

Today

- Moons of the solar system
- Rings

Events

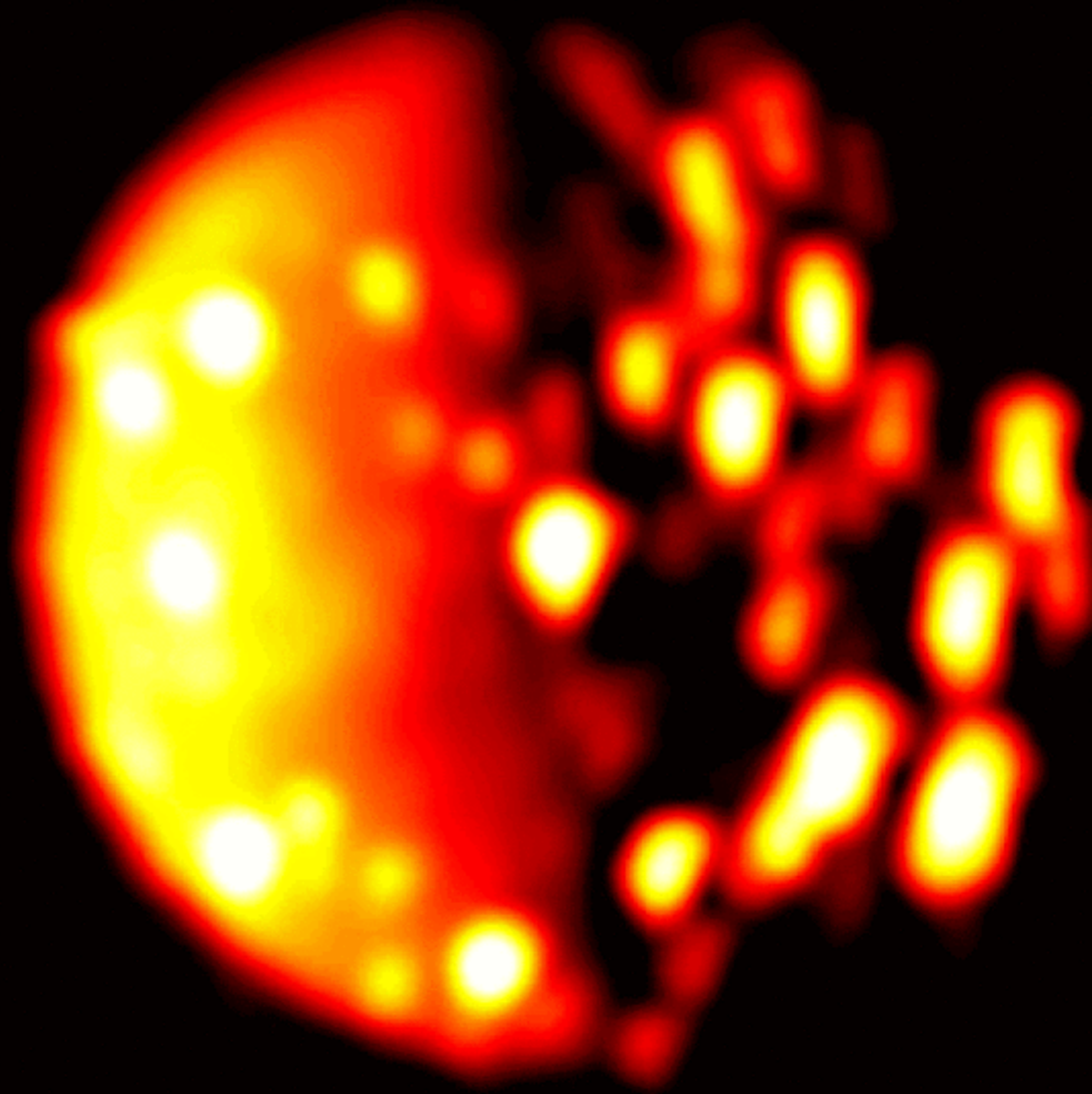
- Homework 5
- Due

The moons of the Jupiter

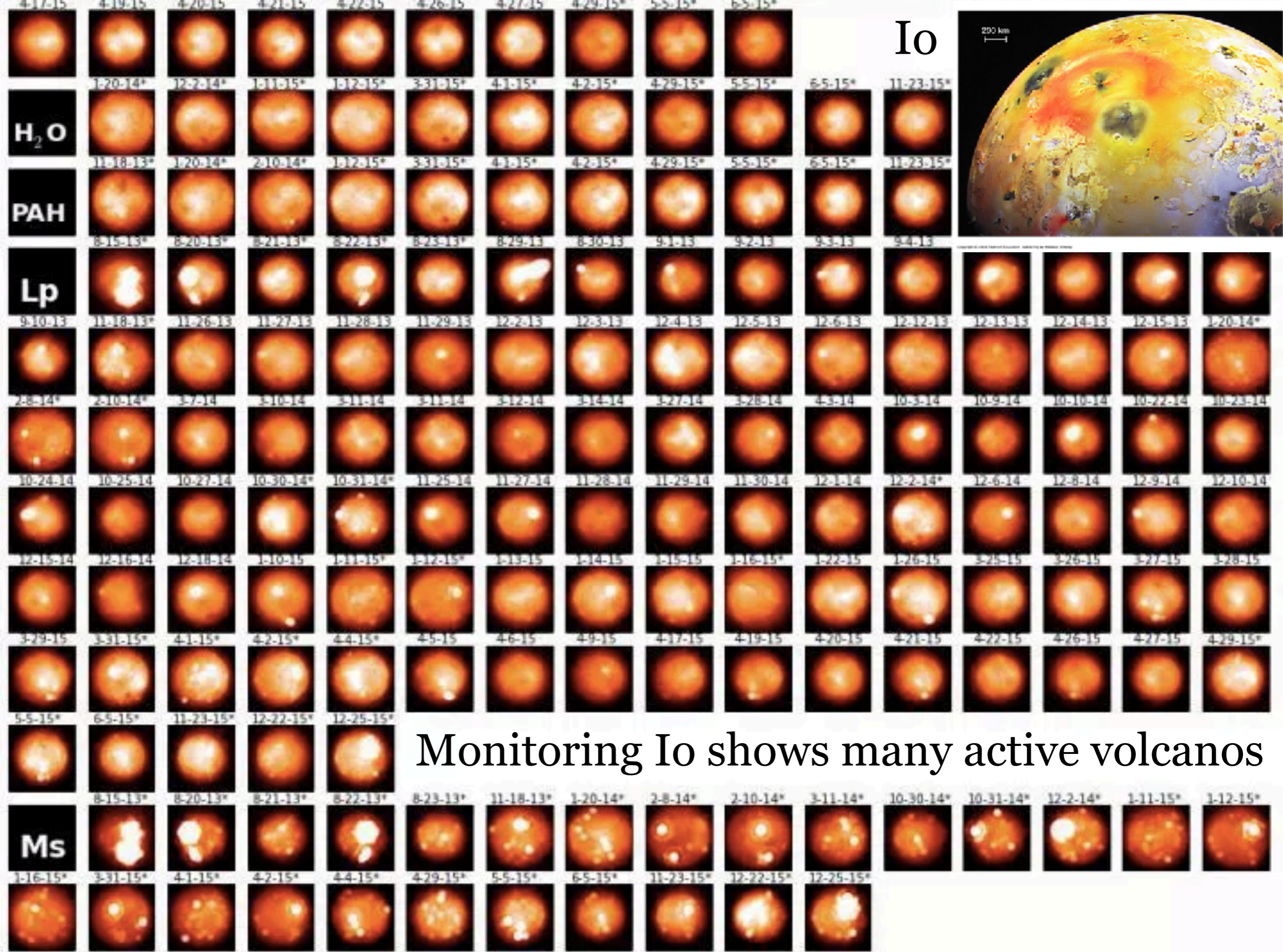


Io

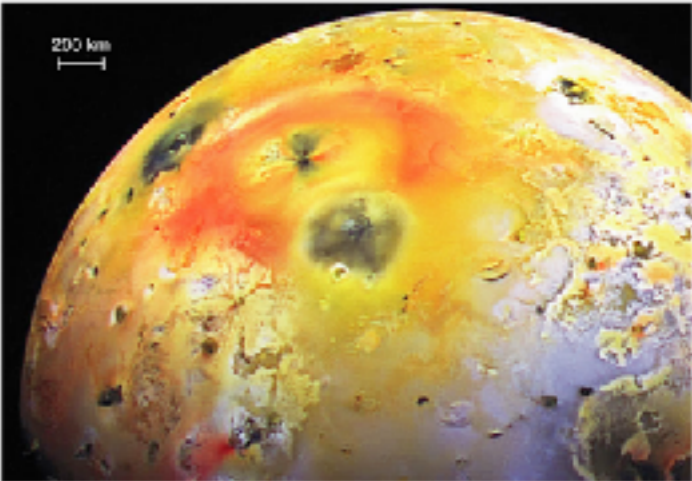
Infrared view of Io



The glowing spots are active volcanoes

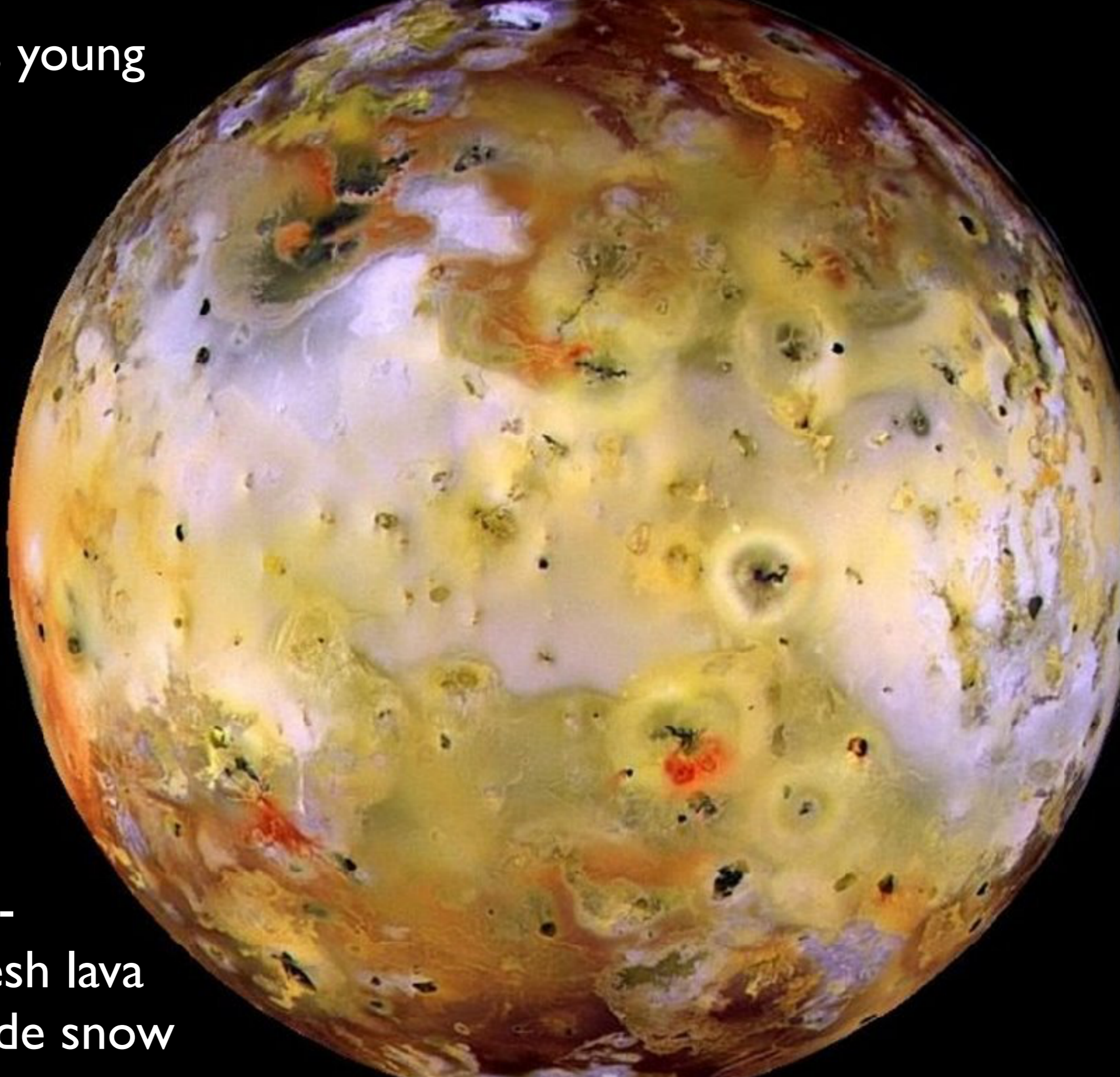


Io



Monitoring Io shows many active volcanos

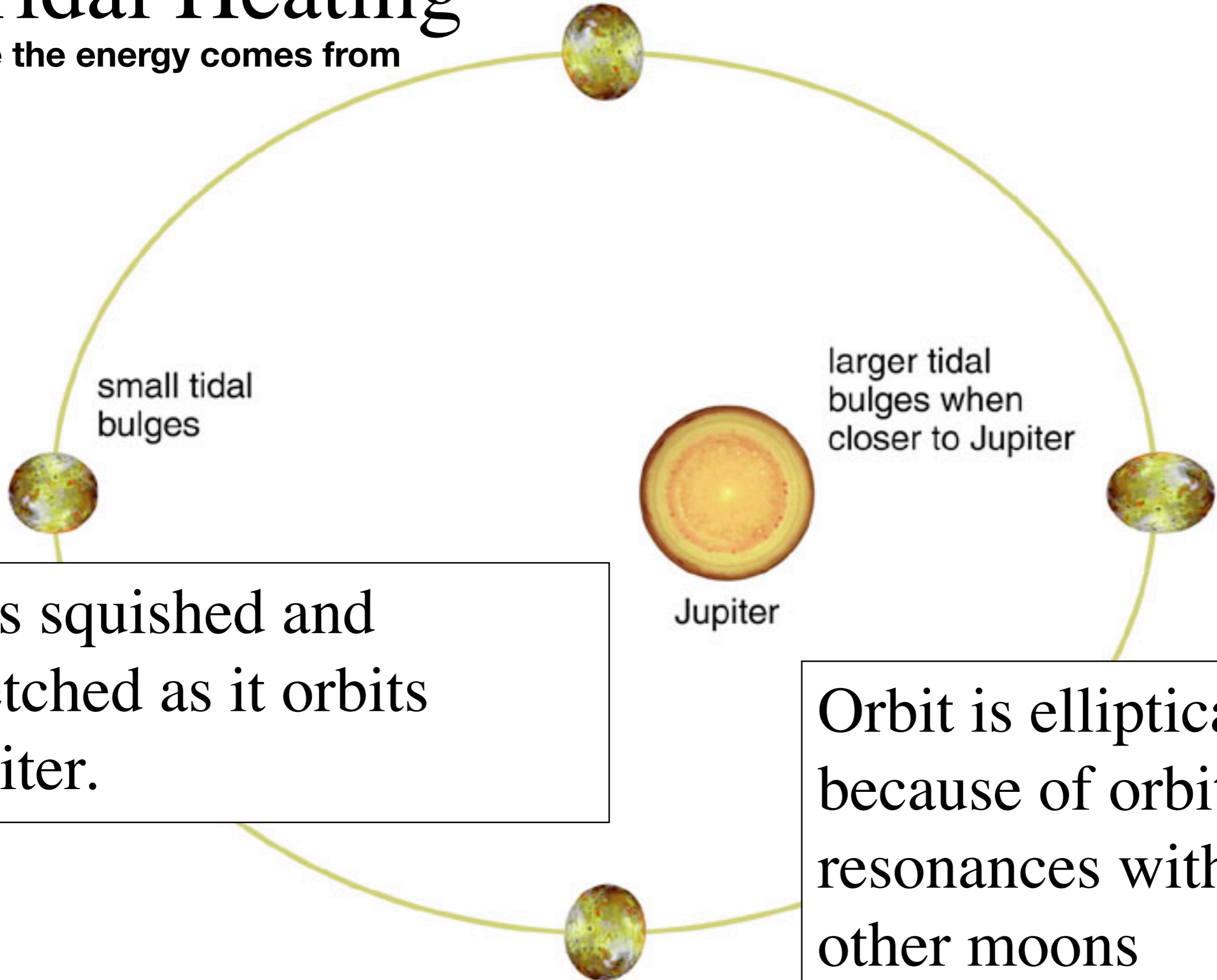
Io's surface is young



Constantly re-
covered in fresh lava
& sulfur dioxide snow

Tidal Heating

where the energy comes from

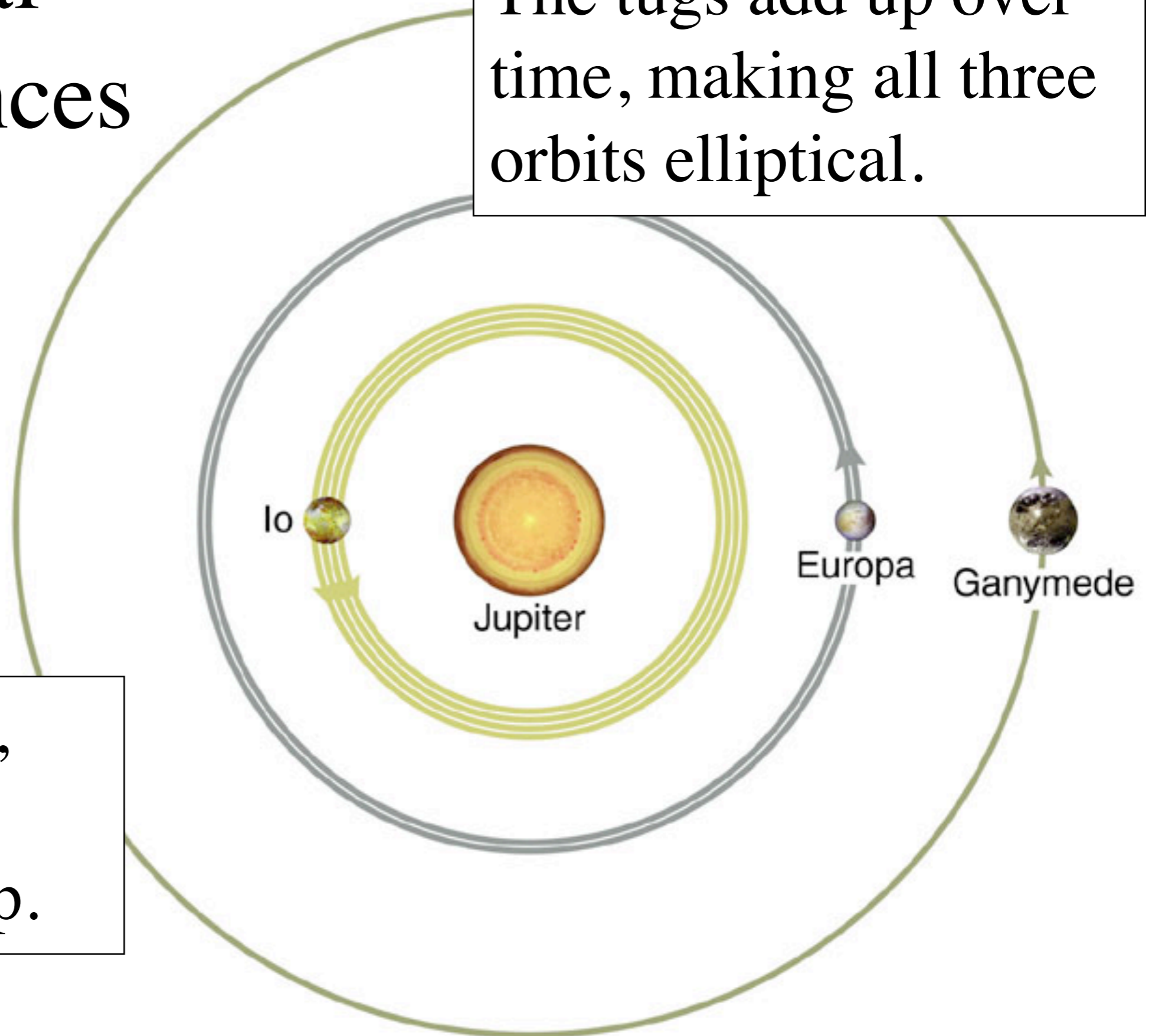


Io is squished and stretched as it orbits Jupiter.

Orbit is elliptical because of orbital resonances with other moons

Orbital Resonances

The tugs add up over time, making all three orbits elliptical.



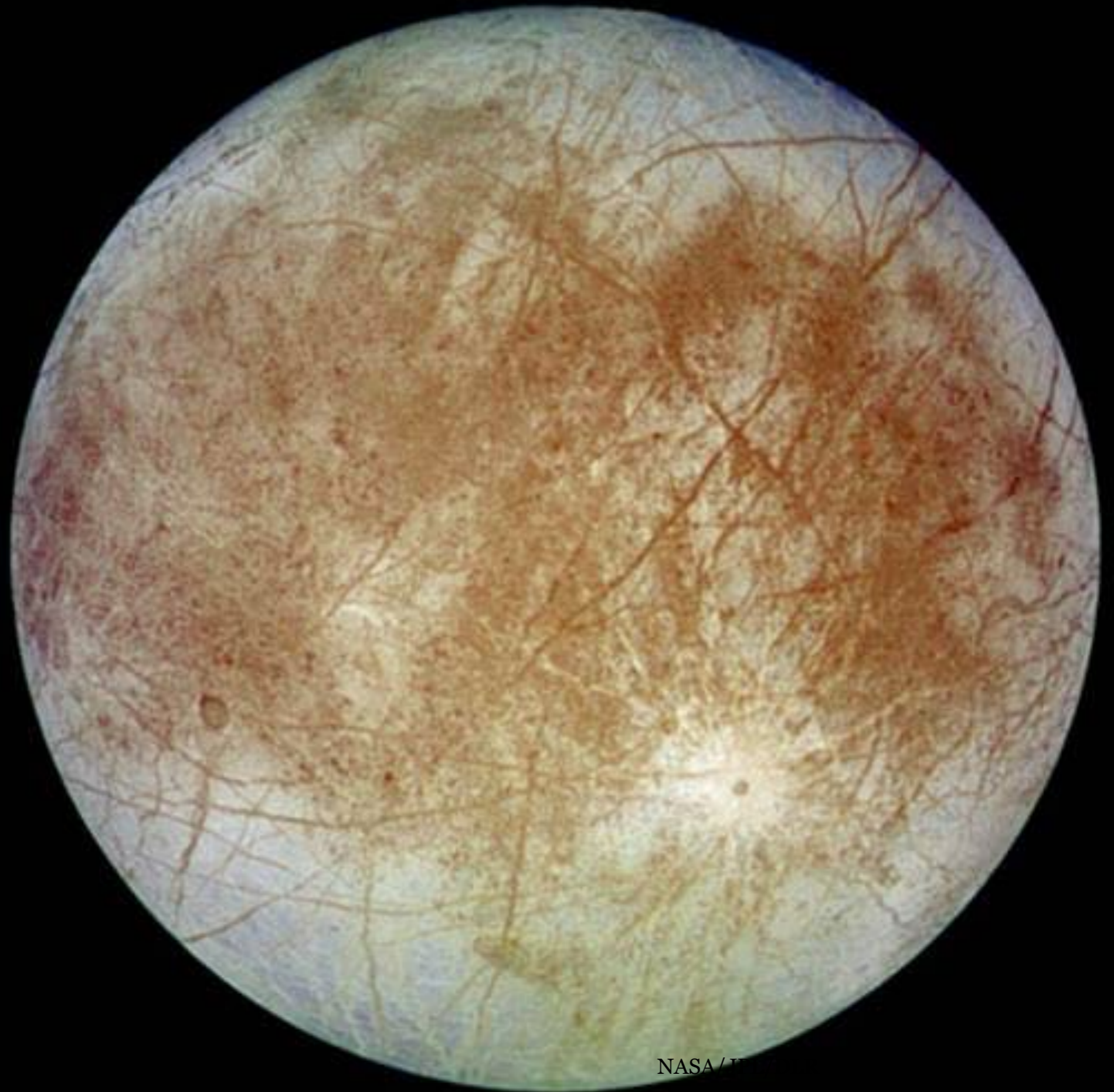
Every 7 days, these three moons line up.

