmosphere. Some freezes out on the night side and evaporates on the day side.



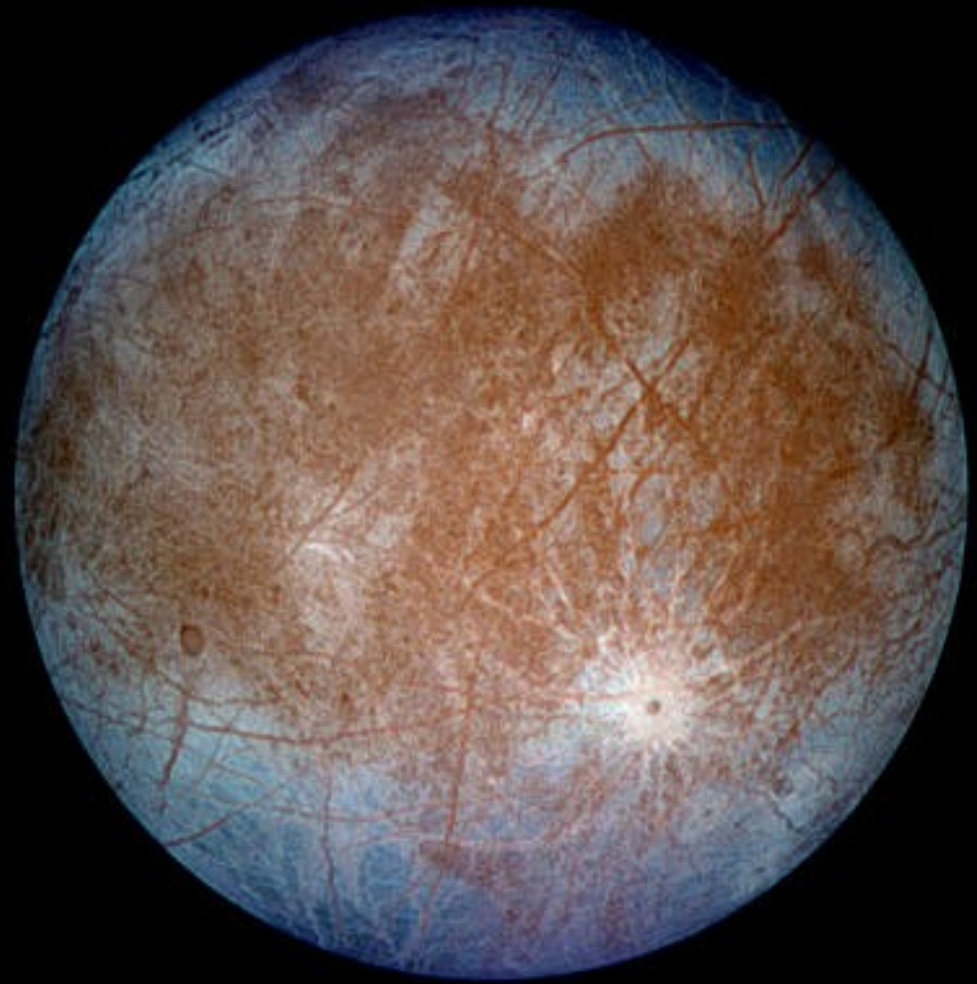
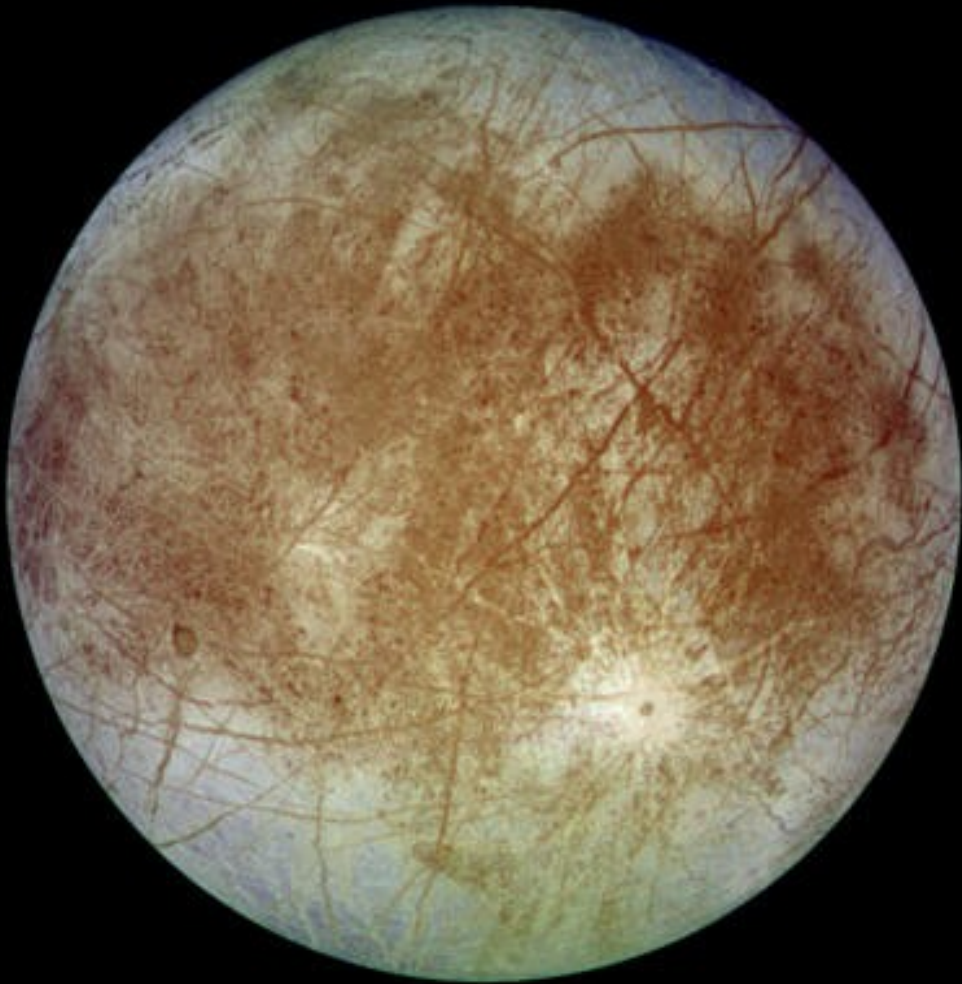
# Europa





# Europa

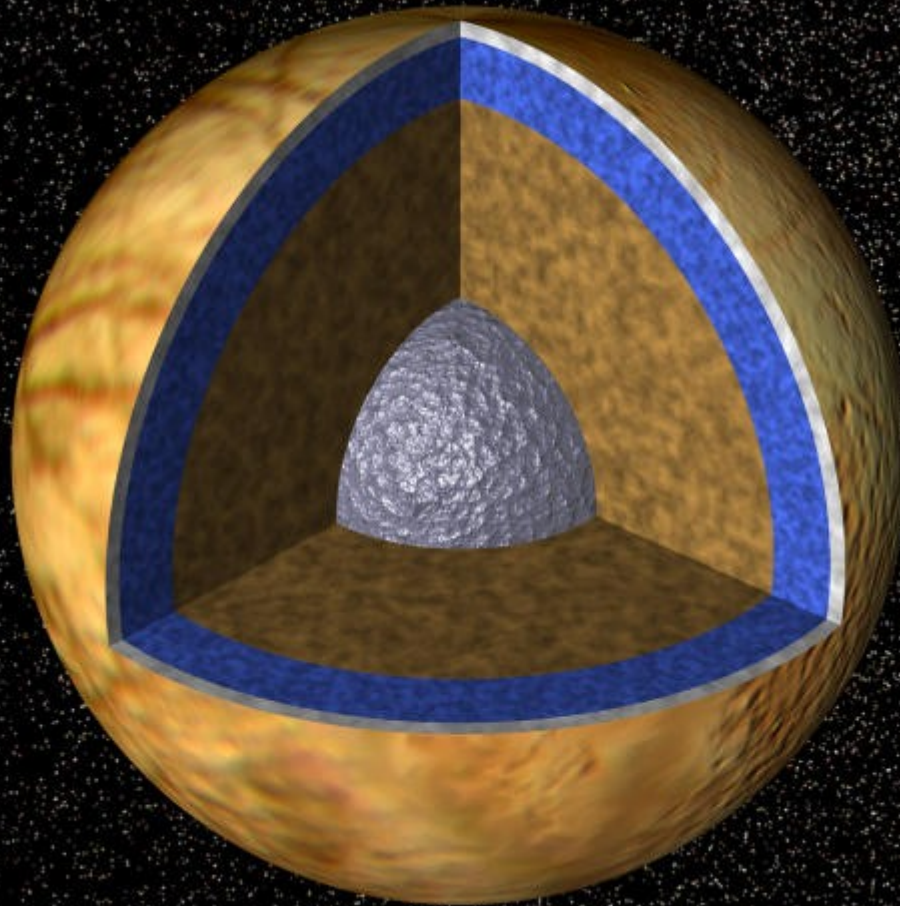
Also caught in a tug-of-war between massive Jupiter and other large moons, Europa has a fairly young surface, with only a few impact craters.



# Europa's structure: Icy moon, warm interior.

Europa has a thin (3 miles thick) crust made mostly of water-ice. Underneath lies a vast liquid layer of water, perhaps 30 miles thick.

But most of the moon is made of rock, with perhaps an iron core.

