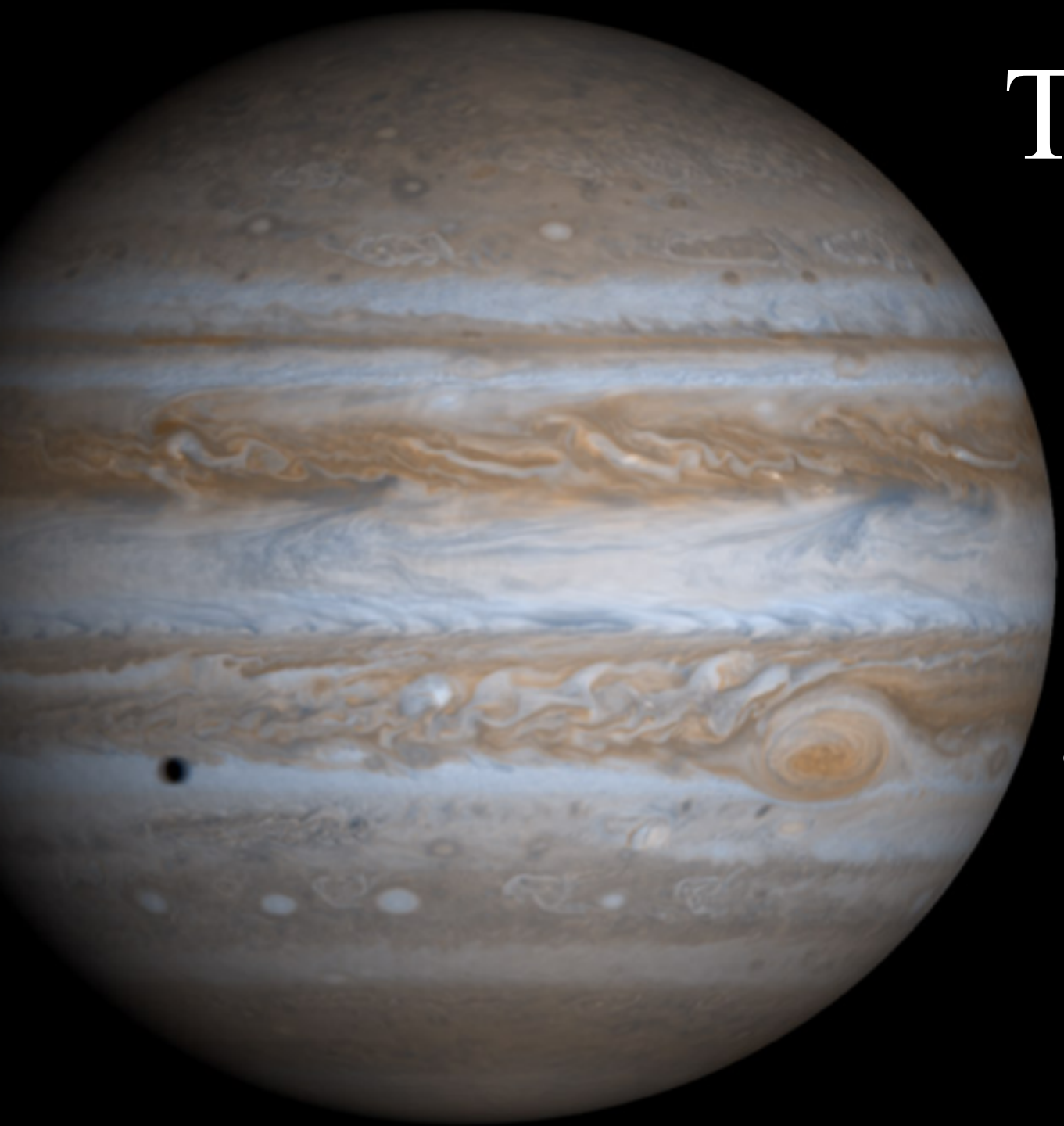


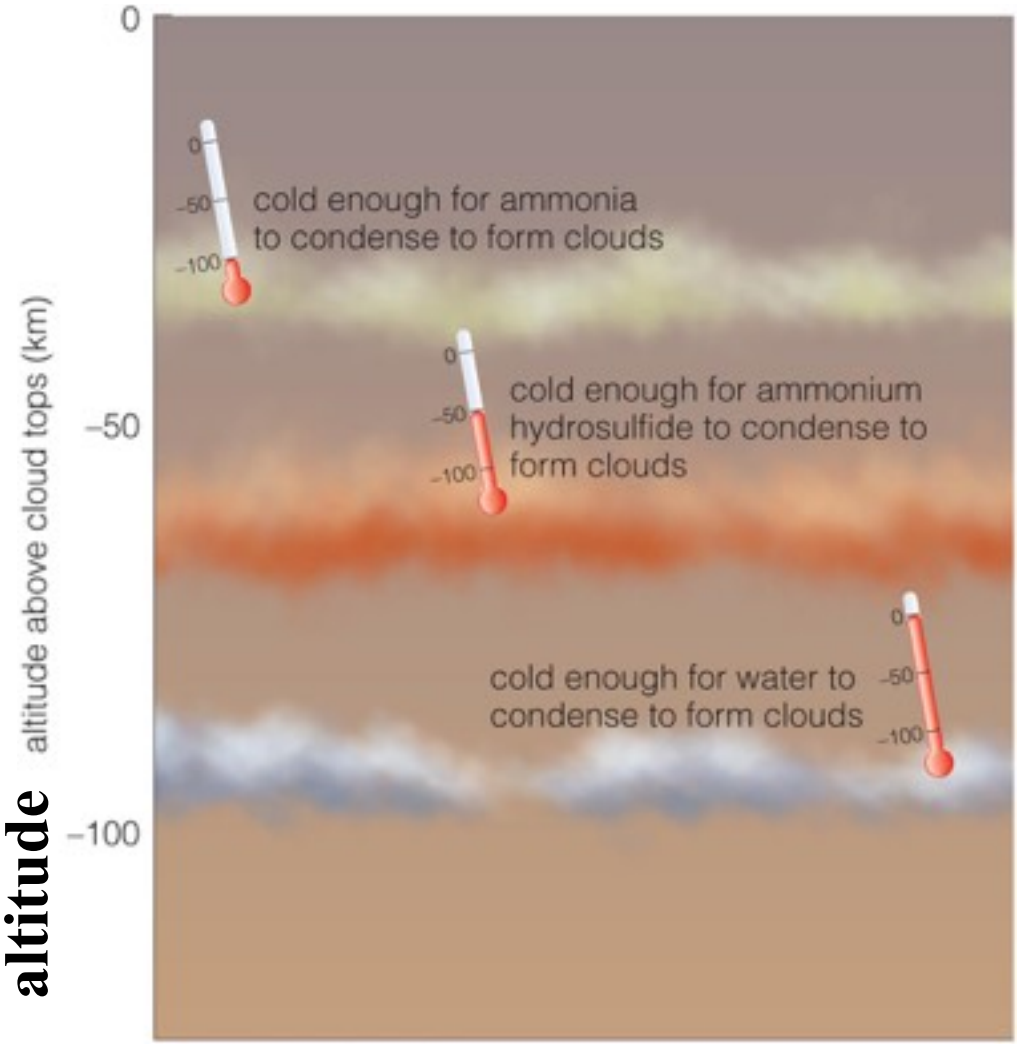
Today

- Jovian planets
- their moons

Events

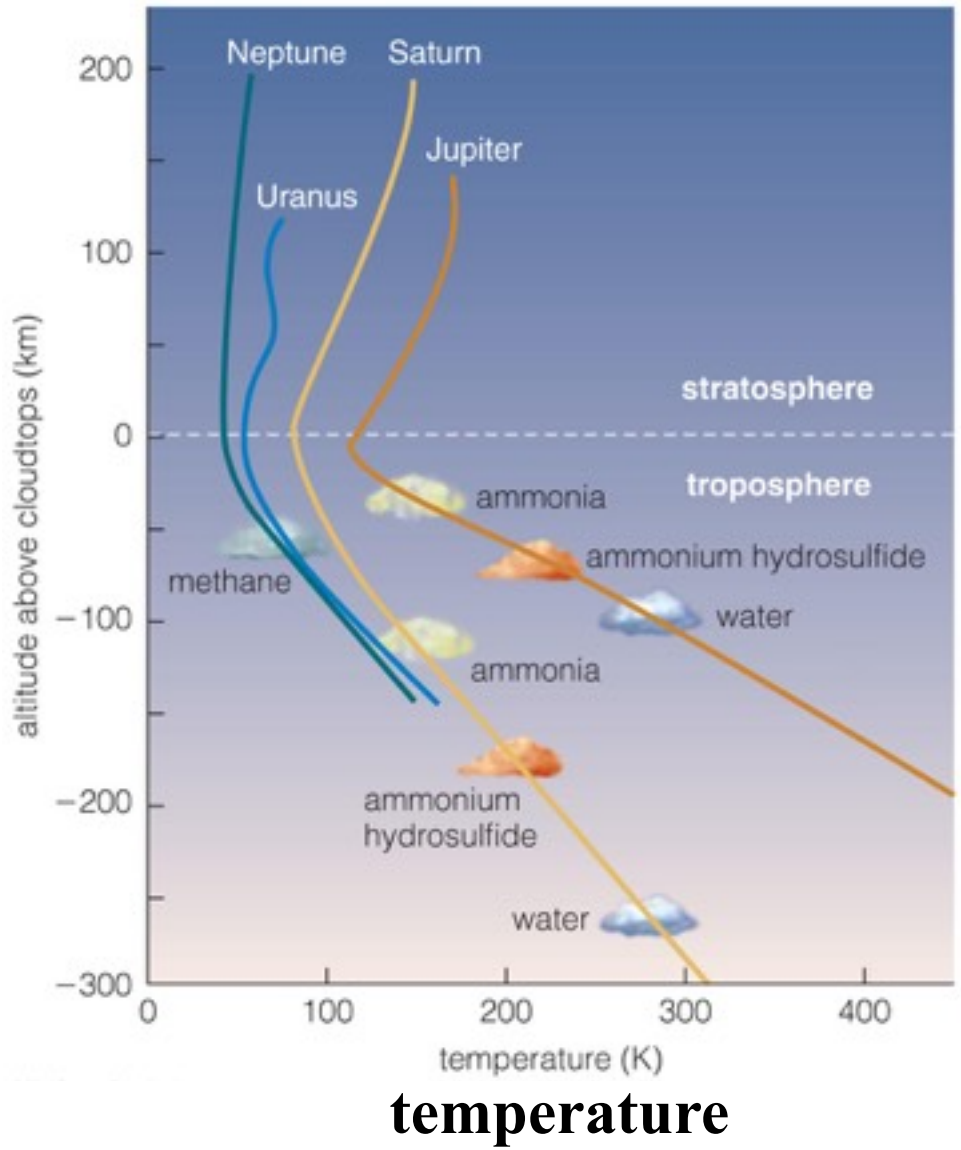
- Homework 5
  - Due next time

Jupiter's Atmosphere



- Hydrogen compounds in Jupiter form clouds.
- Different cloud layers correspond to freezing points of different hydrogen compounds.
- Other jovian planets have similar cloud layers.

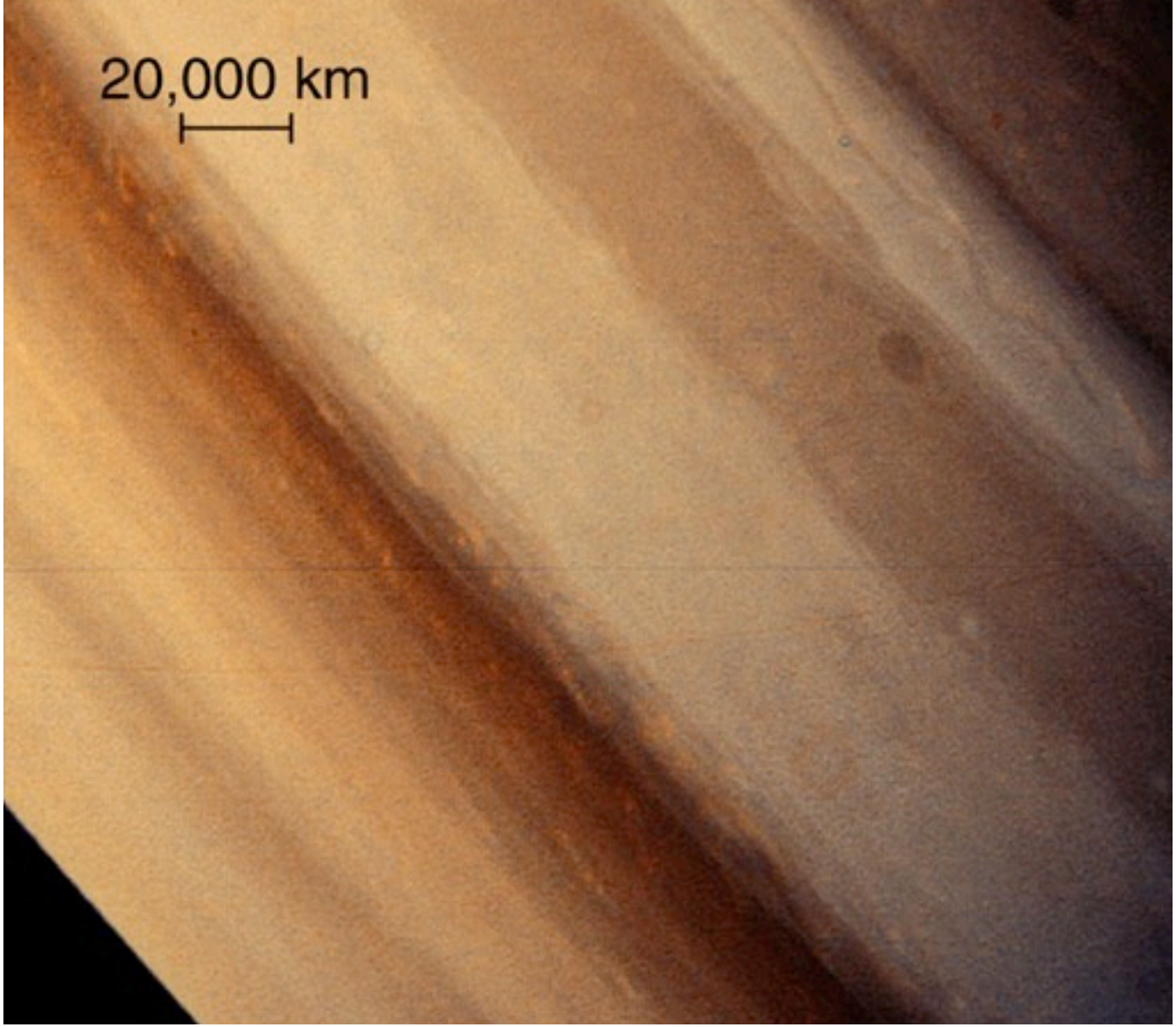
Jovian Planet Atmospheres



- Other jovian planets have cloud layers similar to Jupiter's.
- Different compounds make clouds of different colors.
- Reveal conditions to different depths in each planet

Jupiter's Colors

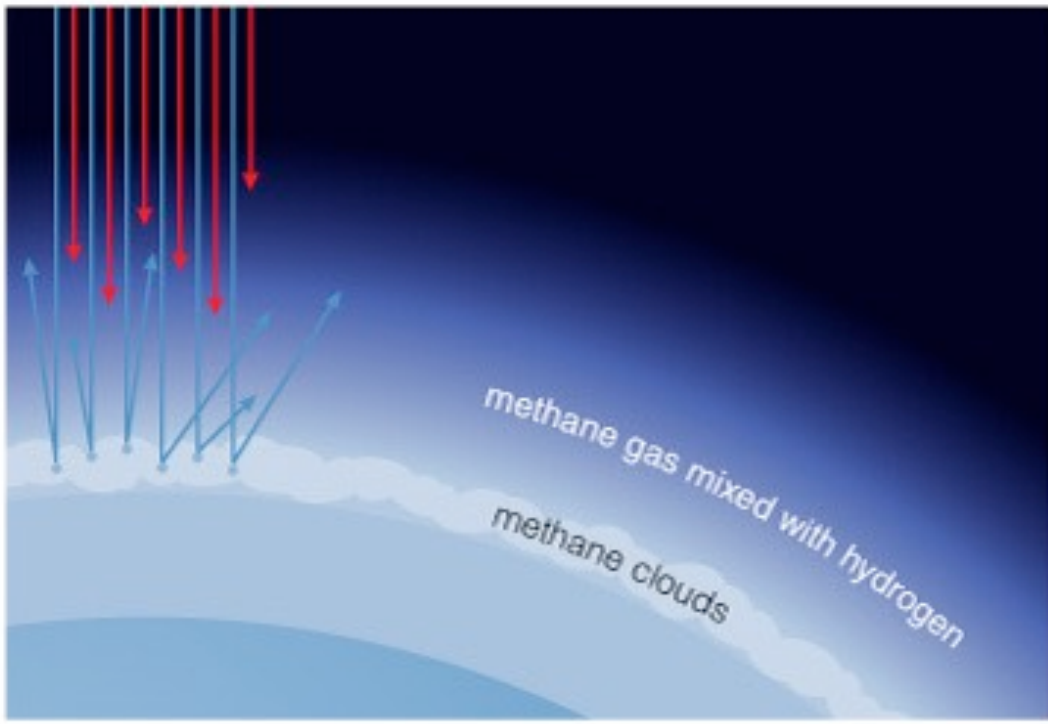
- Ammonium sulfide clouds (NH_4SH) reflect red/brown.
- Ammonia, the highest, coldest layer, reflects white.



Saturn's Colors

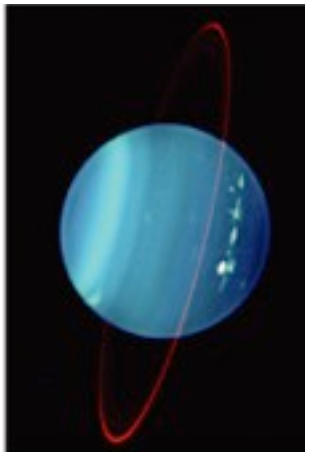
- Saturn's layers are similar but are deeper in and farther from the Sun — more subdued.

Methane on Uranus and Neptune



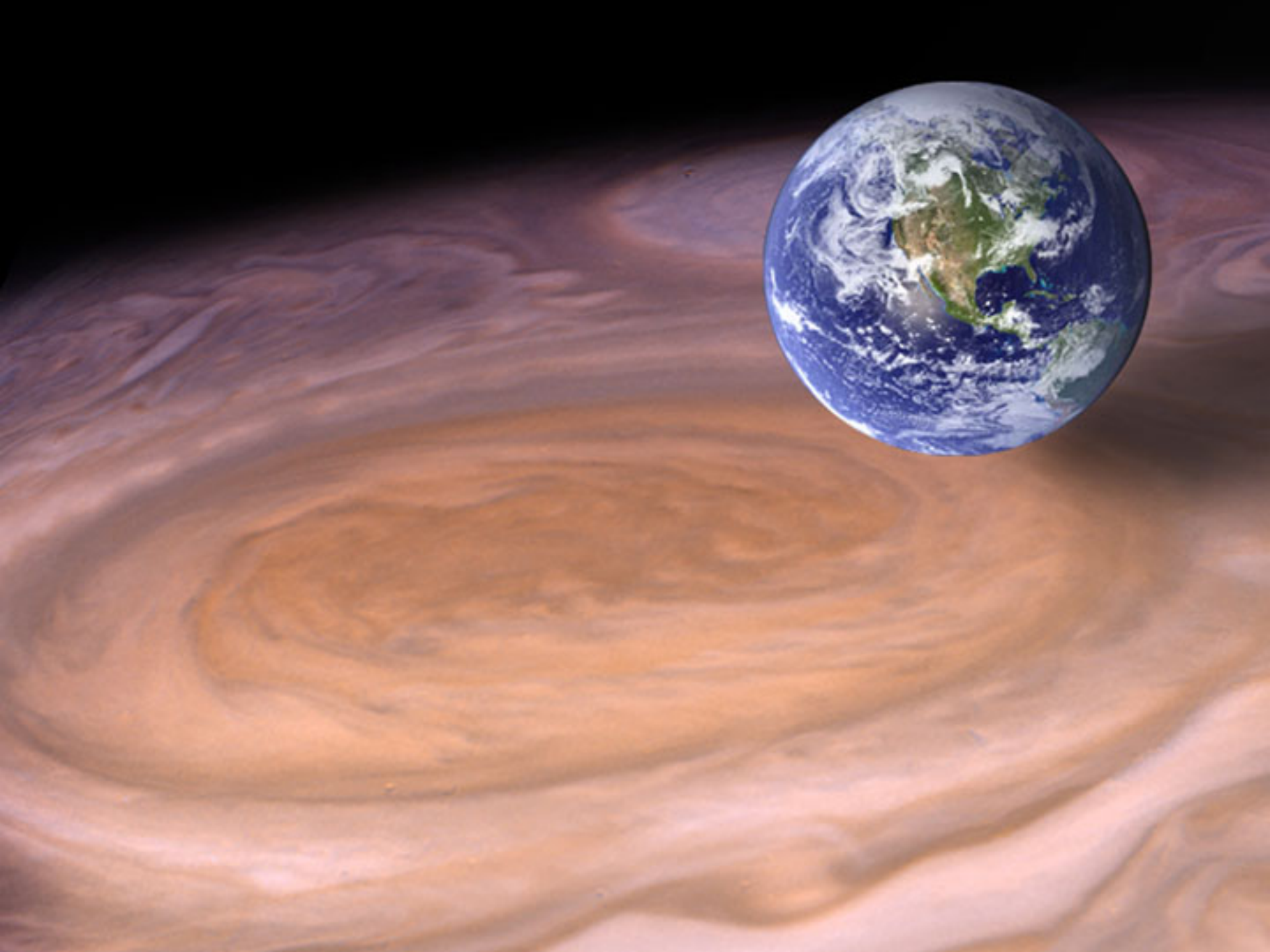
- Methane gas on Neptune and Uranus absorbs red light but reflects blue light.
- Blue light reflects off methane clouds, making those planets look blue.