The moons of the Jovian planets

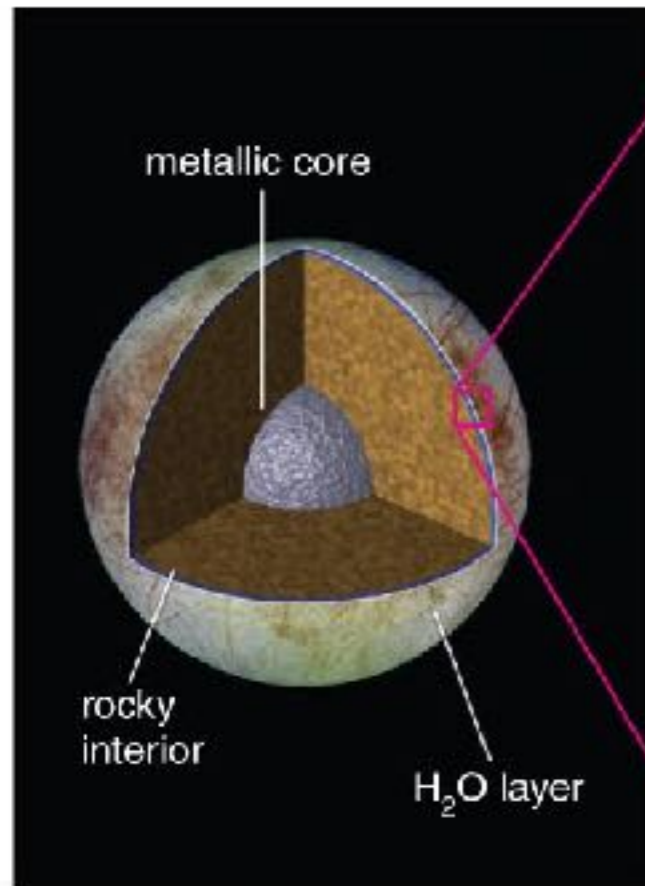


Europa

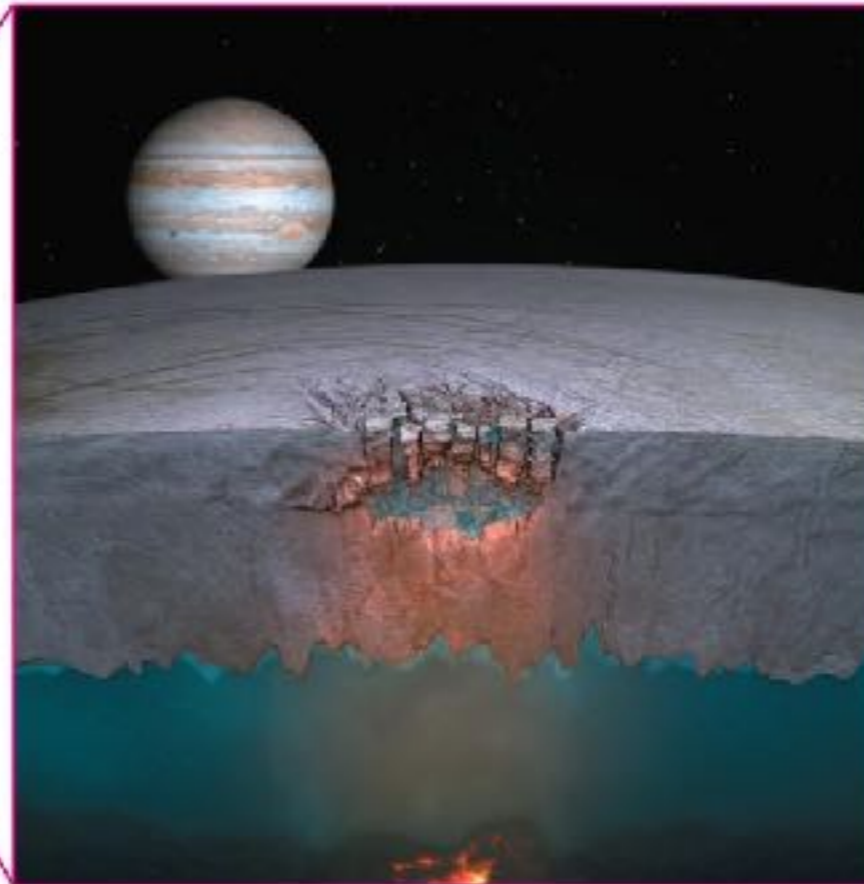
Europa



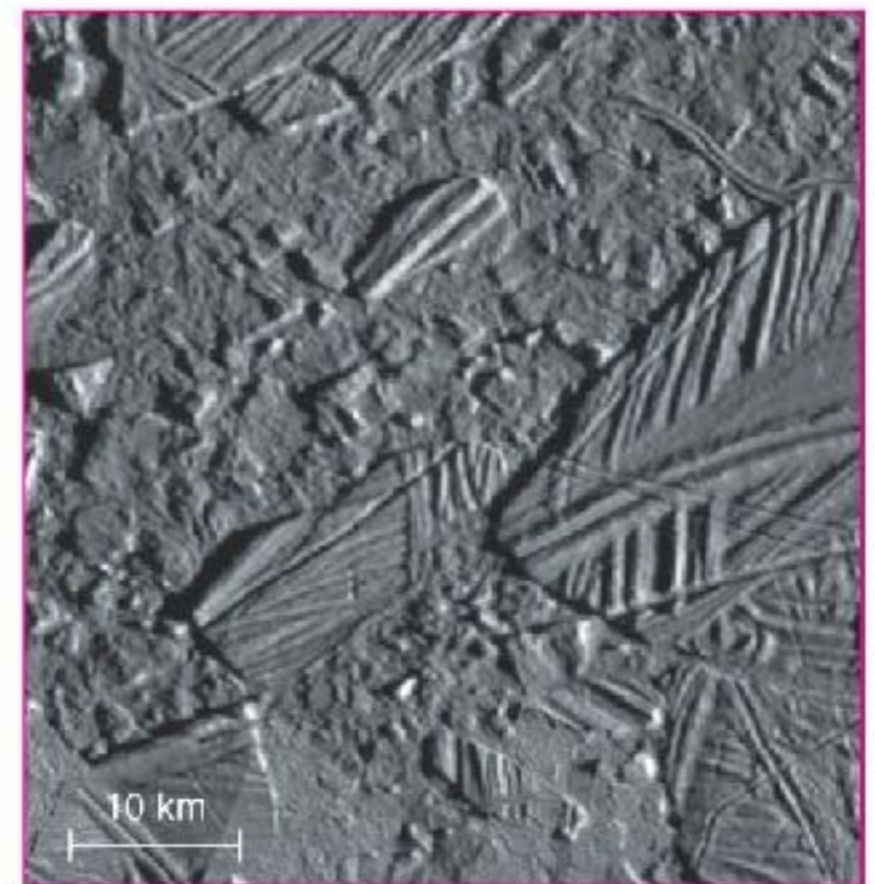
Europa's interior also warmed by tidal heating.



Europa may have a 100-km-thick ocean under an icy crust.



Rising plumes of warm water may sometimes create lakes within the ice, causing the crust above to crack . . .



. . . explaining surface terrain that looks like a jumble of icebergs suspended in a place where liquid or slushy water froze.

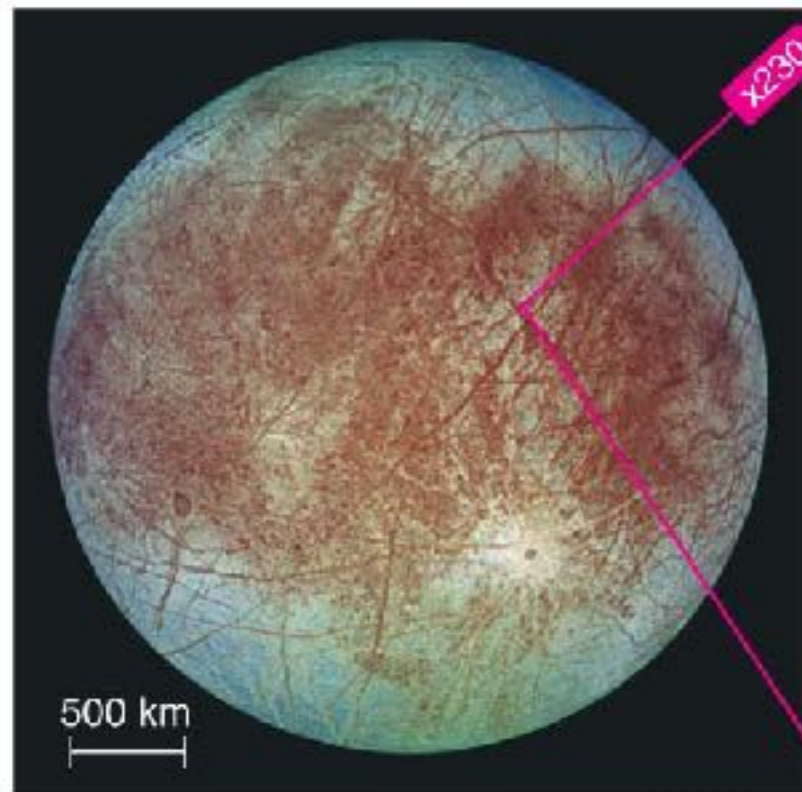
- **metallic core**
- **rocky mantle**
- **briny global ocean**
- **ice crust**

Ice crust stressed and sometimes melted from below...

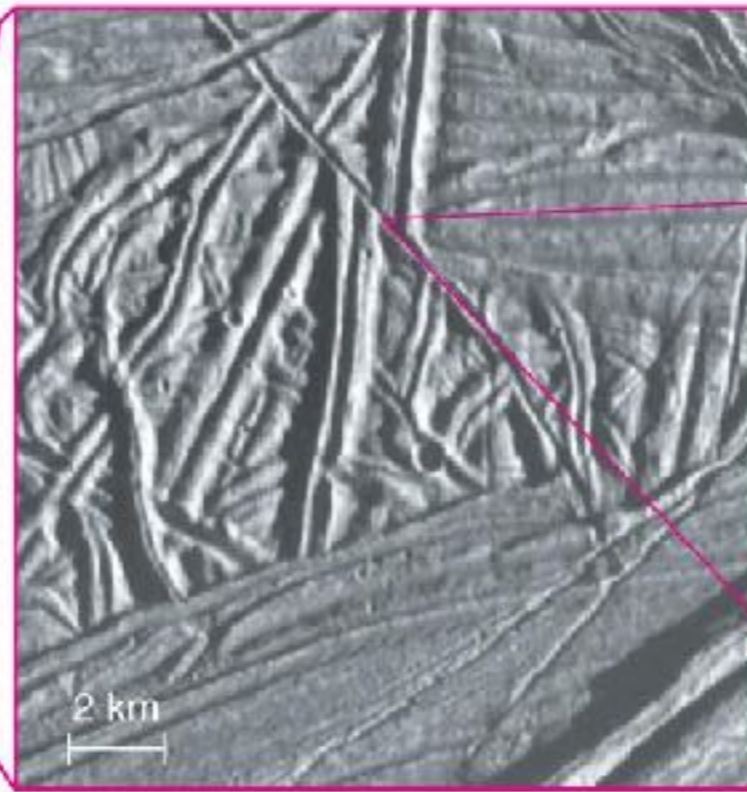
... resulting in a jumbled terrain of broken ice sheets

Energy source: tidal heating again important, just not as strong as on Io

Tidal stresses crack Europa's surface ice.

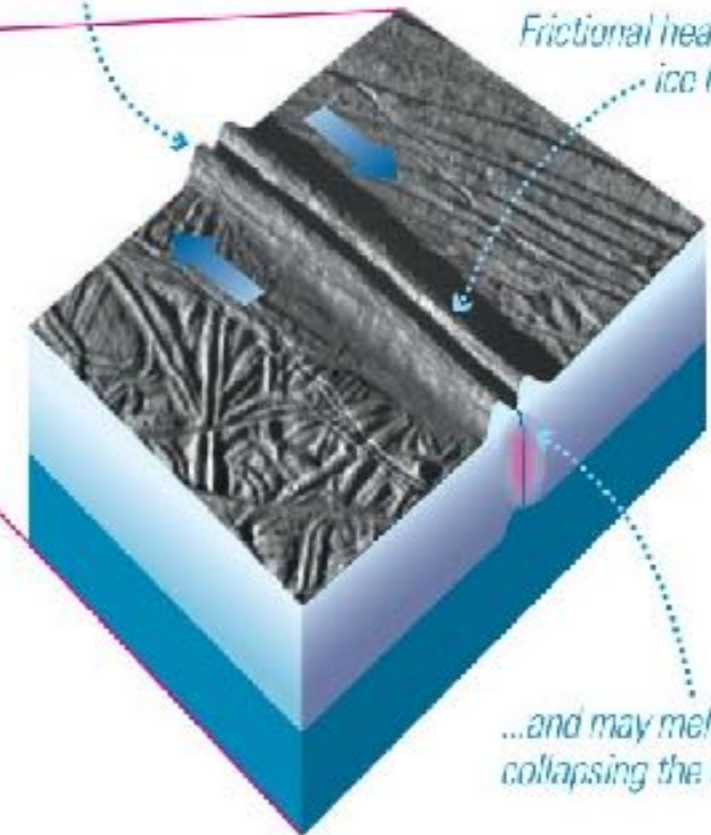


Europa's surface appears heavily cracked even from a distance.



Close-up photos show double-ridged cracks, best explained by an icy crust moving upon a soft or liquid layer below.

Tidal stresses cause parts of Europa's icy crust to slowly slide past each other.



Frictional heating expands ice here, forming the ridge...

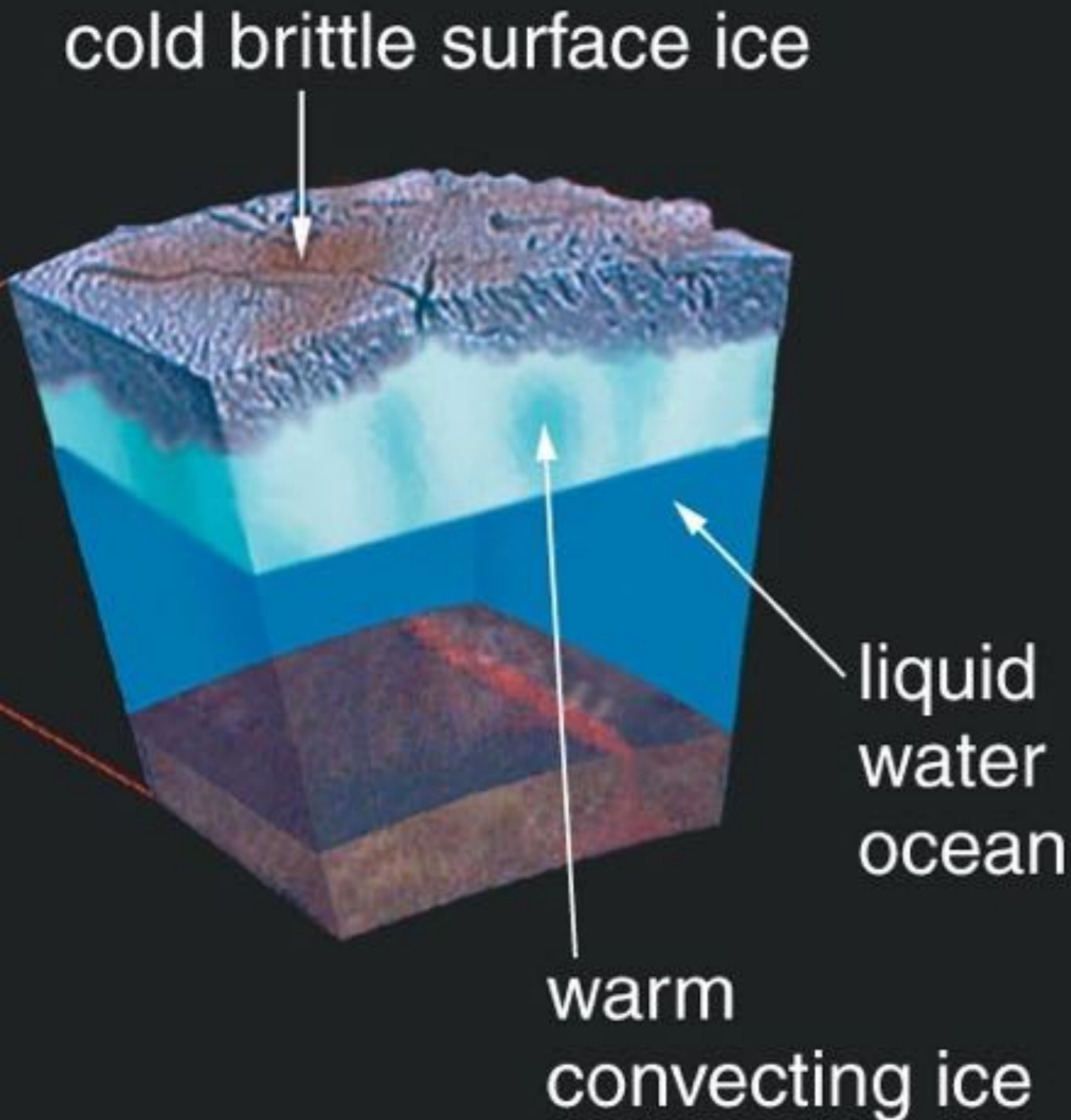
...and may melt ice here, collapsing the ridge center.

- **metallic core**
- **rocky mantle**
- **briny global ocean**
- **ice crust**

Sometimes long tidal cracks and ridges form, a bit like fault lines on the Earth

Energy source: tidal heating again important, just not as strong as on Io

Europa



- Icy surface
 - cracks driven by tidal heating (“geological” activity)
- Liquid ocean beneath
 - popular spot to speculate about the potential for life

2001: A Space Odyssey

made in 1968

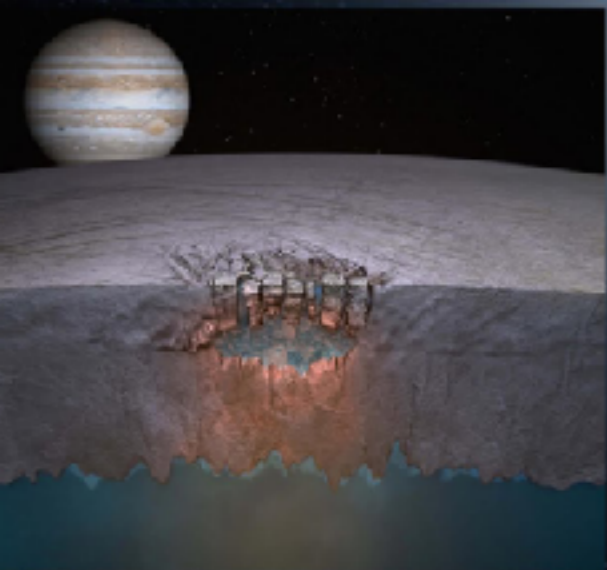


ALL THESE WORLDS
ARE YOURS EXCEPT
EUROPA
ATTEMPT NO
LANDING THERE

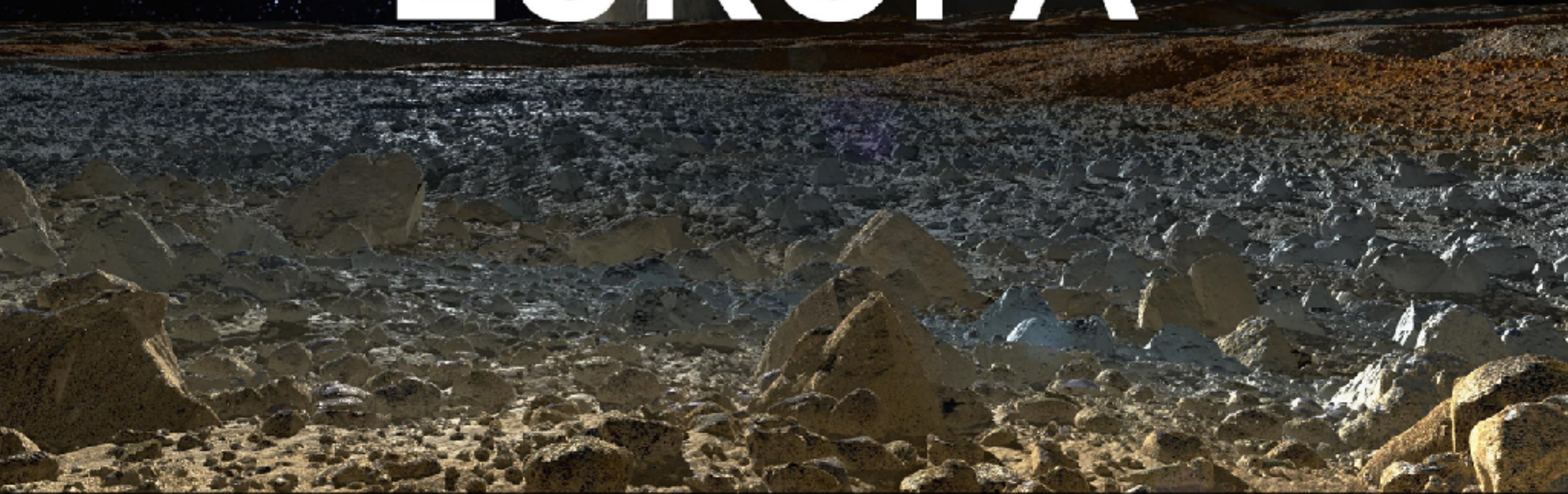


There are serious proposals to send a robotic submersible to Europa.