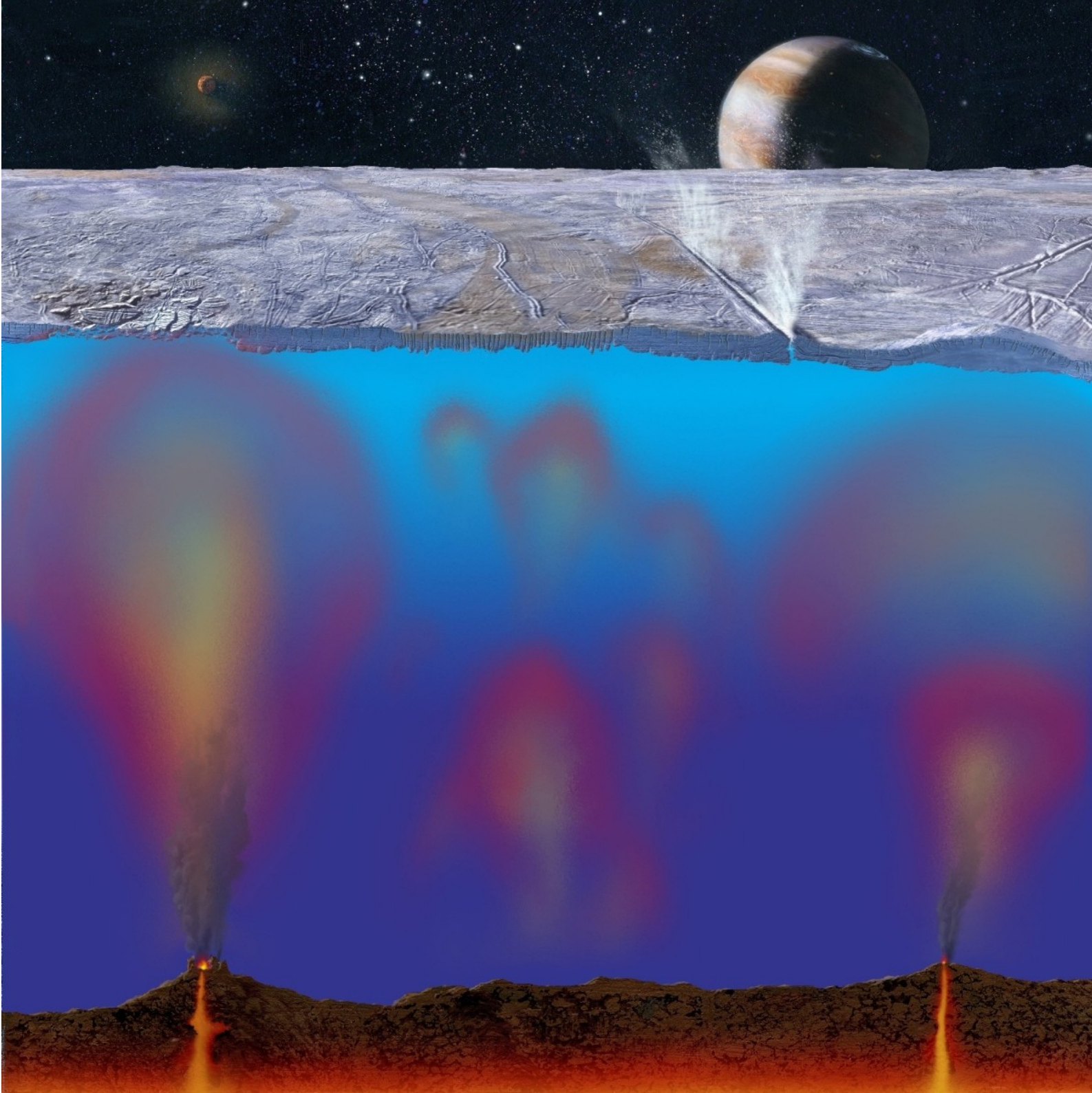


**Density = 3.0 g/cc**

Europa has a thin, Oxygen atmosphere created by charged particles hitting the surface.

Comparable to Earth's atmosphere at an altitude of over 100 miles!

Europa  
has a vast  
under-  
crust  
ocean.  
Kept  
liquid by  
volcanic  
vents.





# Ganymede



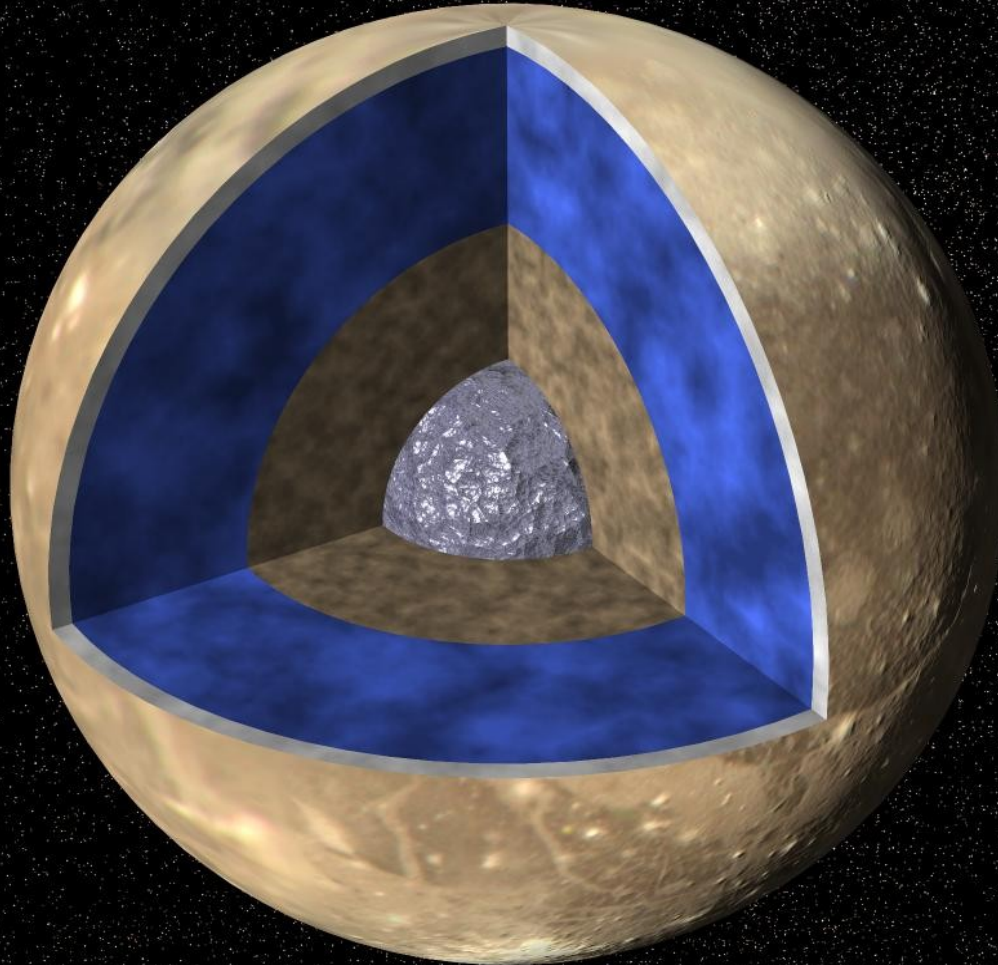
# Ganymede

As we move out from Jupiter, the tidal flexing becomes less, and the surfaces get colder and older. Ganymede is the largest moon in the solar system and also generates its own magnetic field, just like the Earth!



# Ganymede's interior

Like Europa, Ganymede has a thin, mostly ice crust. Underneath is a thick, water-ice layer (mostly frozen). Under that is a rocky mantle surrounding an iron core.

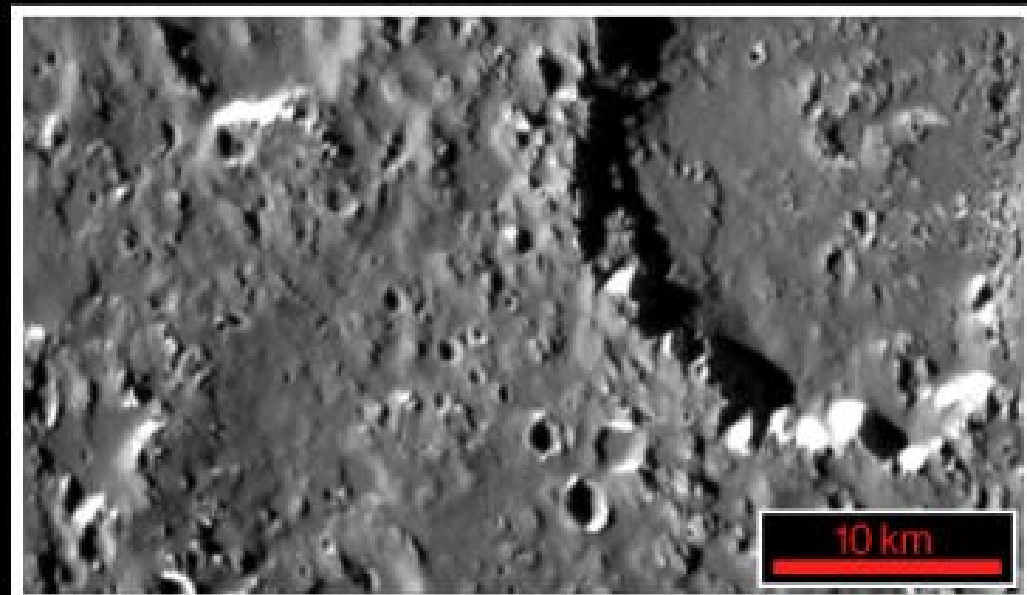
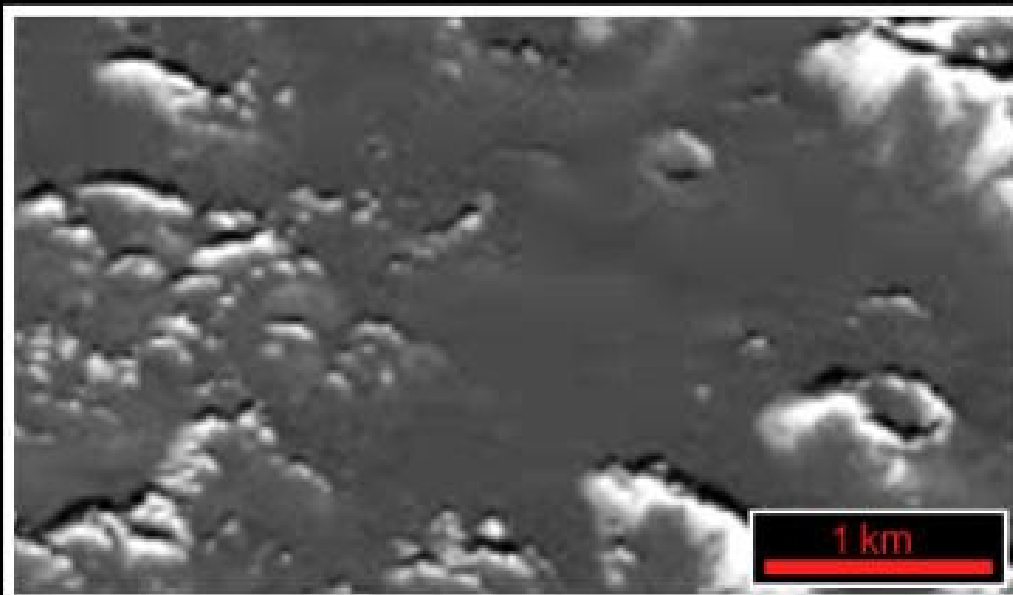
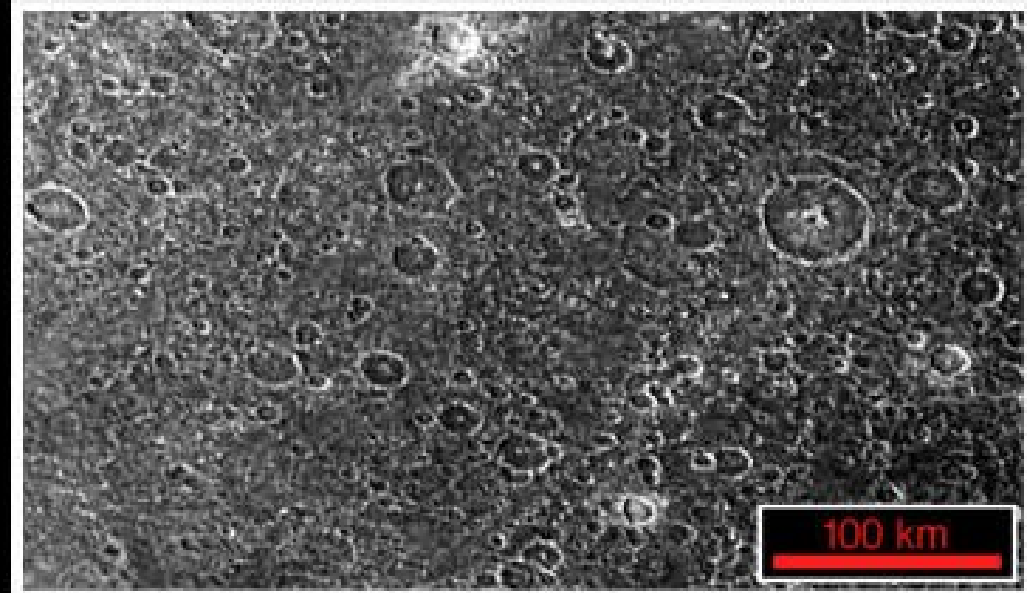
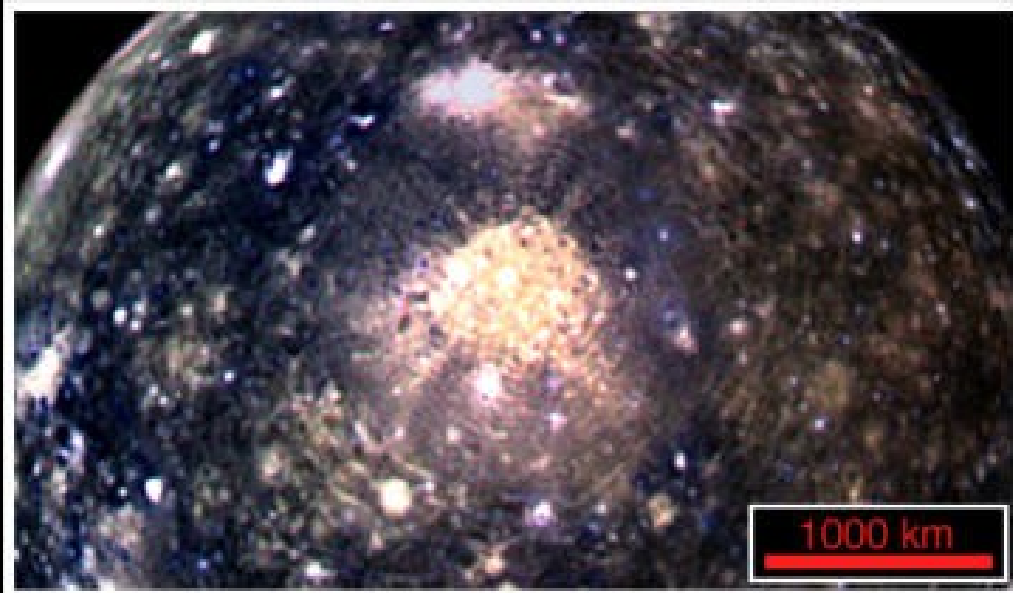