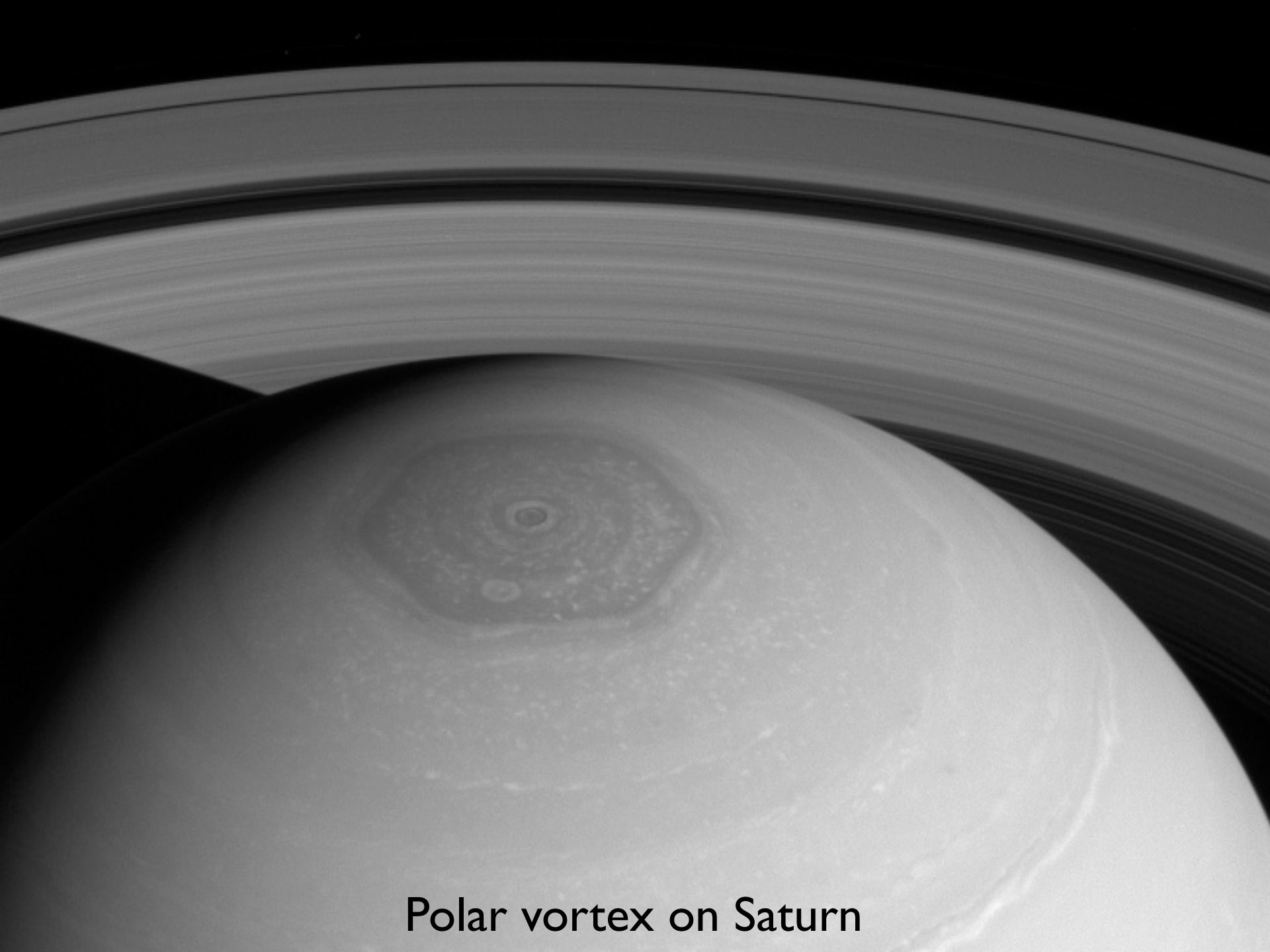
Weather on Jovian Planets



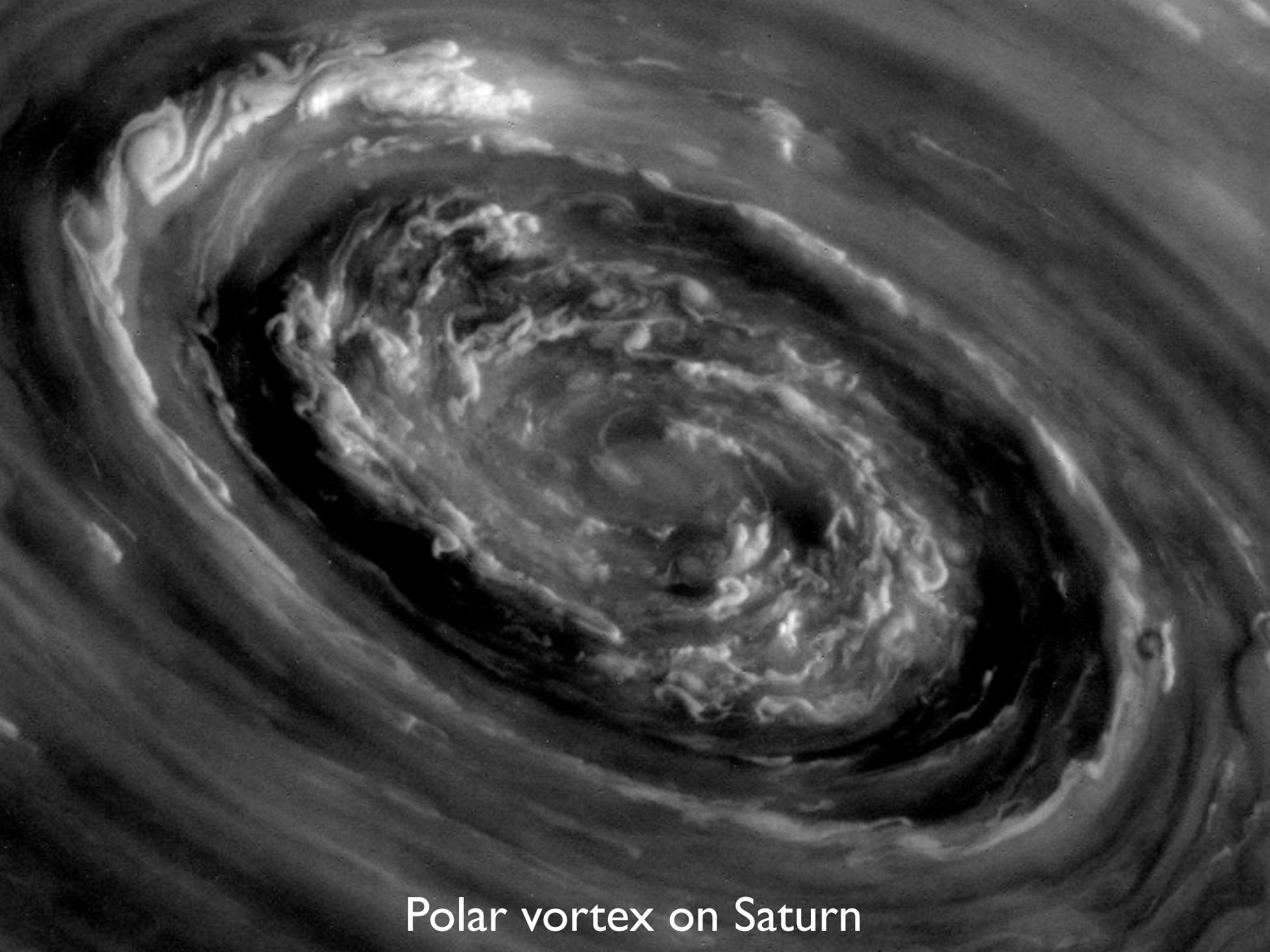
- All the jovian planets have strong winds and storms.

The great red spot on Jupiter is a storm larger than Earth that has persisted for centuries.

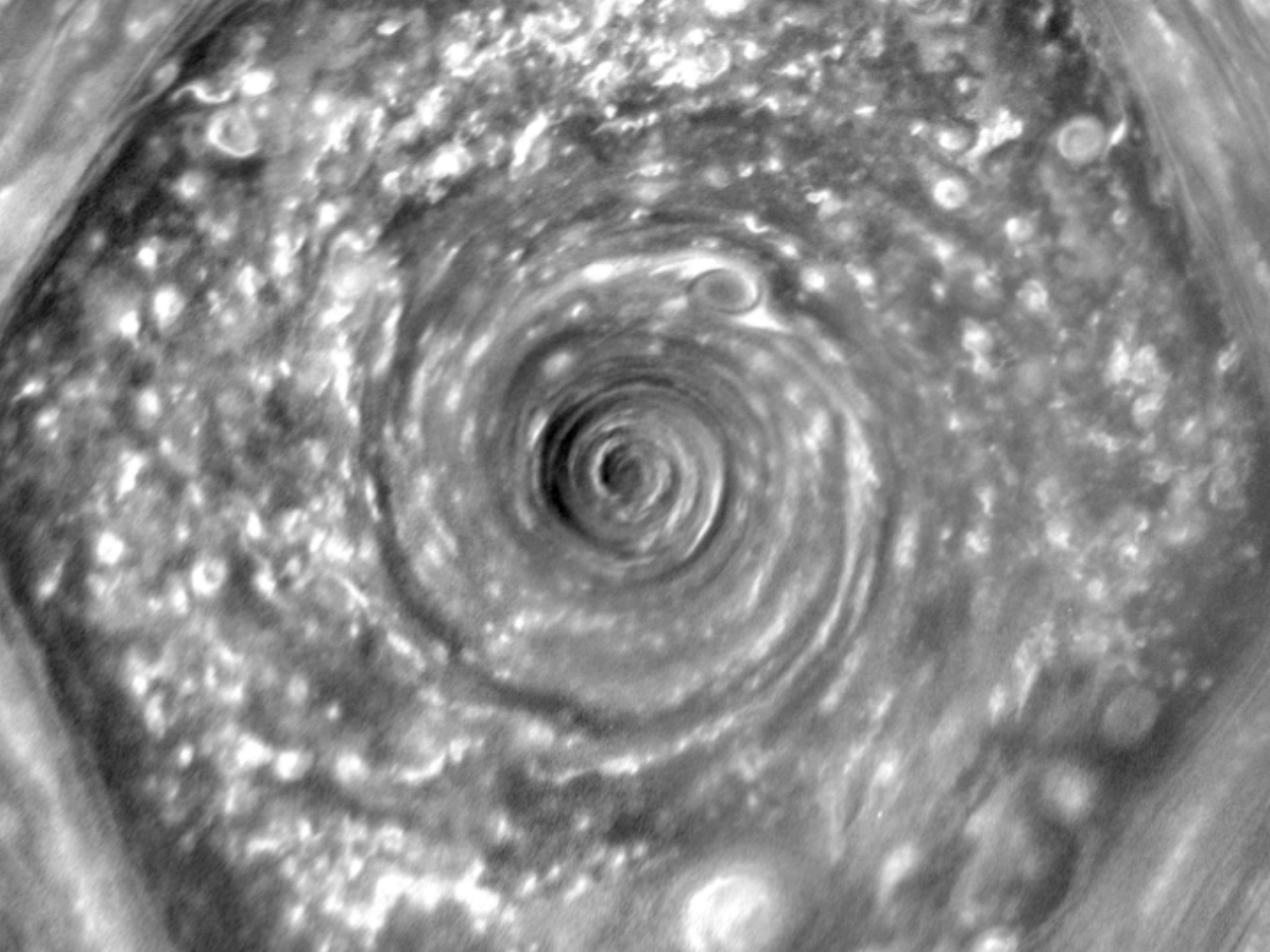




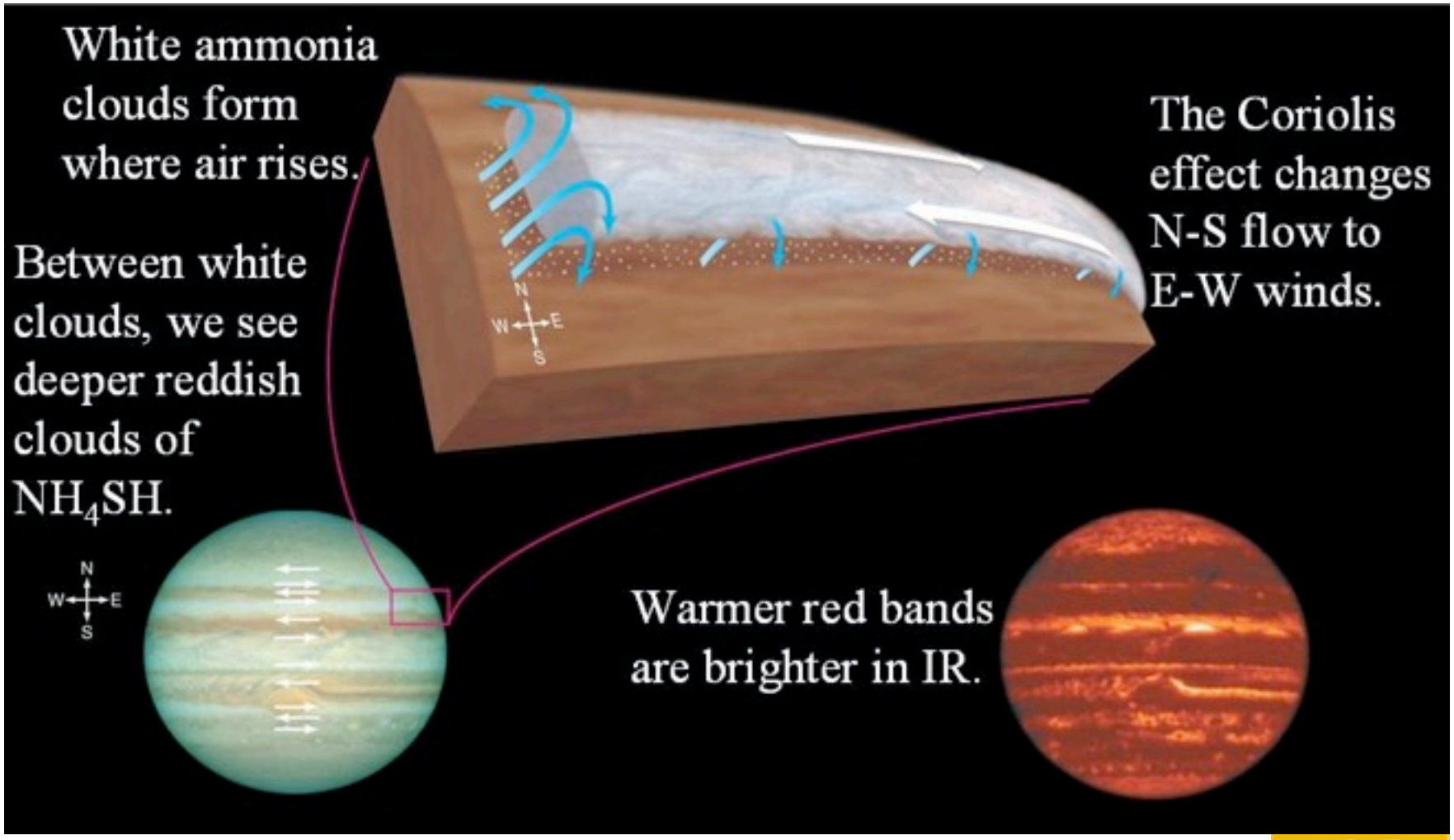
Polar vortex on Saturn



Polar vortex on Saturn

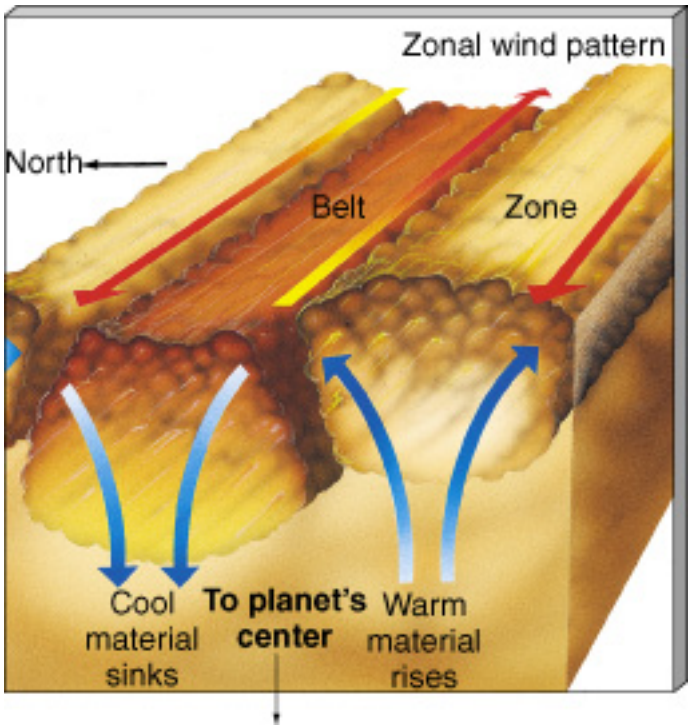


Jupiter's Bands



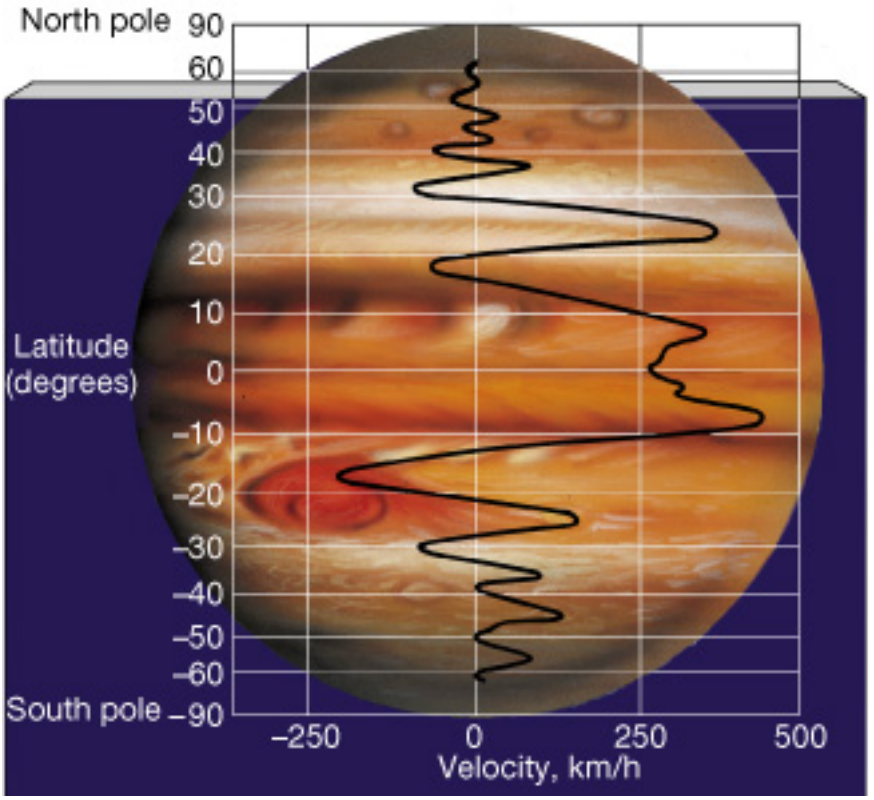
Zonal (band) structure in Jovian planet atmospheres