2001 warned against that because this thing will eat you. ♀



EUROPA



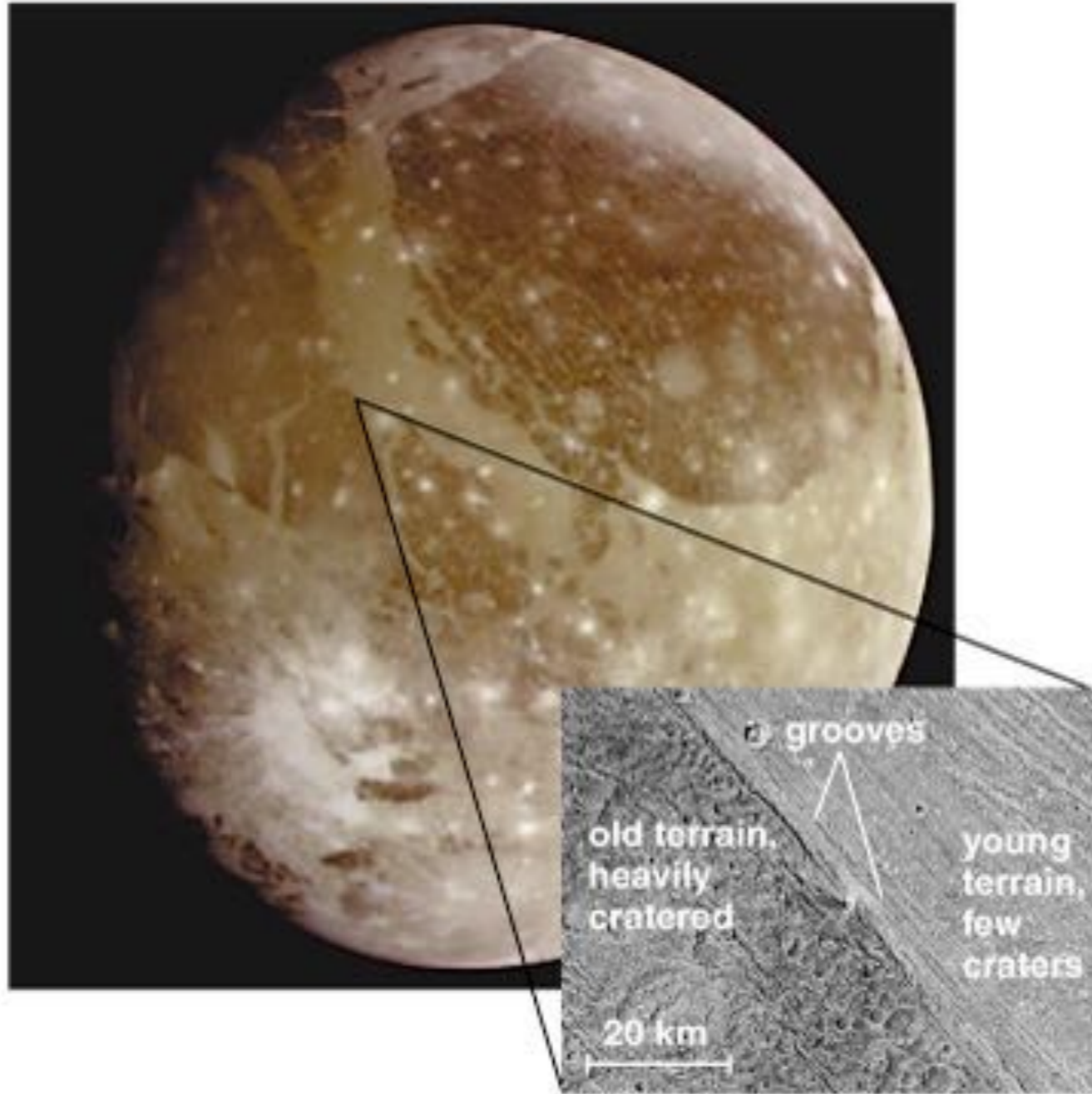
The moons of the Jupiter



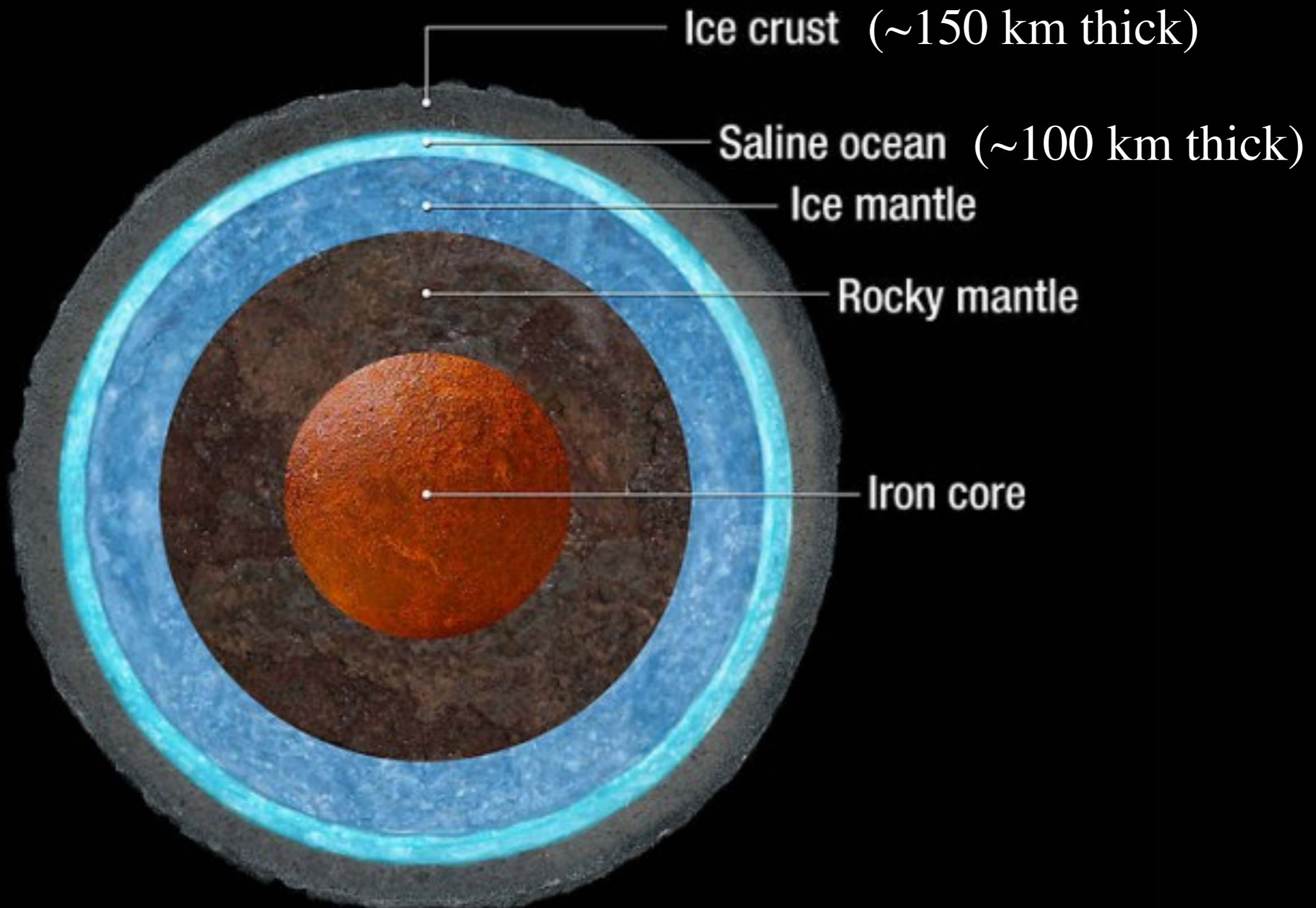
Ganymede

Ganymede

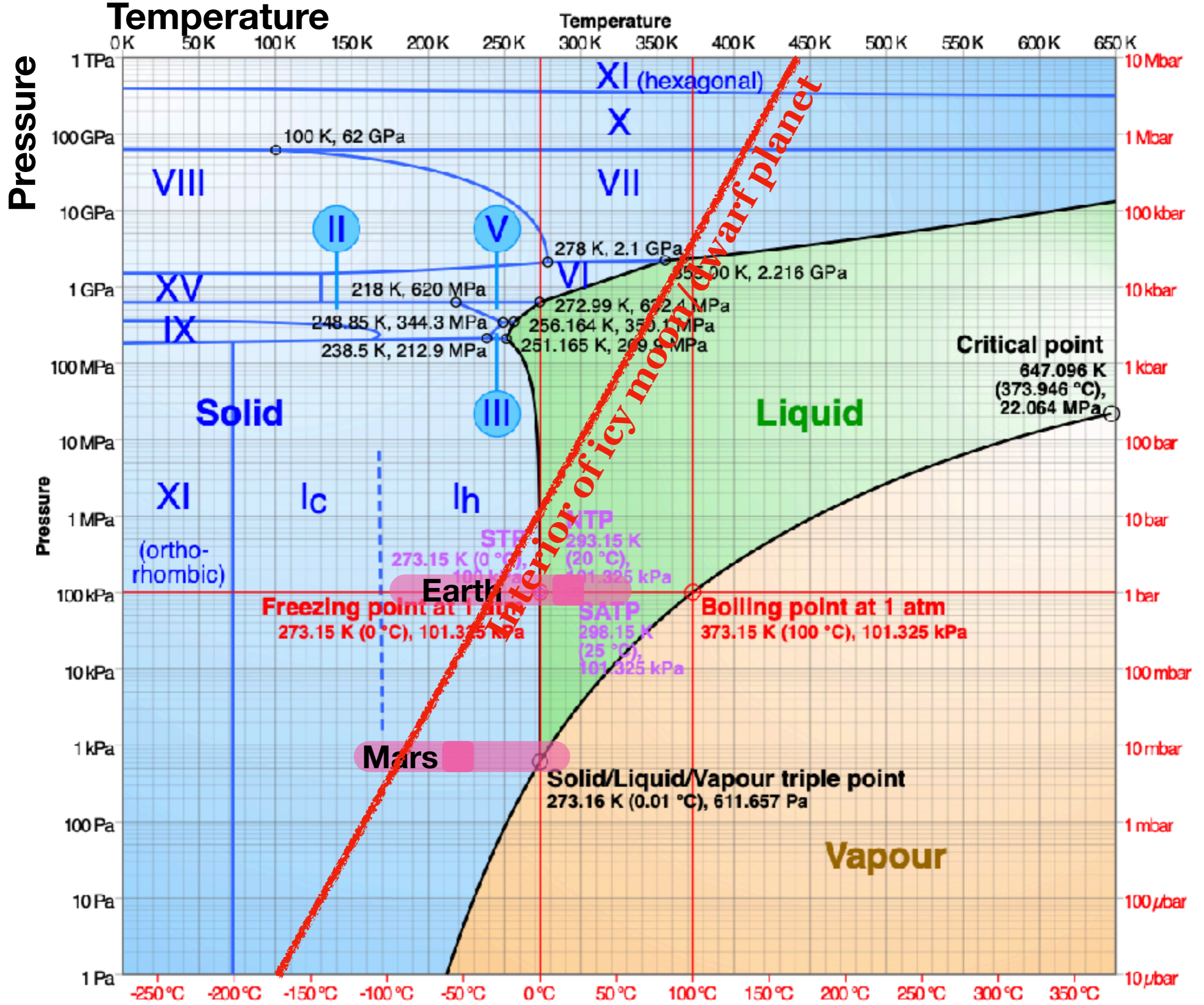
- Largest moon in the solar system
- Clear evidence of geological activity
- Salty ocean under thick crust of ice
- Tidal heating still important, but much less than on Io or Europa



Ganymede Interior



Phase diagram of water

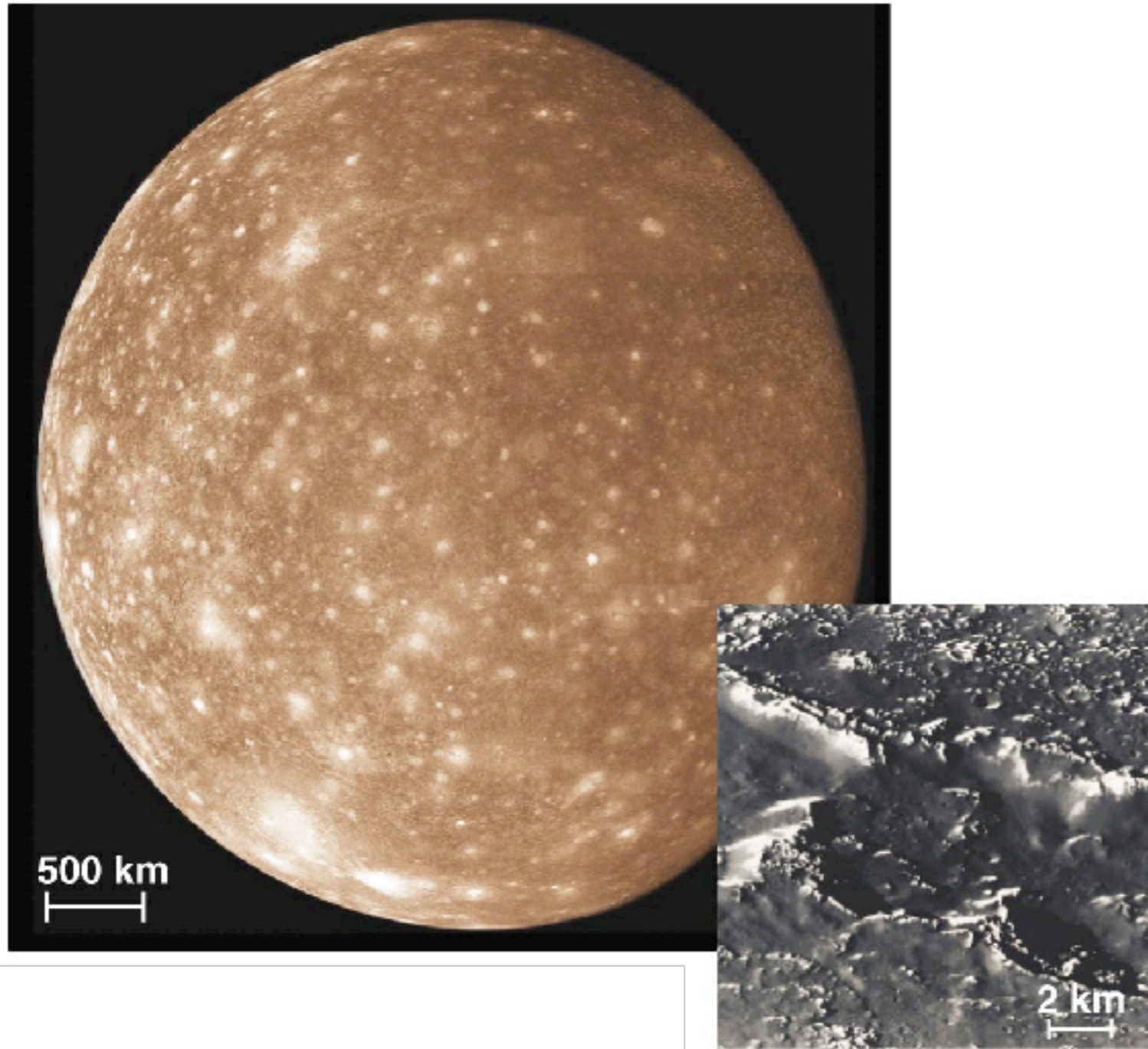


The moons of the Jupiter



Callisto

Callisto



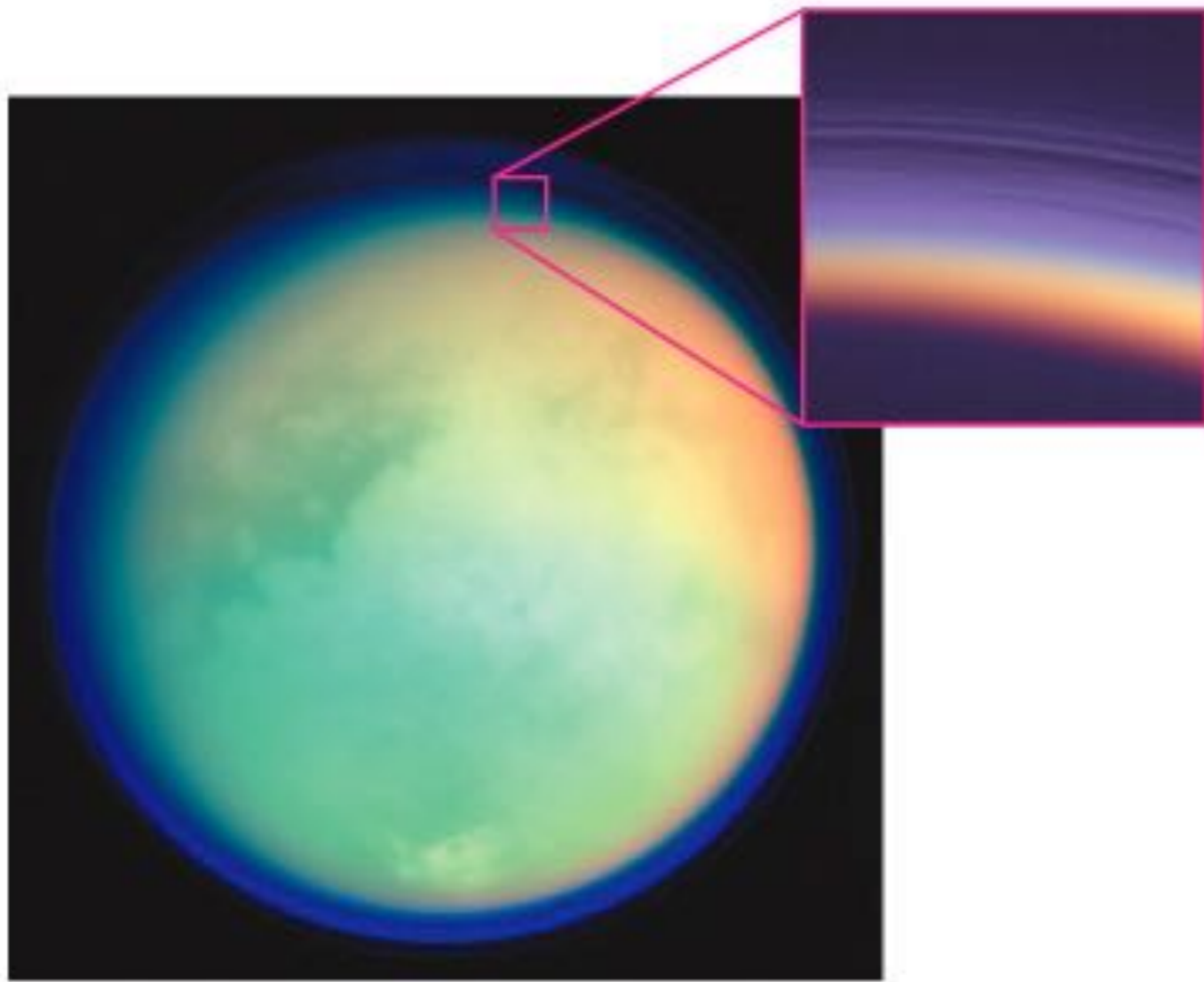
- "Classic" cratered iceball
 - very thick ice crust
- No orbital resonances
 - No tidal heating

Saturn's moons

- Saturn has one large moon - **Titan**
- a large number of medium-sized and small moons
- Rings composed of many tiny icy moonlets

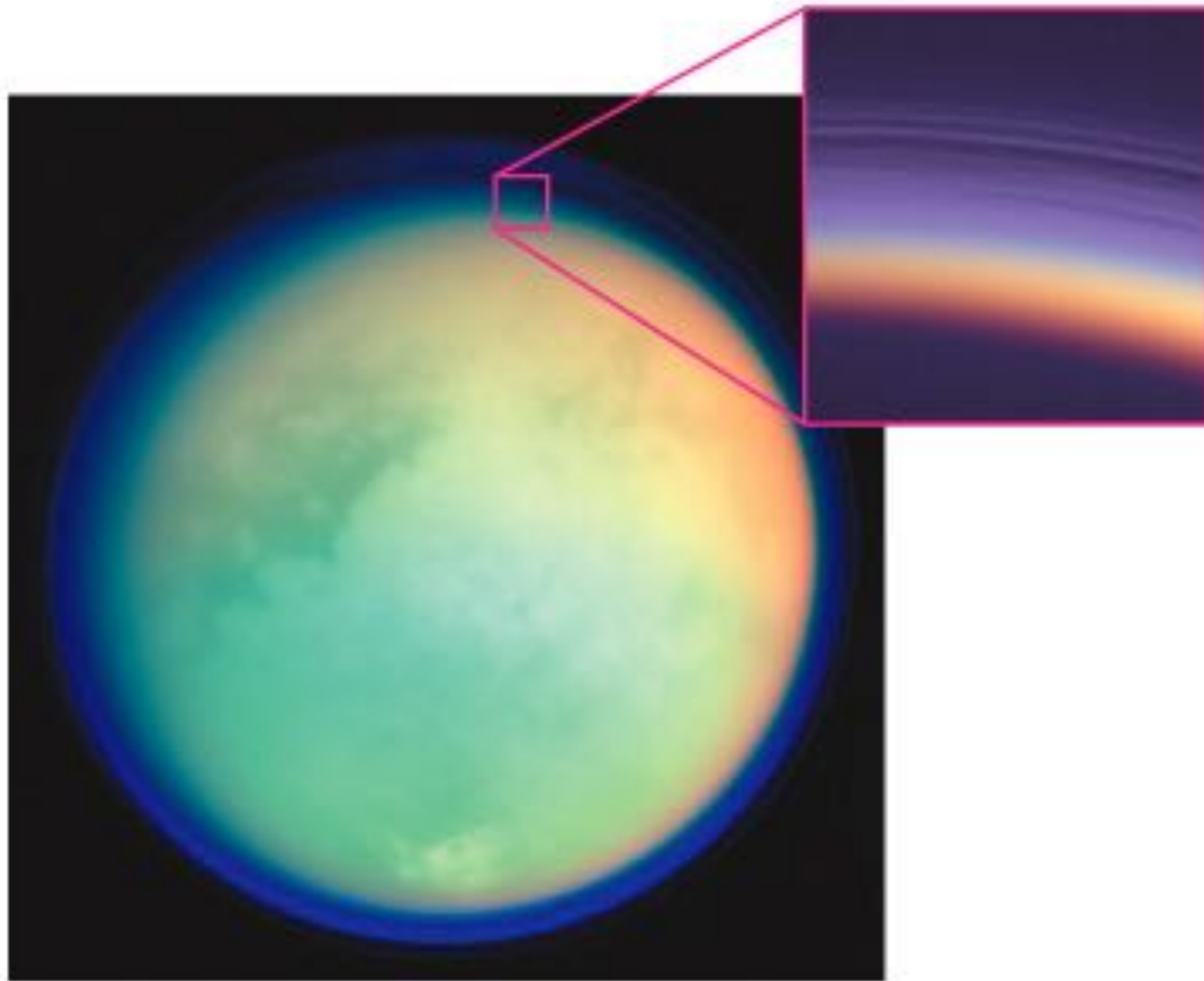


Saturn's large moon Titan



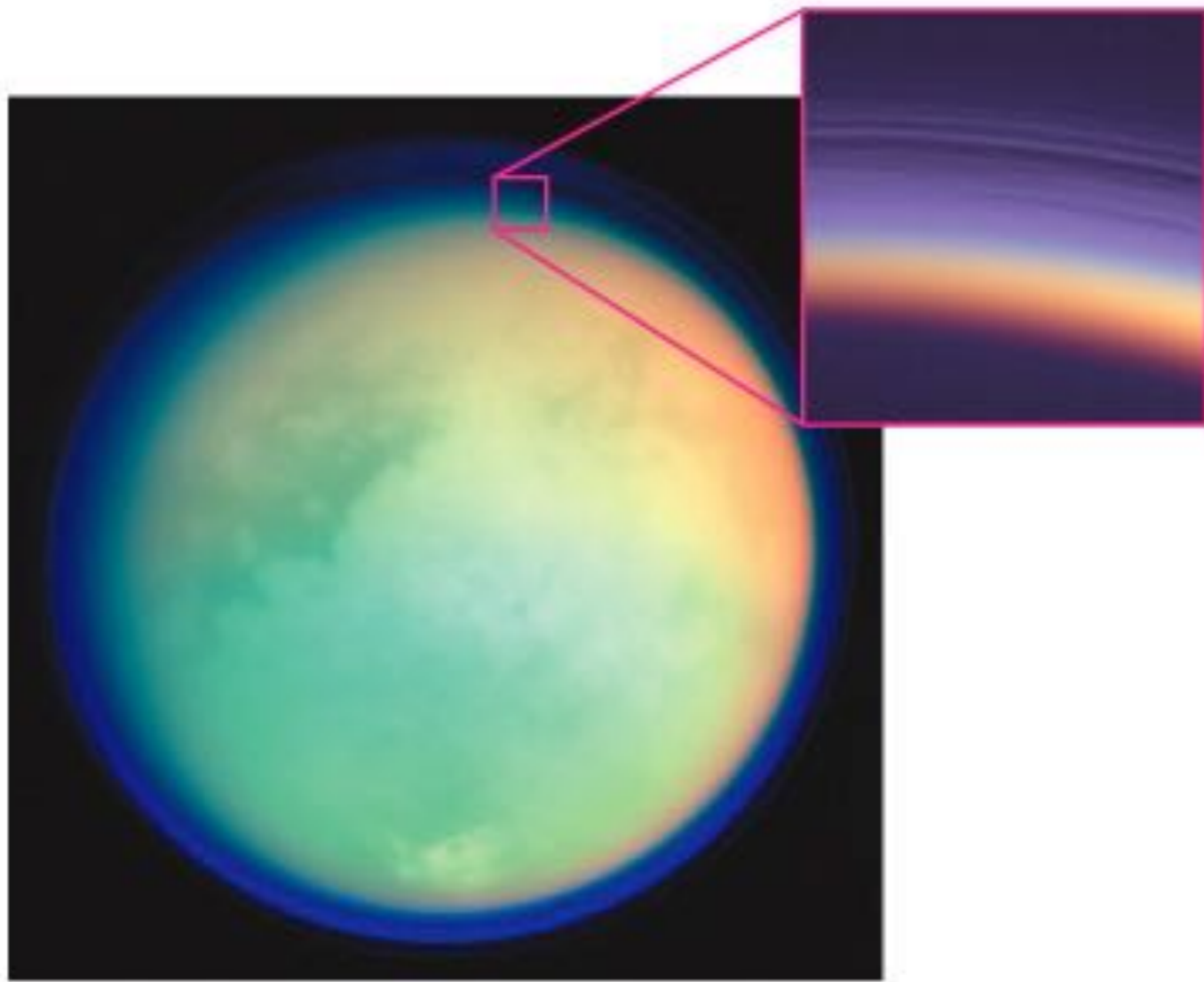
- Titan is the only moon in the solar system which has a thick atmosphere.
- It has a thick haze layer that obscures the surface at optical wavelengths.