Density = 1.9 g/cc

Like Europa, Ganymede has an extremely thin Oxygen atmosphere created by charged particles hitting the ice surface.

# Callisto

Callisto's surface is old and heavily cratered.



# Callisto's structure

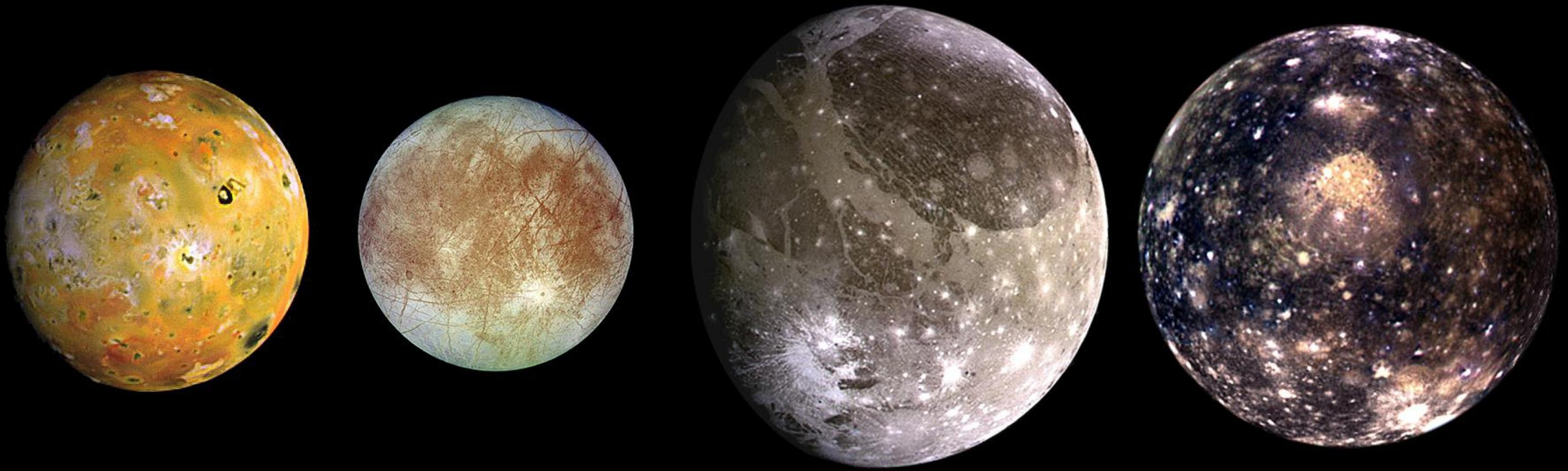
Being the furthest moon from Jupiter and under the least tidal stress, Callisto did not have time to differentiate much before it became frozen.



Density =  
1.9 g/cc

However, Callisto shows signs of a variable magnetic field, an indication of a subterranean, salty ocean.

Older & colder the farther away from Jupiter.



Io < few million, Europa ~20-180 million years,  
Ganymede ~3 billion years, Callisto: 4-4.5 billion years old

Structure changes as they get further from Jupiter.

Surface Age:  
Io < few million

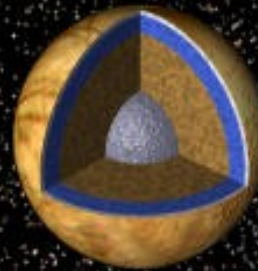
Europa ~20-180  
million years

Ganymede ~3  
billion years

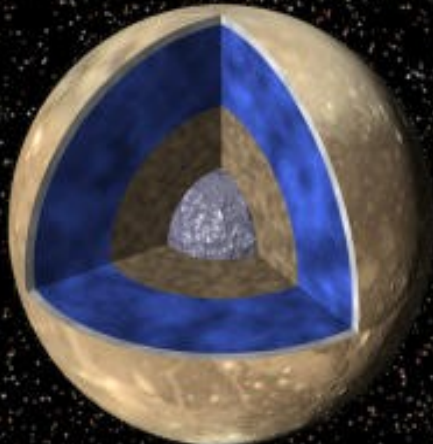
Callisto: 4-4.5  
billion years old



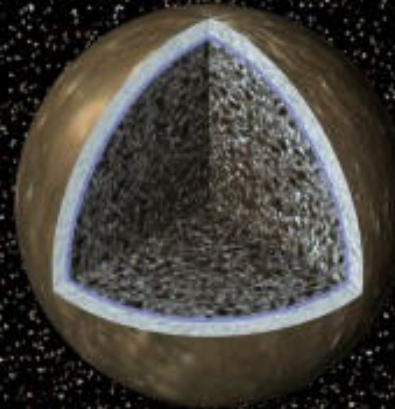
Density = 3.5 g/cc



Density = 3.0 g/cc

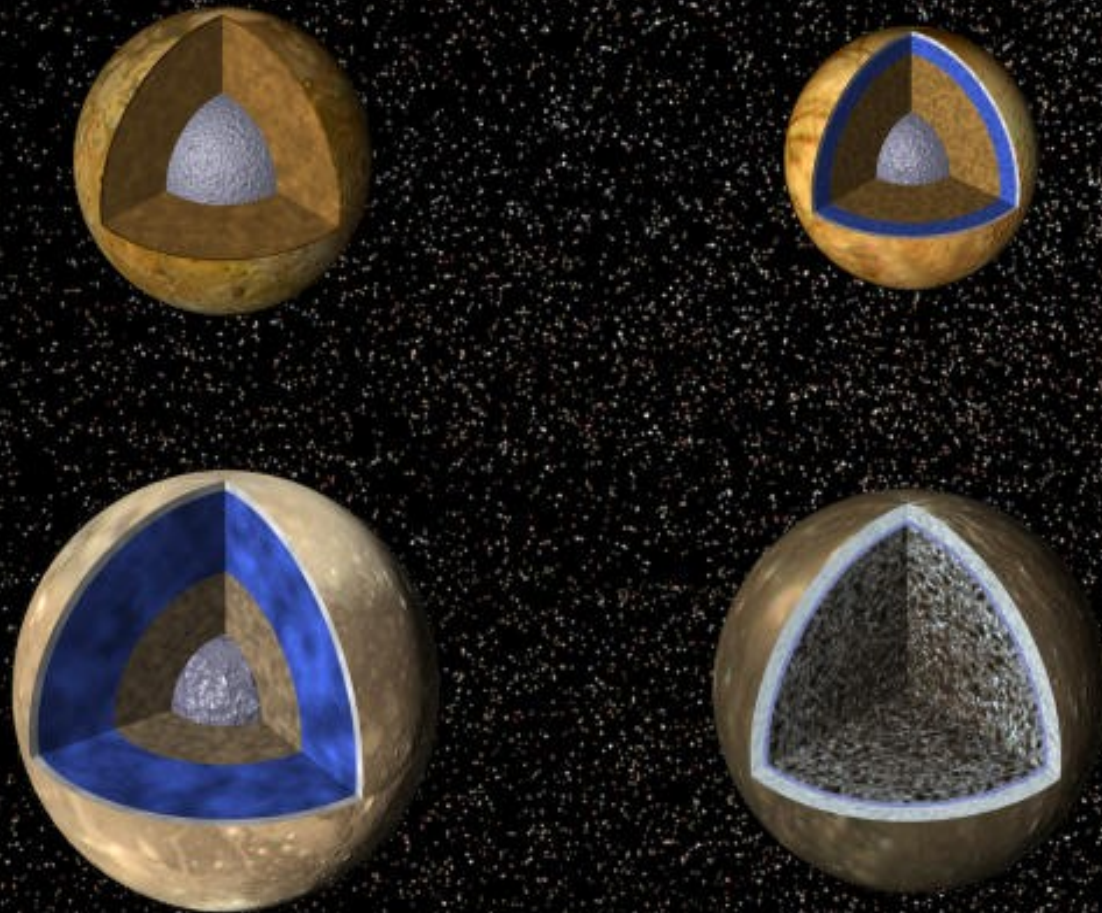


Density = 1.9 g/cc



Density = 1.8 g/cc

Structure changes slightly as they get further from Jupiter.