Zonal wind pattern



Hot rising and cool sinking material separate into band structure

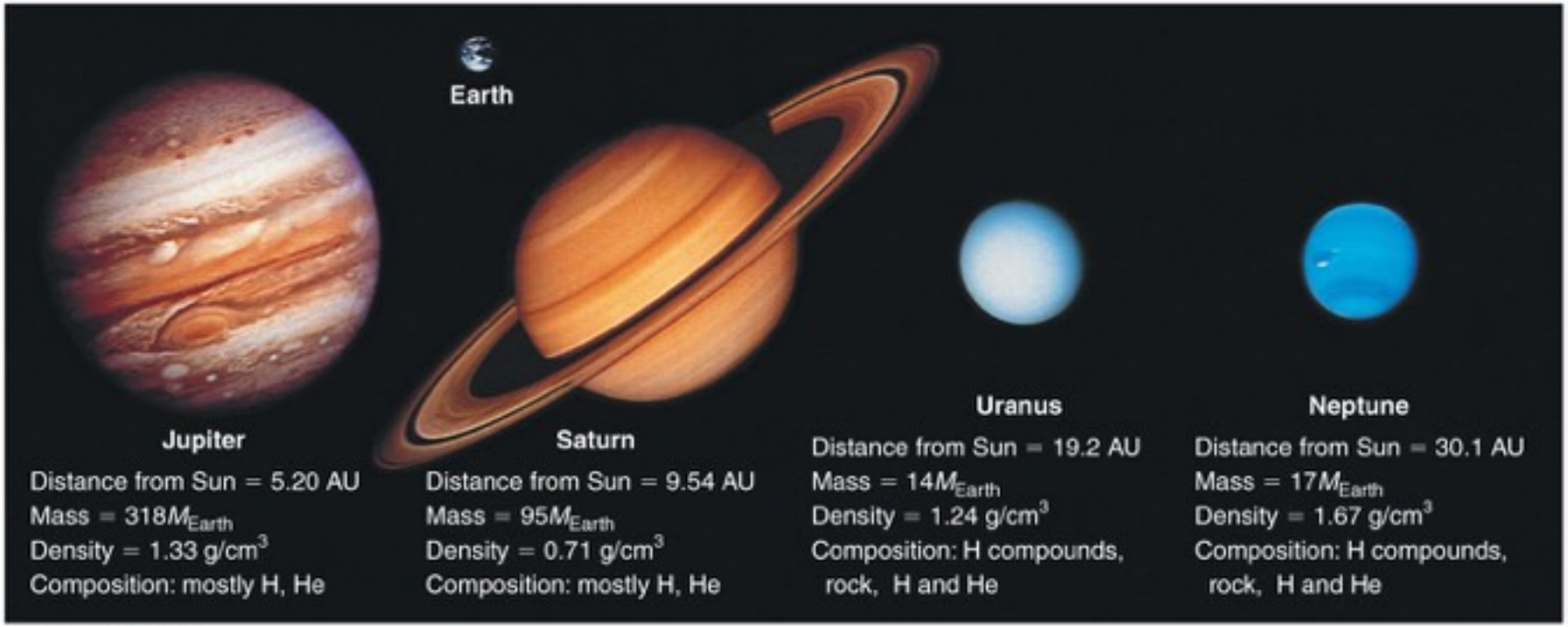
Zonal wind speed



Rapid rotation causes many zones (more than Earth's 3) with high wind speeds

show Jovian cloud layers

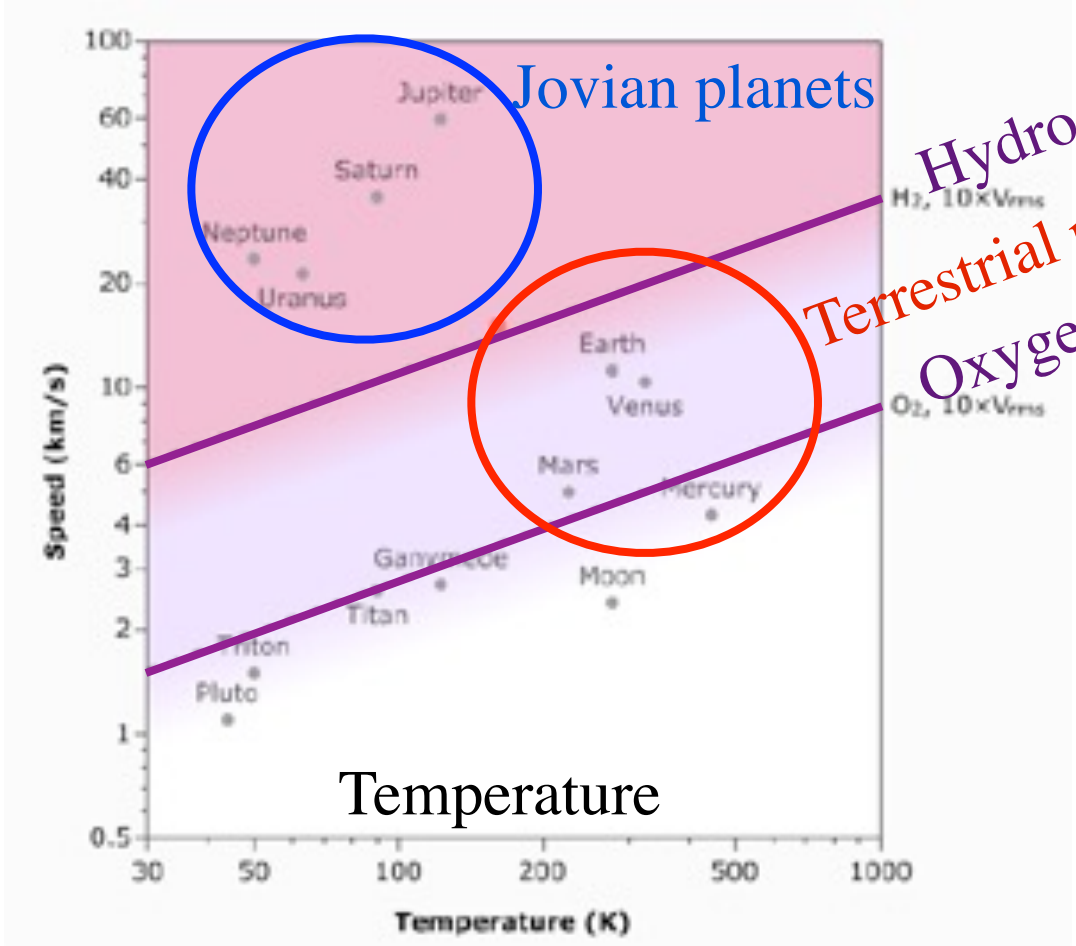
Weather on Jovian Planets



- All the jovian planets have strong winds and storms.

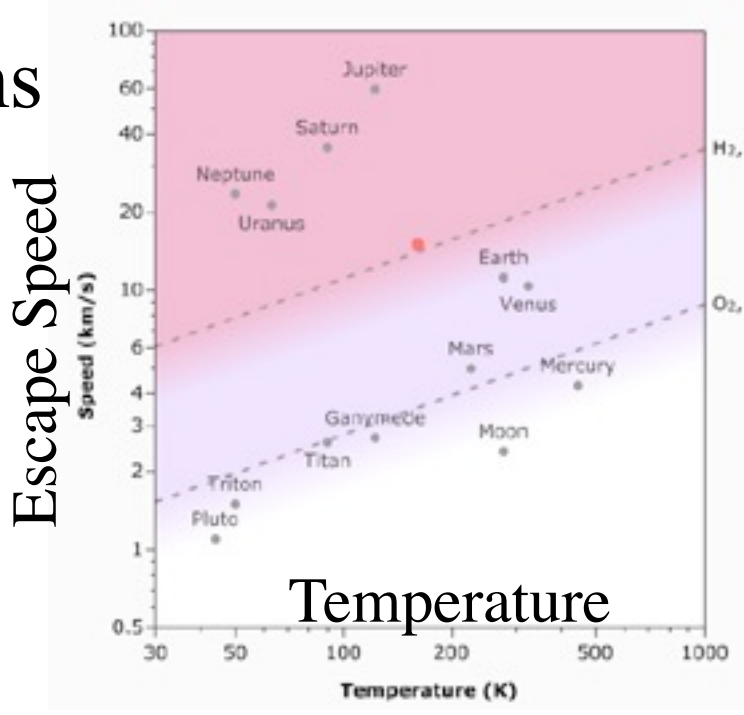
Jovian planets are

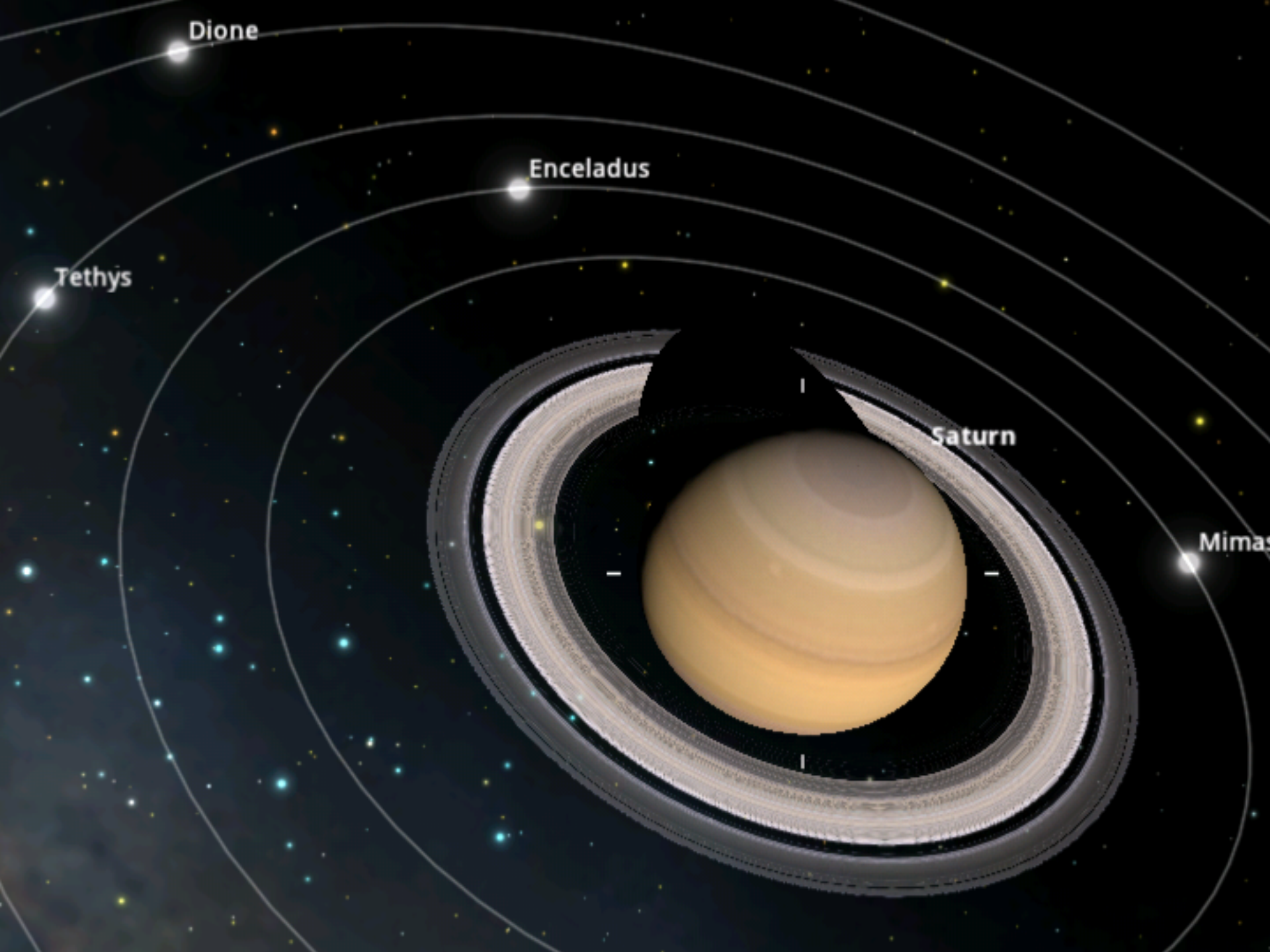
- Big
  - massive and cold, they can retain light elements like hydrogen and helium



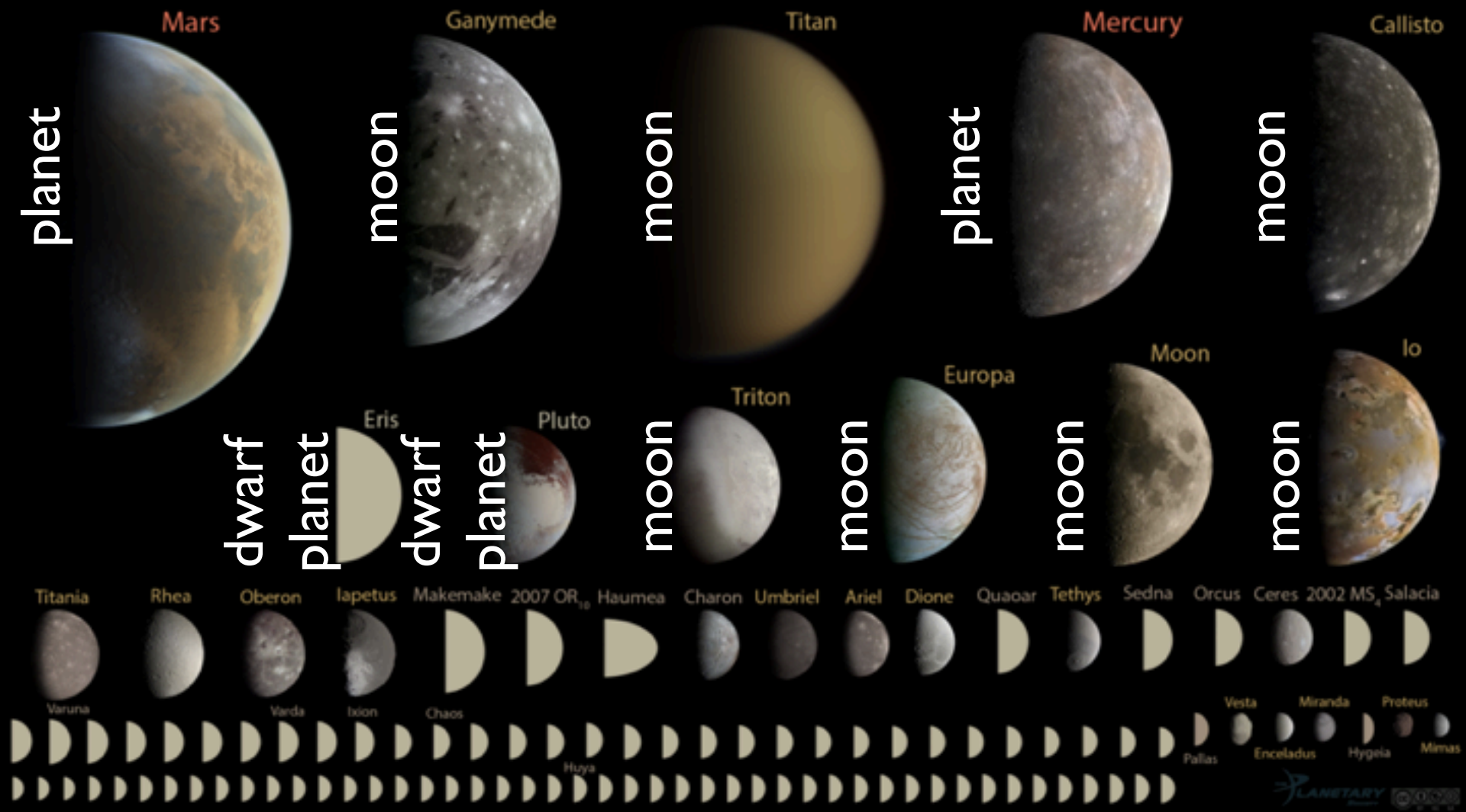
Jovian planets are

- Big
  - massive and cold, they can retain light elements like hydrogen and helium
  - their composition is like that of the stars
  - the smaller terrestrial planets are the abnormal planets in terms of composition
- Like miniature solar systems
  - moons
  - rings