Saturn's large moon Titan



- Atmospheric composition:
 - 90% N_2
 - 5% Argon
 - 5% CH_4 (methane)
 - other hydrocarbons
- Hazy

Saturn's large moon Titan

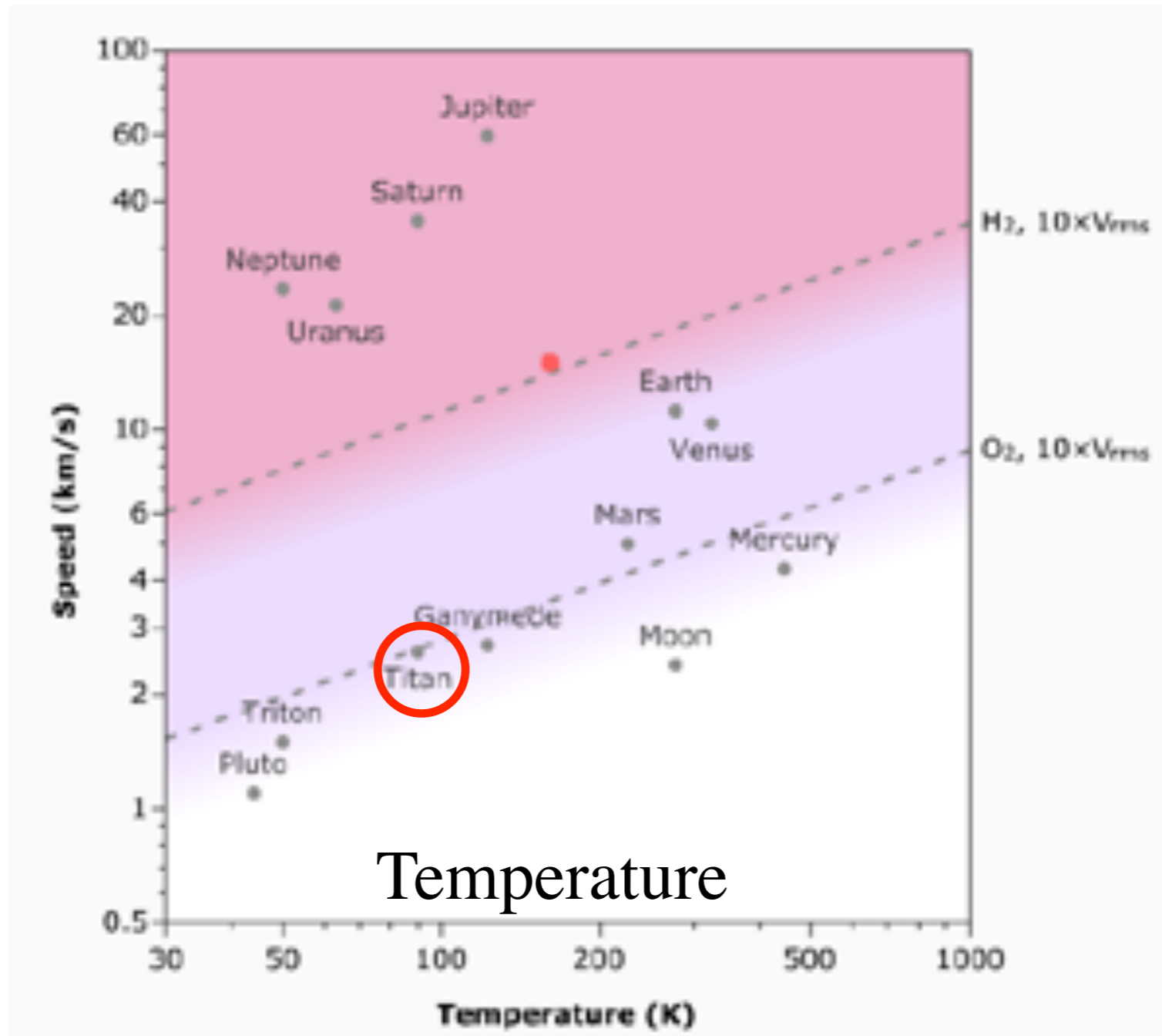


- Relative to Earth:
 - 1.5 Atm pressure
 - 4x denser
 - comparable total mass (1.2x)
 - more extended
 - due to lower gravity
- Cold
 - -180°C

Titan is

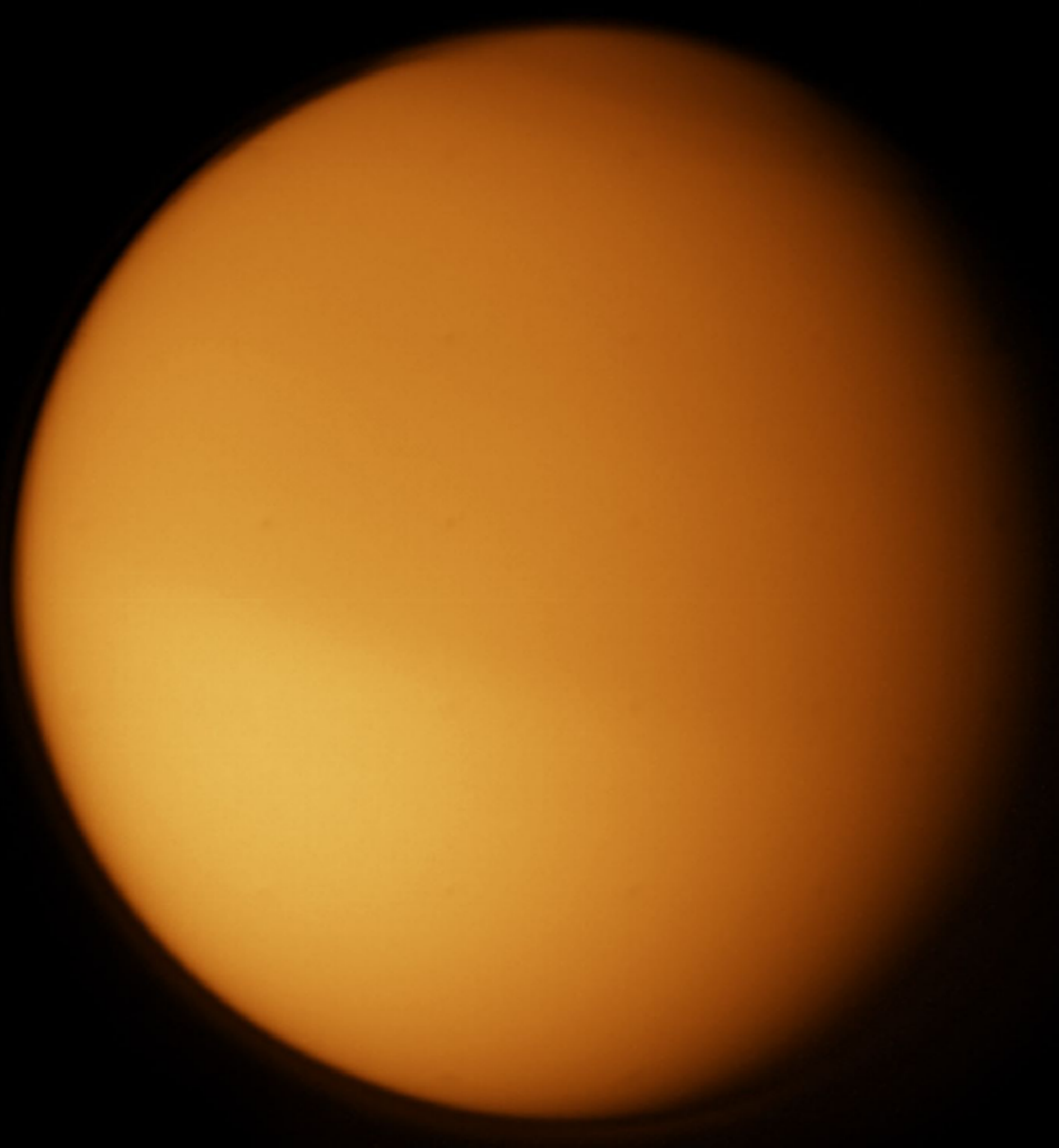
- Big for a moon, and
- cold - can retain an atmosphere

Escape Speed

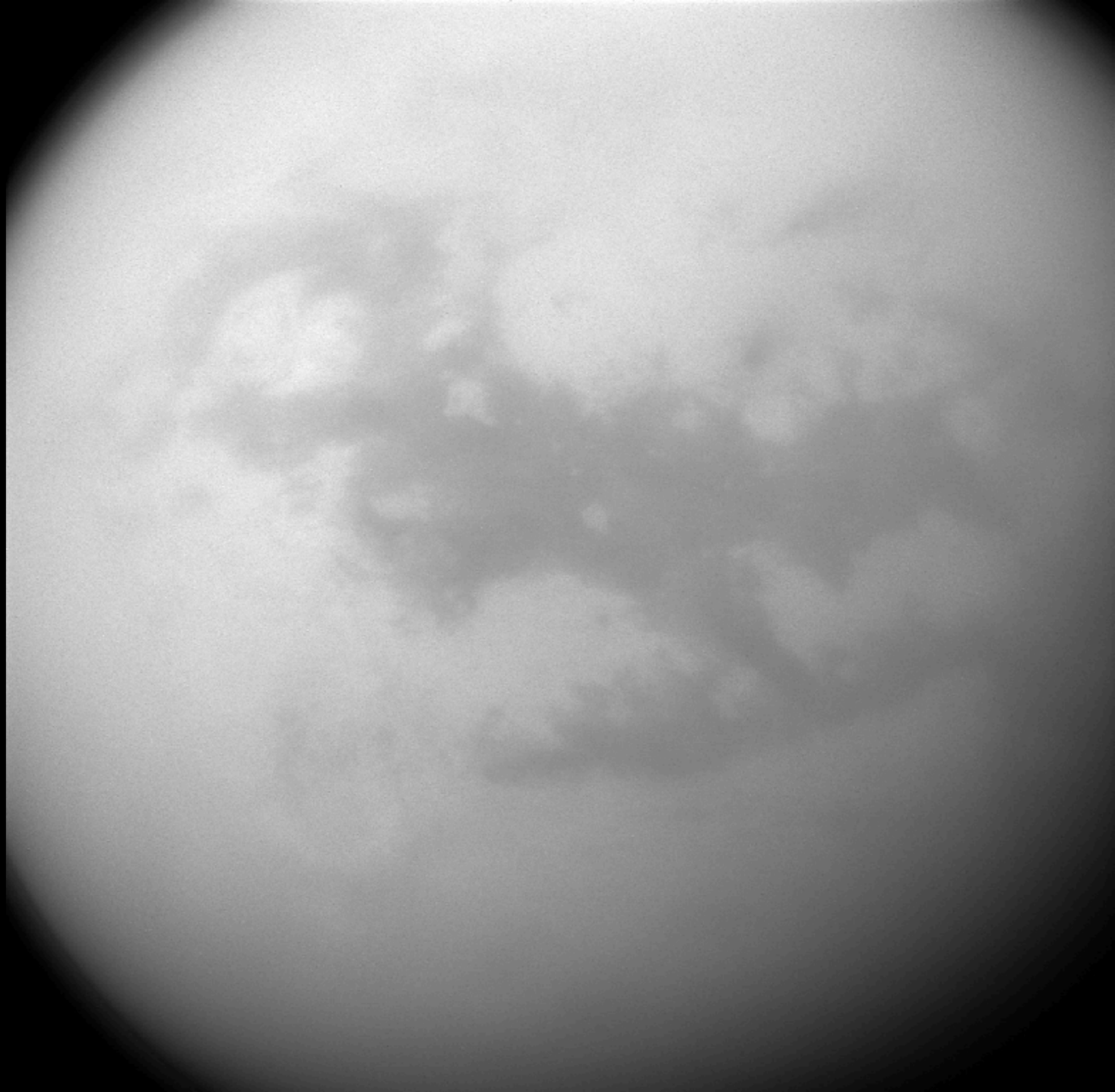


Temperature

atmospheric haze
in optical light

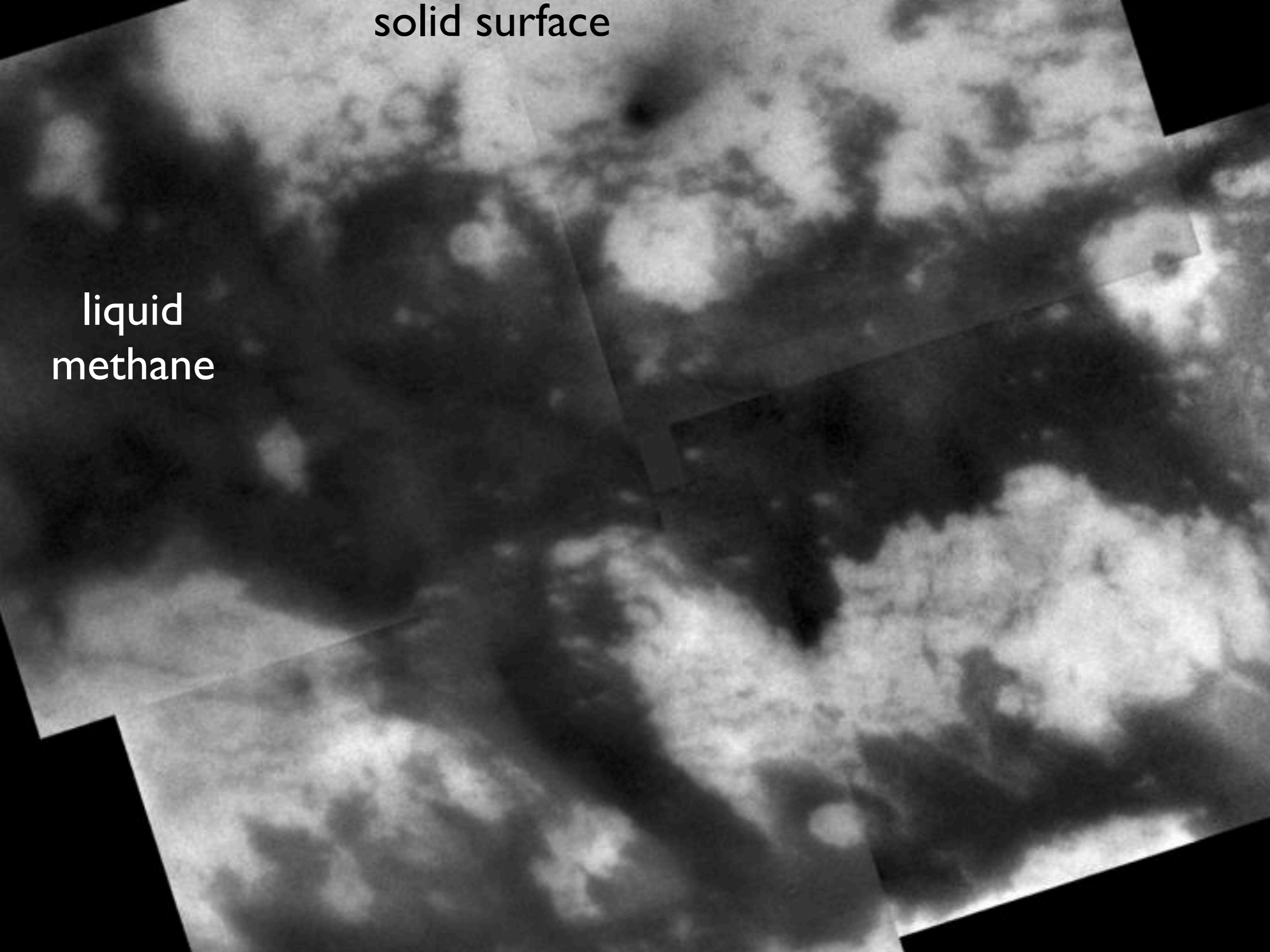


Underneath the
atmosphere is
terrain, including
seas of liquid
hydrocarbons

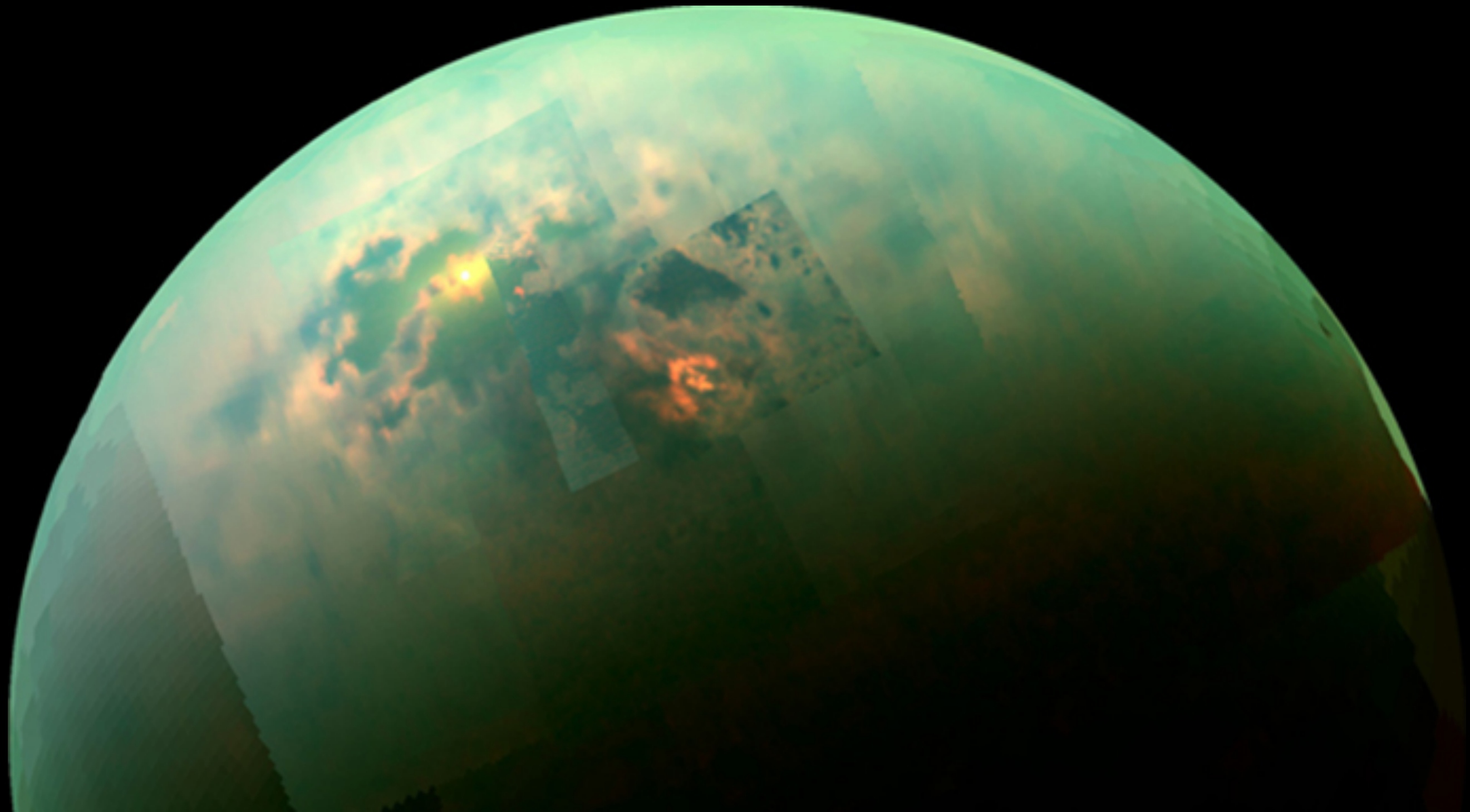


solid surface

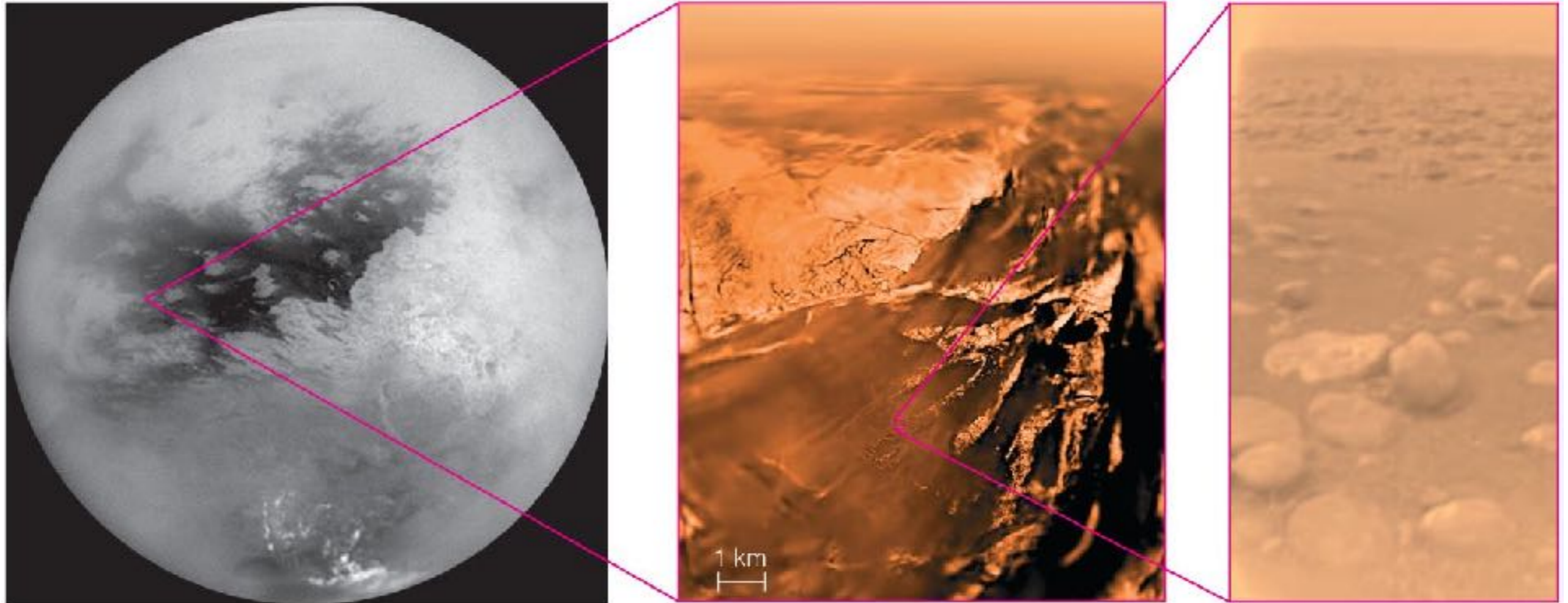
liquid
methane



Some transparent windows in the infrared.
Reveals widespread lakes of liquid methane.
Weather on Titan involves methane clouds and rain.



Titan's Surface



- The *Huygens* probe provided a first look at Titan's surface in early 2005.
- It had liquid methane, “rocks” made of ice.
Huygens descent movie

<https://www.youtube.com/watch?v=YErUVO0FSS8>

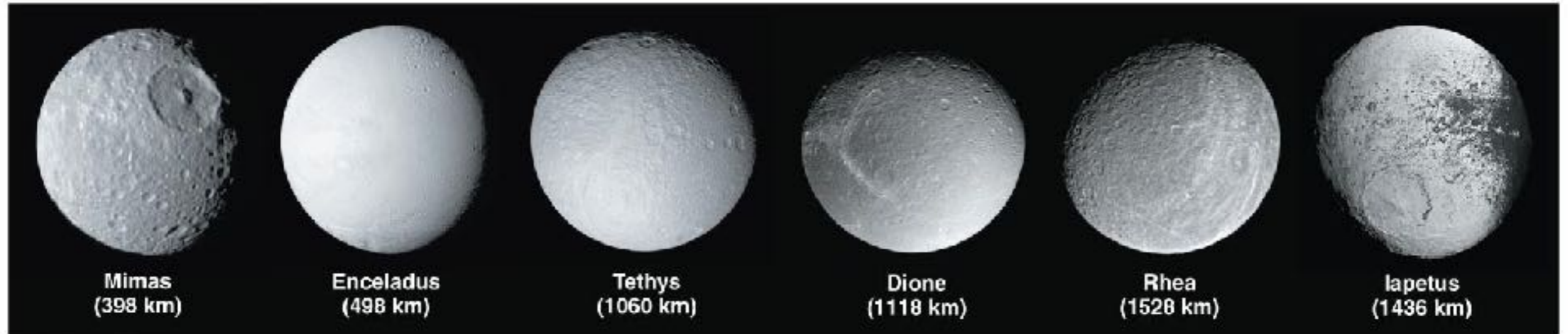
NASA
“Visions of the
Future”
poster series
- free for download



TITAN

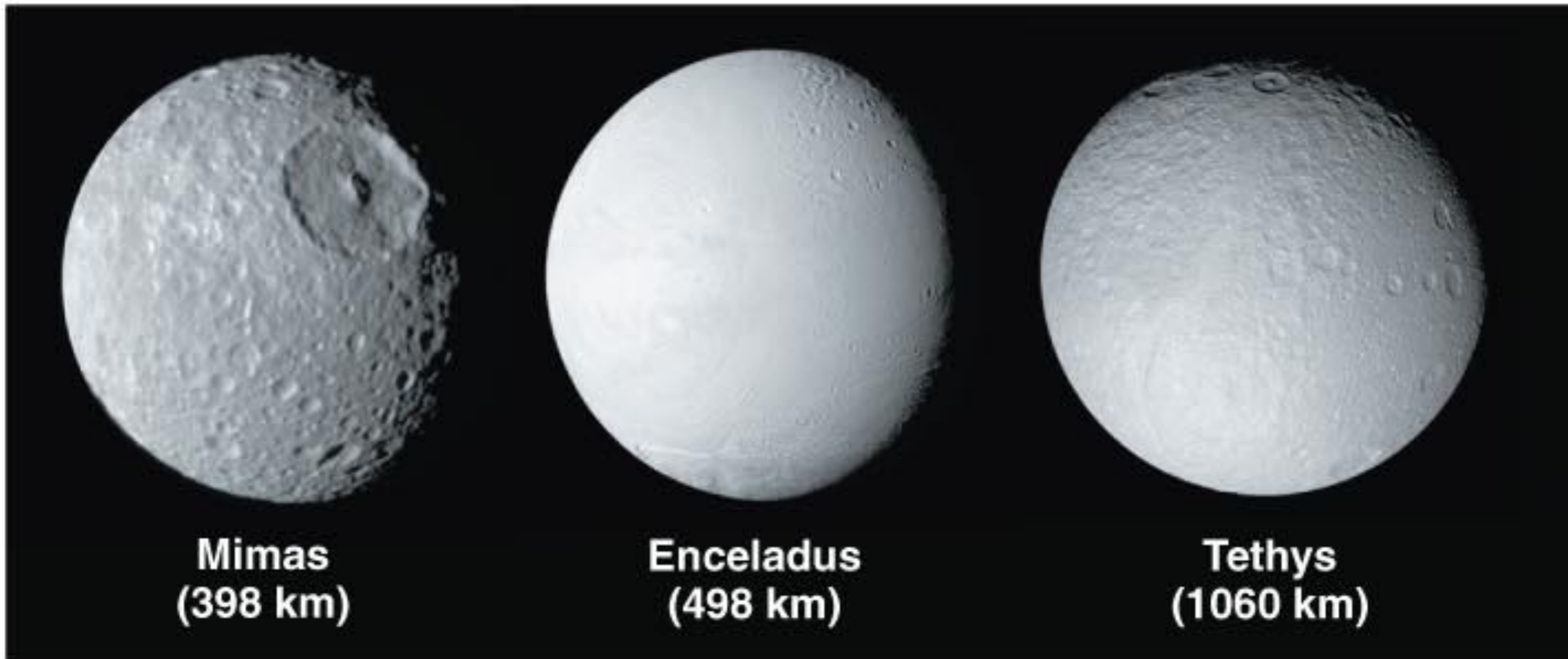
RIDE THE TIDES THROUGH THE THROAT OF KRAKEN

Medium Sized Moons of Saturn



- Almost all of them show evidence of past volcanism and/or tectonics.