Notice how prevalent water is in the solar system!  
Europa, Callisto (liquid?)  
Ganymede, Moon, Mercury (ice)



**Jupiter also has lots of smaller, irregular moons. Jupiter has 63 moons in total.**

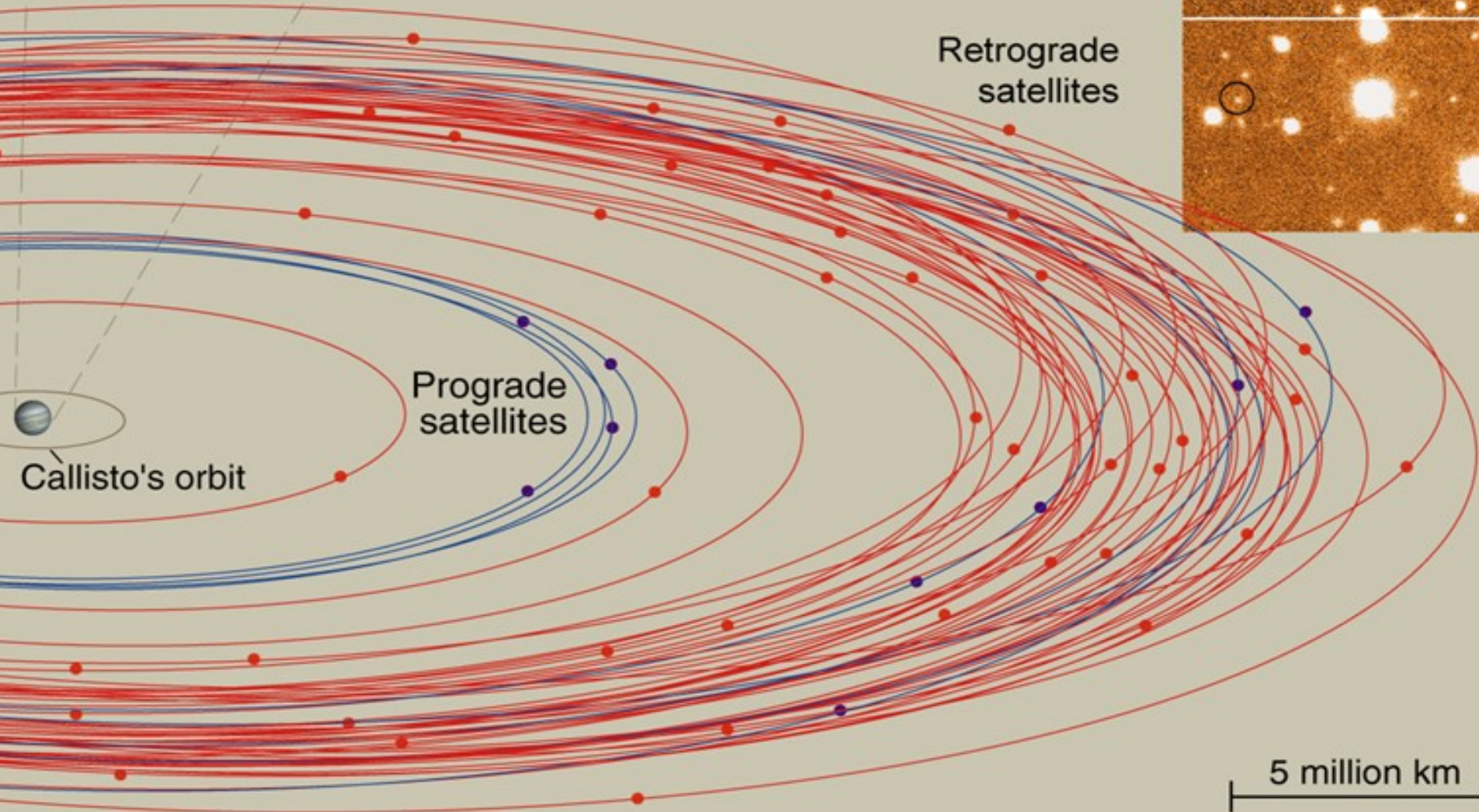




# Schematic of Jupiter's Outer Satellites

University of Hawai'i, Institute for Astronomy

*44 New satellite orbits are shown in red*

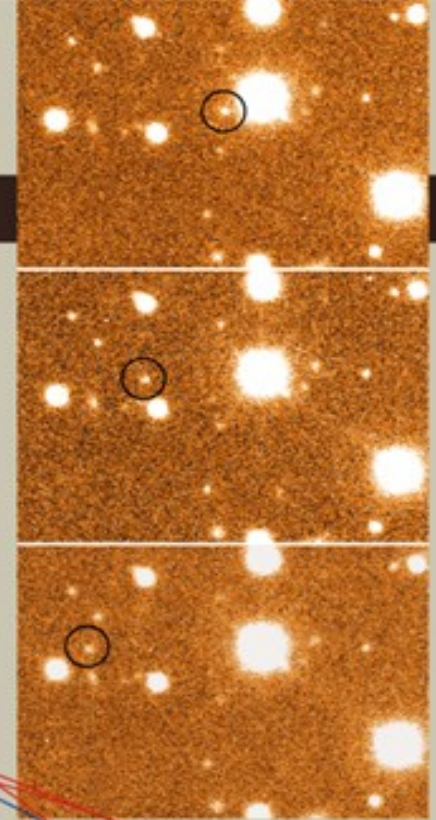


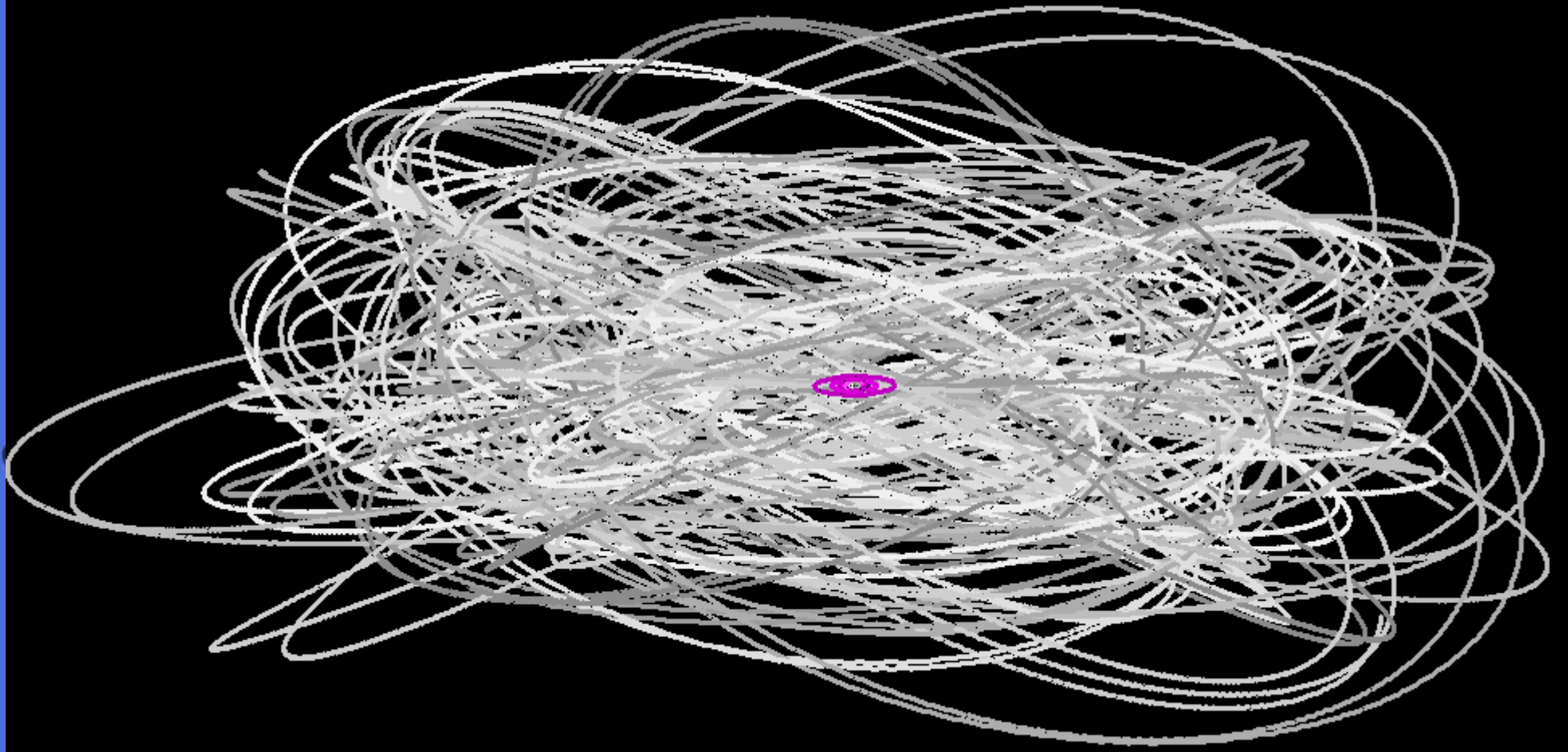
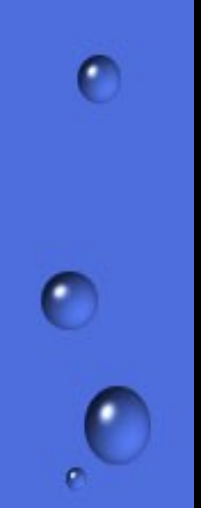
Retrograde satellites