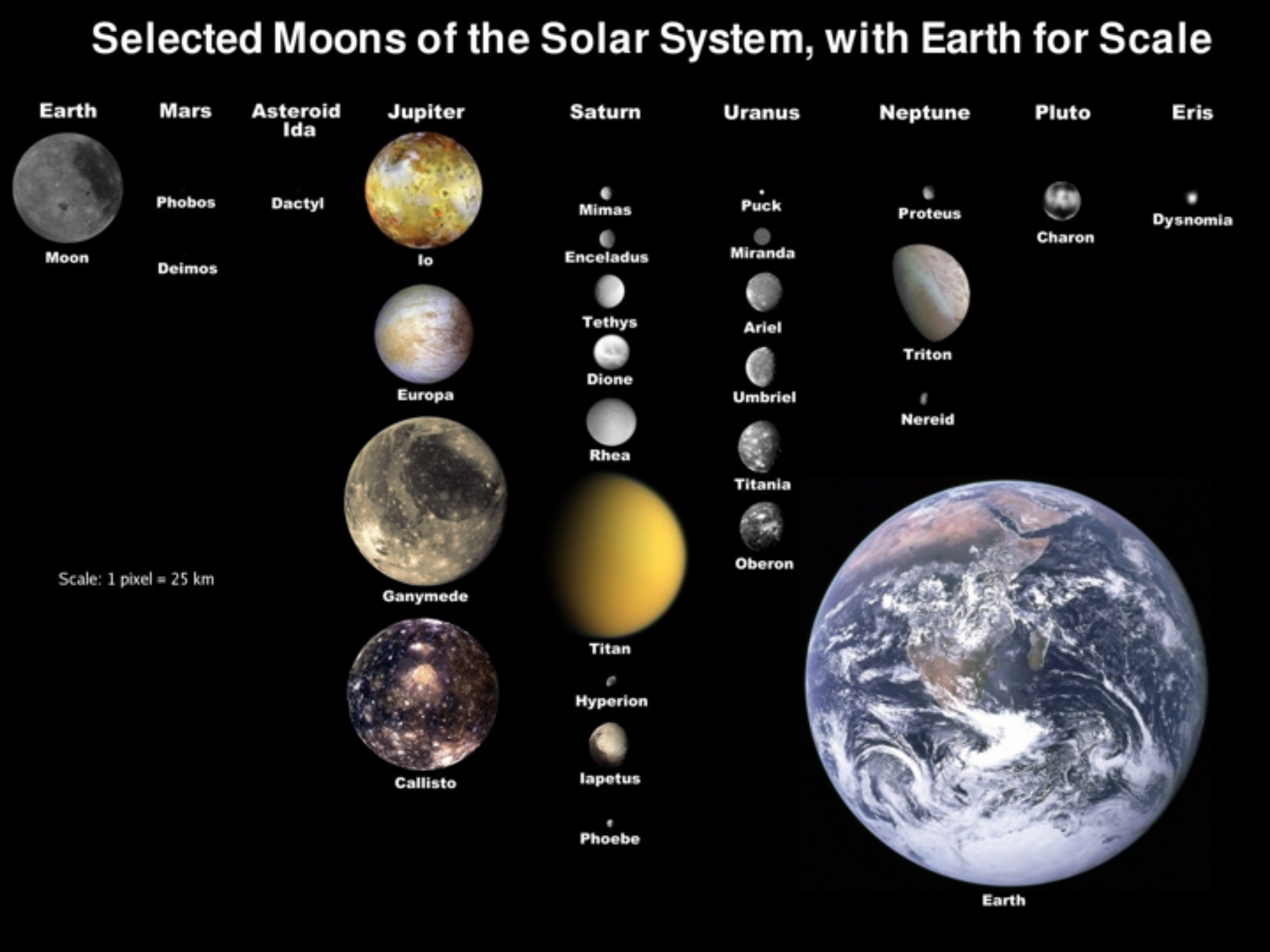



Dione
Enceladus
Tethys
Saturn
Mimas

Round objects in the solar system with diameter < 10,000 km



Selected Moons of the Solar System, with Earth for Scale



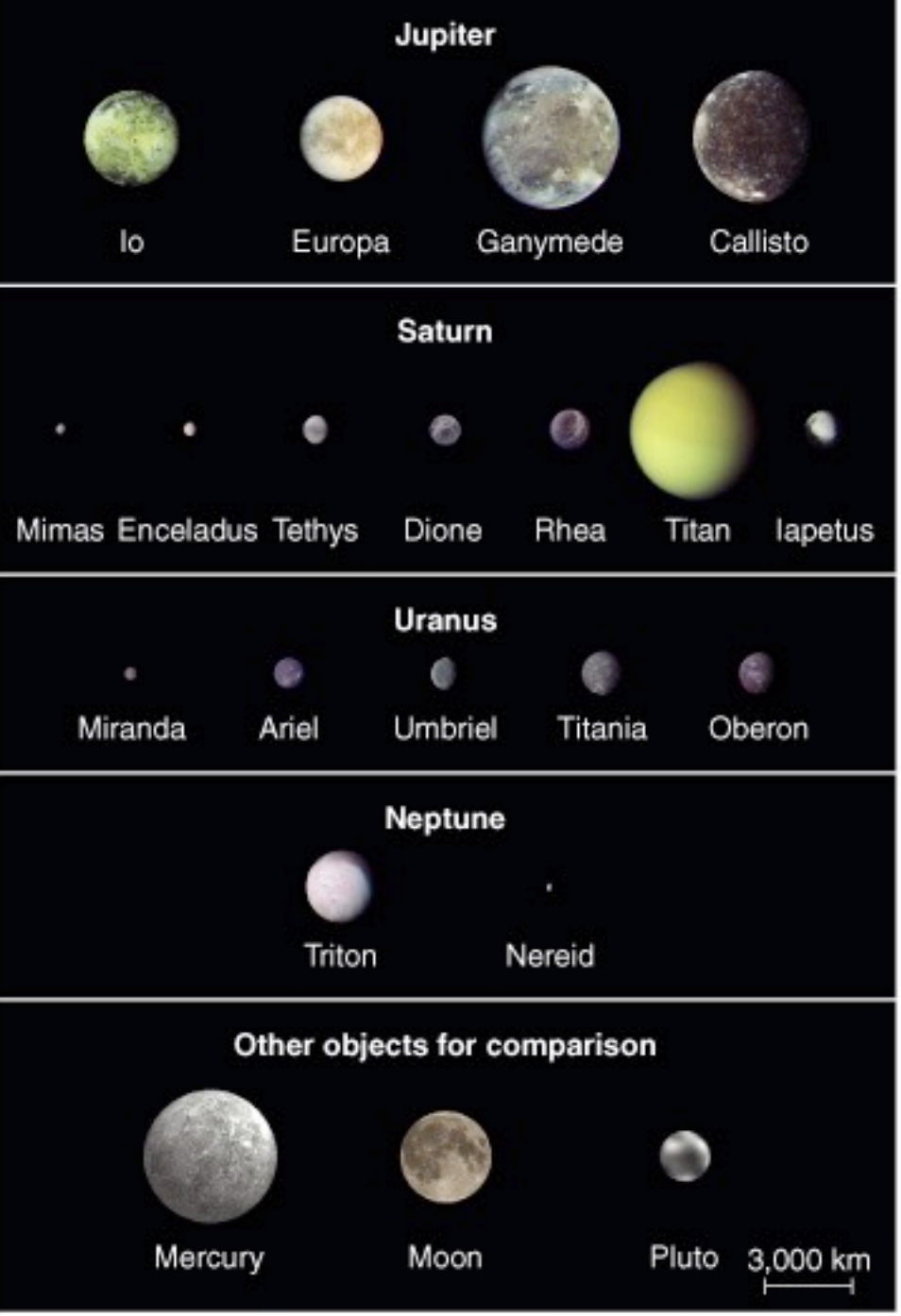
Obvious Definition

- A moon is an object that orbits a planet

Sizes of Moons

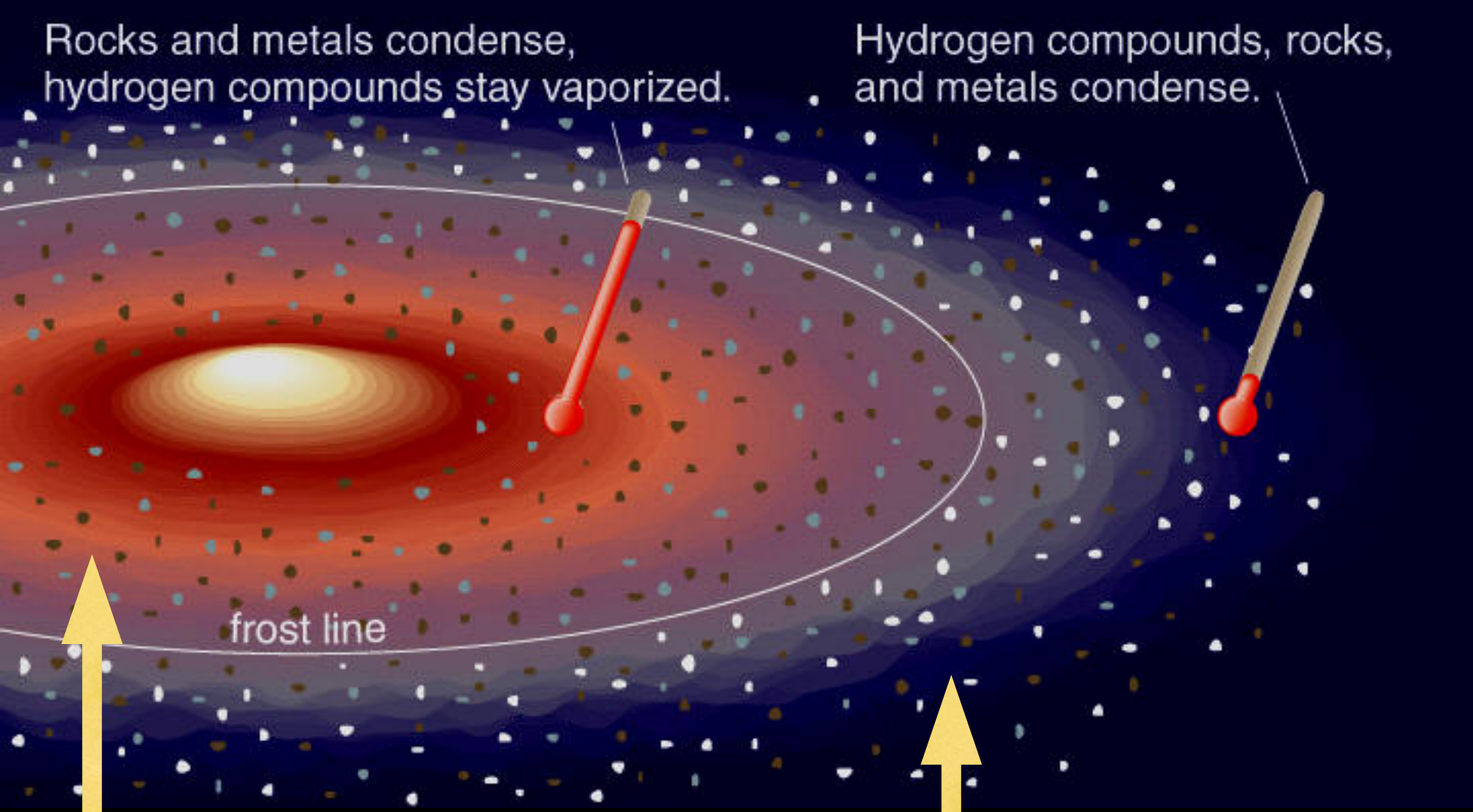
- Small moons (< 300 km)
  - — No geological activity
- Medium-sized moons (300–1,500 km)
  - — Geological activity in past
- Large moons (> 1,500 km)
  - — Ongoing geological activity

crudely speaking



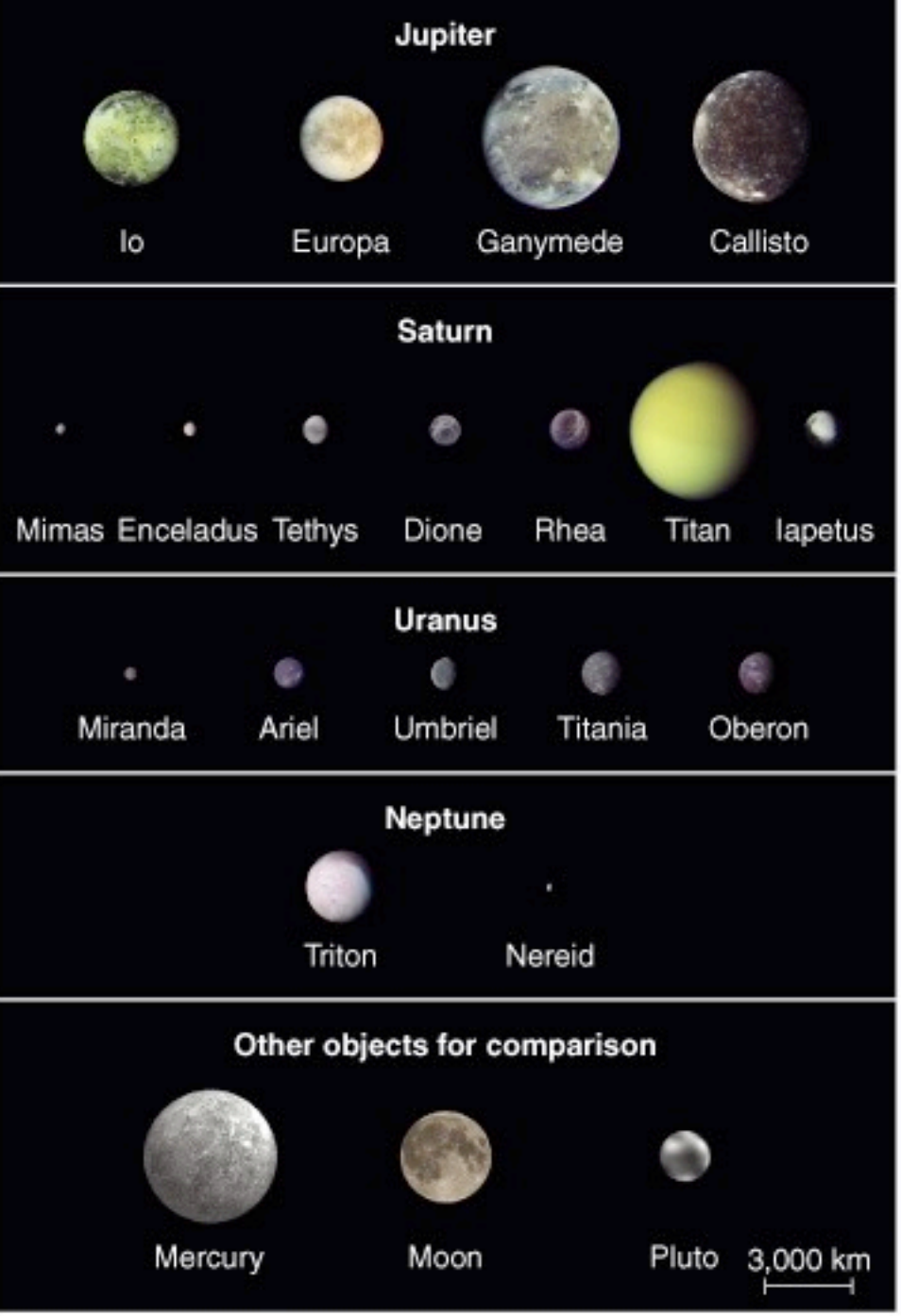
Medium and Large Moons

- Enough self-gravity to be spherical
- Have substantial amounts of ice - as important as rock to overall composition
- Formed in orbit around jovian planets
- Circular orbits mostly in the same direction as planet rotation



Inside frost line: terrestrial planets

Beyond frost line: Gas giants, icy moons, dwarf planets, comets

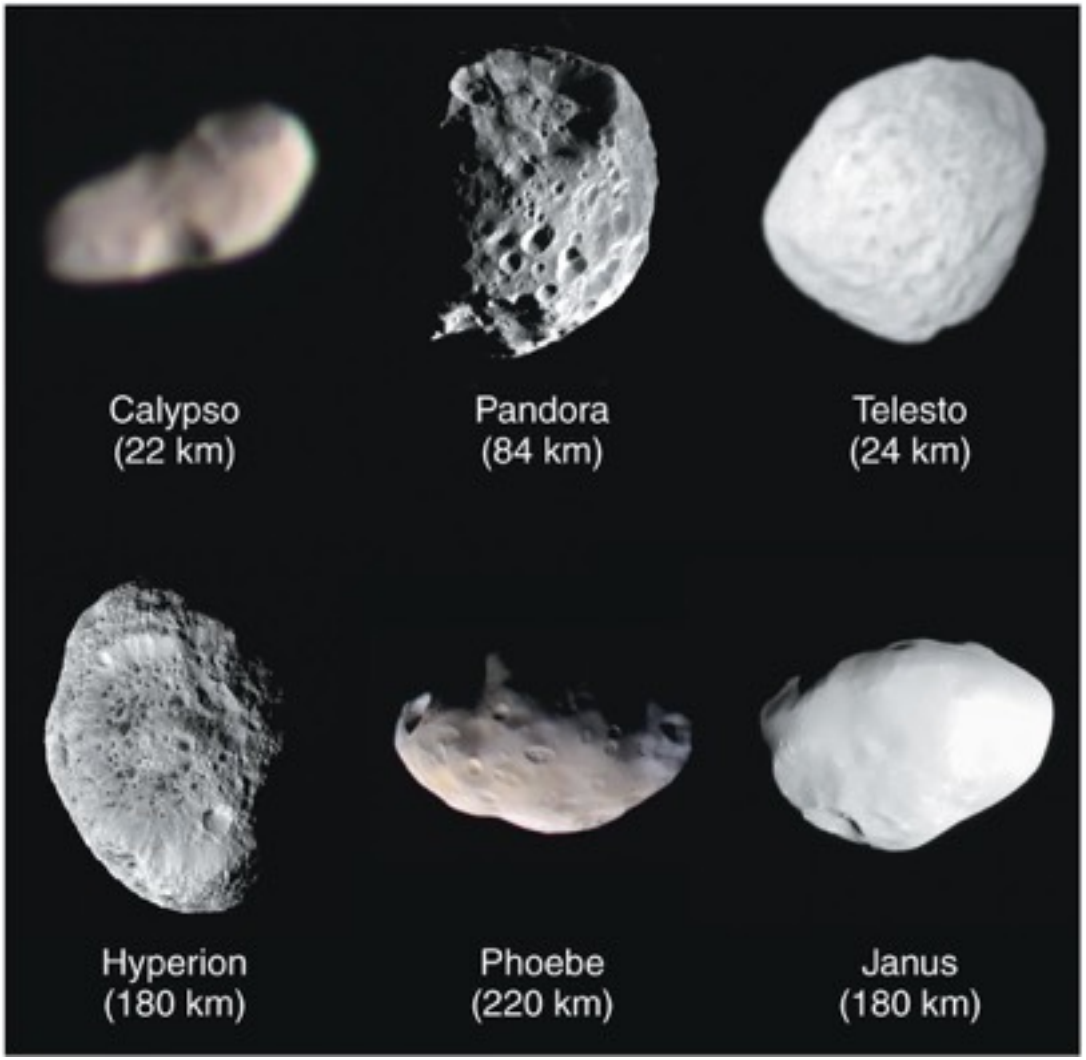


Medium and Large Moons

- Density
  - low
  - typically ~2 g/cc
  - more than Gas giants
  - less than Terrestrials
- Composition
  - rock
  - ice / subsurface water

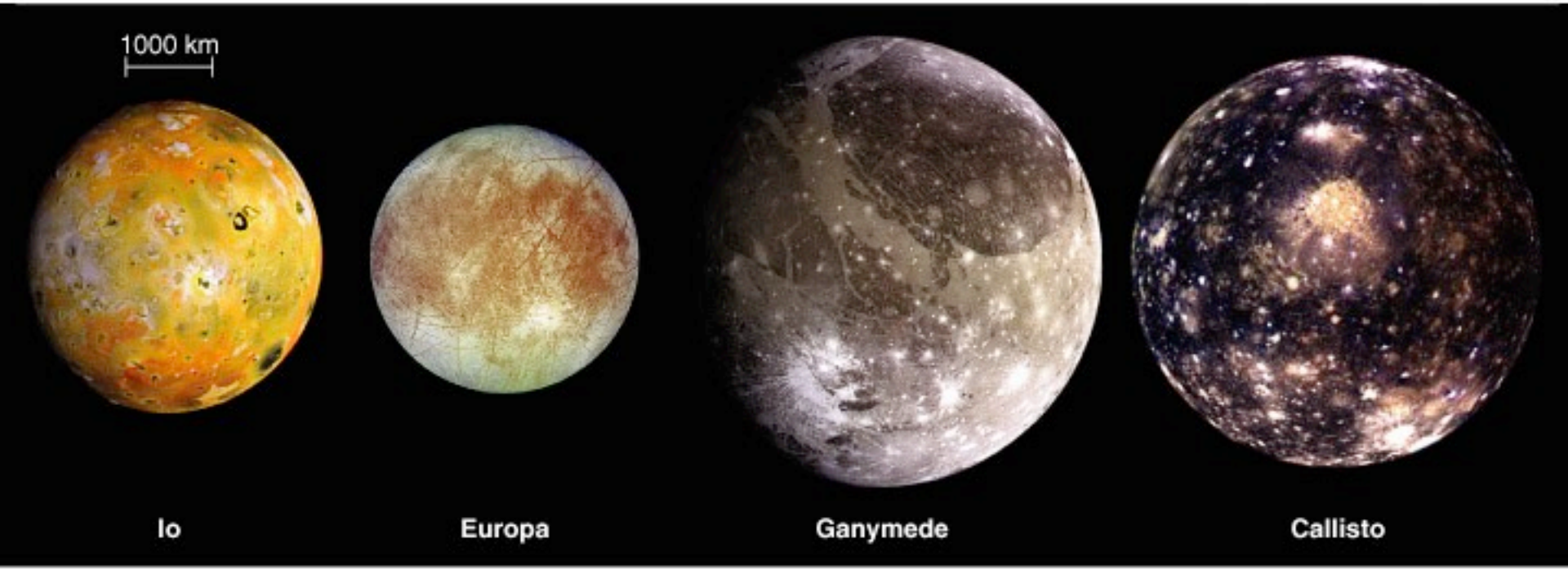
Ice is just another common "rock" mineral in the outer solar system.