Medium Moons of Saturn



Mimas
(398 km)

Enceladus
(498 km)

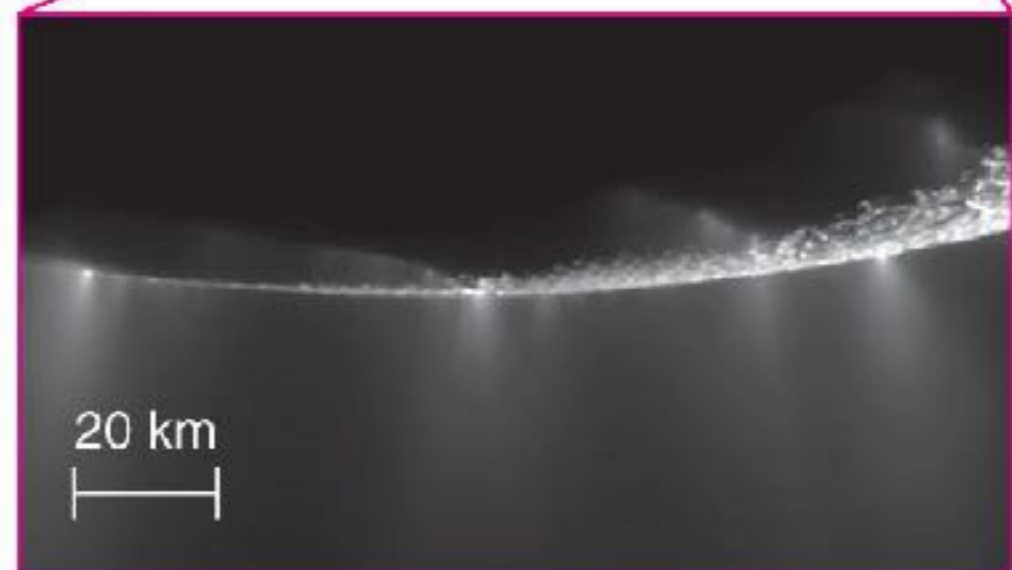
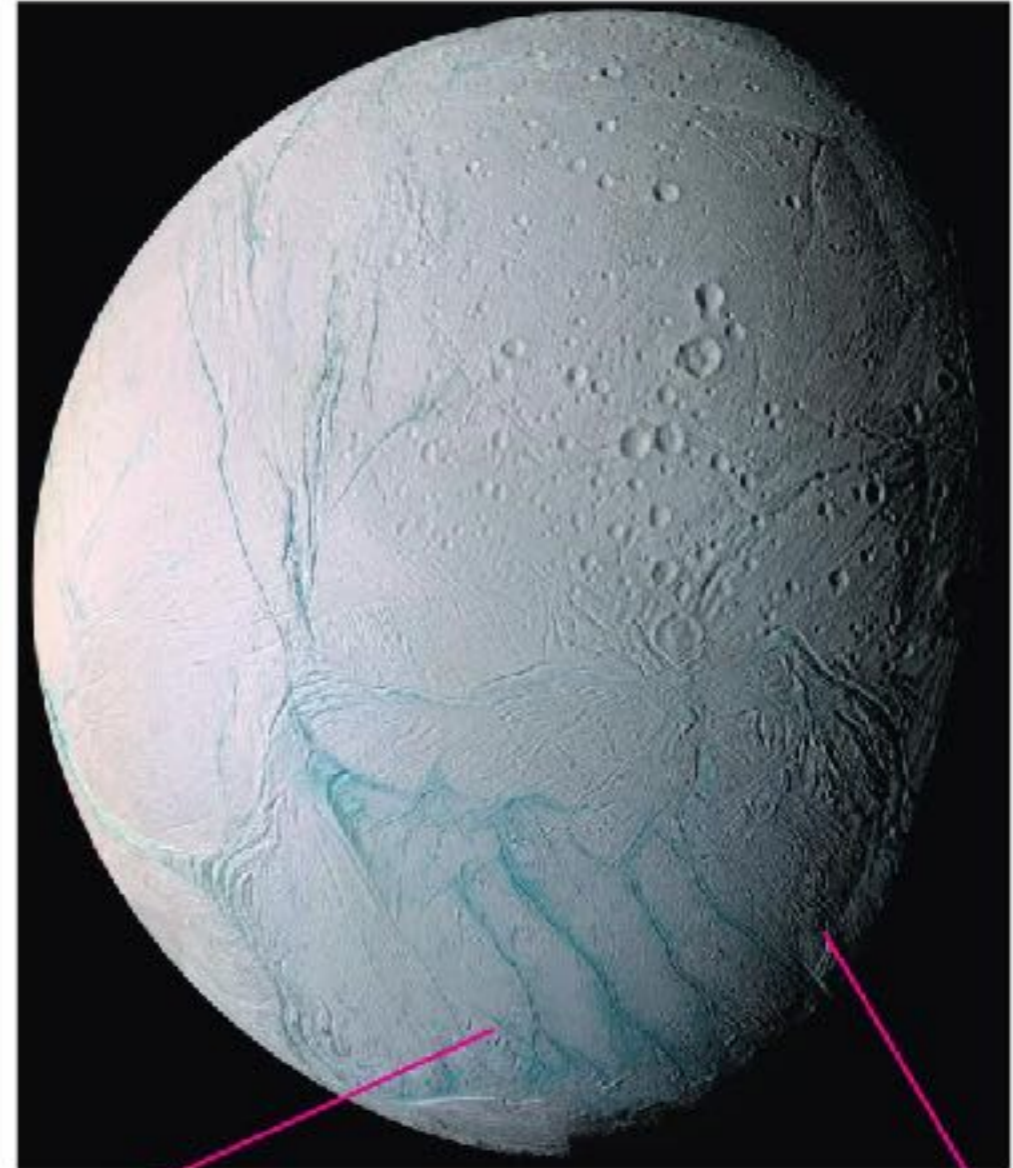
Tethys
(1060 km)

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- Mimas has a big crater that makes it look like the Death Star.

Medium Moons of Saturn

- Ice fountains of Enceladus suggest it has a subsurface ocean.
- “Cryovolcanism” - the “magma” is water.



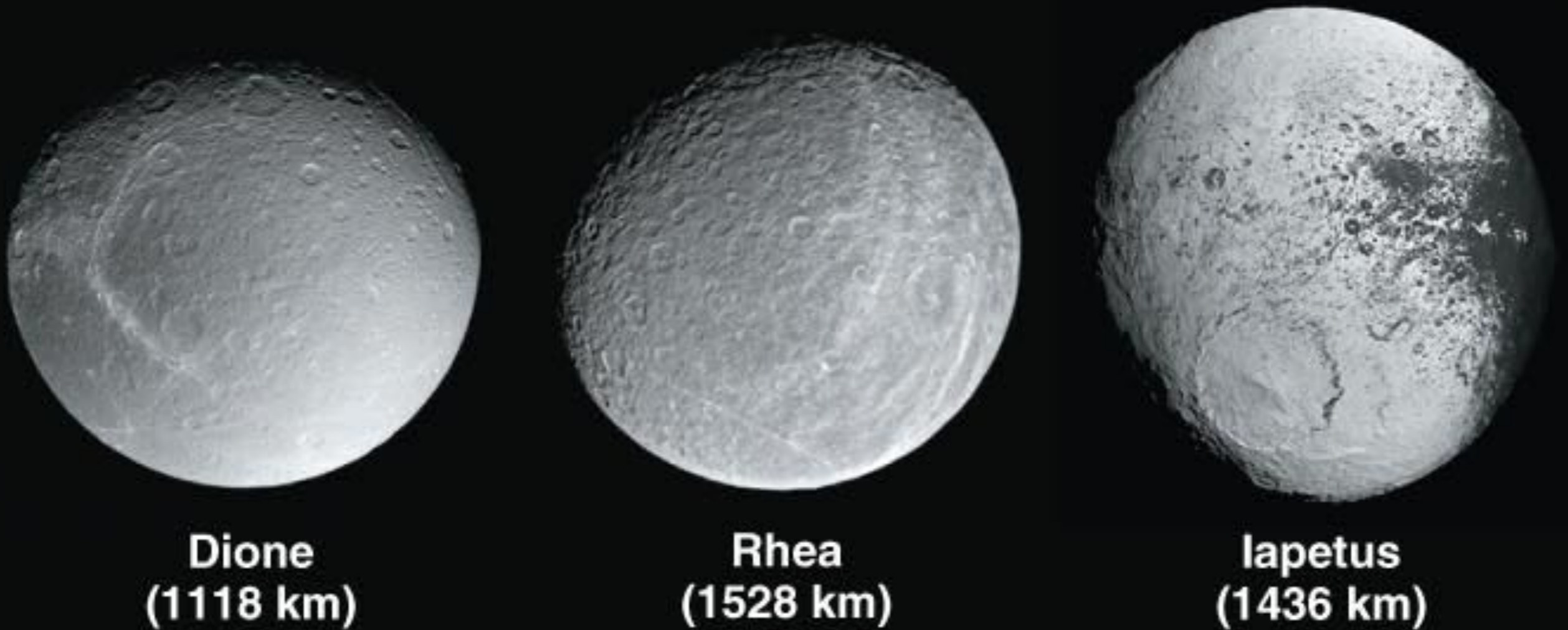
NASA
“Visions of the
Future”
poster series

Apparently NASA
artists think you’ll
need a cane.

In zero g.



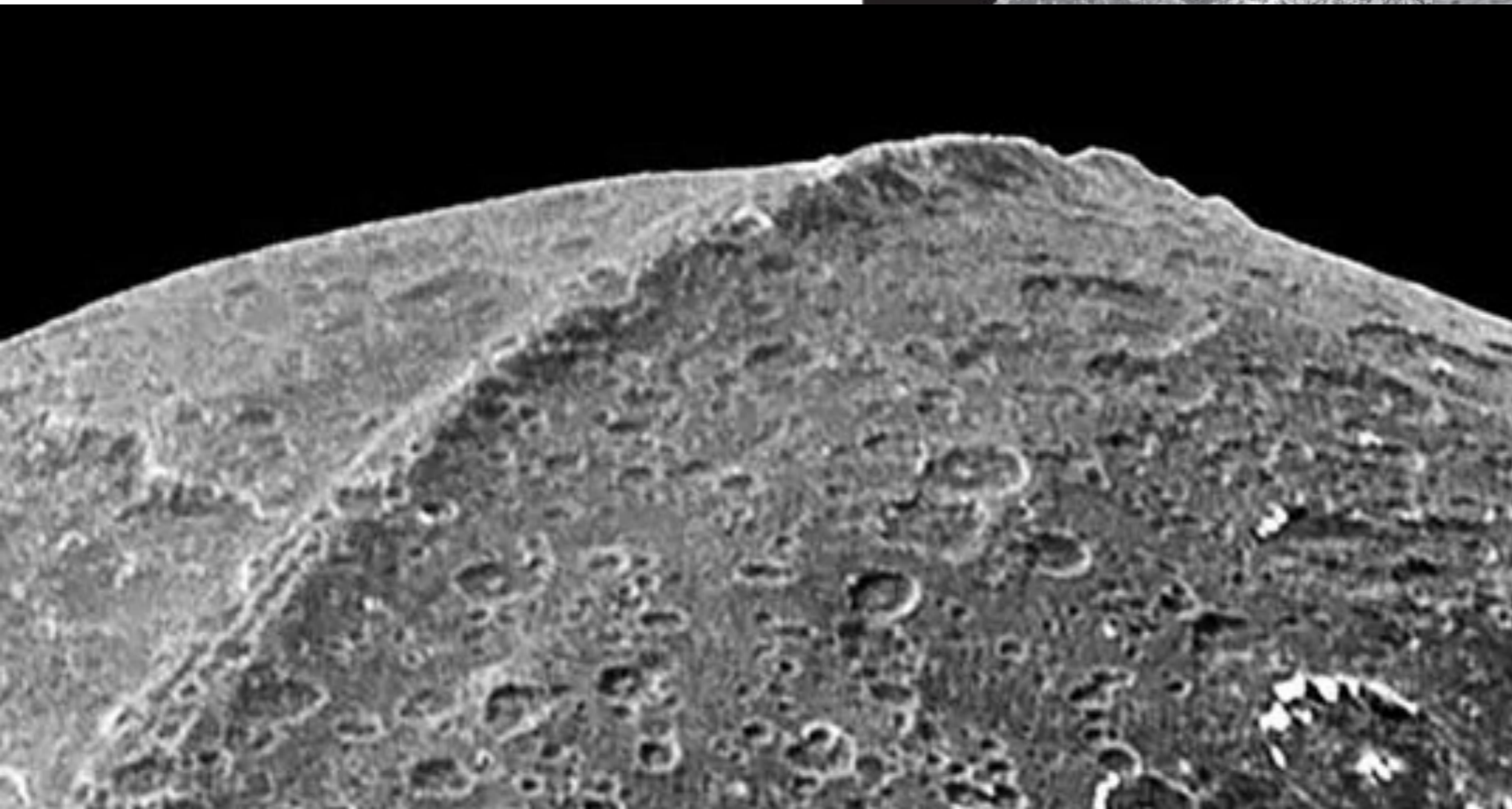
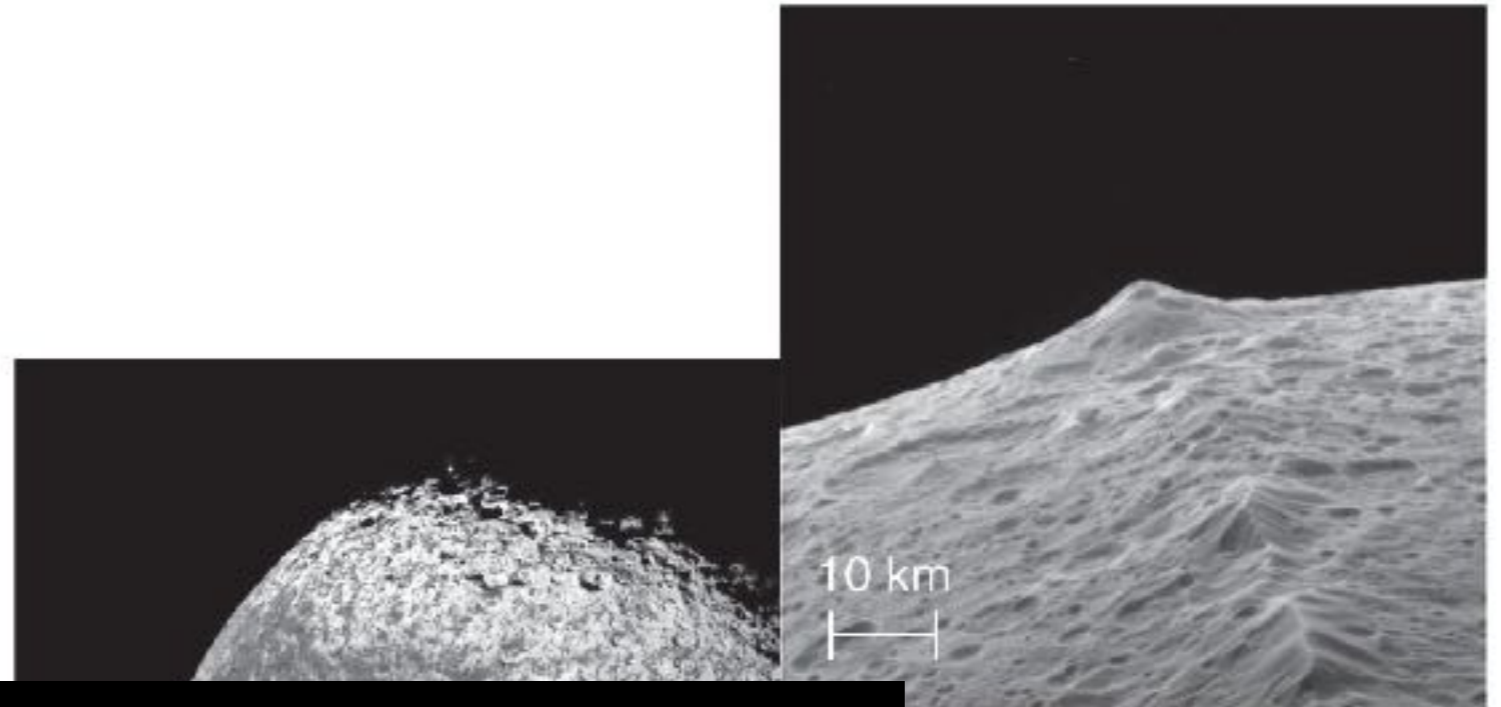
Medium Moons of Saturn



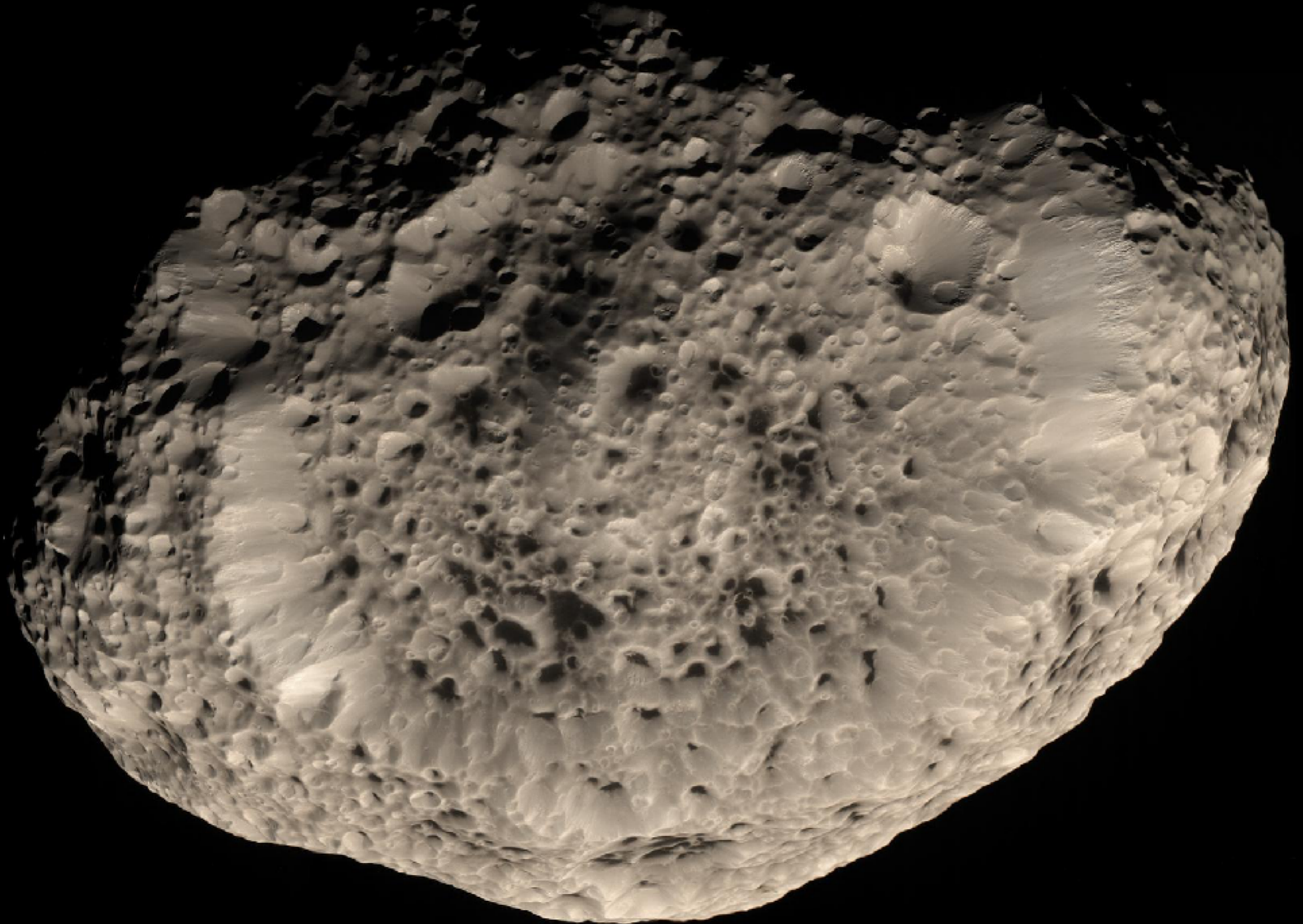
- Iapetus is dark on one side & bright on the other. It seems to have collected a goo of space debris emitted by Phoebe on the leading (dark) side of its orbit.

Medium Moons of Saturn

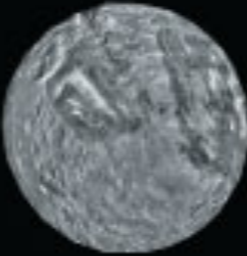
- Iapetus has a curious ridge around much of its equator



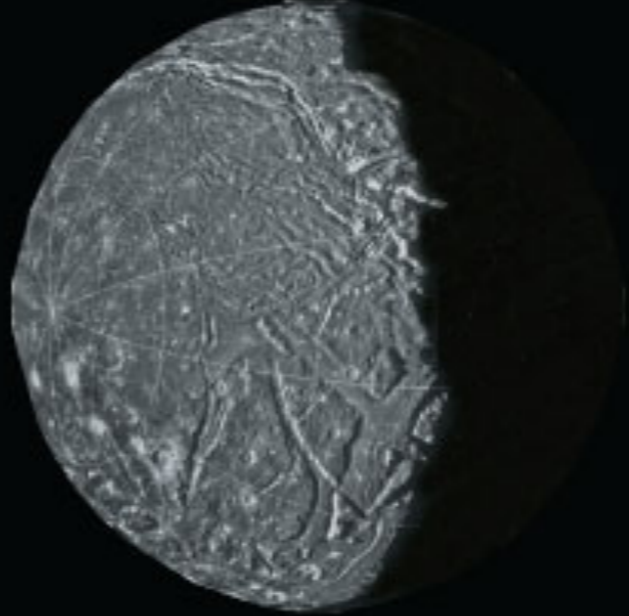
Small moons can also be weird. Hyperion looks like a sponge.