Prograde satellites

Callisto's orbit

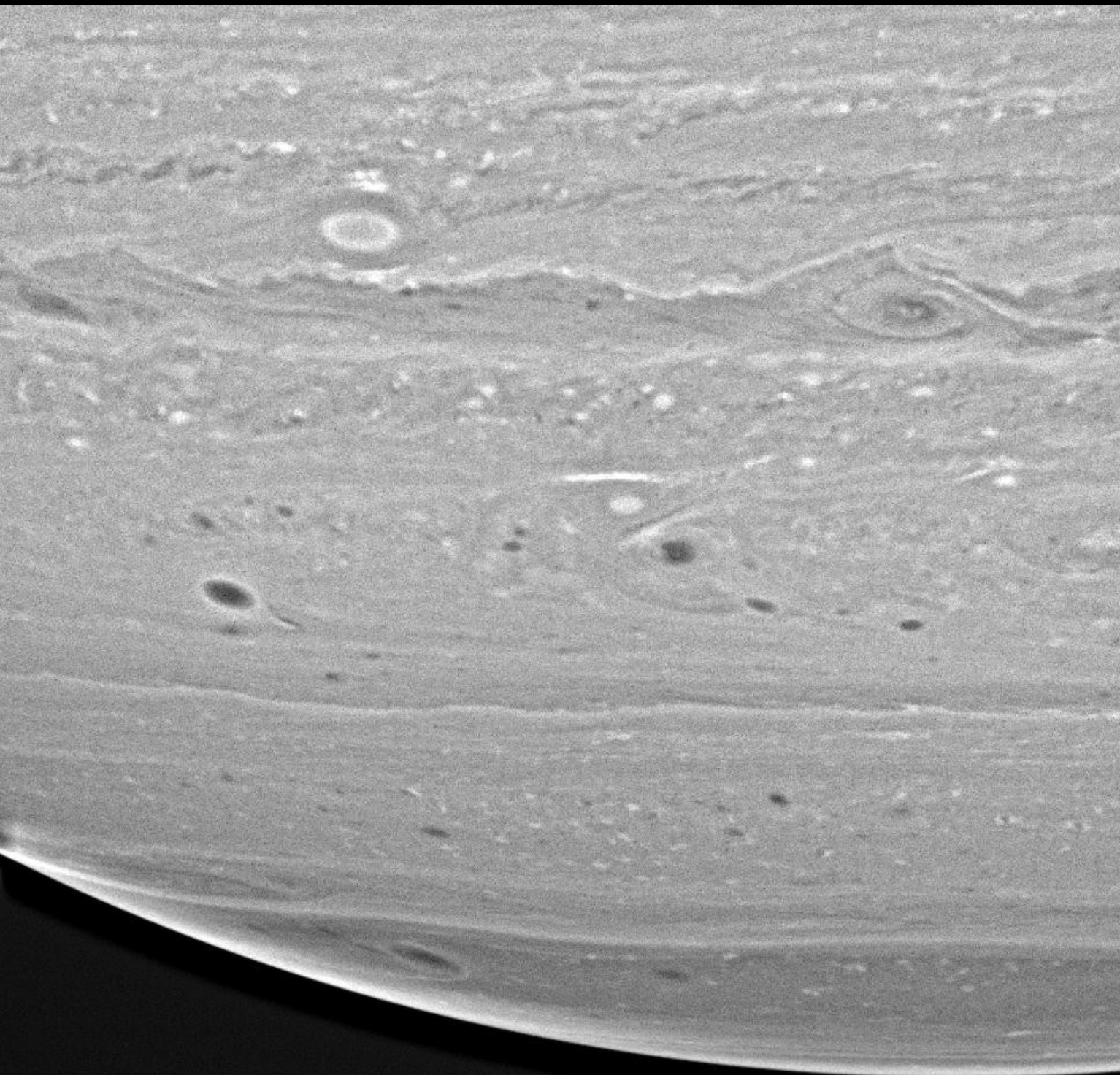
5 million km





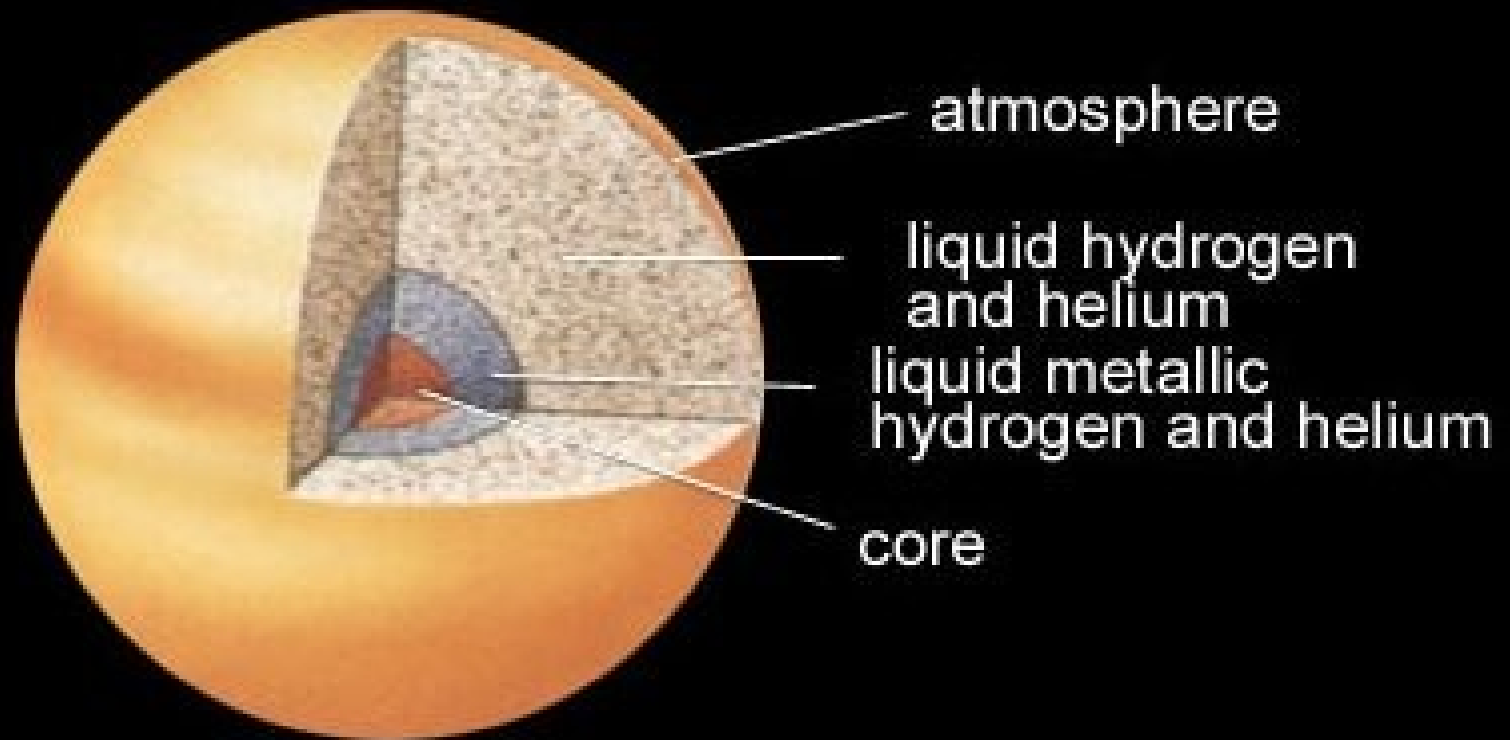
# Saturn





Infrared  
view

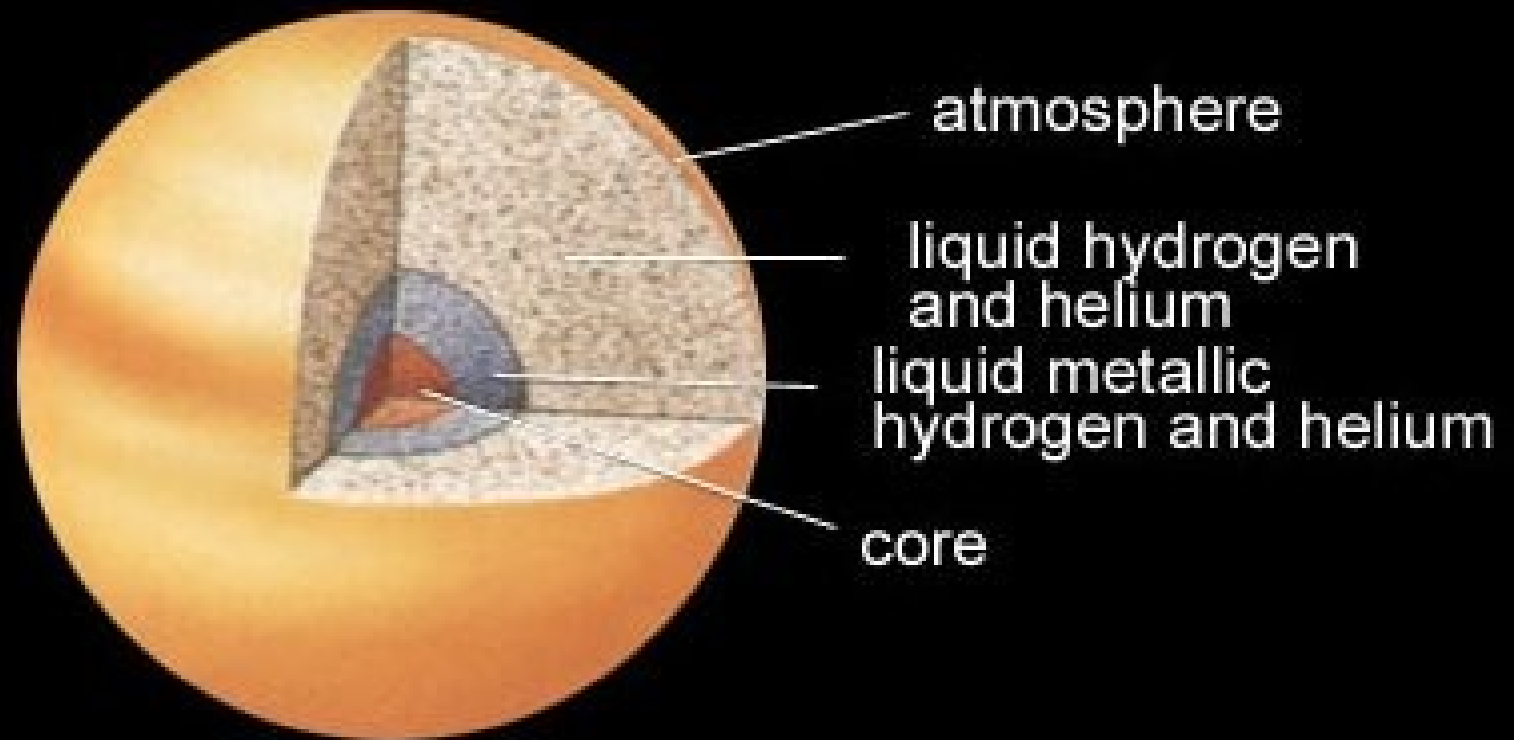
Saturn's structure is very similar to Jupiter's.  
Clouds which thicken to liquid  
Metallic hydrogen interior  
Rocky core  
Density = 0.7 **less than water!**



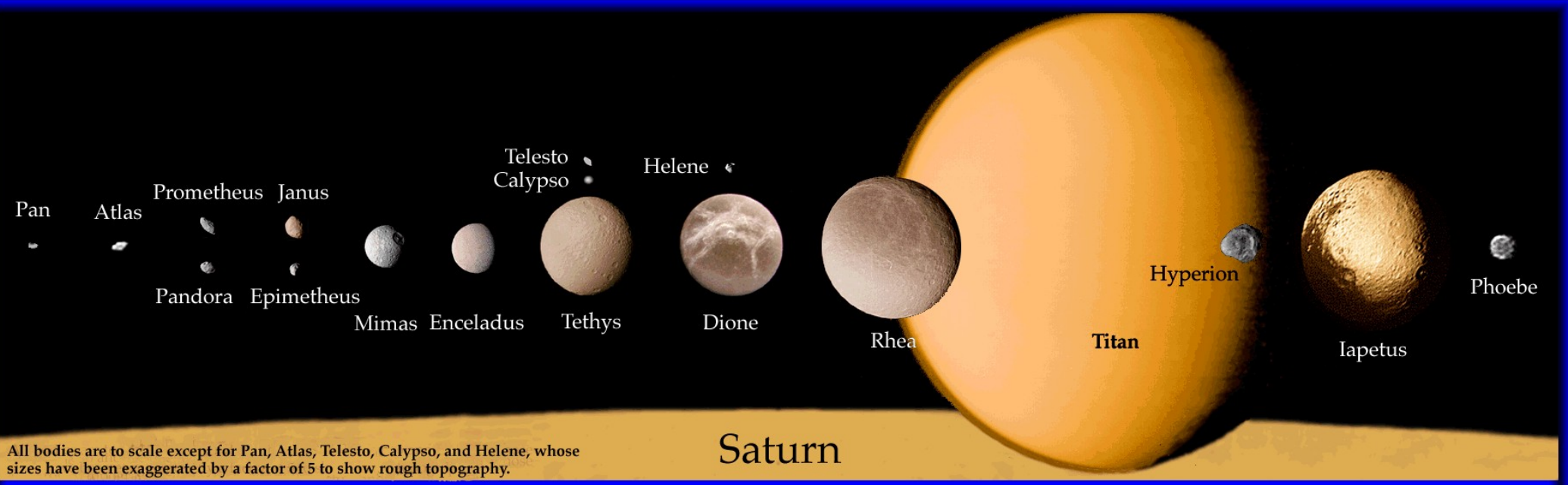
Solar day = 10 hours 40 minutes

This spin is so fast that Saturn is visibly larger at the equator than the poles.

95 times more massive than Earth.