Small Moons



- Far more numerous than the medium and large moons
- Not enough gravity to be spherical: "potato-shaped"
- Often just captured asteroids

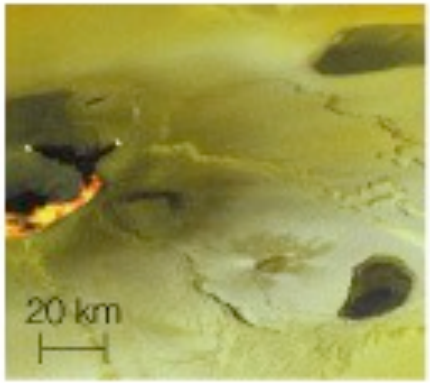
The moons of the Jovian planets

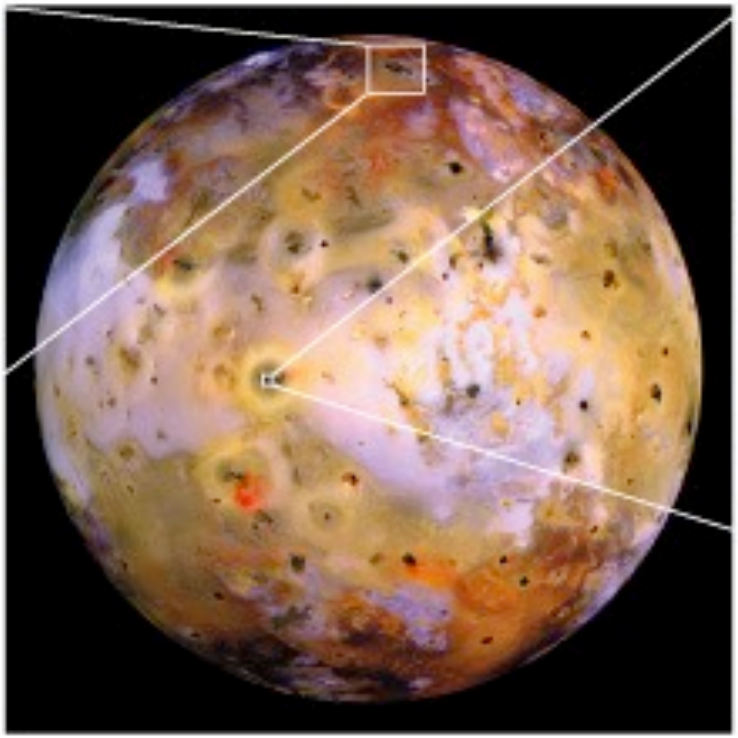


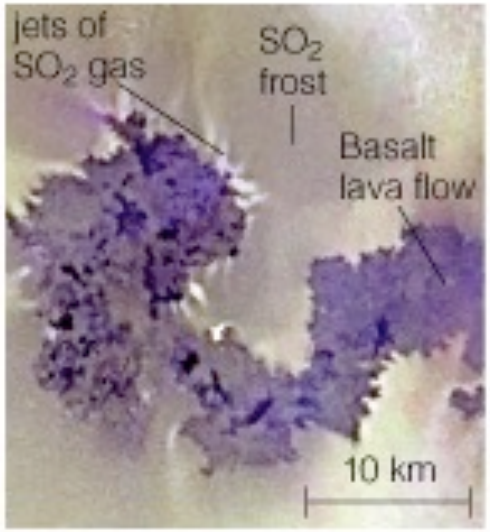
2006 Pearson Education, Inc., publishing as Addison Wesley

Galilean moons of Jupiter
("Medici stars")

Io



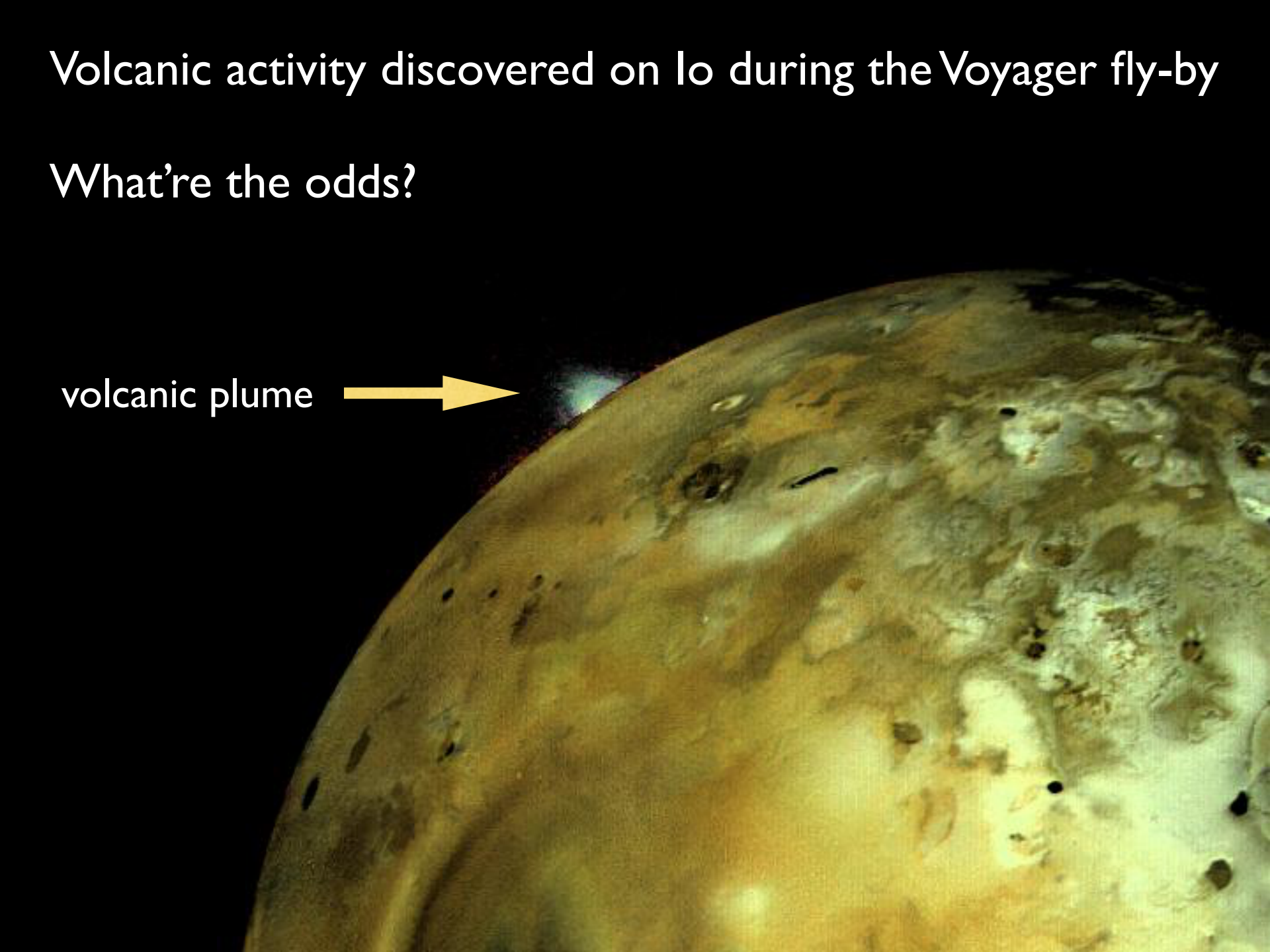




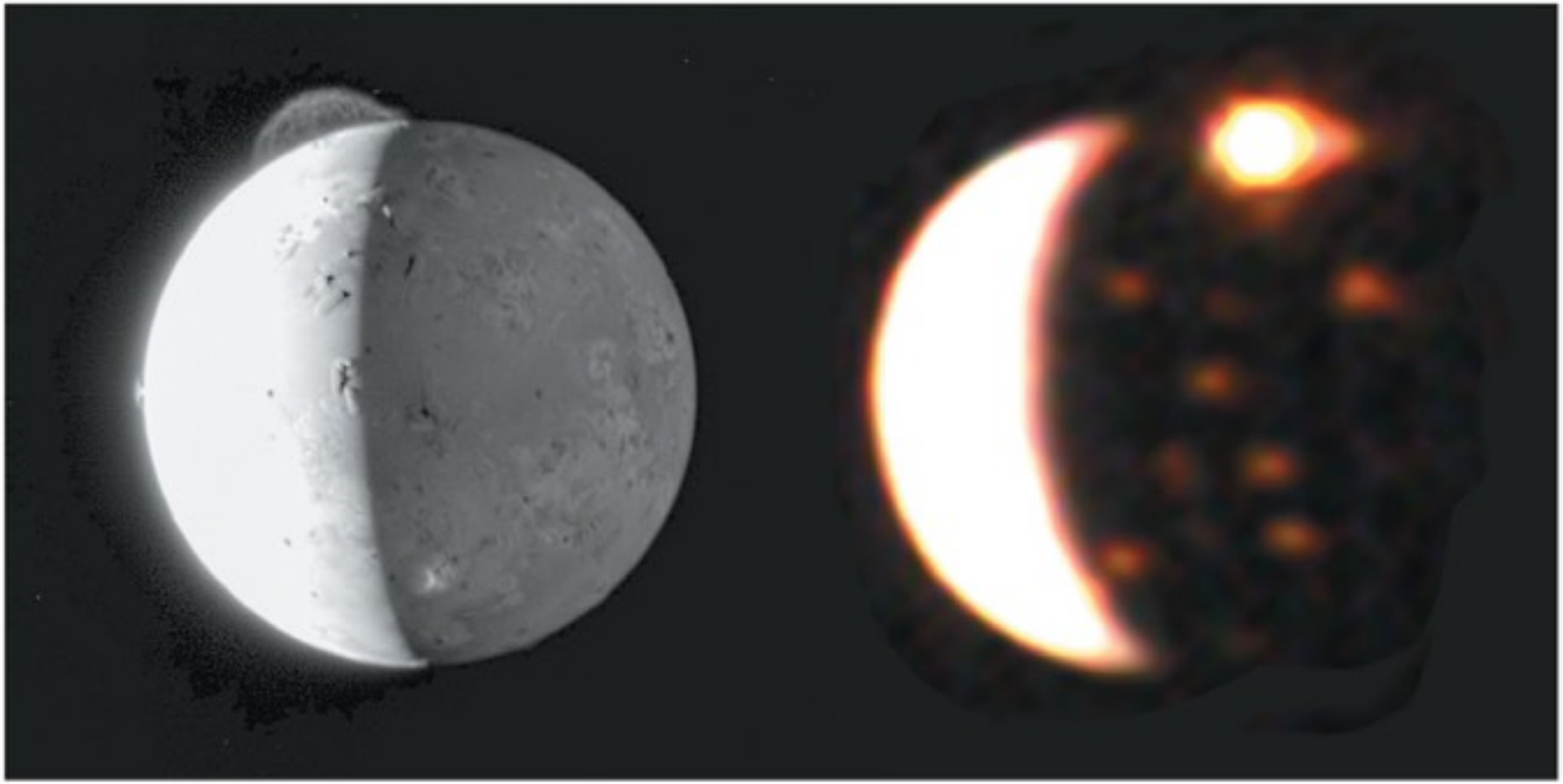
- Io is the most volcanically active body in the solar system.

Volcanic activity discovered on Io during the Voyager fly-by

What're the odds?

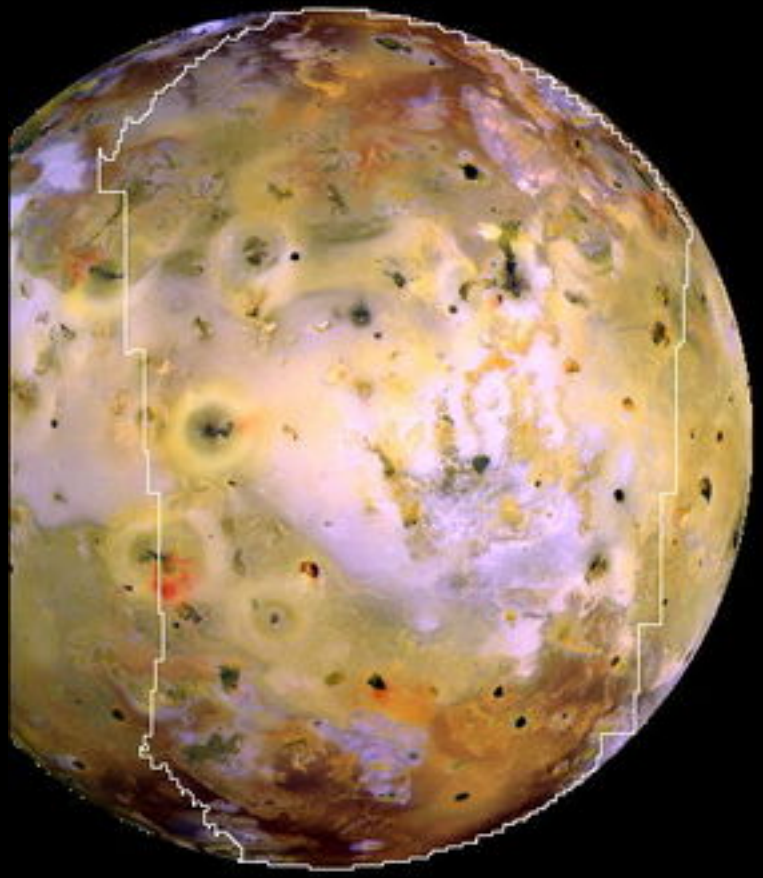


Io's Volcanoes

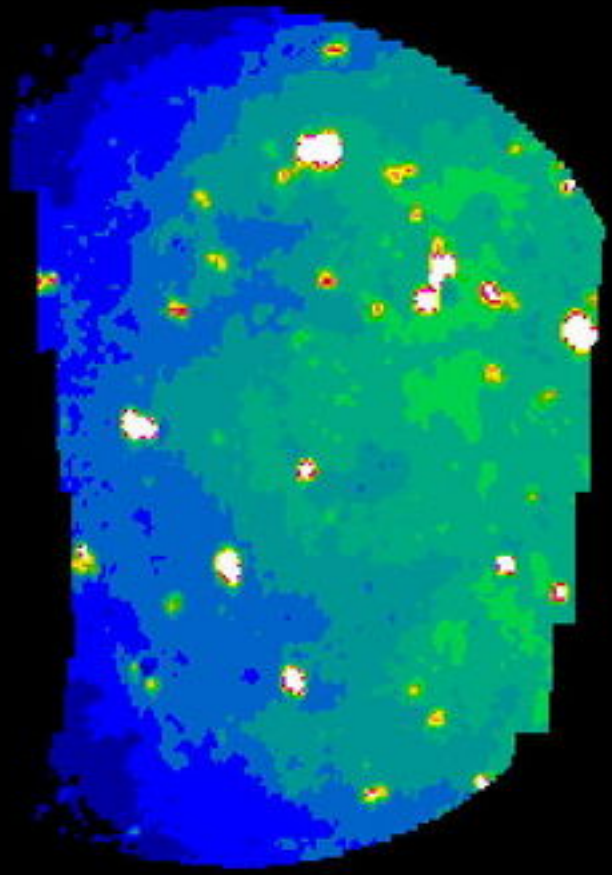


- Volcanic eruptions continue to change Io's surface.

optical

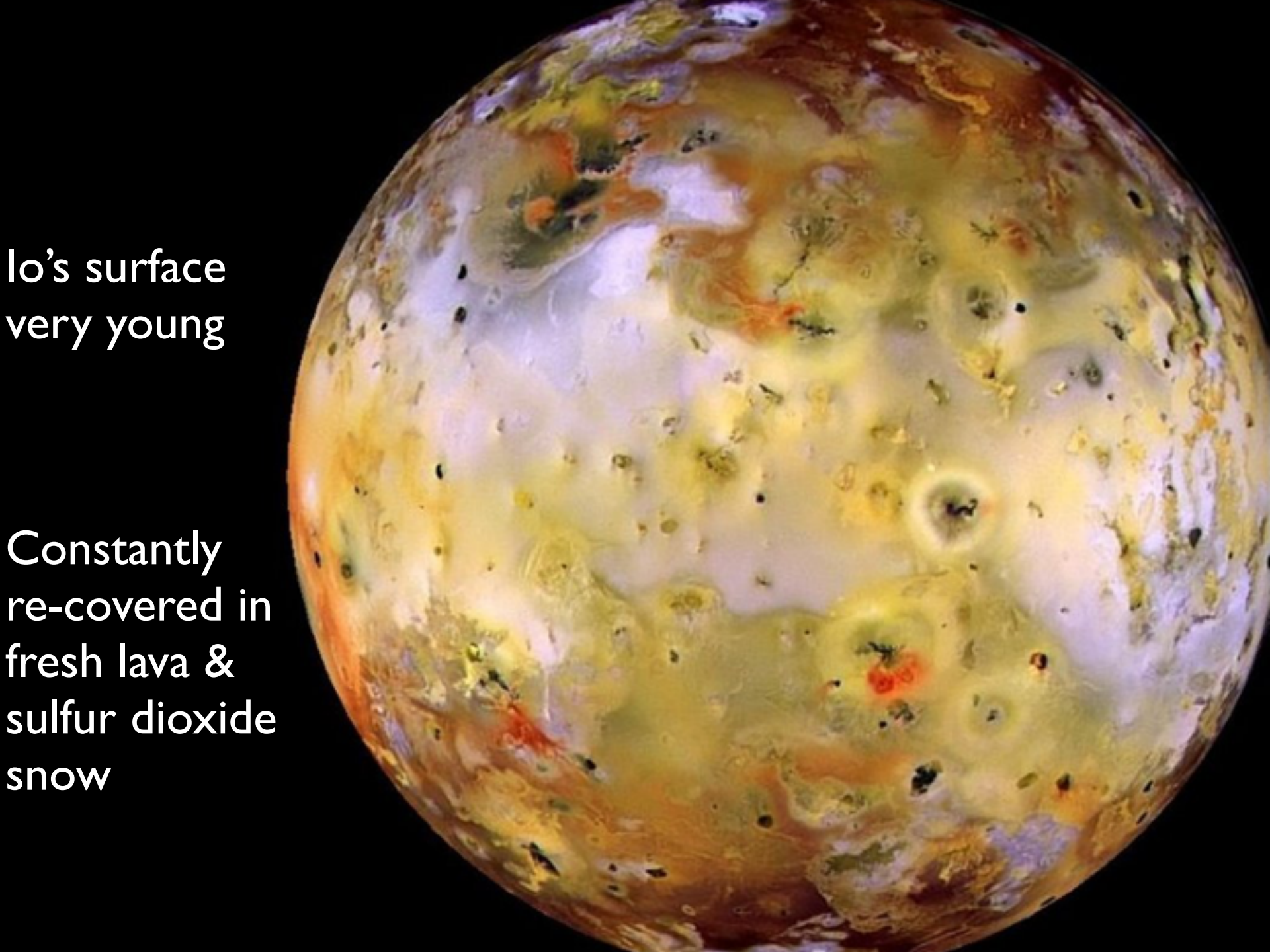


infrared

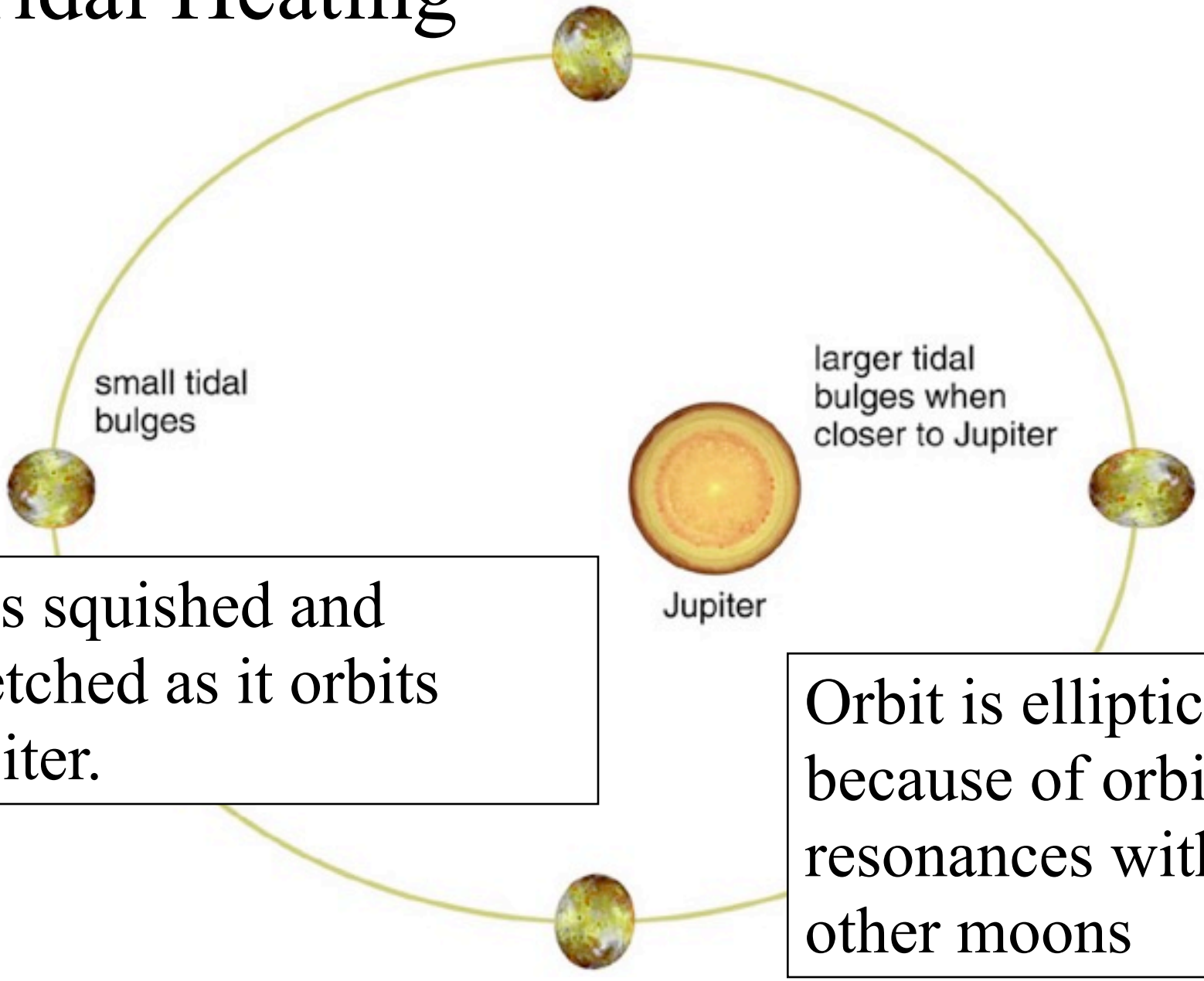


dark volcanic craters in the optical
correspond to hot spots in the infrared

show interactive optical/IR image


Io's surface very young
Constantly re-covered in fresh lava & sulfur dioxide snow