Moons of Uranus



Miranda



Ariel



Umbriel



Oberon



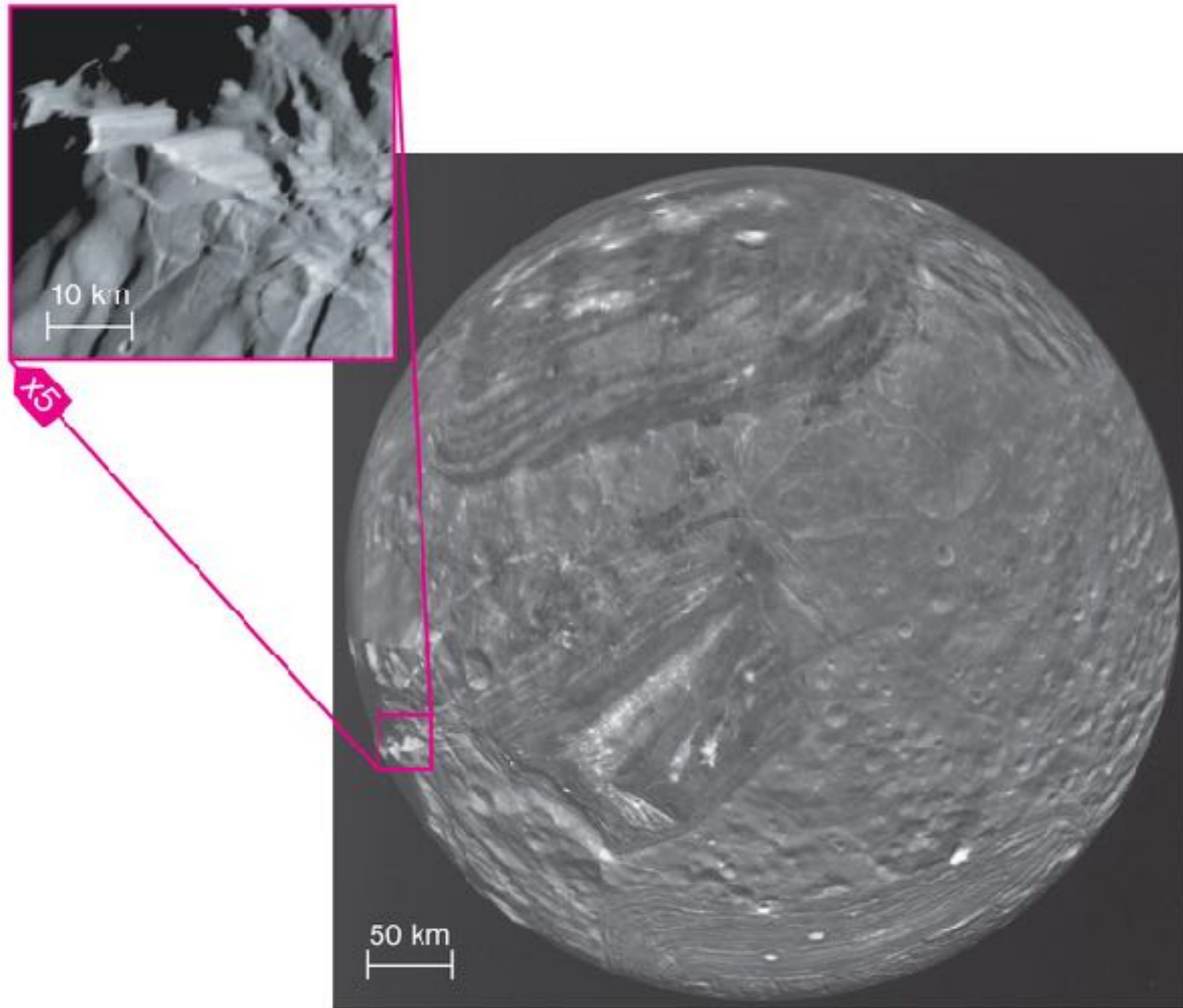
Earth's Moon



Titania

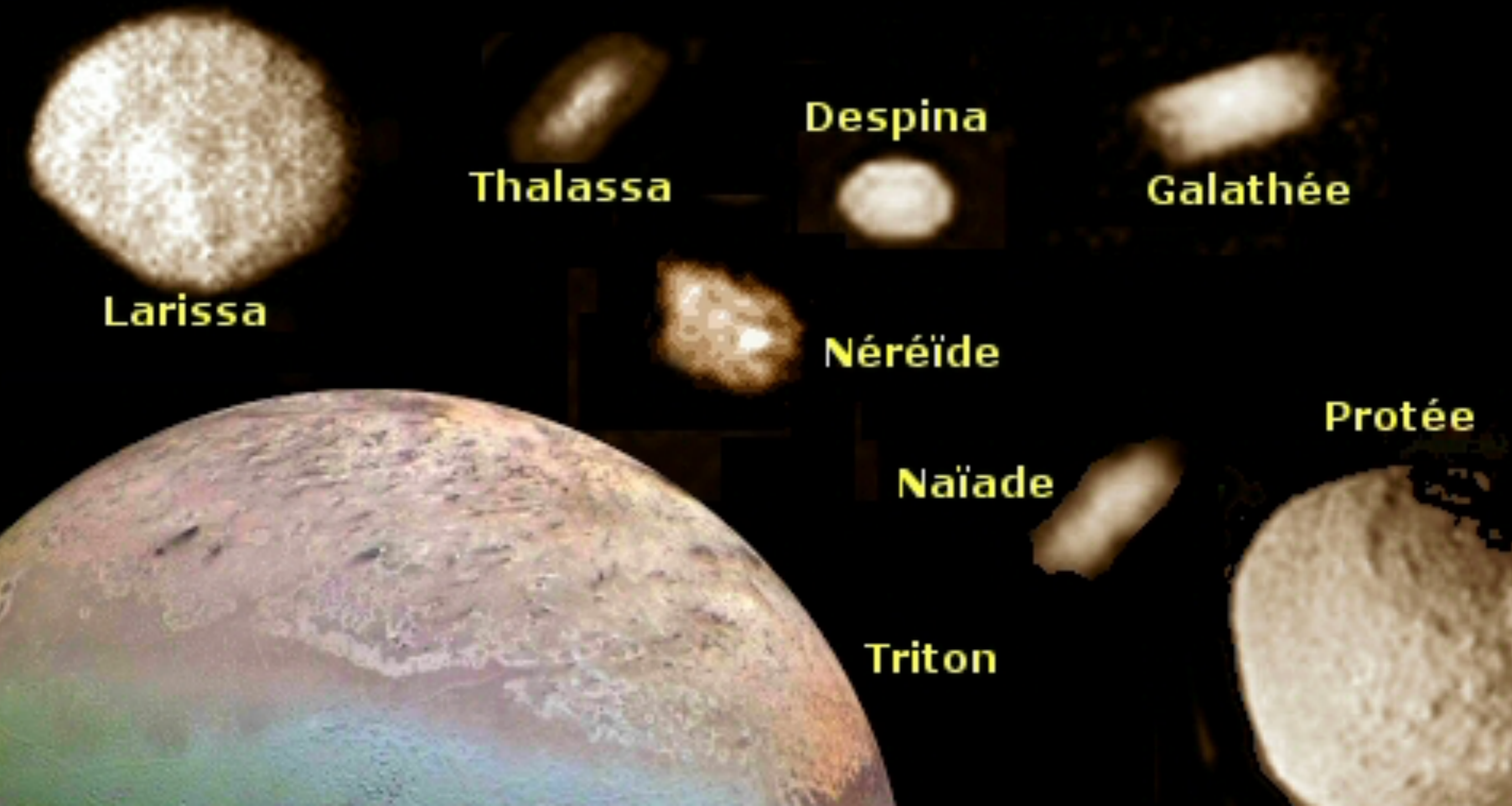


Medium Moons of Uranus

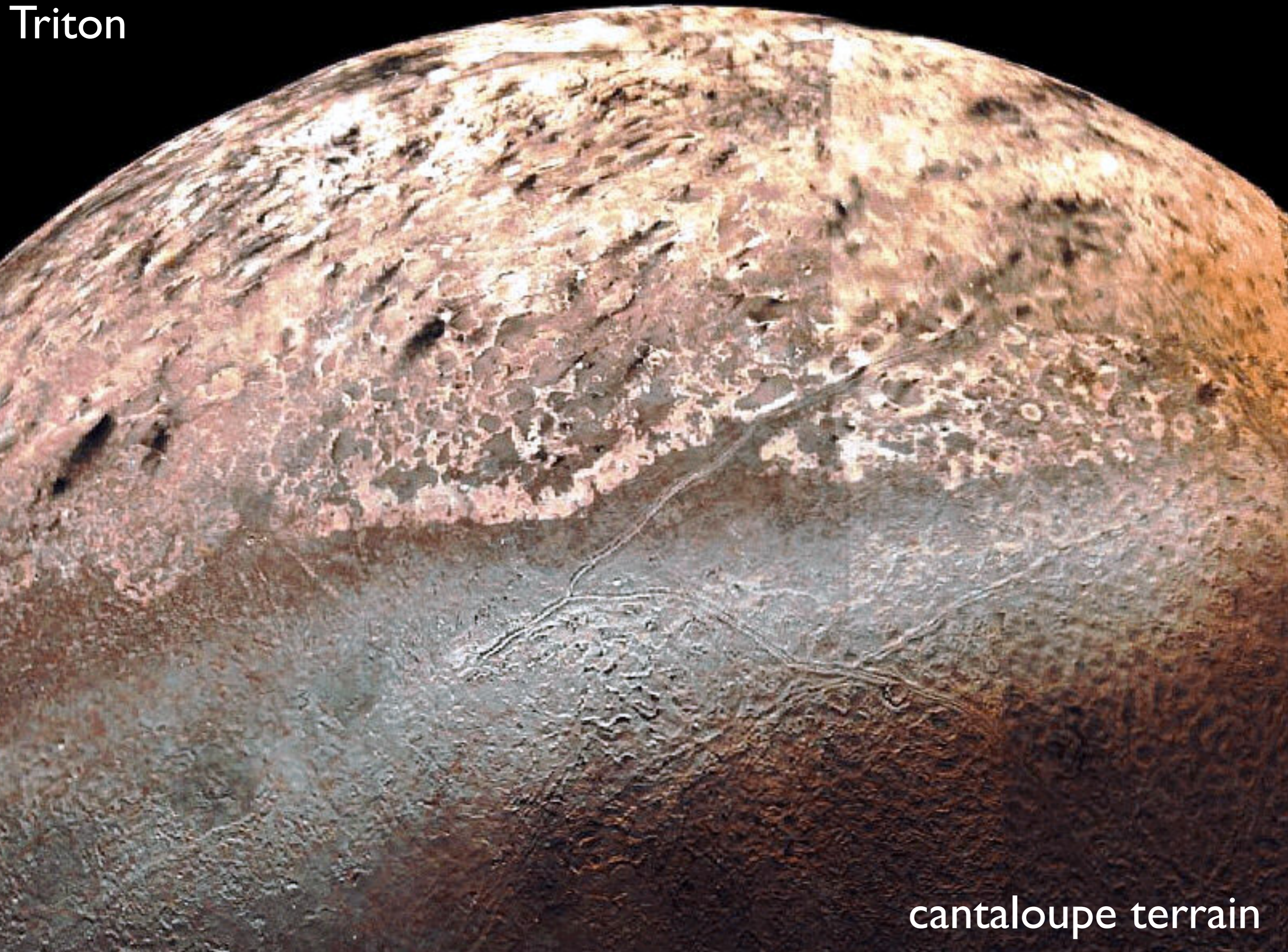


- They have varying amounts of geological activity.
- Miranda has large tectonic features and few craters (possibly indicating an episode of tidal heating in past).
- Frankenstein's moon

Moons of Neptune



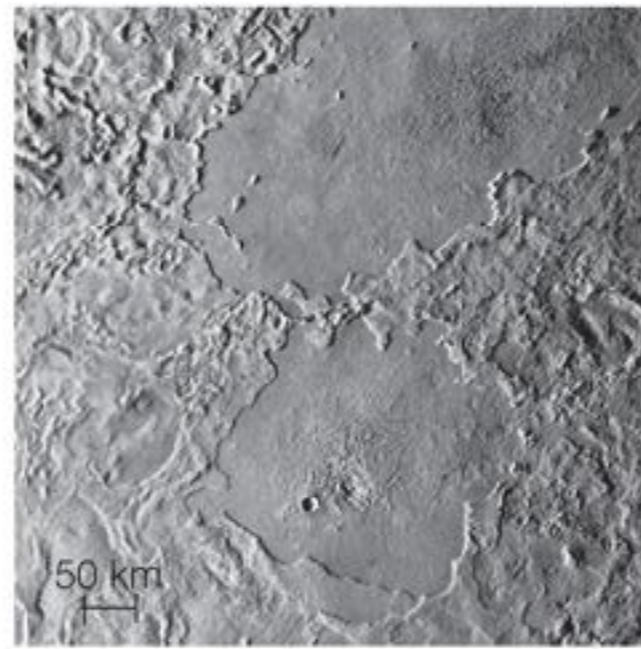
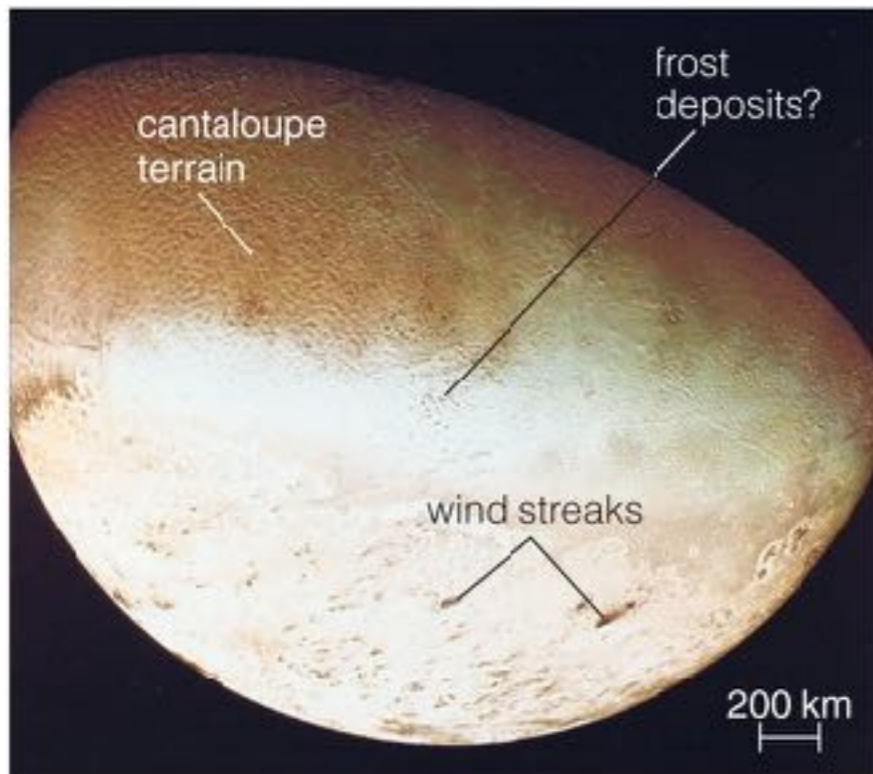
Triton



cantaloupe terrain

Neptune's Moon Triton

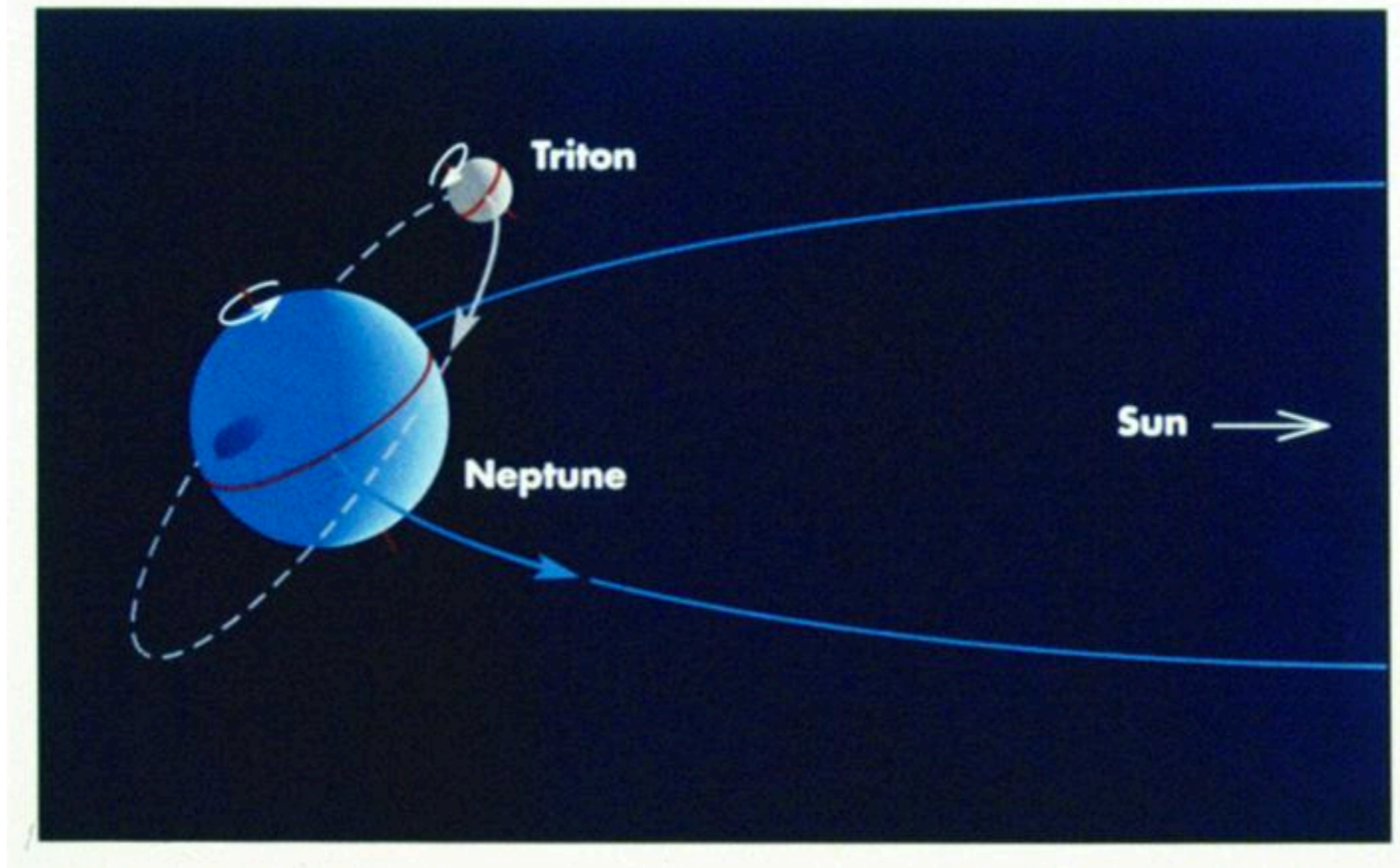
- larger than Pluto!
- Evidence for past geological activity
- orbits retrograde
 - unique for such a large moon
 - may have been a binary partner of Pluto captured by Neptune



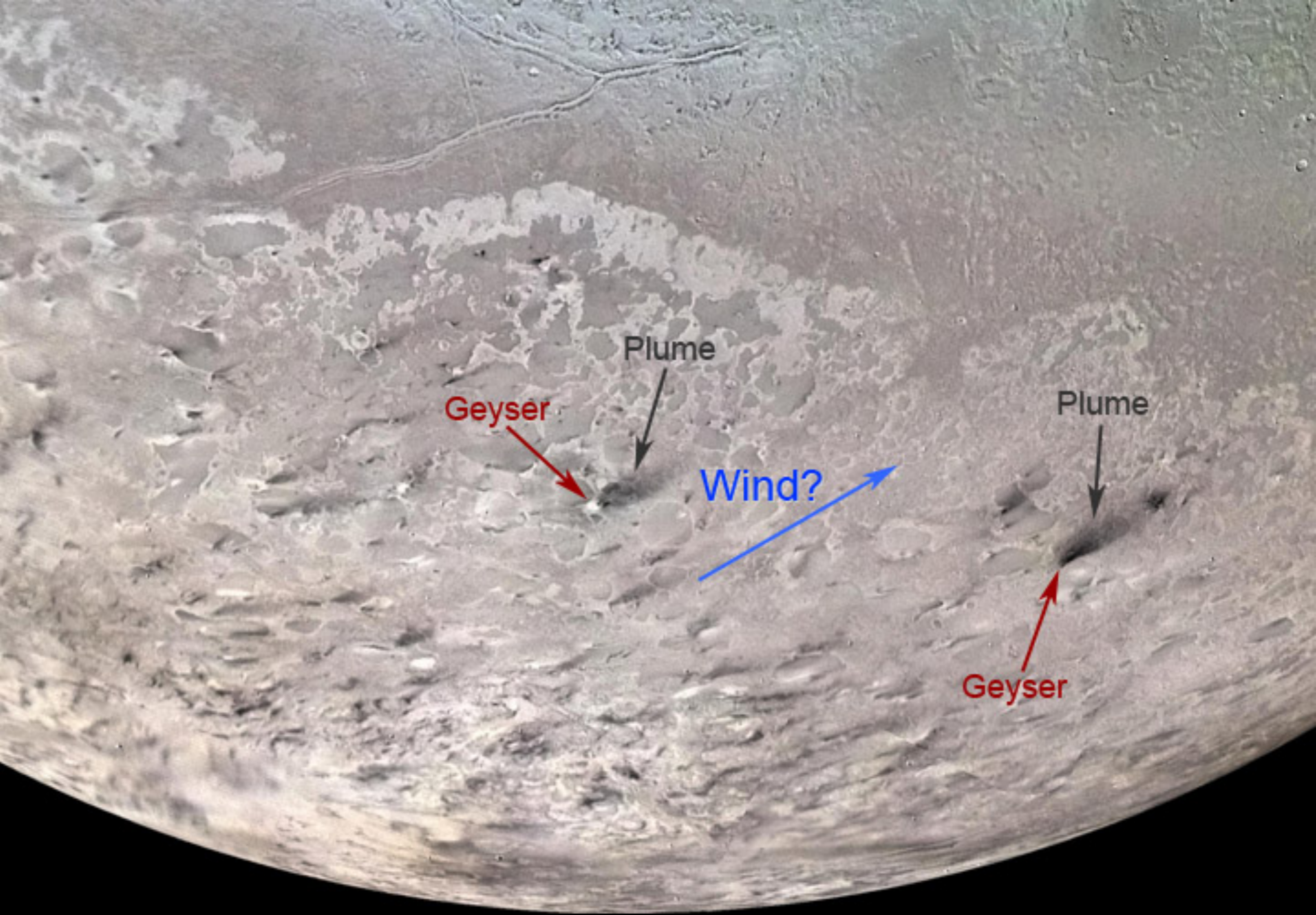
This close-up shows lava-filled impact basins similar to the lunar maria, but the lava was water or slush rather than molten rock.

Triton's southern hemisphere as seen by *Voyager 2*.

The occasional geyser, heated by sunlight, streaks the downwind terrain with dark material

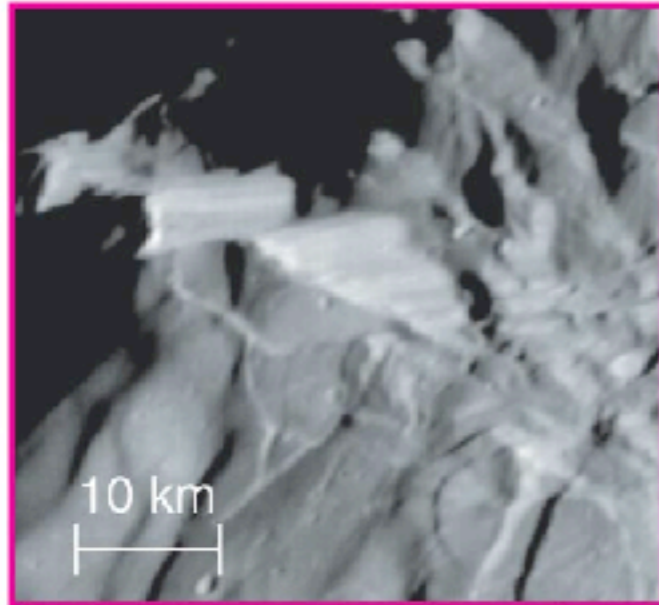


- tidally locked, like Earth's moon
- orbit is retrograde
- and highly inclined (40 degrees)
 - not stable - being pulled *in* by tides
 - will eventually make rings!