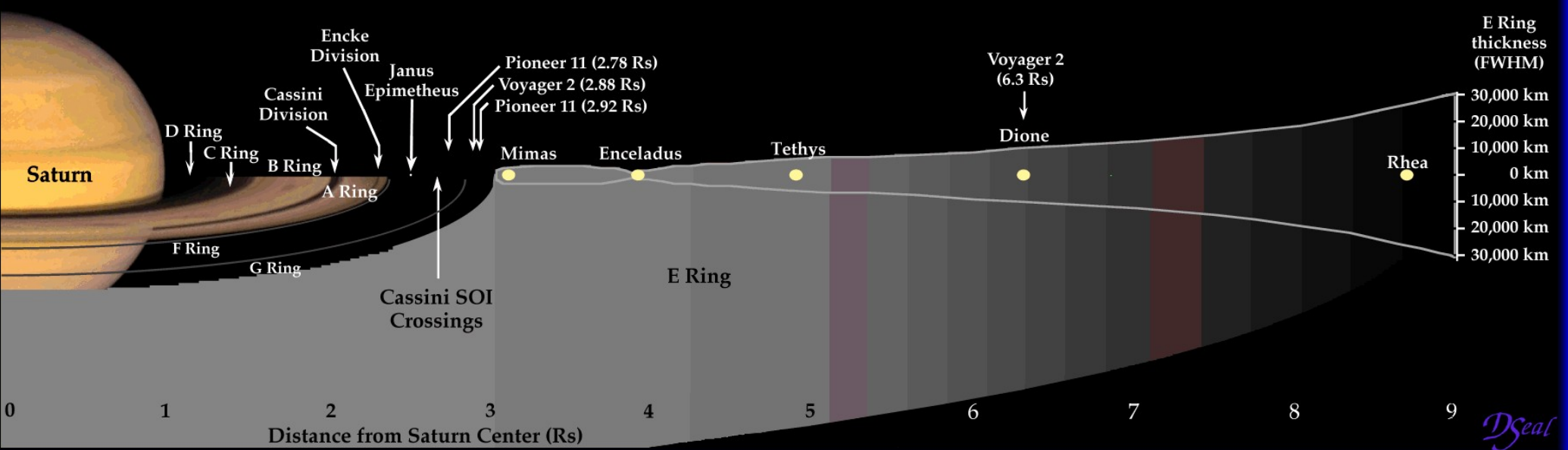


# Saturn's Satellites and Ring Structure 56 known moons



All bodies are to scale except for Pan, Atlas, Telesto, Calypso, and Helene, whose sizes have been exaggerated by a factor of 5 to show rough topography.

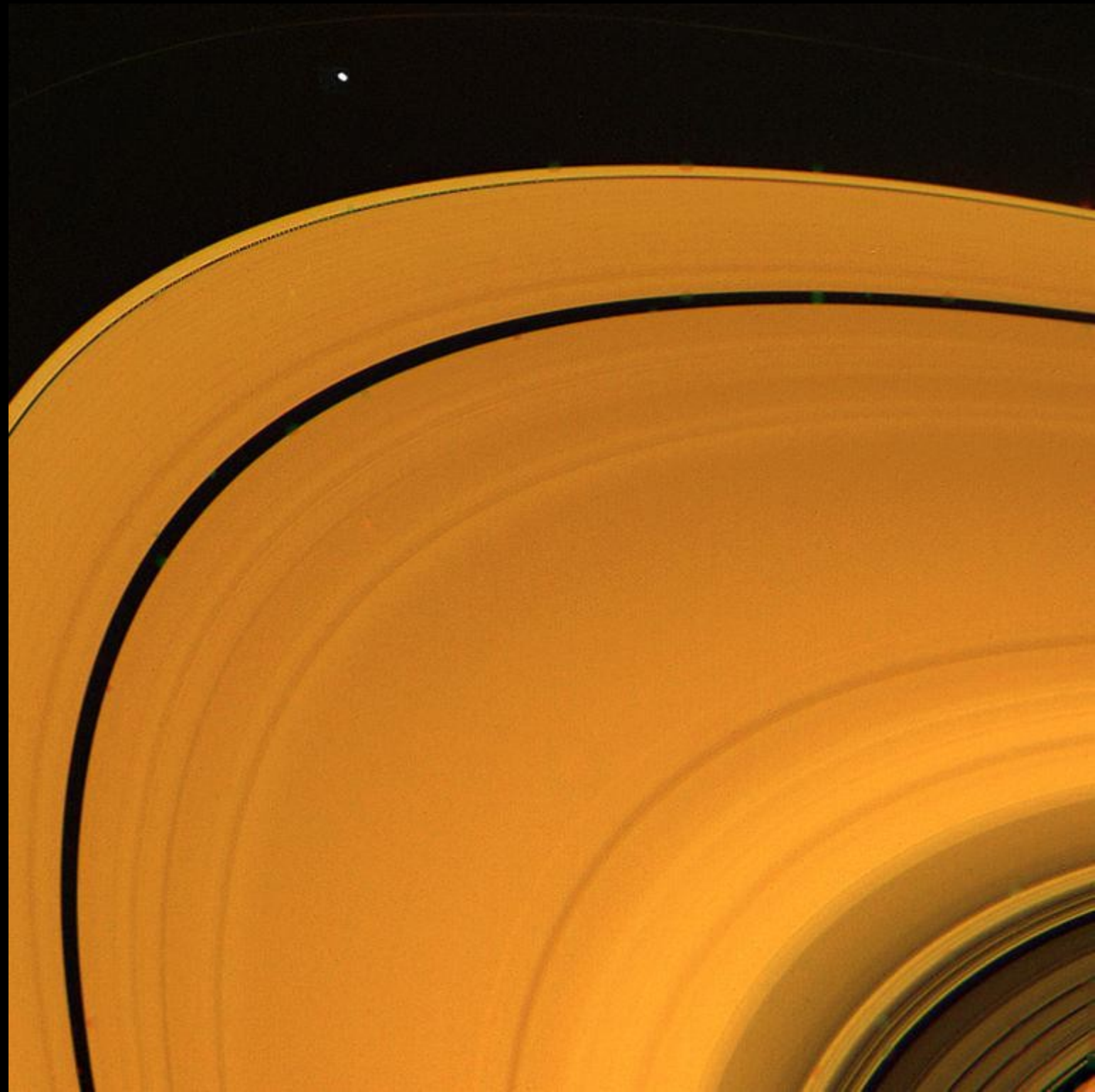
Not shown:	
Pan	2.22 Rs
Atlas	2.28 Rs
Prometheus	2.31 Rs
Pandora	2.35 Rs
Titan	20.3 Rs
Hyperion	24.6 Rs
Iapetus	59.1 Rs
Phoebe	214.9 Rs



This graphic is available in color if required.

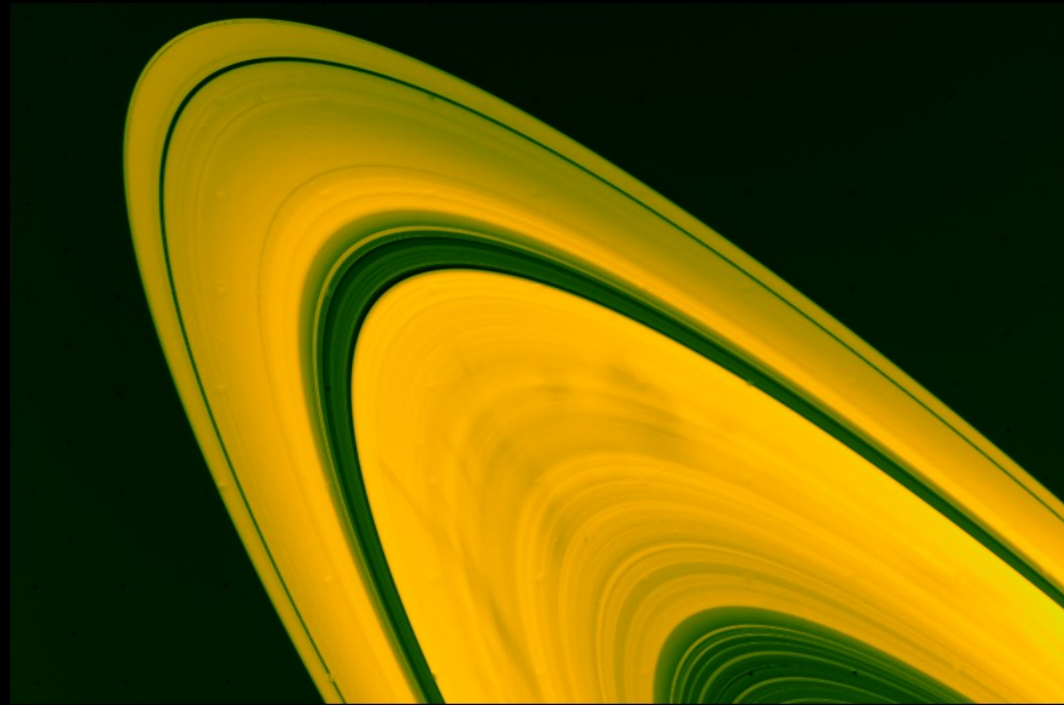


Describe  
Saturn's rings.