Tidal Heating

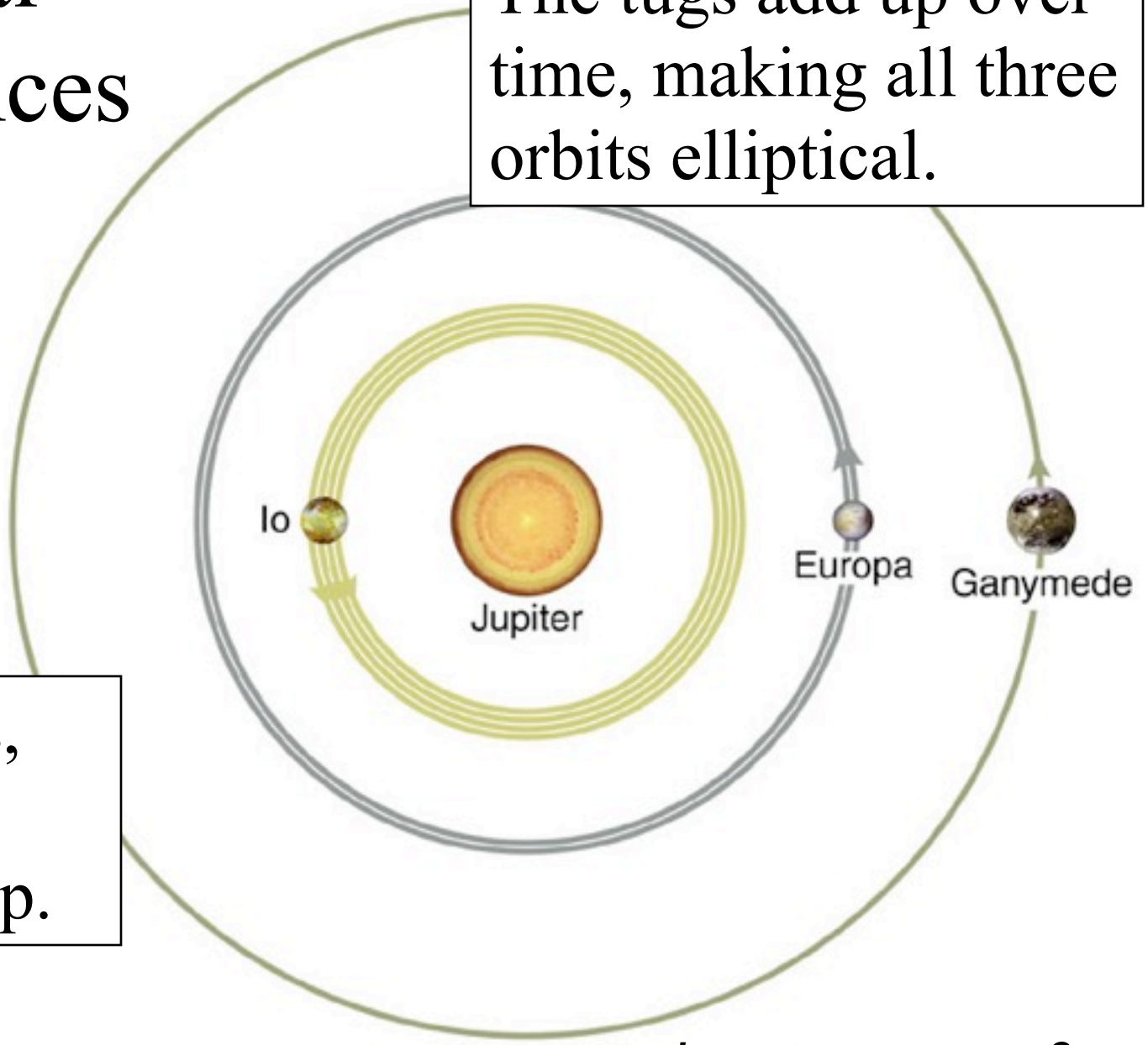


Io is squished and stretched as it orbits Jupiter.

Orbit is elliptical because of orbital resonances with other moons

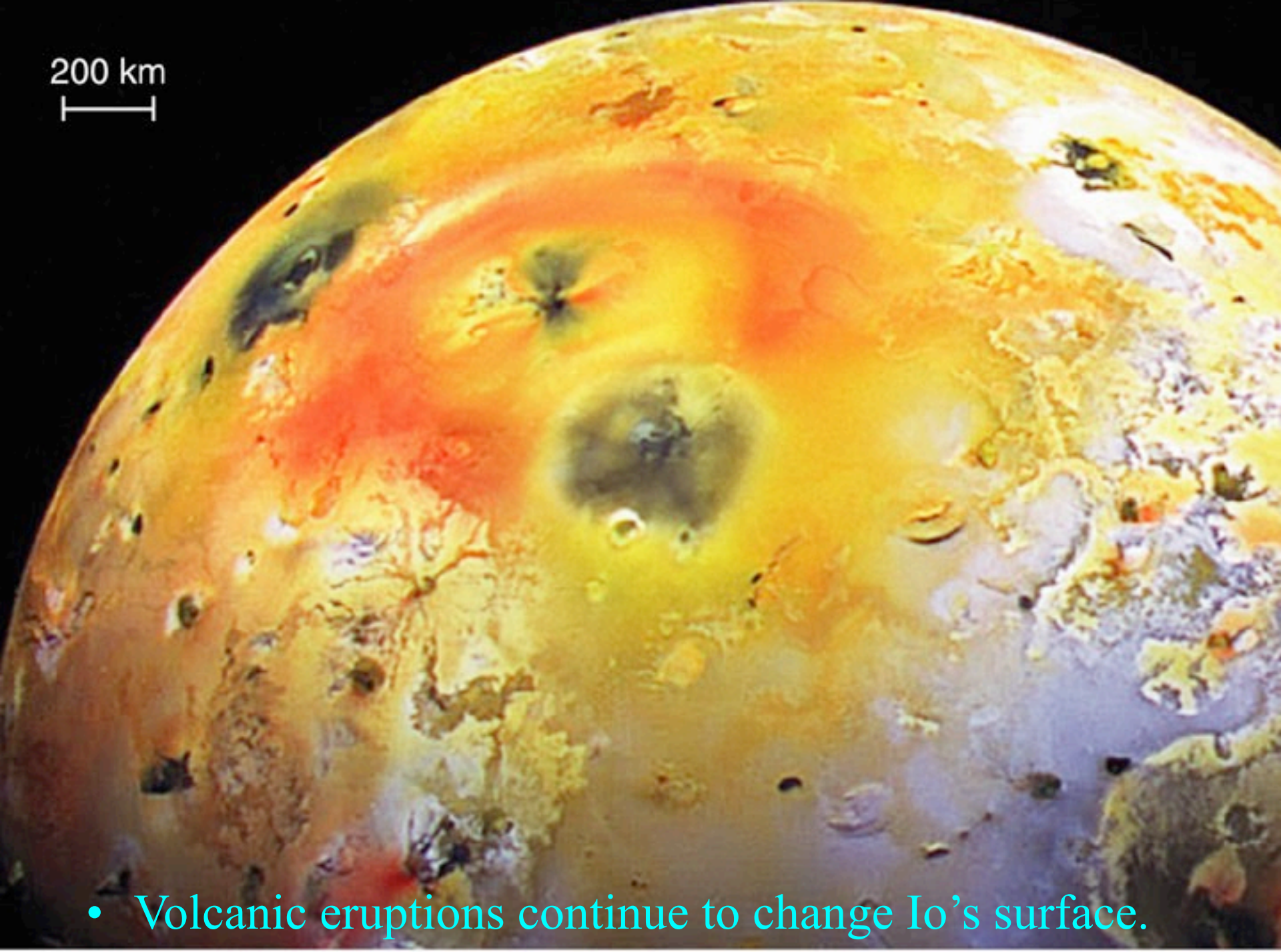
Orbital Resonances

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



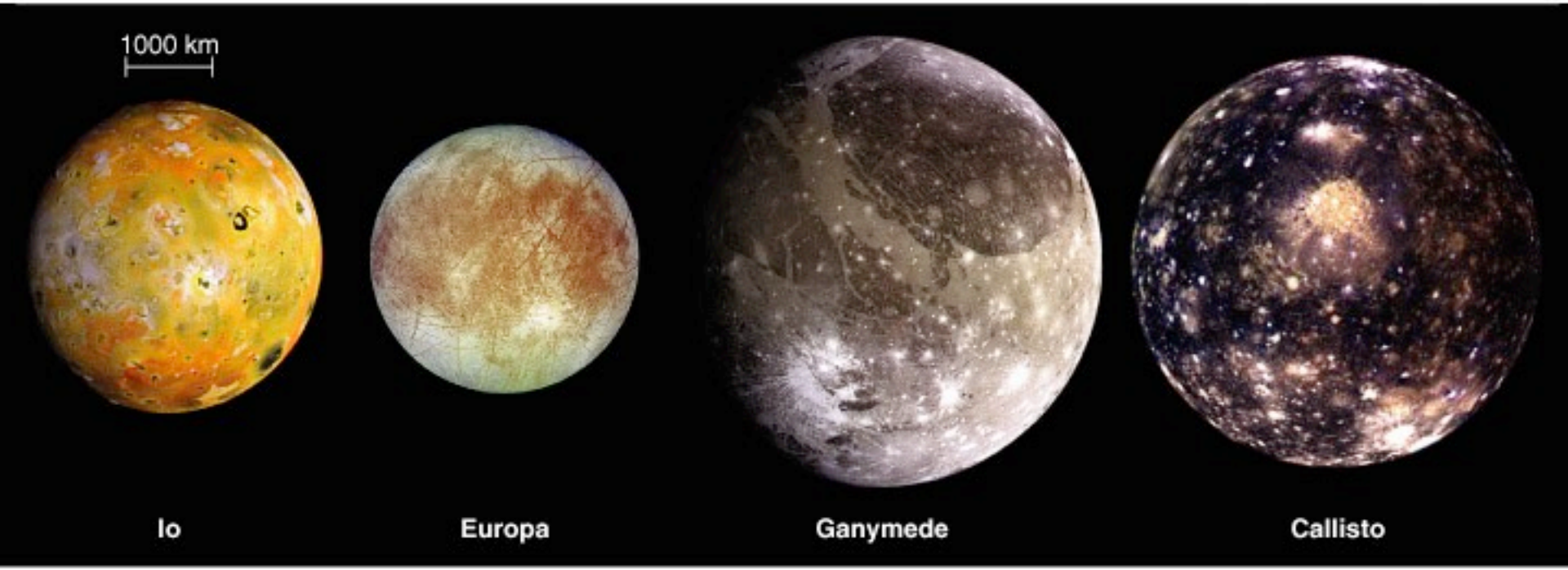
Every 7 days, these three moons line up.

show interactive figure

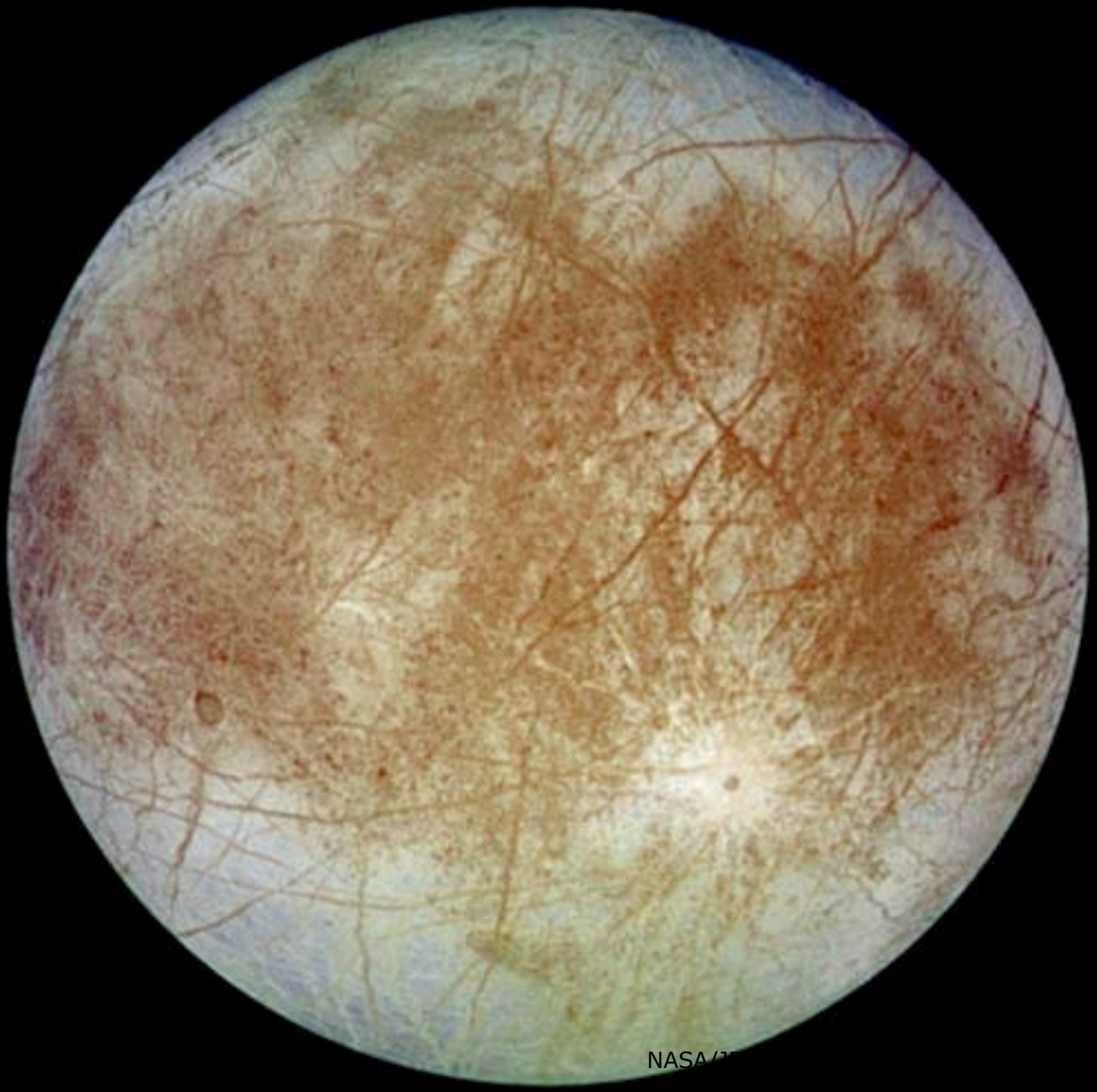


- Volcanic eruptions continue to change Io's surface.

The moons of the Jovian planets

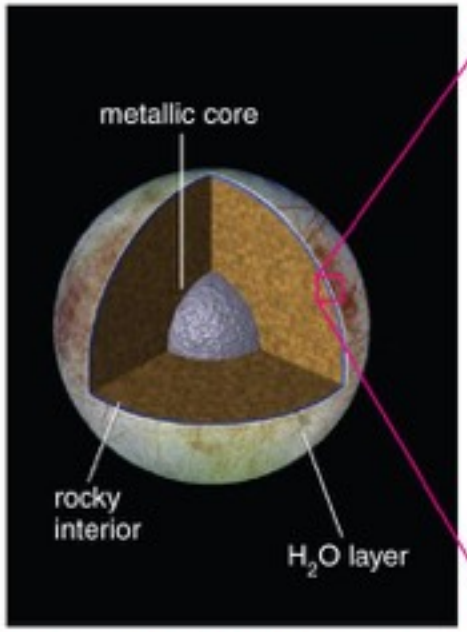


Europa

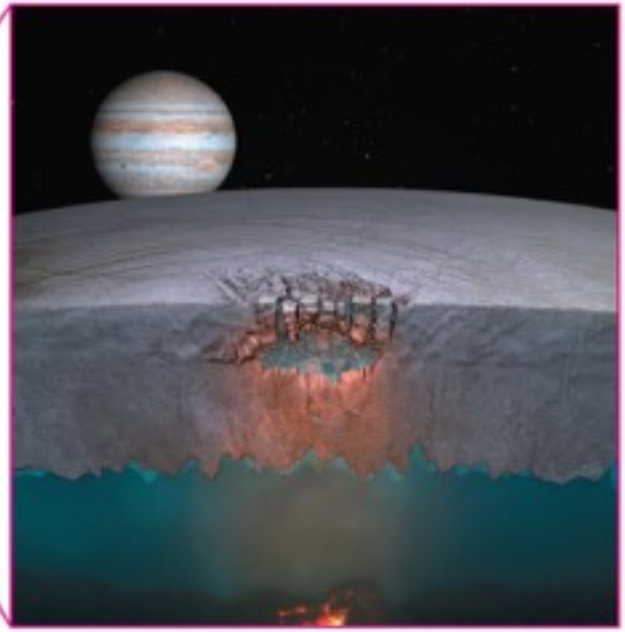


NASA/J

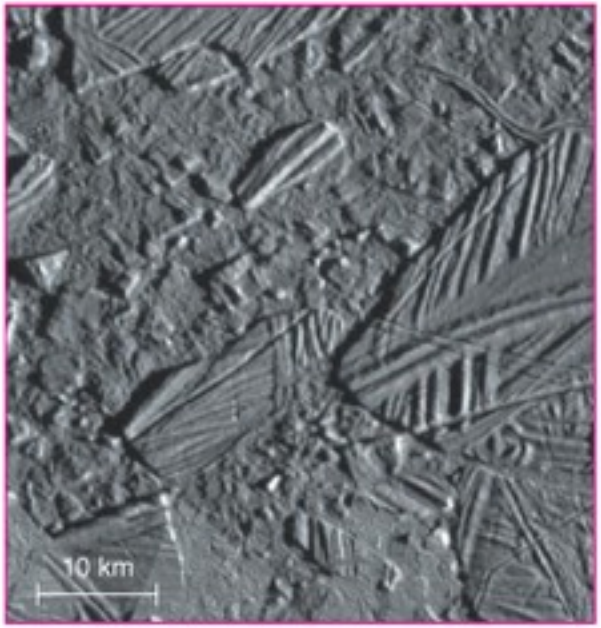
Europa's interior also warmed by tidal heating.