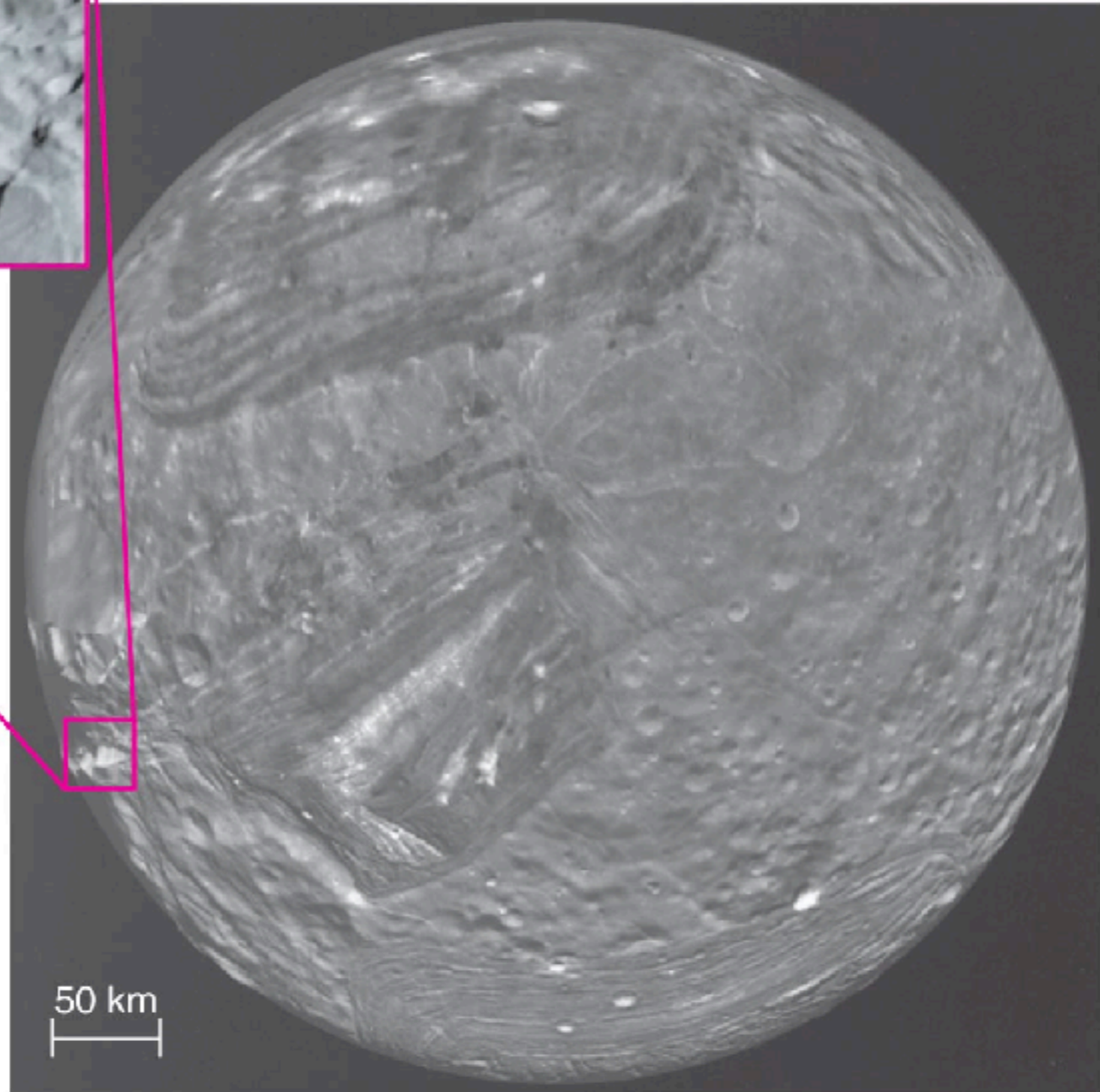


geysers

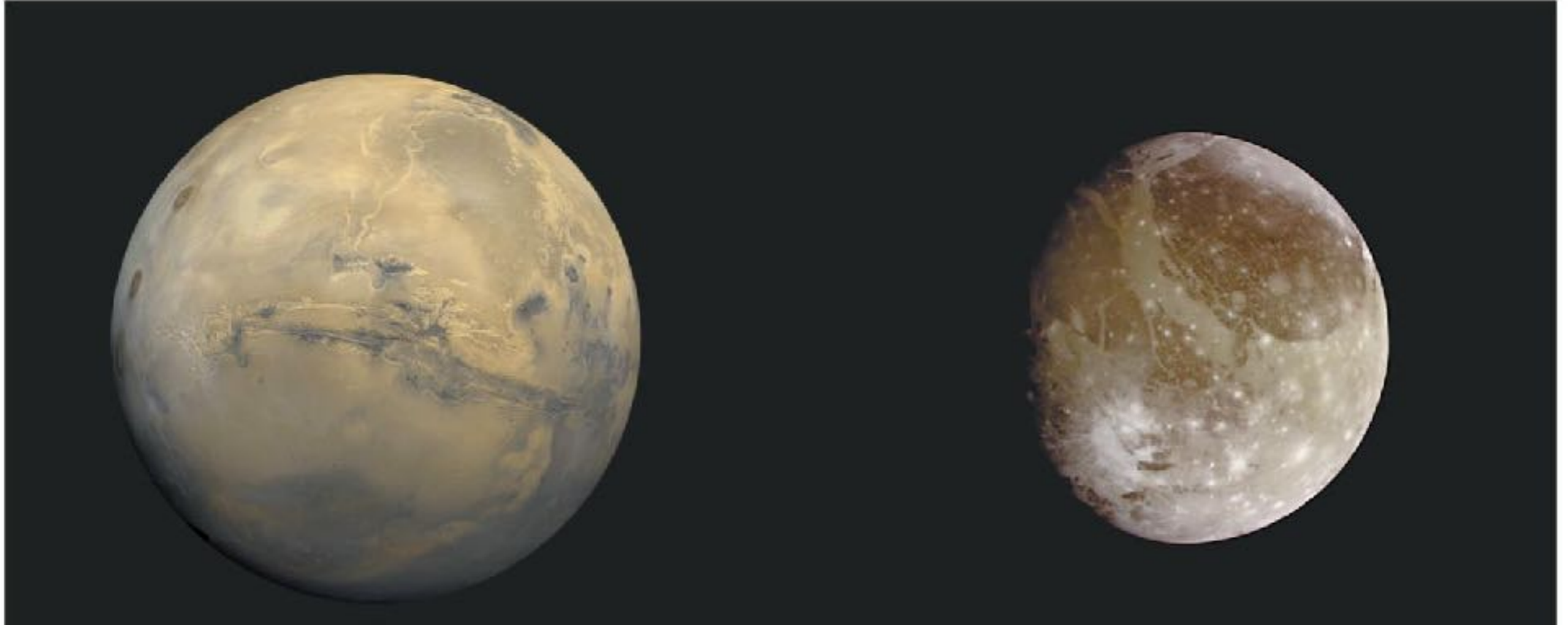
Why are small icy moons more geologically active than small rocky planets?



x5



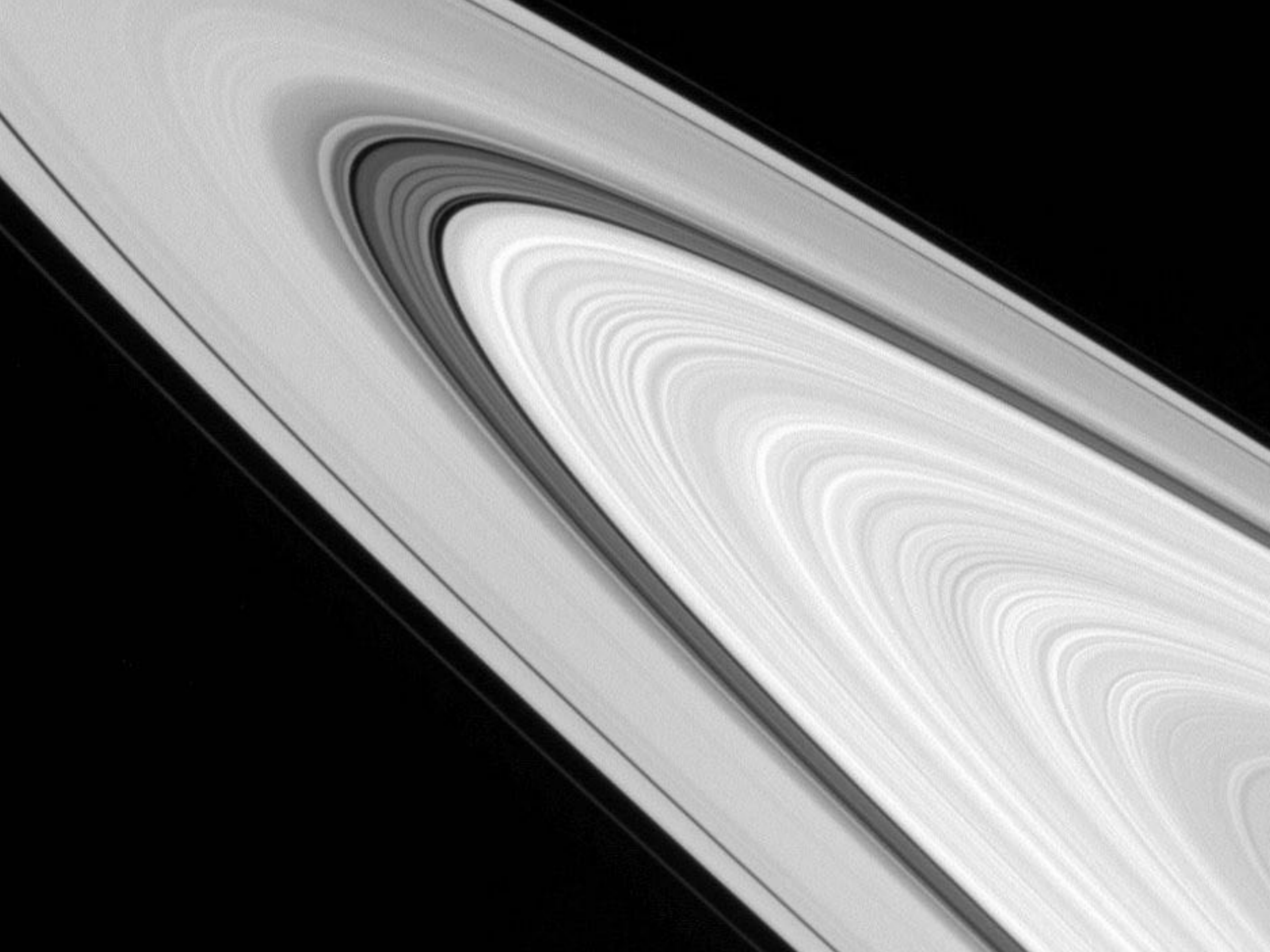
Rocky Planets versus Icy Moons



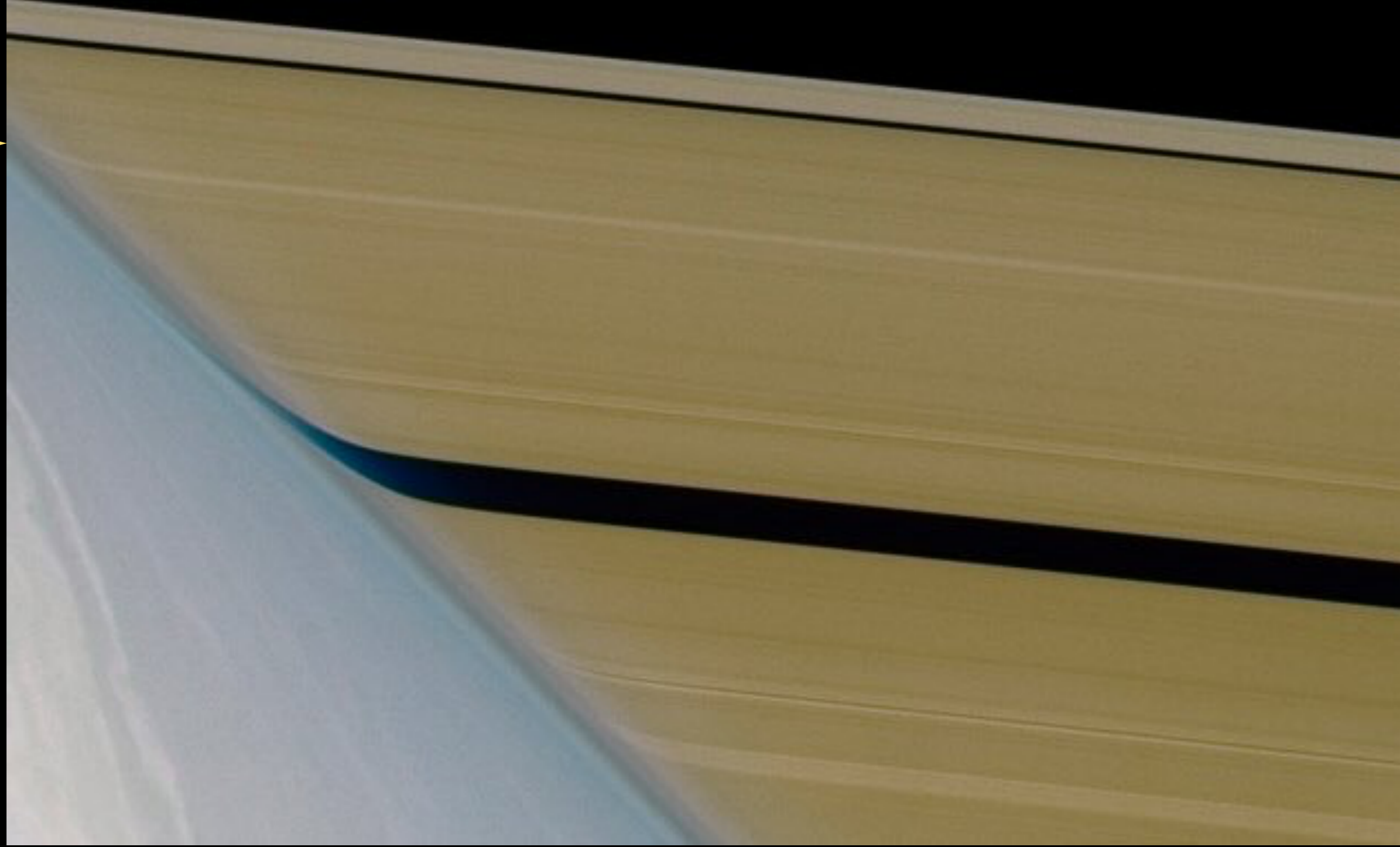
- Rock melts at higher temperatures.
- Only large rocky planets have enough heat for activity.
- Ice melts at lower temperatures.
- Tidal heating can melt internal ice, driving activity.

Saturn's rings





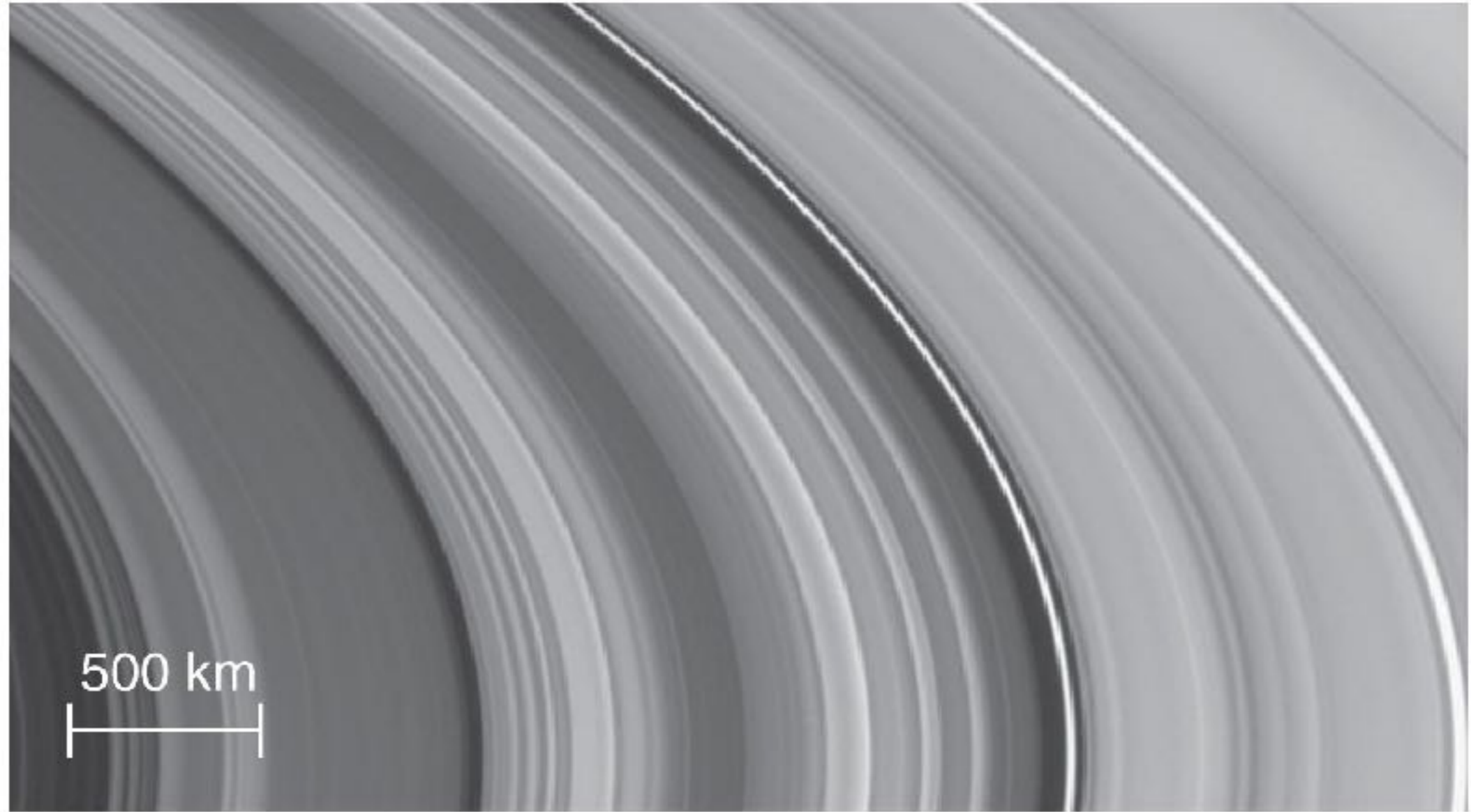
Note refraction in atmosphere



What are Saturn's rings like?

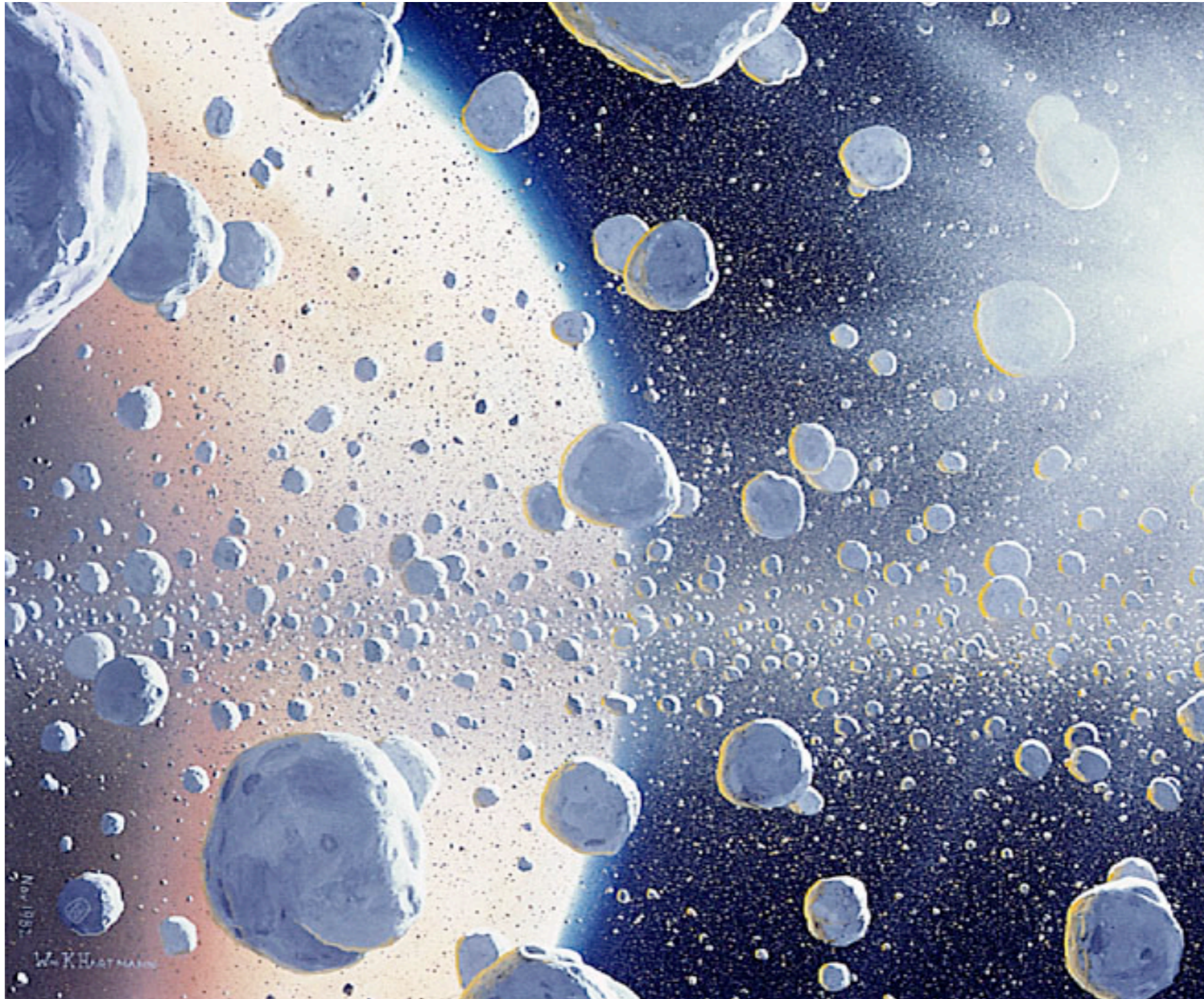
- They are made up of numerous, small, icy particles.
- They orbit over Saturn's equator.
- They are very thin.

Spacecraft View of Ring Gaps



b This image of Saturn's rings from the *Cassini* spacecraft reveals many individual rings separated by narrow gaps.

Artist's Conception in Ring

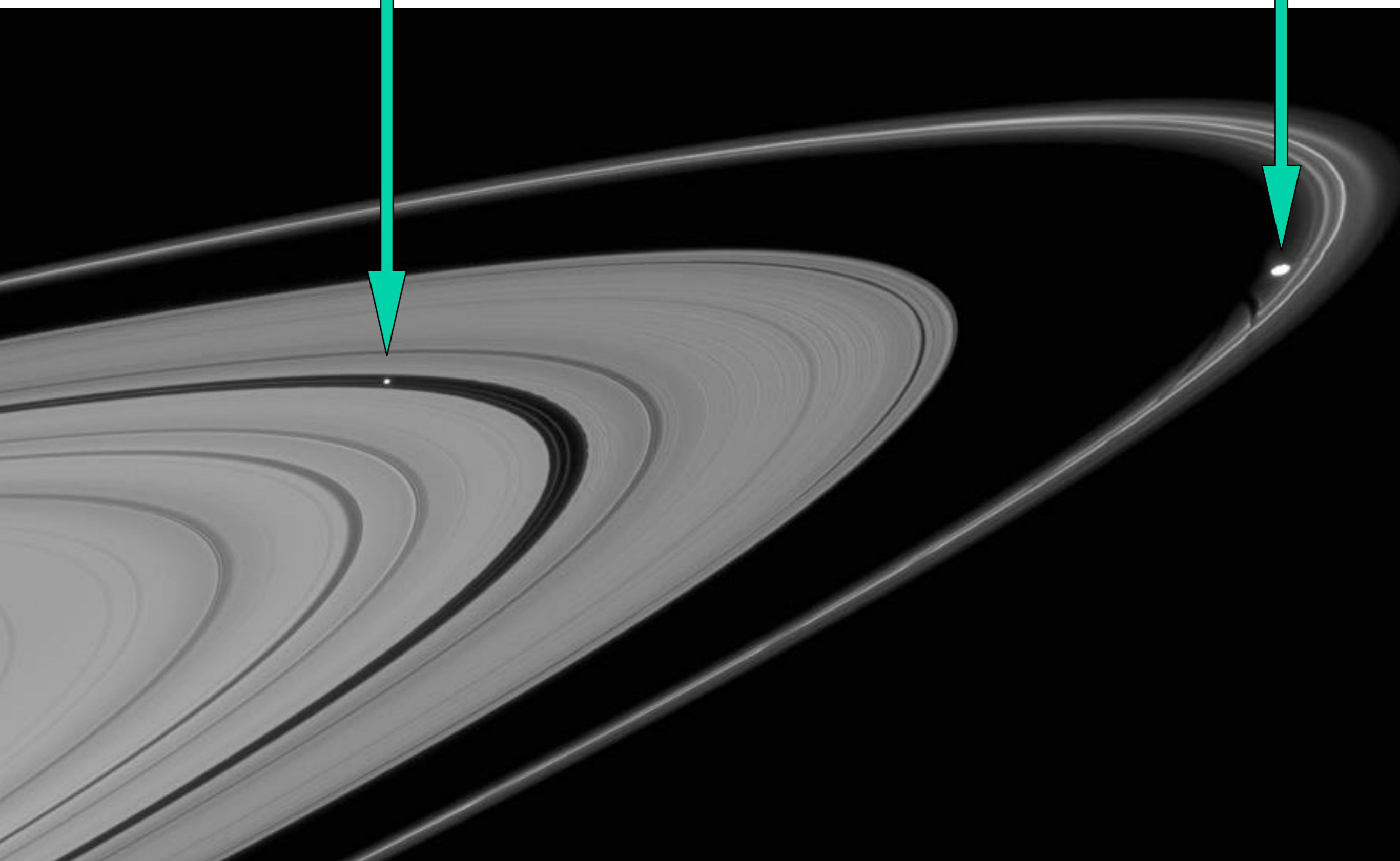


Elaborate structure in rings controlled by the gravity of “shepherd” moons

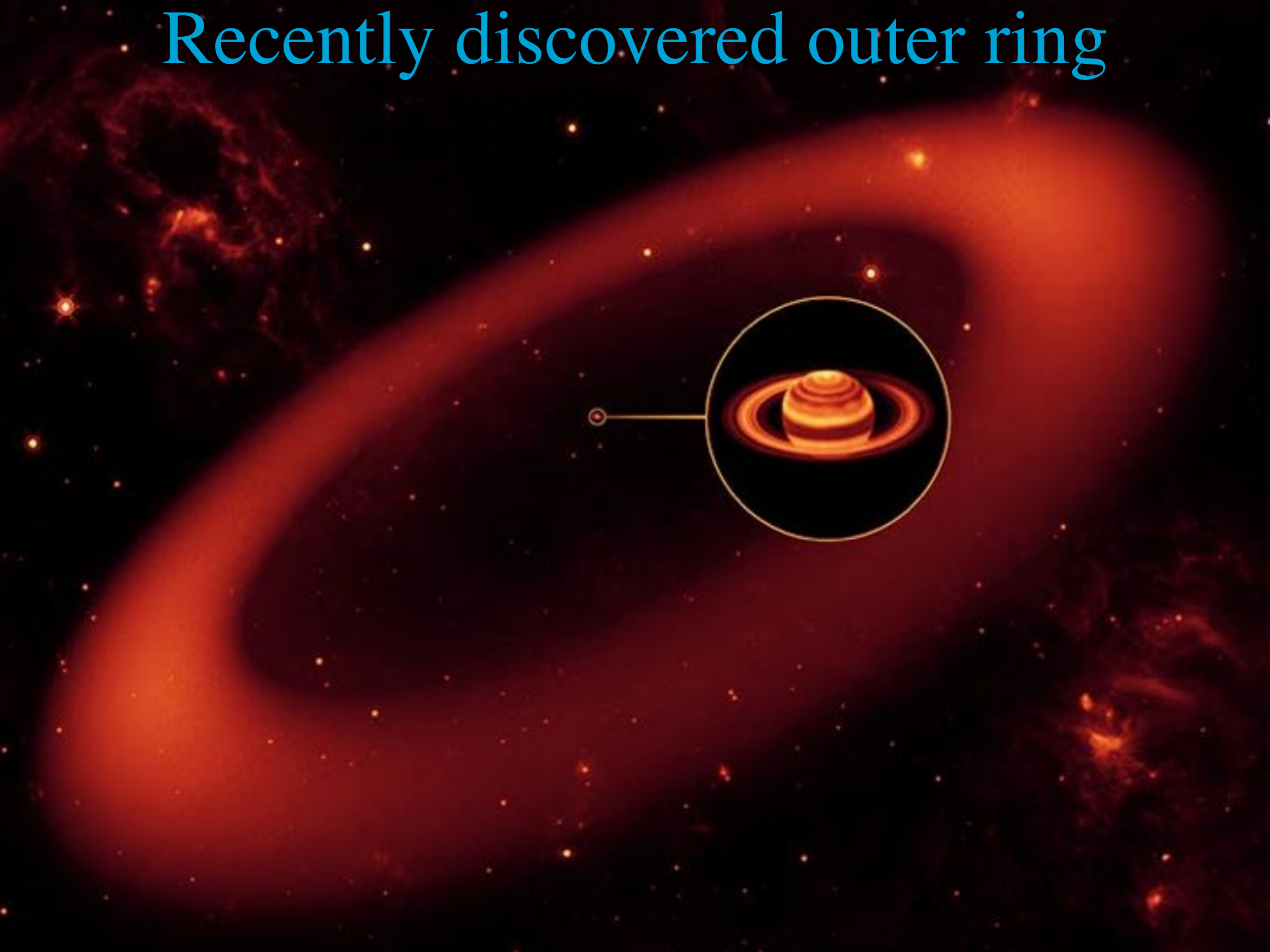
Pan



Prometheus



Recently discovered outer ring



Saturn

Debris knocked loose from Phoebe creates a dust ring that tints the leading side of Iapetus