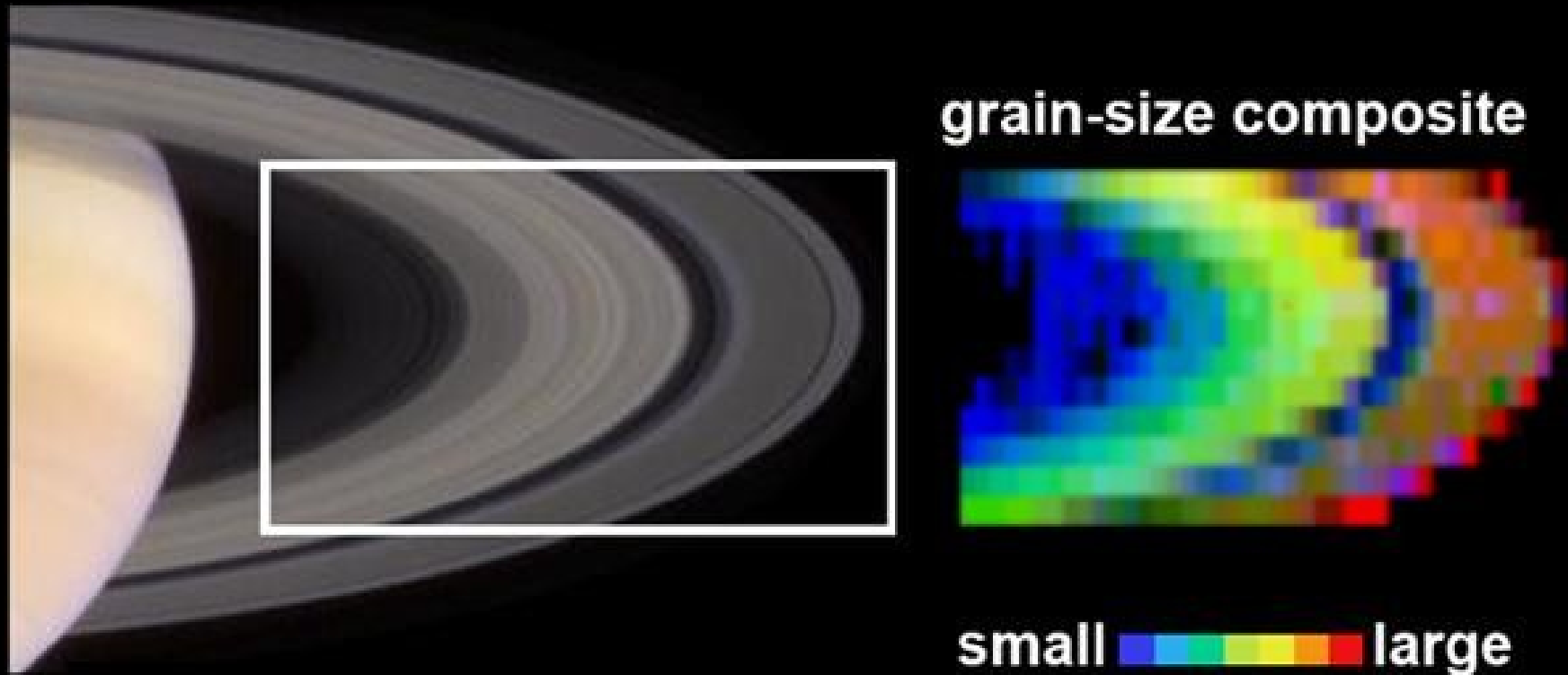


## Saturn's Rings.

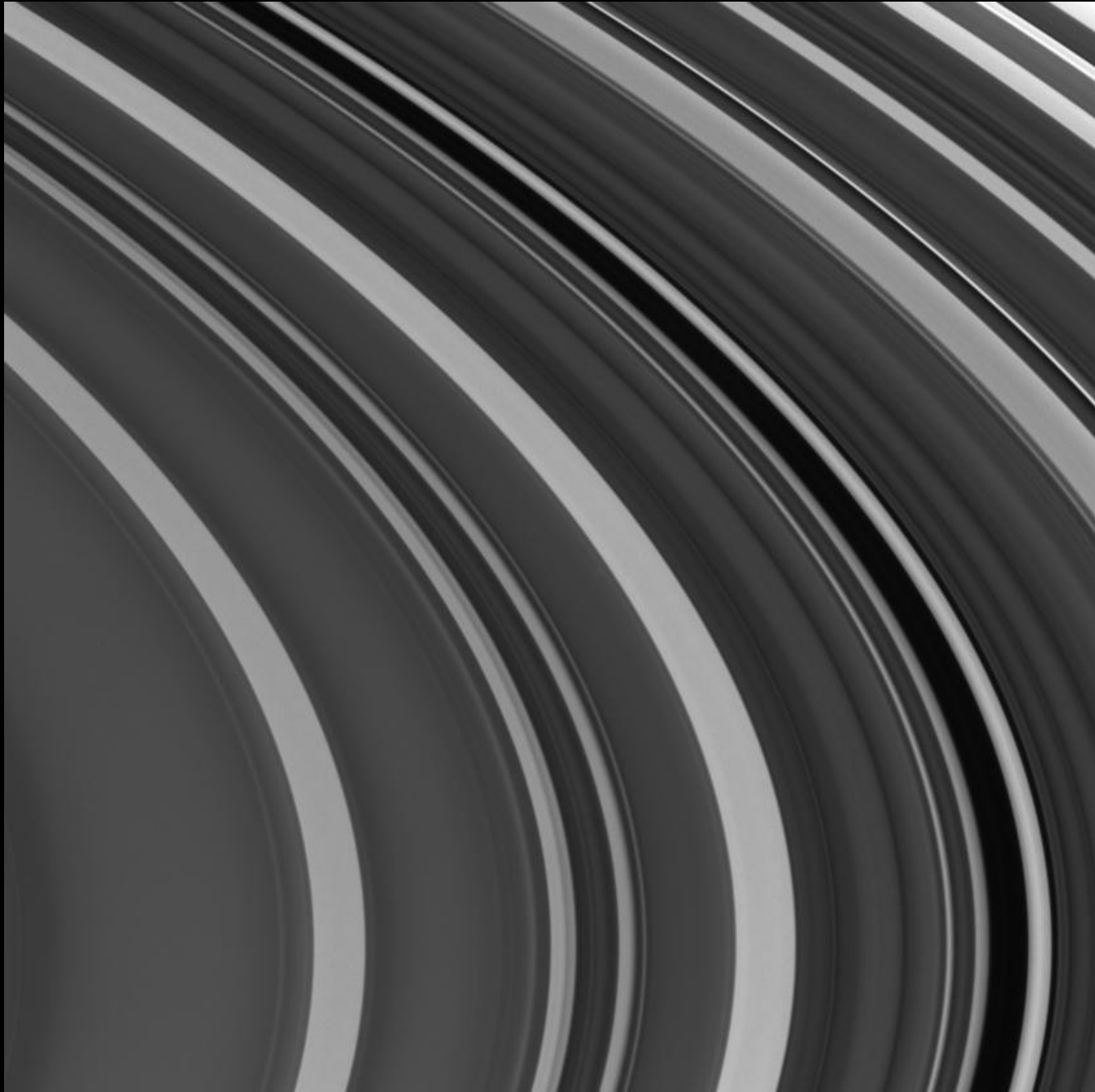
- \* Are extremely thin: 200,000km across, but typically about 200m thick!
- \* Made of millions of particles- but not very thick!
  - 1cm to 10m in diameter
  - mostly ice or ice-covered rocks
  - all the ring material, compressed into a rock would only be 100km across.