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

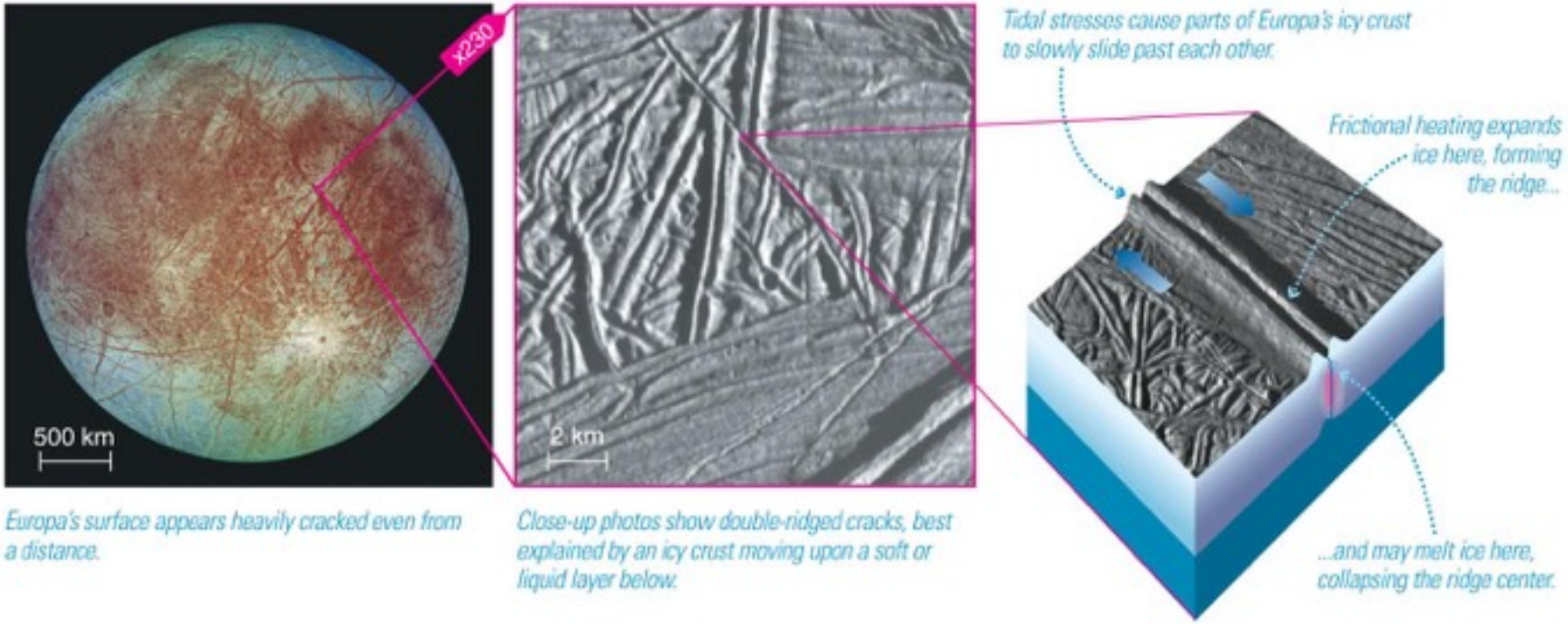


Rising plumes of warm water may sometimes create lakes within the ice, causing the crust above to crack . . .



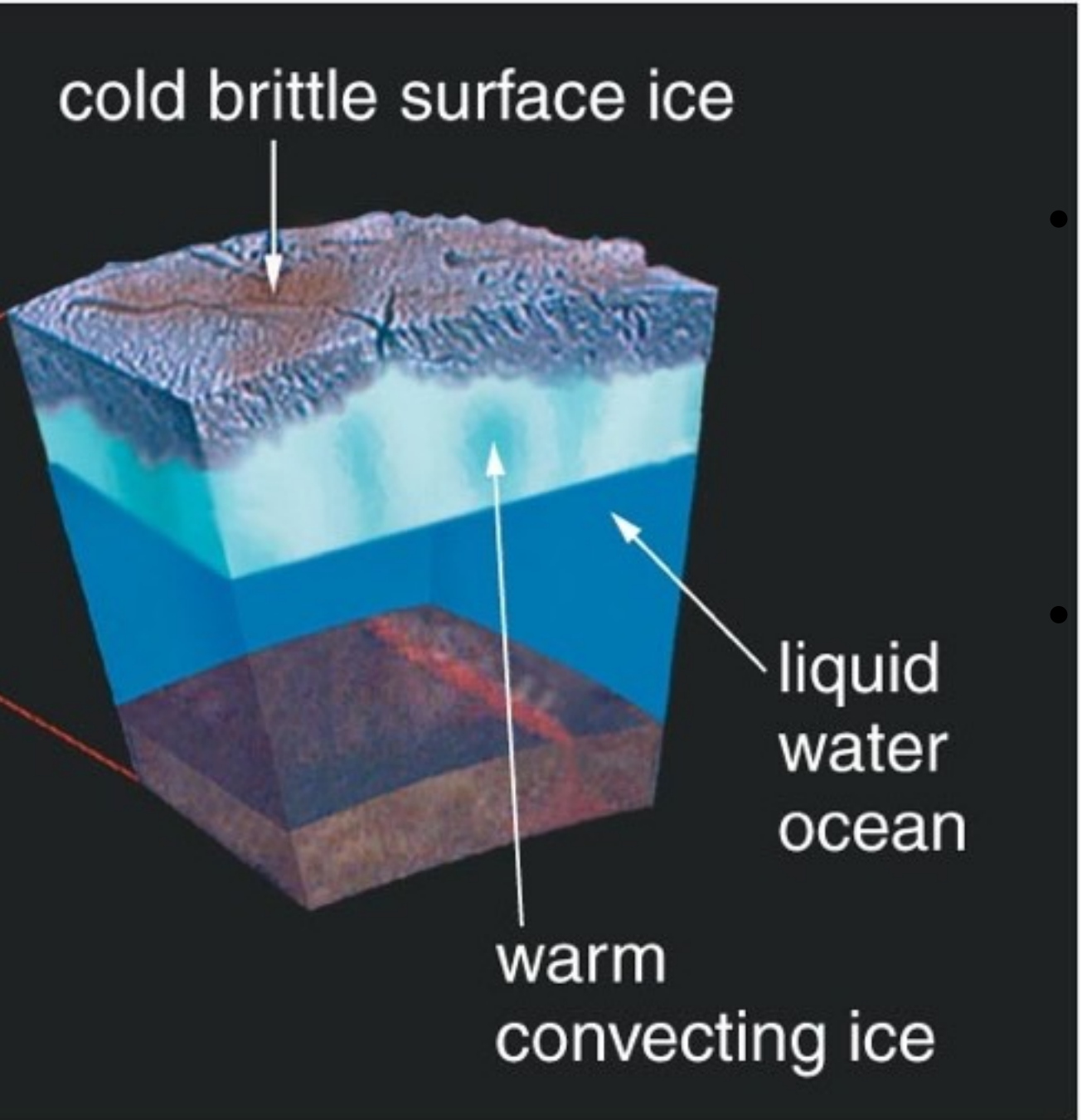
. . . explaining surface terrain that looks like a jumble of icebergs suspended in a place where liquid or slushy water froze.

Tidal stresses crack Europa's surface ice.



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

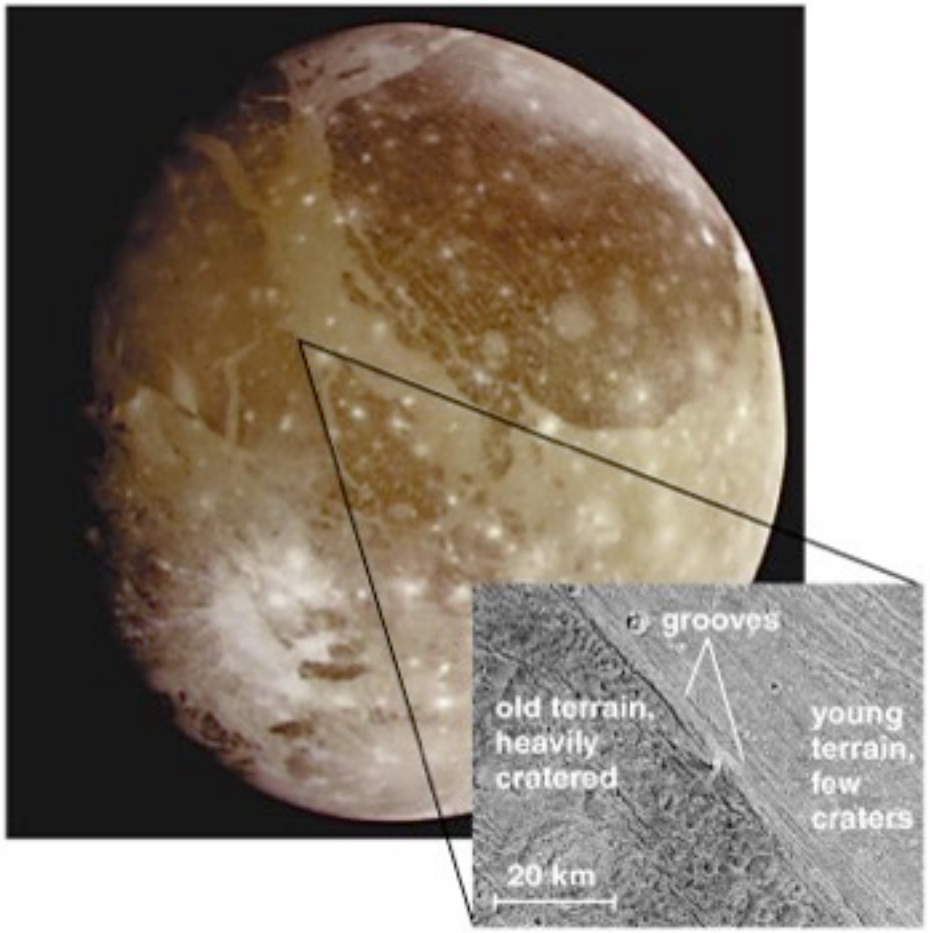
Close-up photos show double-ridged cracks, best explained by an icy crust moving upon a soft or liquid layer below.



Europa

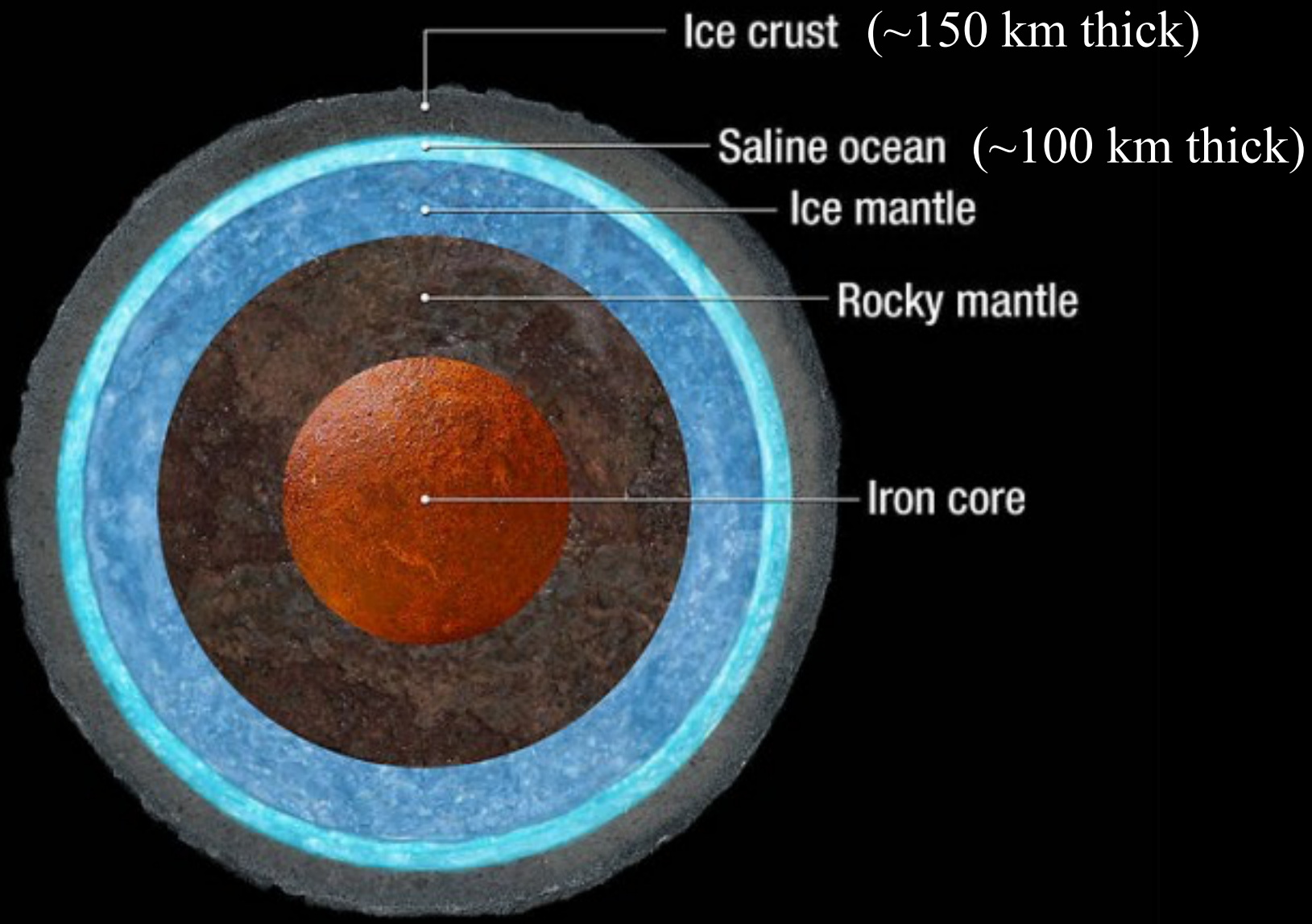
- Icy surface
  - cracks driven by some "geological" activity
- Liquid ocean beneath?
  - popular spot to speculate about the potential for life

Ganymede

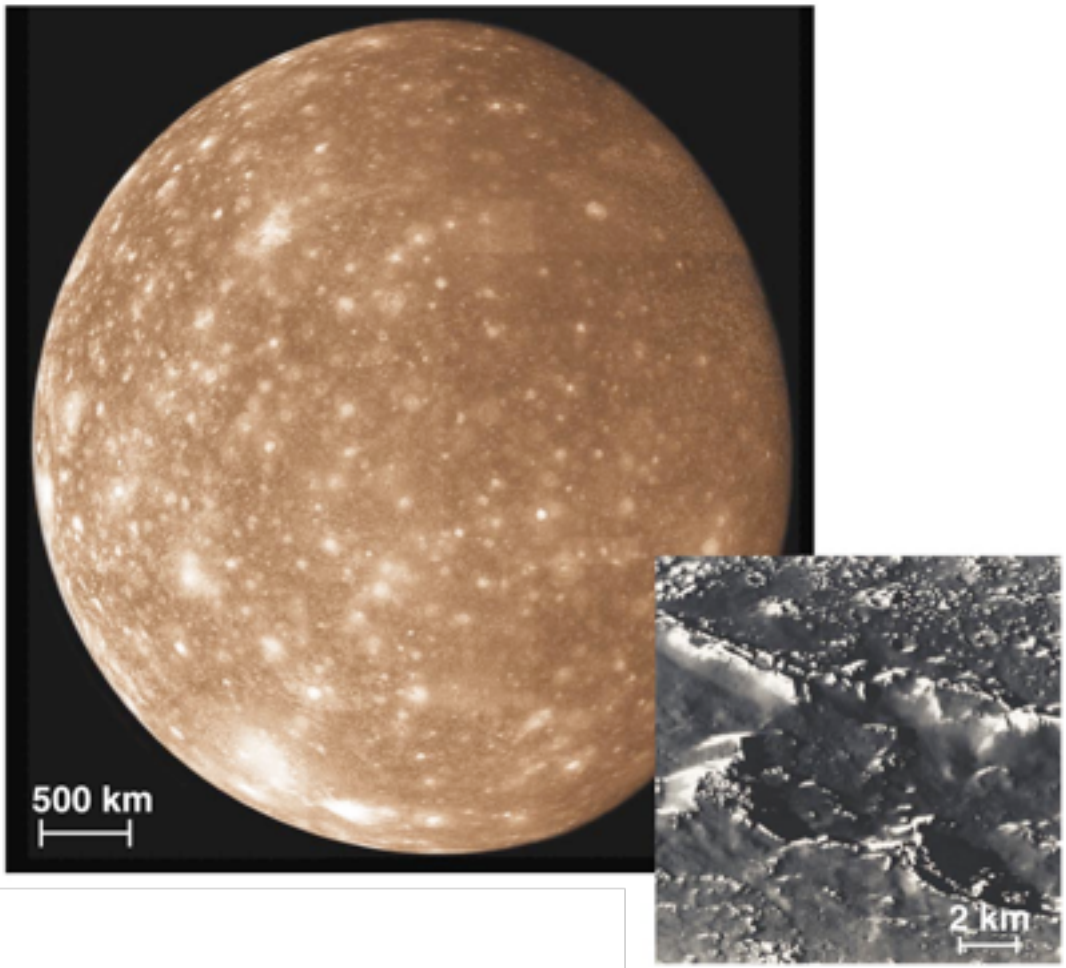


- Largest moon in the solar system
- Clear evidence of geological activity
- Salty ocean under thick crust of ice
- Tidal heating plus heat from radio-active decay?