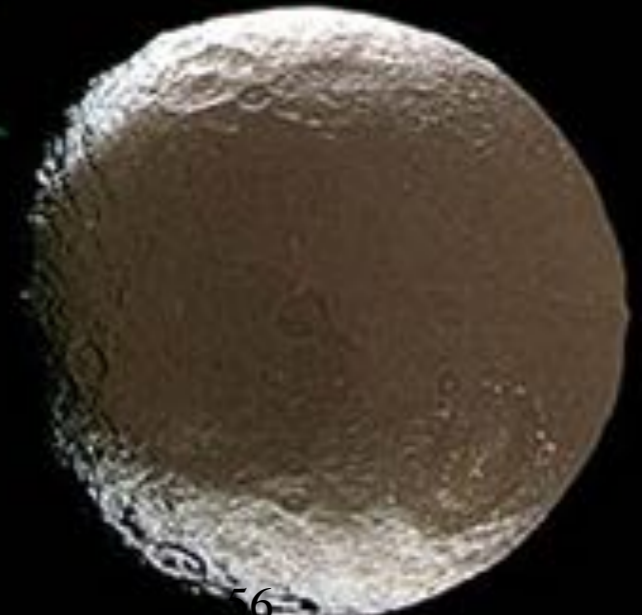
Phoebe



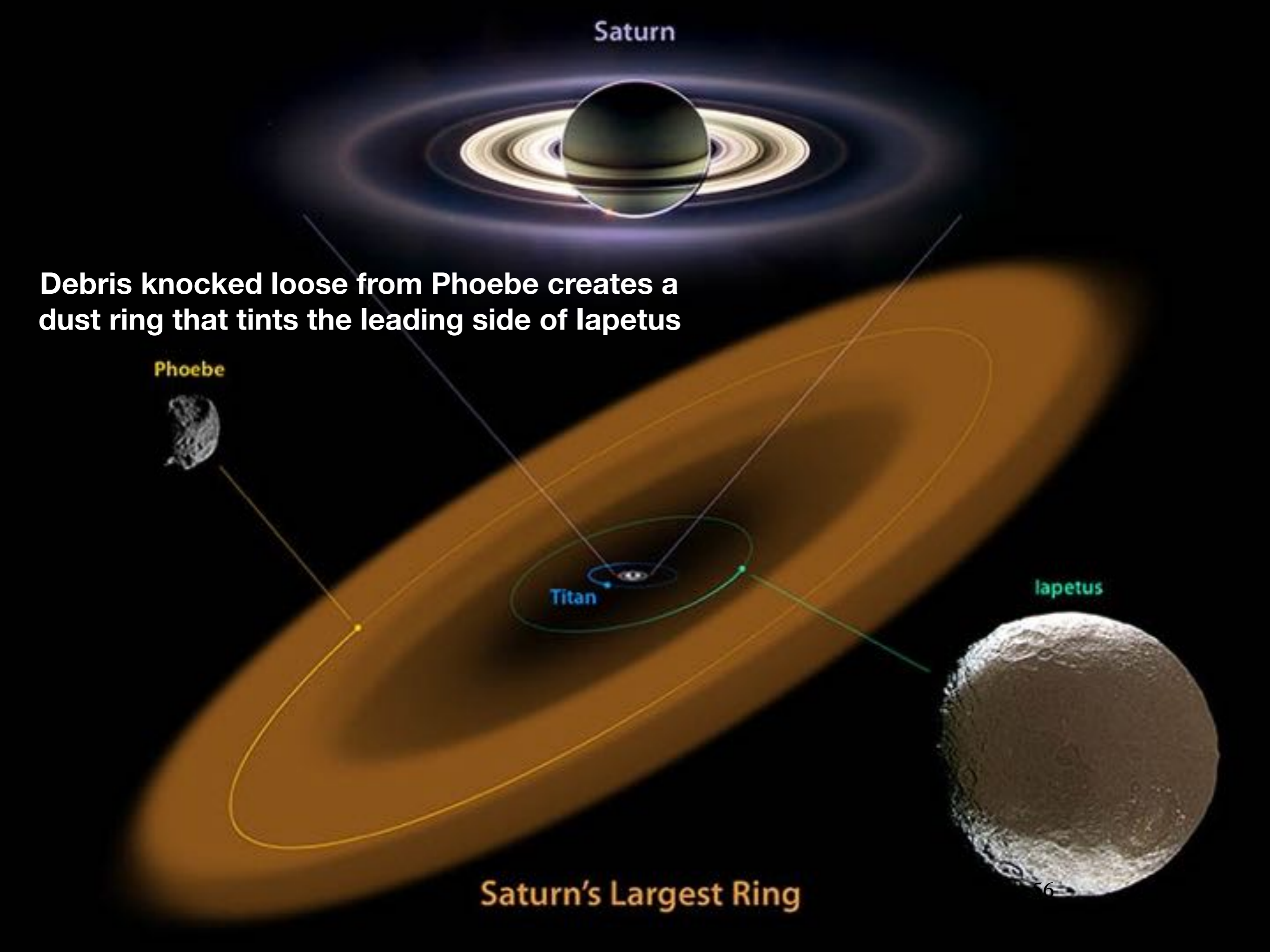
Titan



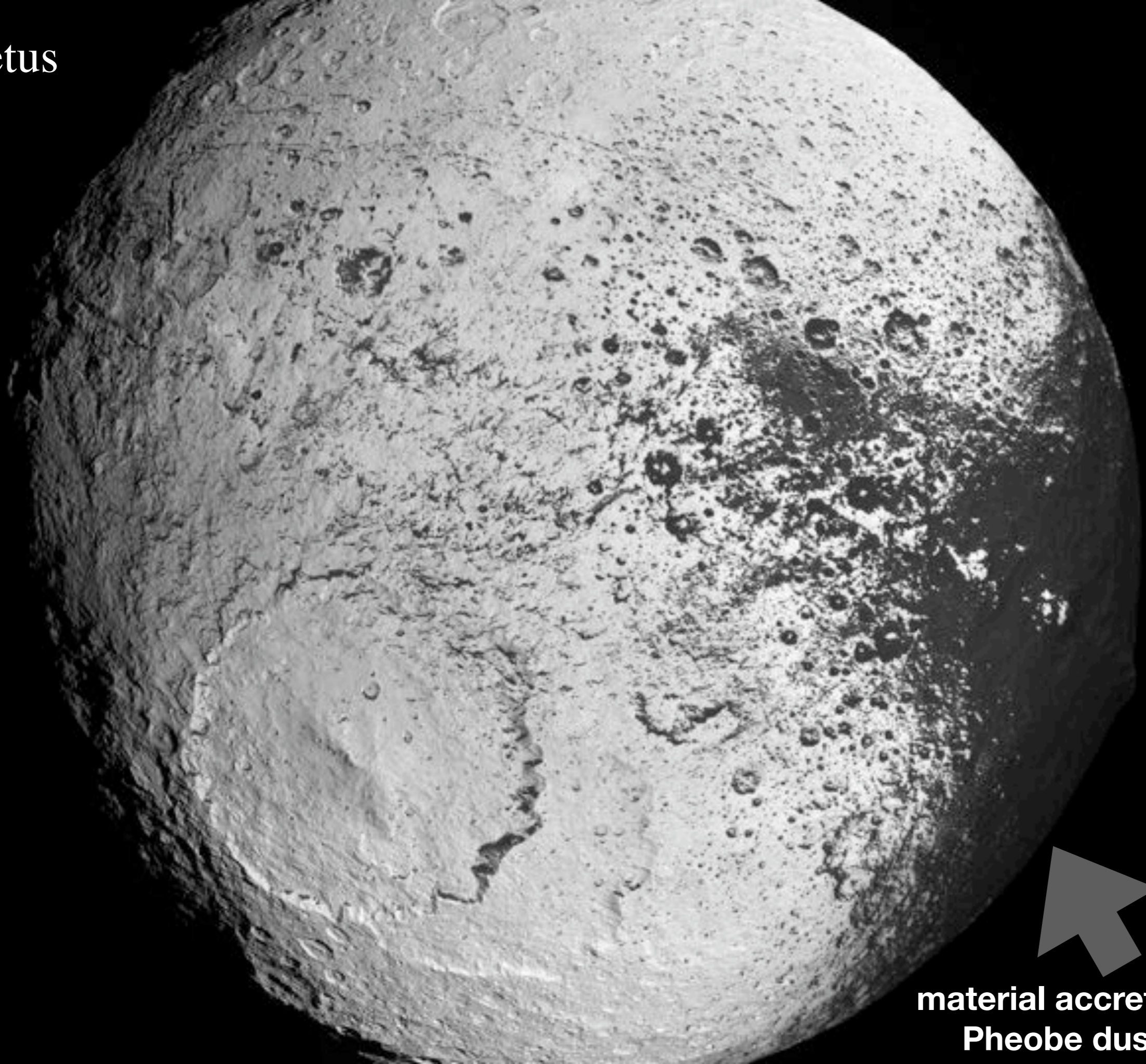
Iapetus



Saturn's Largest Ring

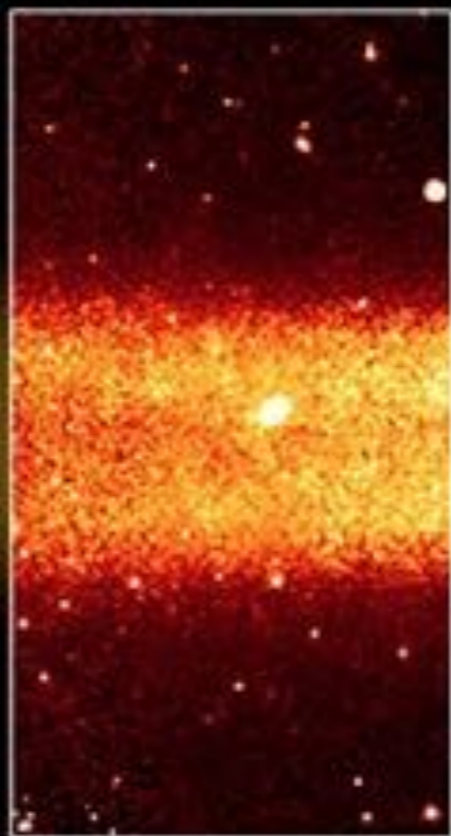


Iapetus



**material accreted from
Pheobe dust ring**

actual data



Dust Ring

Saturn

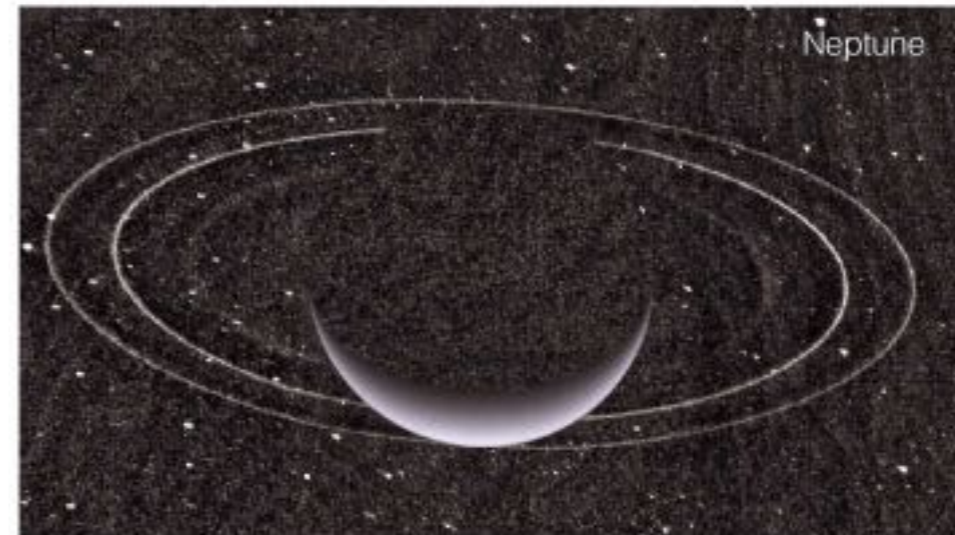
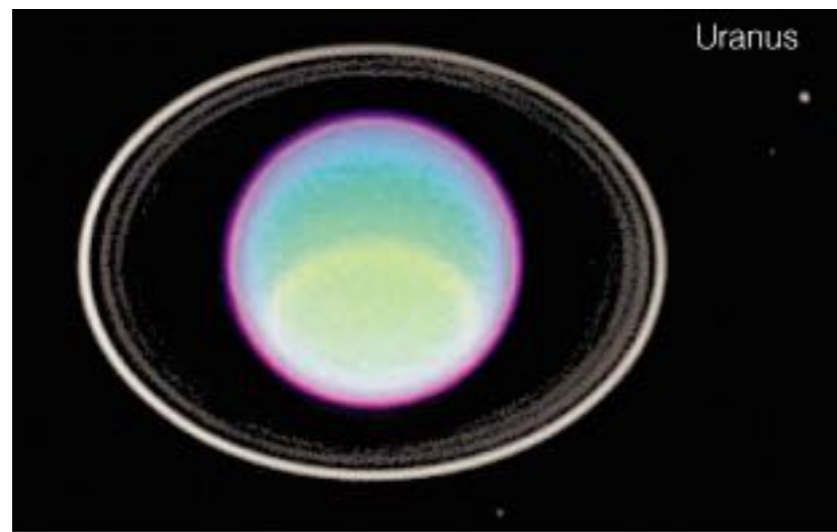
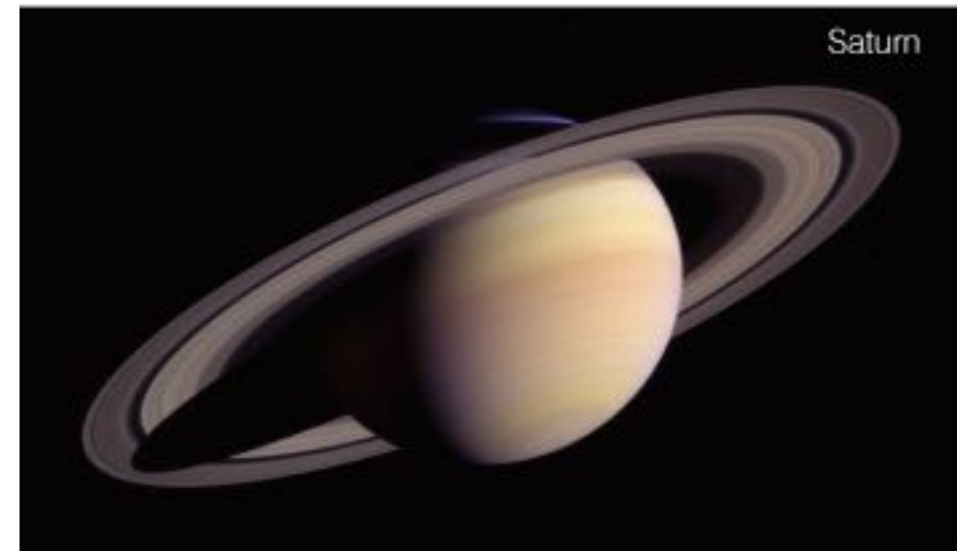
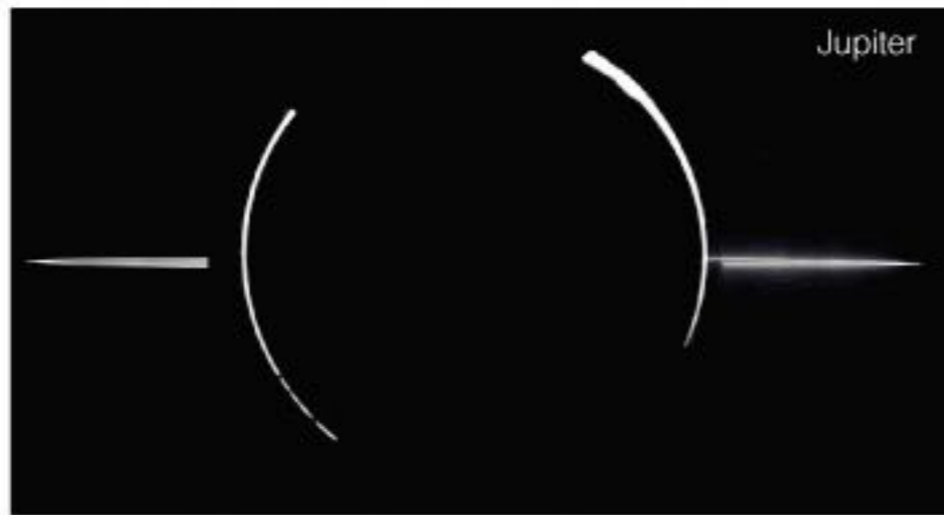


How do other jovian ring systems compare to Saturn's?

Jupiter

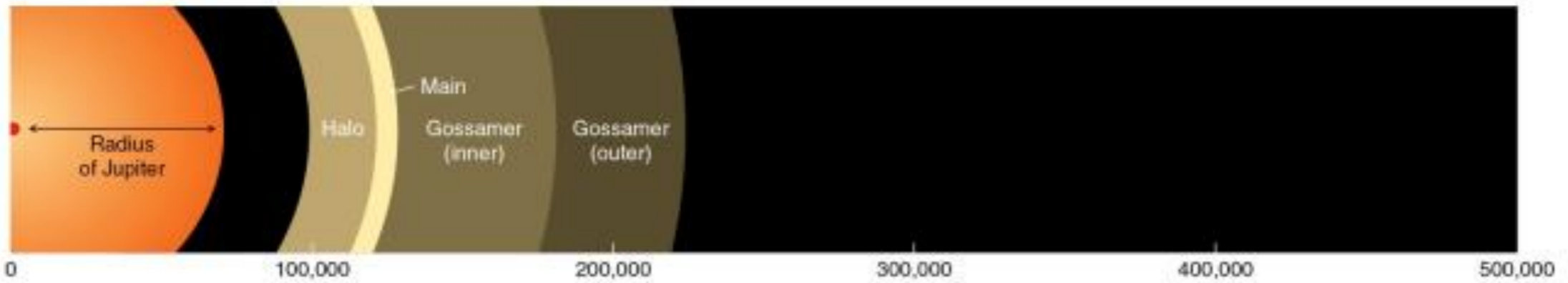


Jovian Ring Systems

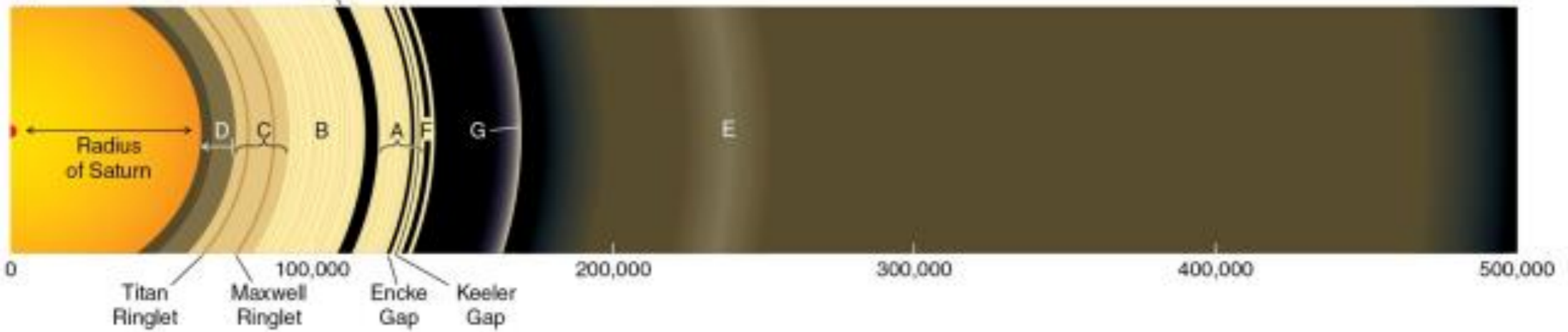


- All four jovian planets have ring systems.
- Others have smaller, darker ring particles than does Saturn.
- Rings and moons ubiquitous around Jovian planets
 - like small solar systems.

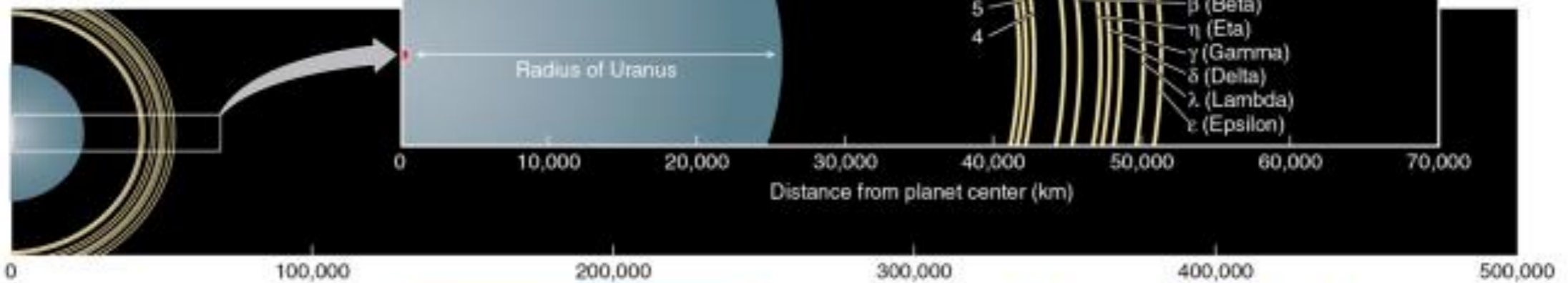
(a) JUPITER



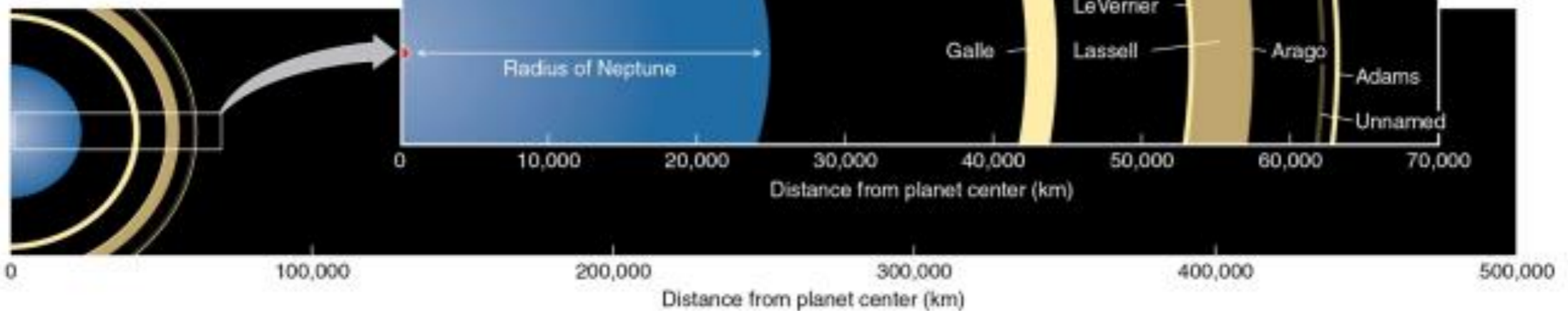
(b) SATURN



(c) URANUS



(d) NEPTUNE



Rings are short-lived yet ubiquitous

- Rings form from dust created in impacts on moons orbiting the Jovian planets.
- There must be a continuous replacement of tiny particles.
 - The tiny particles that make up the rings are subject to non-gravitational forces (photon pressure, solar wind) that push them out of orbit.
- The most likely source is impacts with jovian moons.
 - The dust emitted by Phoebe is an example of ring building in progress.
 - can also form from the break-up of a large moon that falls within the Roche limit for tidal destruction
 - Saturn's rings; Triton's ultimate fate?