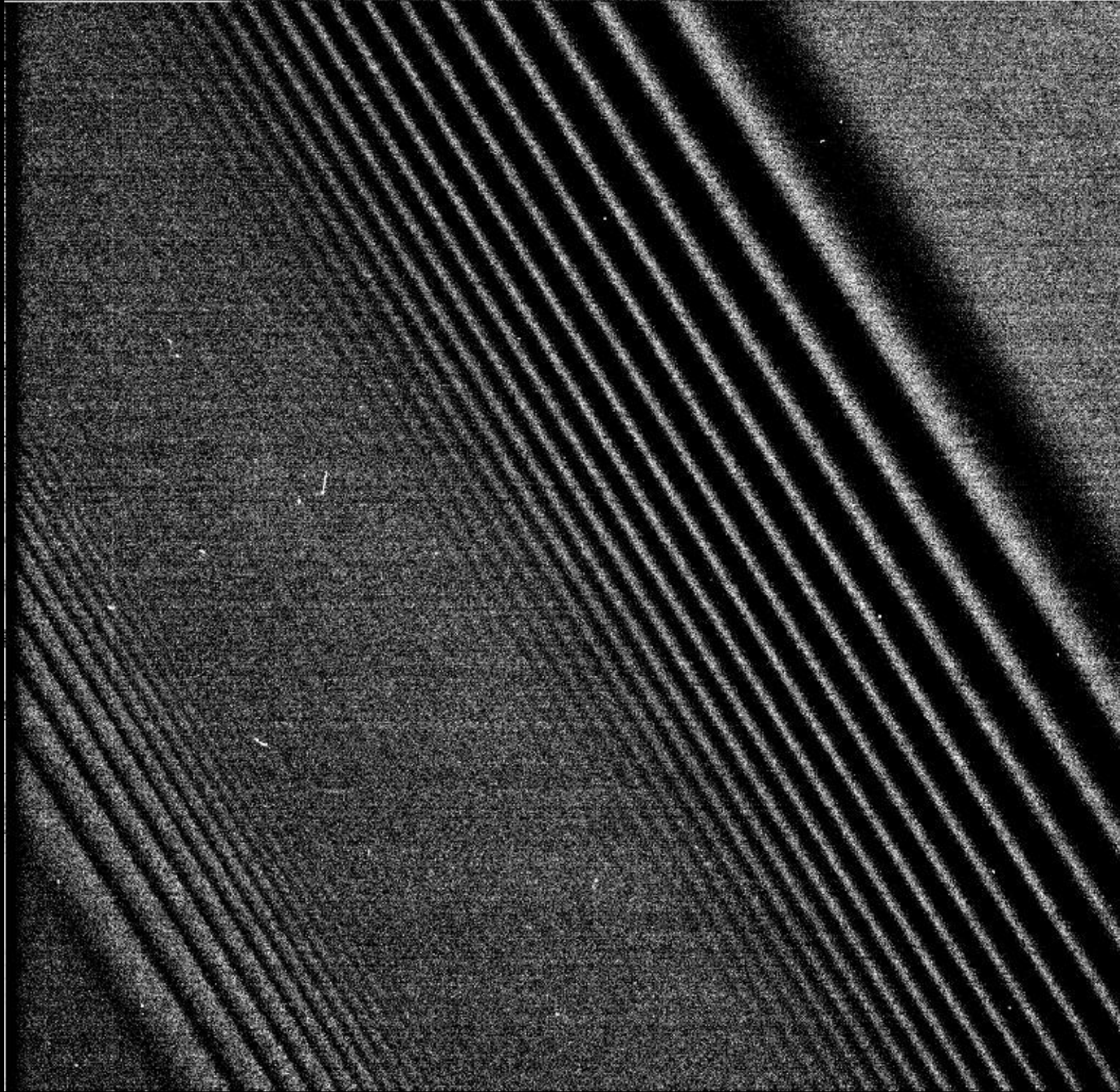


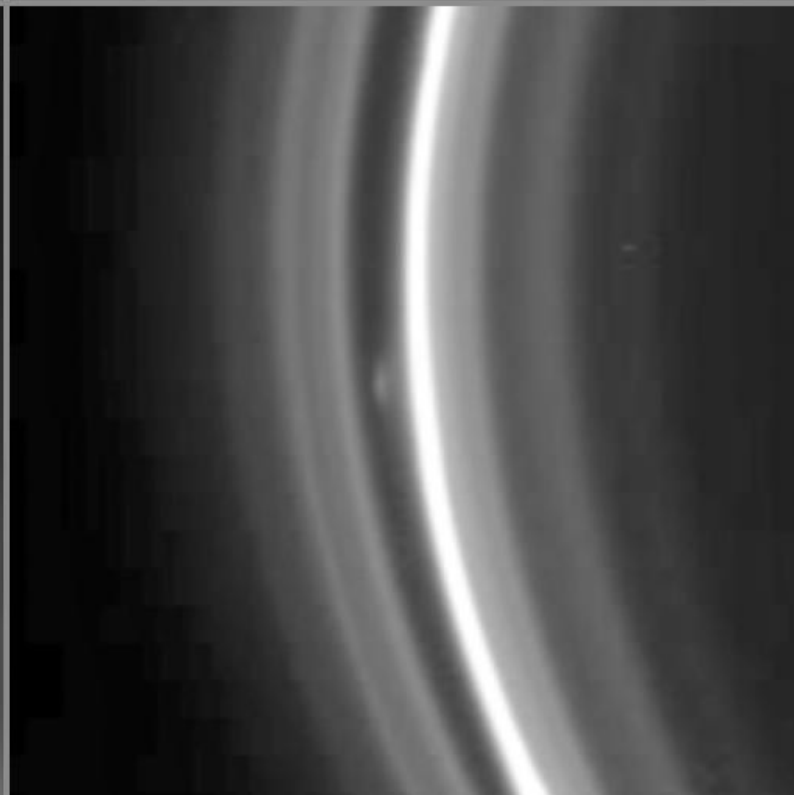
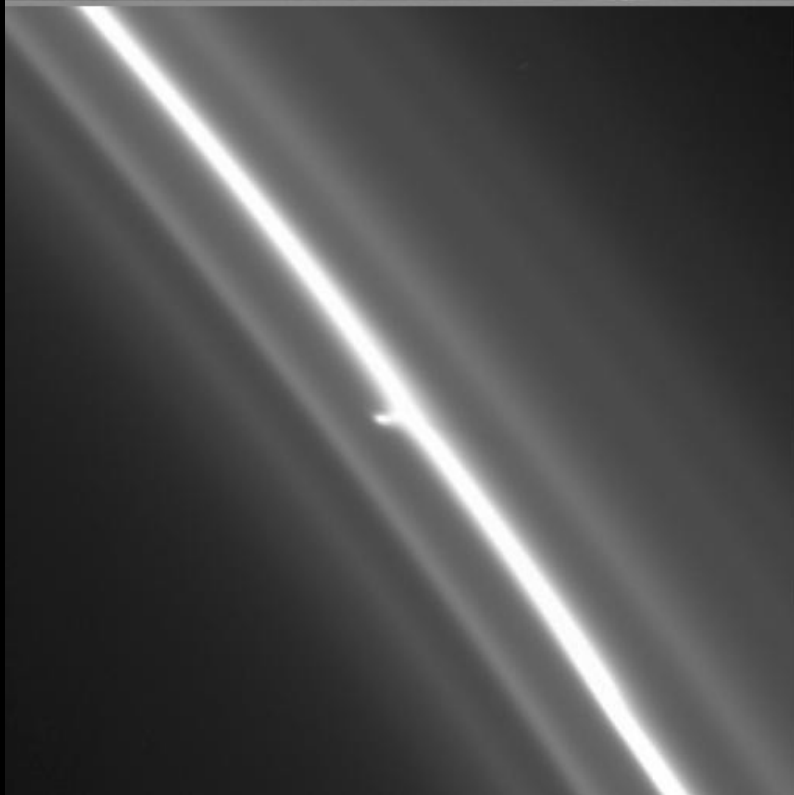
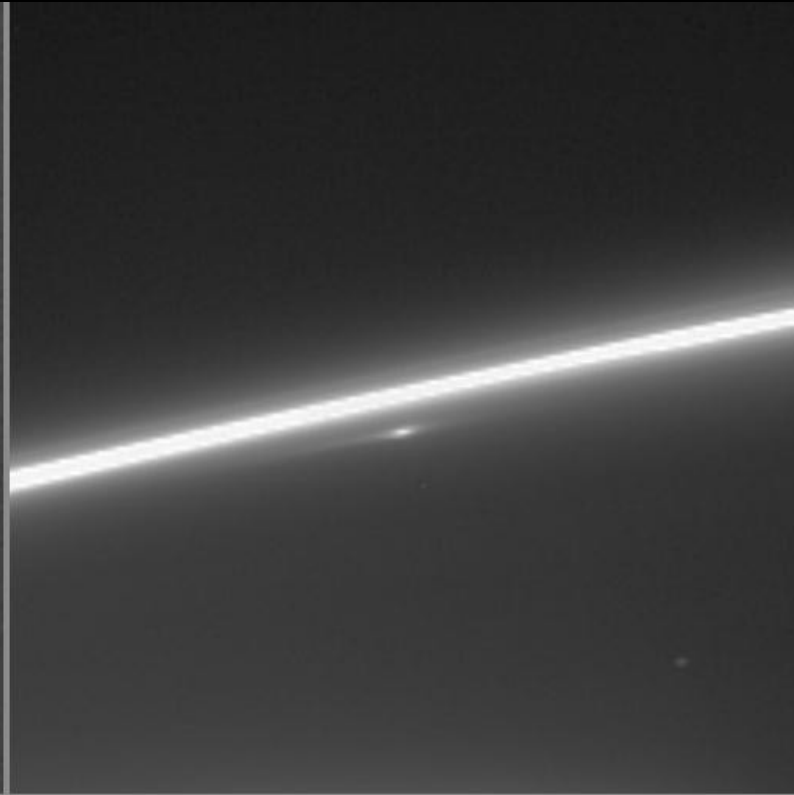
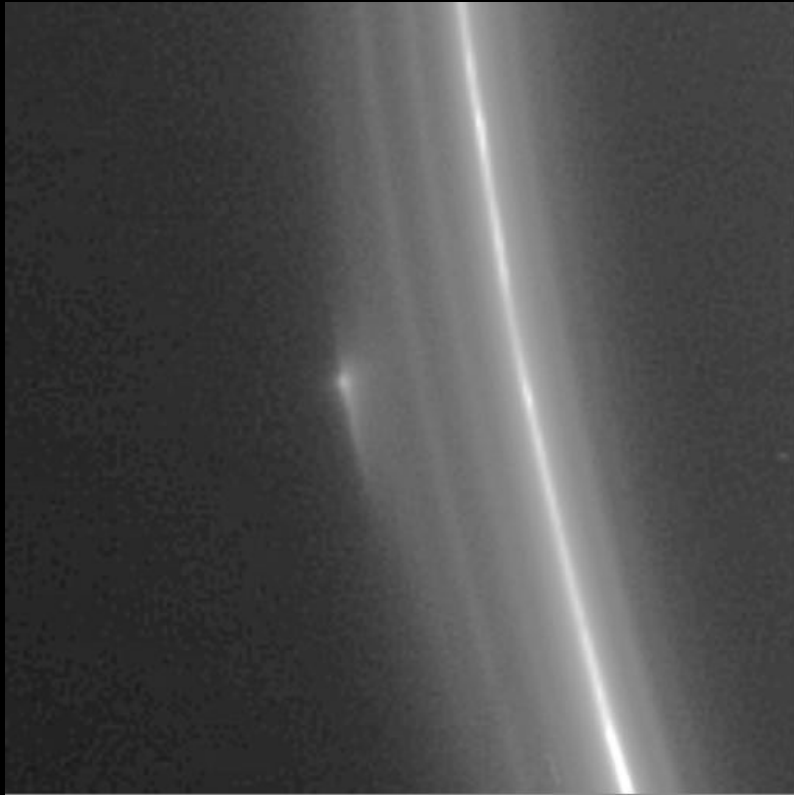
# Cassini Visual and Infrared Mapping Spectrometer



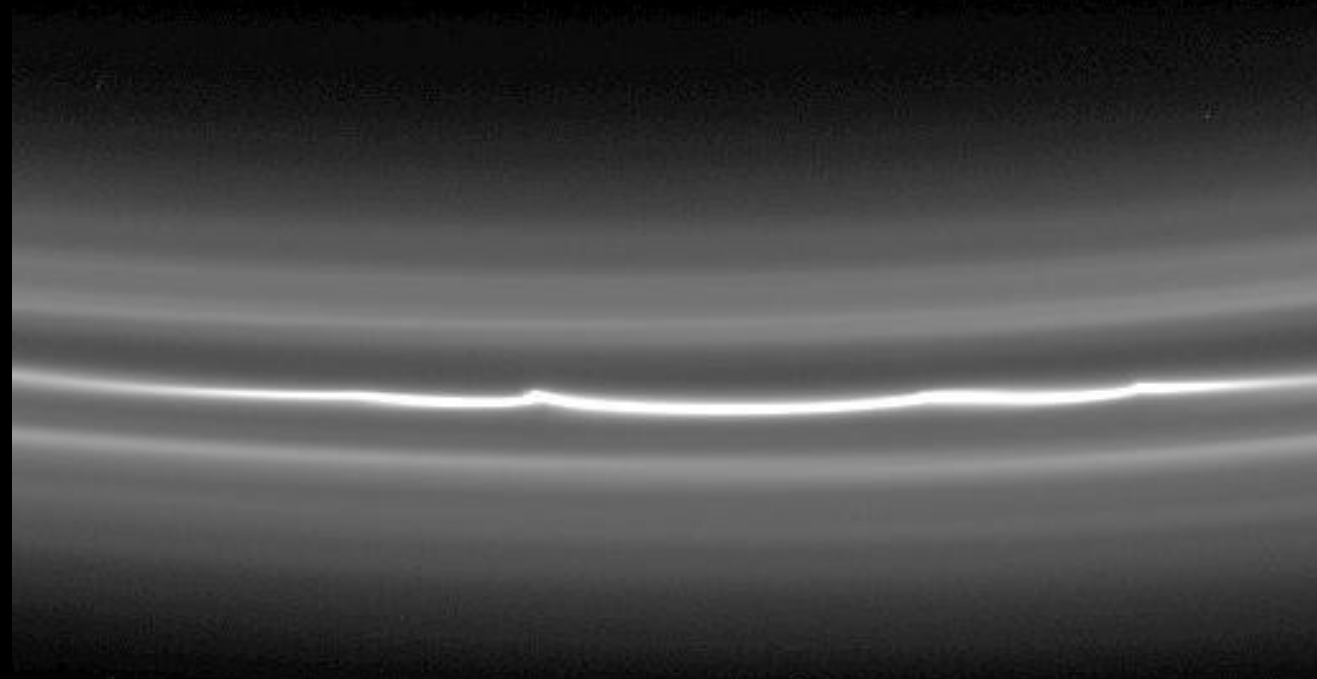
How many rings do you see?



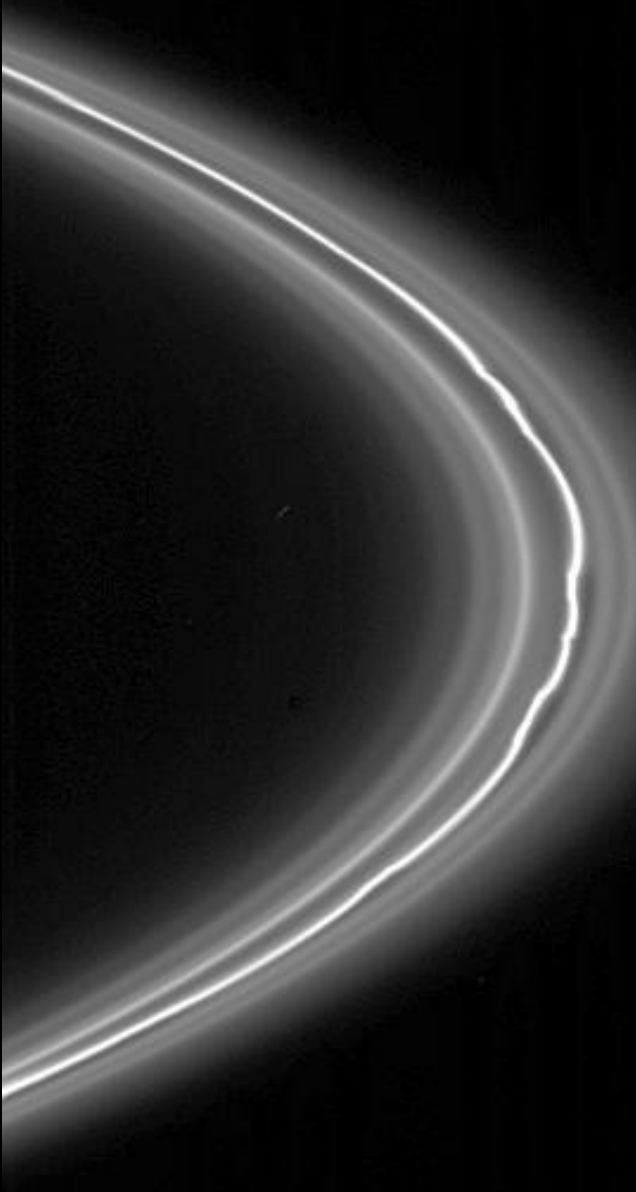












Shepherd moons shape the rings. But do they make them stable? An open question. Prior to Galileo's study of the rings, it was thought they were about 200Myrs old and would only last another 200Myrs.