Ganymede Interior

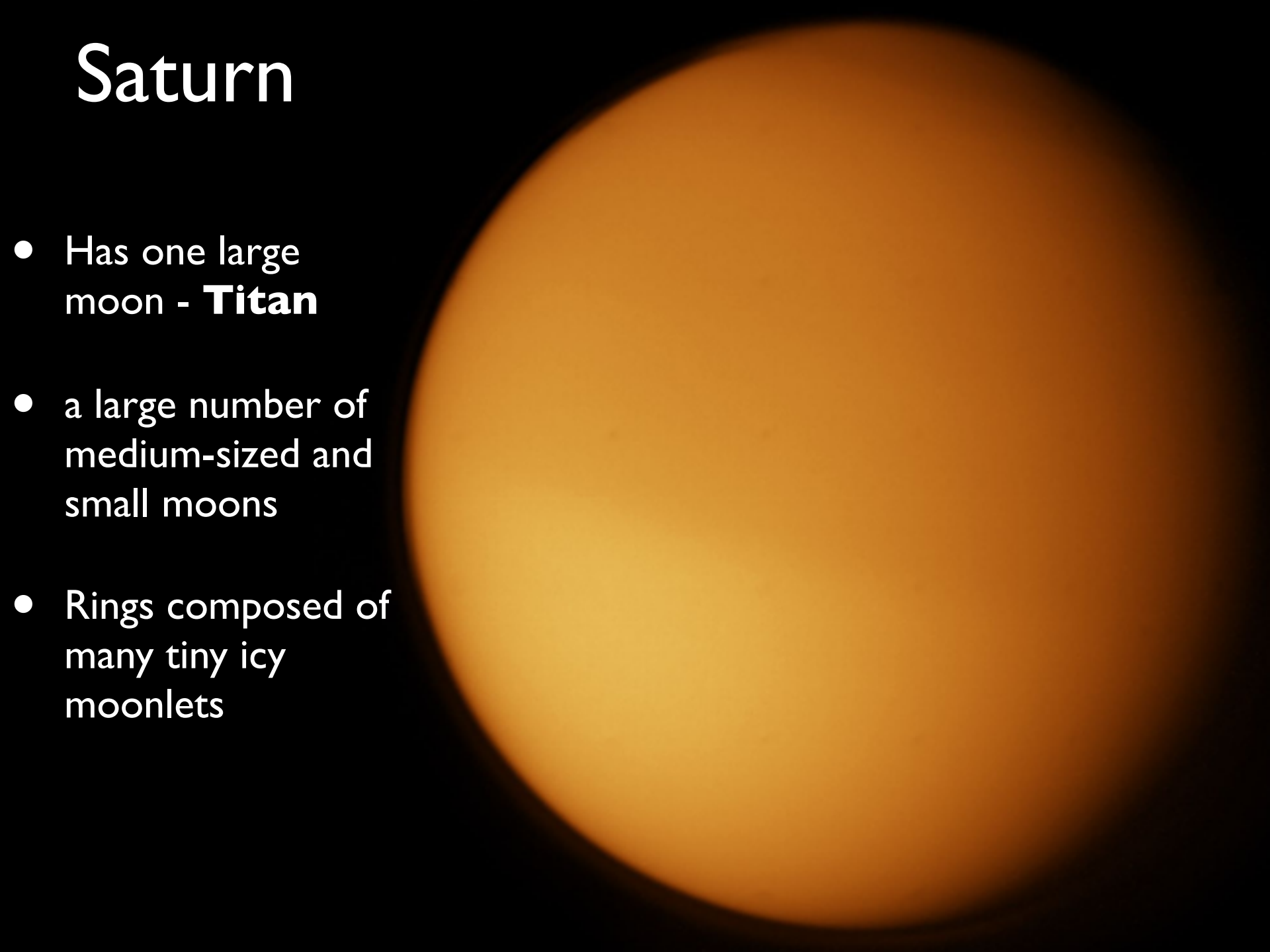


Callisto



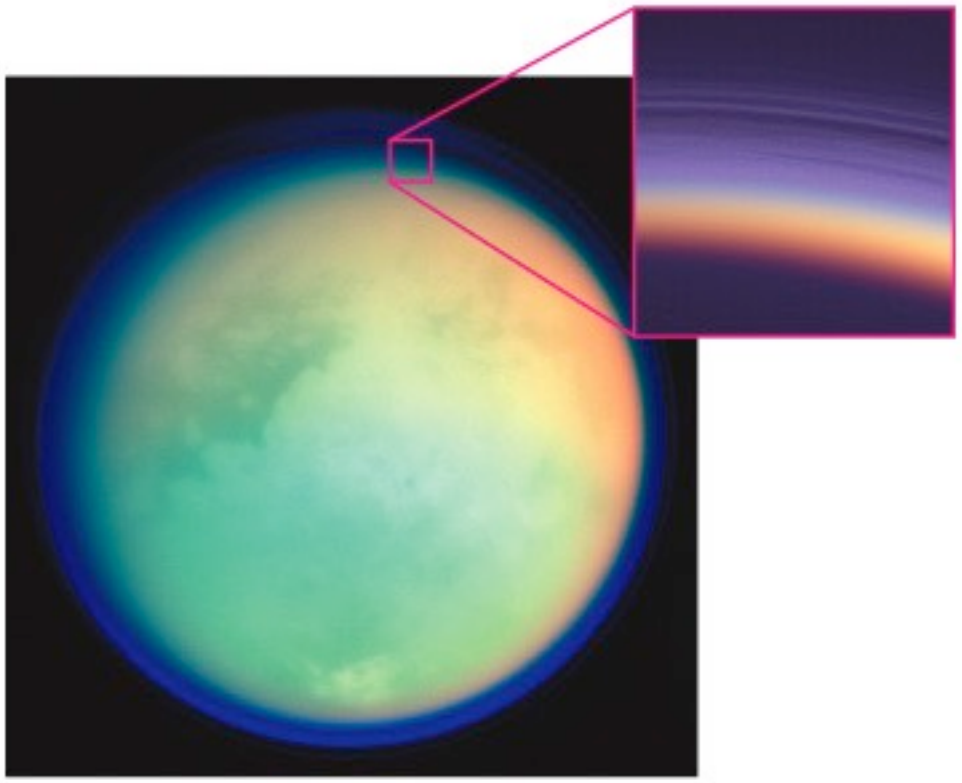
- "Classic" cratered iceball
- No tidal heating, no orbital resonances

Saturn



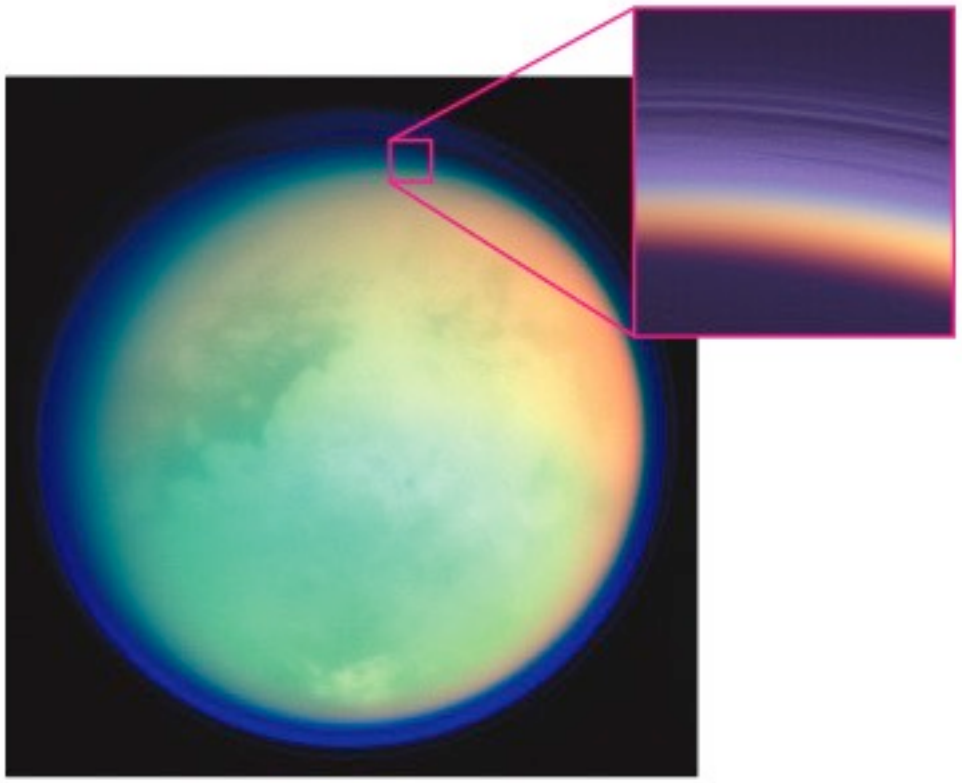
- Has one large moon - **Titan**
- a large number of medium-sized and small moons
- Rings composed of many tiny icy moonlets

Saturn's large moon Titan



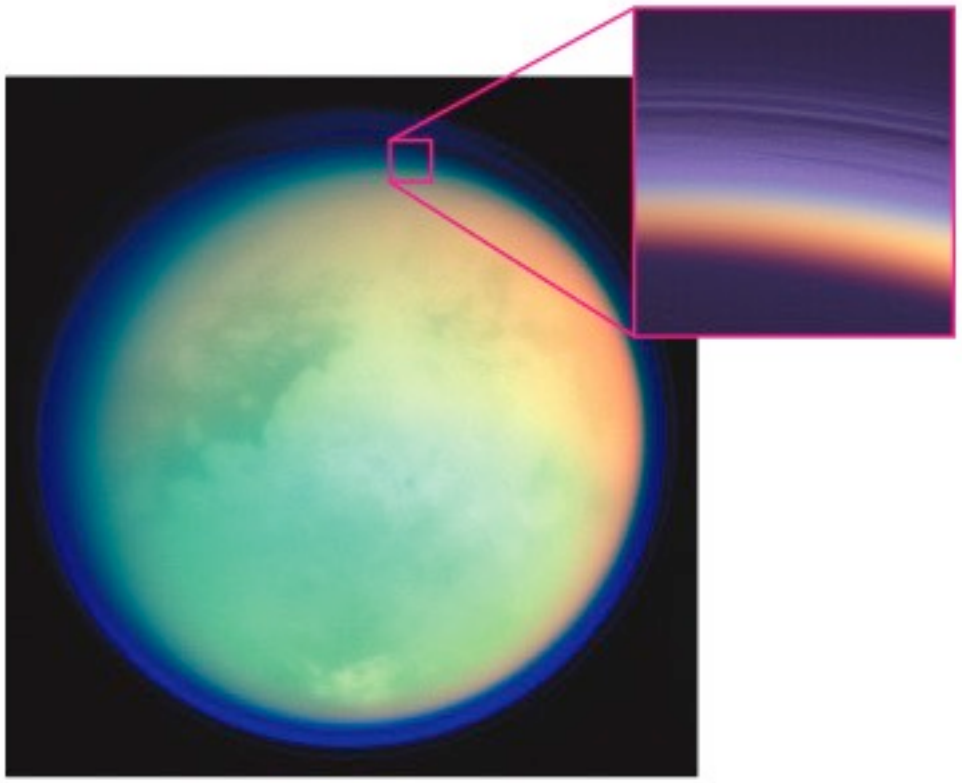
- Titan is the only moon in the solar system which has a thick atmosphere.
- It has a thick haze layer that obscures the surface at optical wavelengths.

Saturn's large moon Titan



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

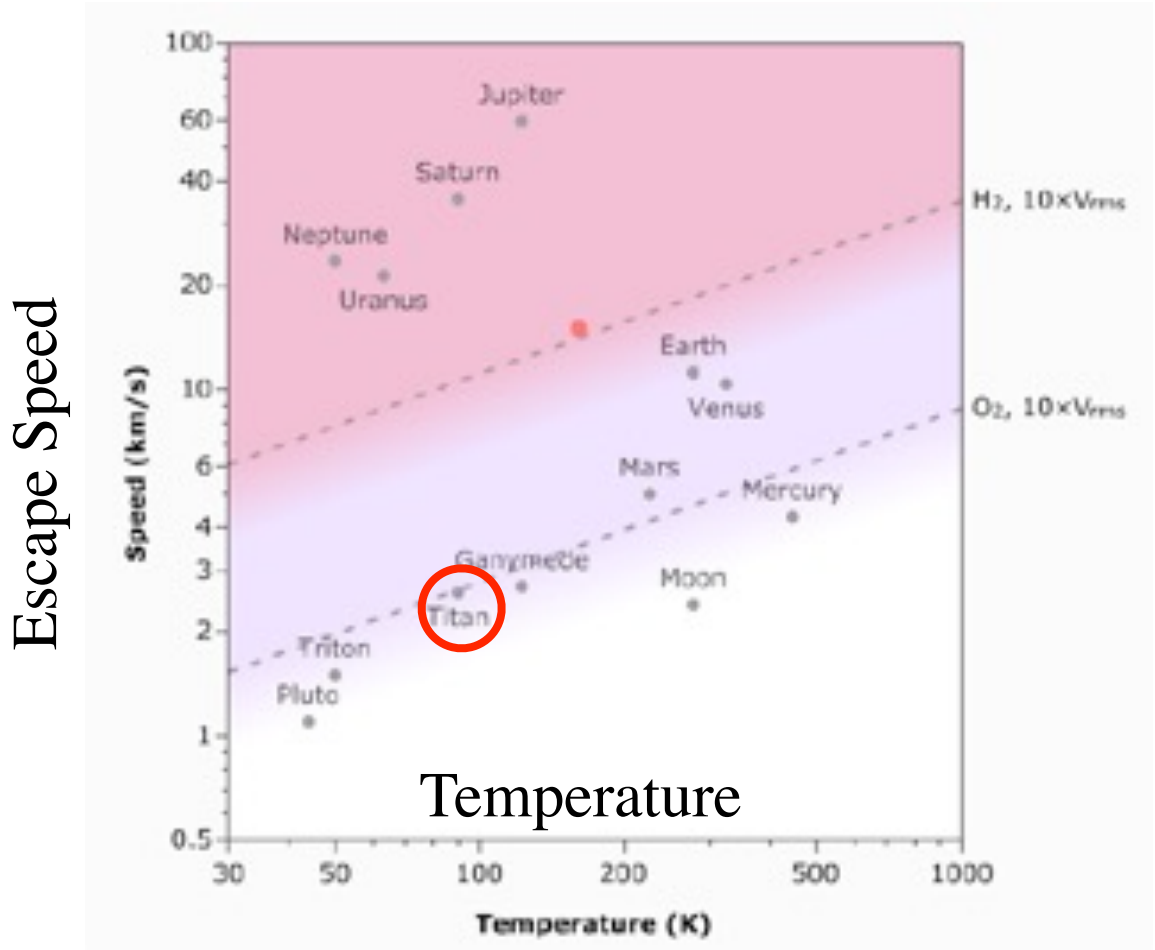
Saturn's large moon Titan



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

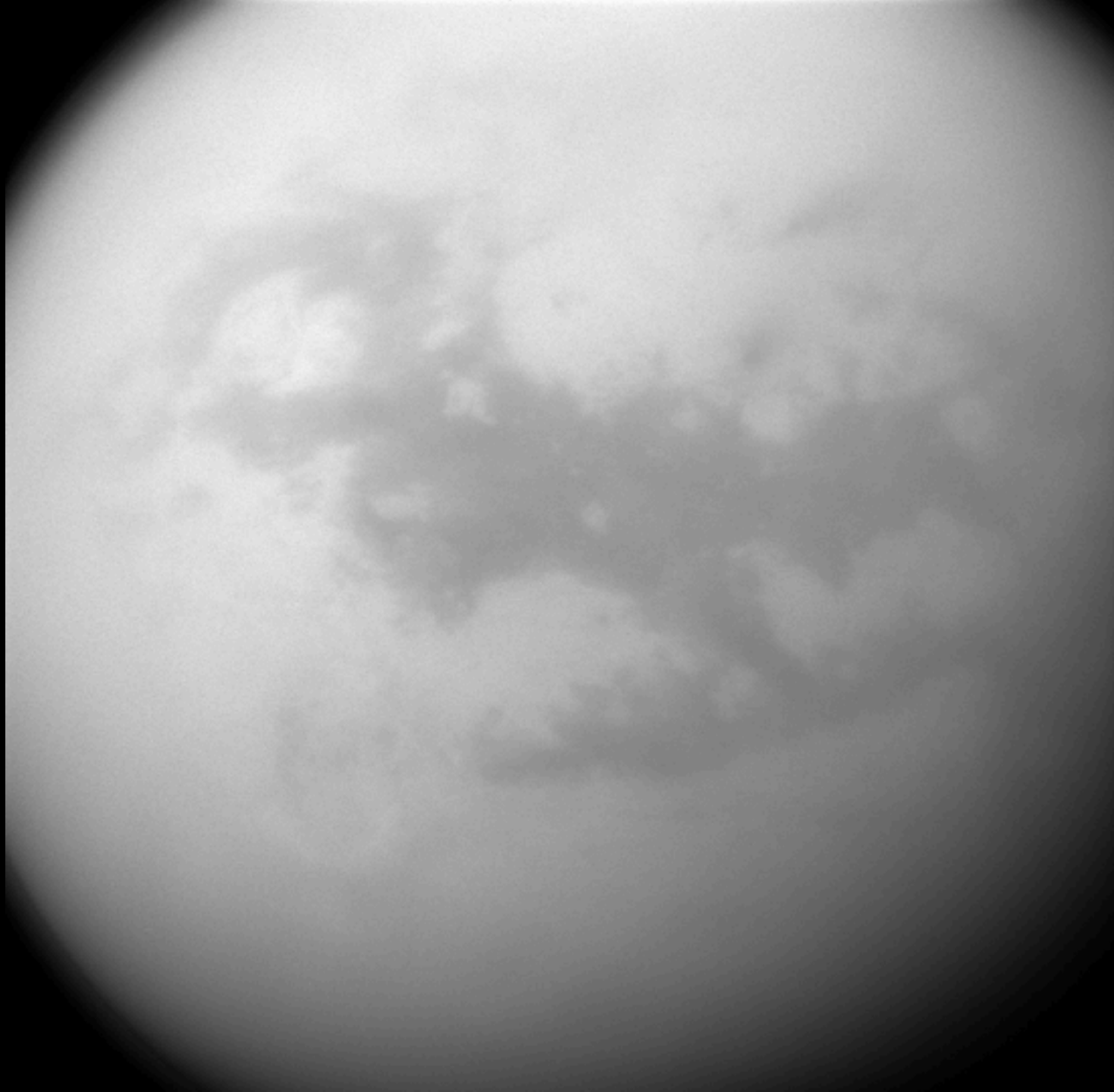
Titan is

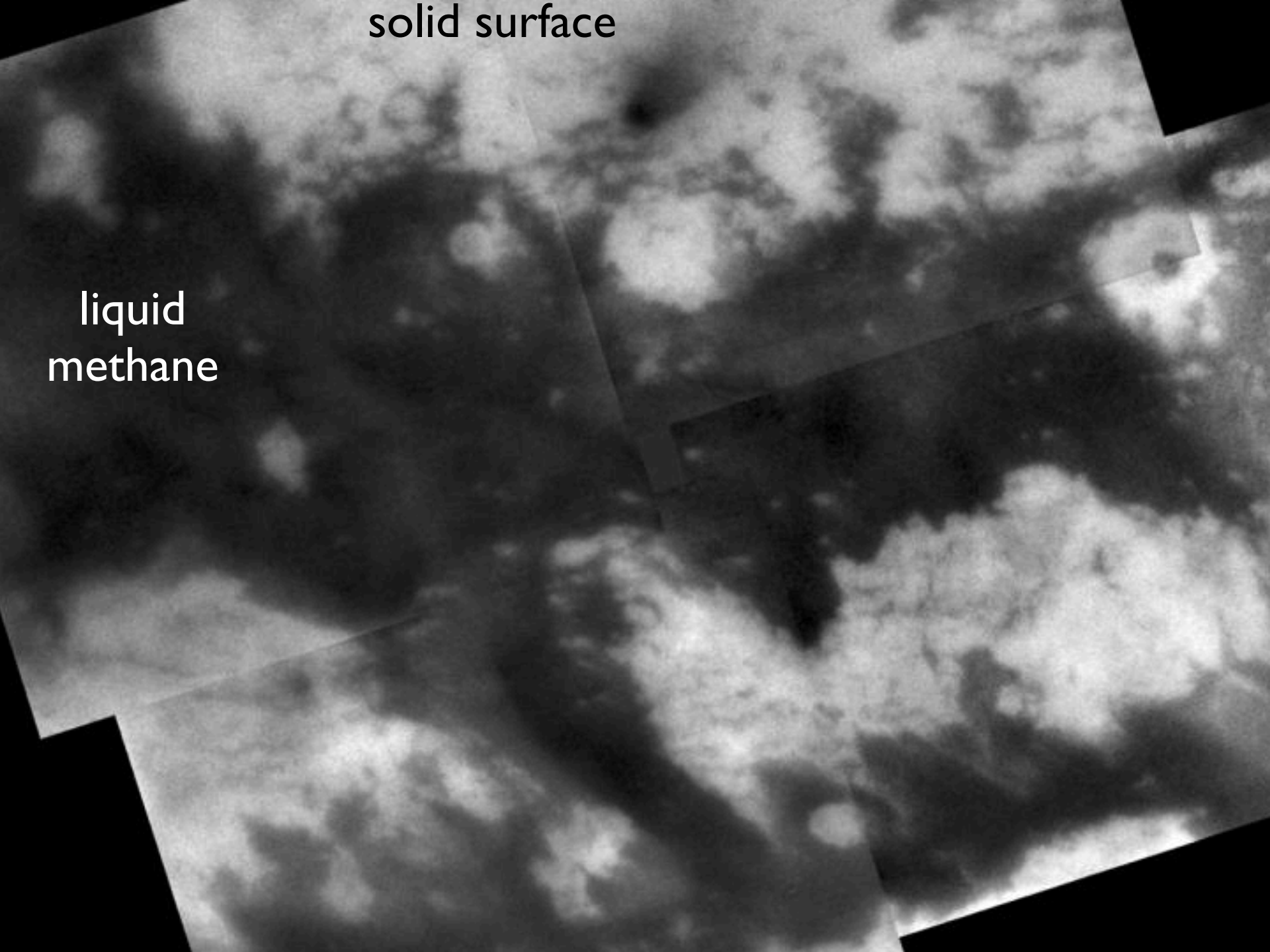
- Big for a moon, and
- cold - can retain an atmosphere



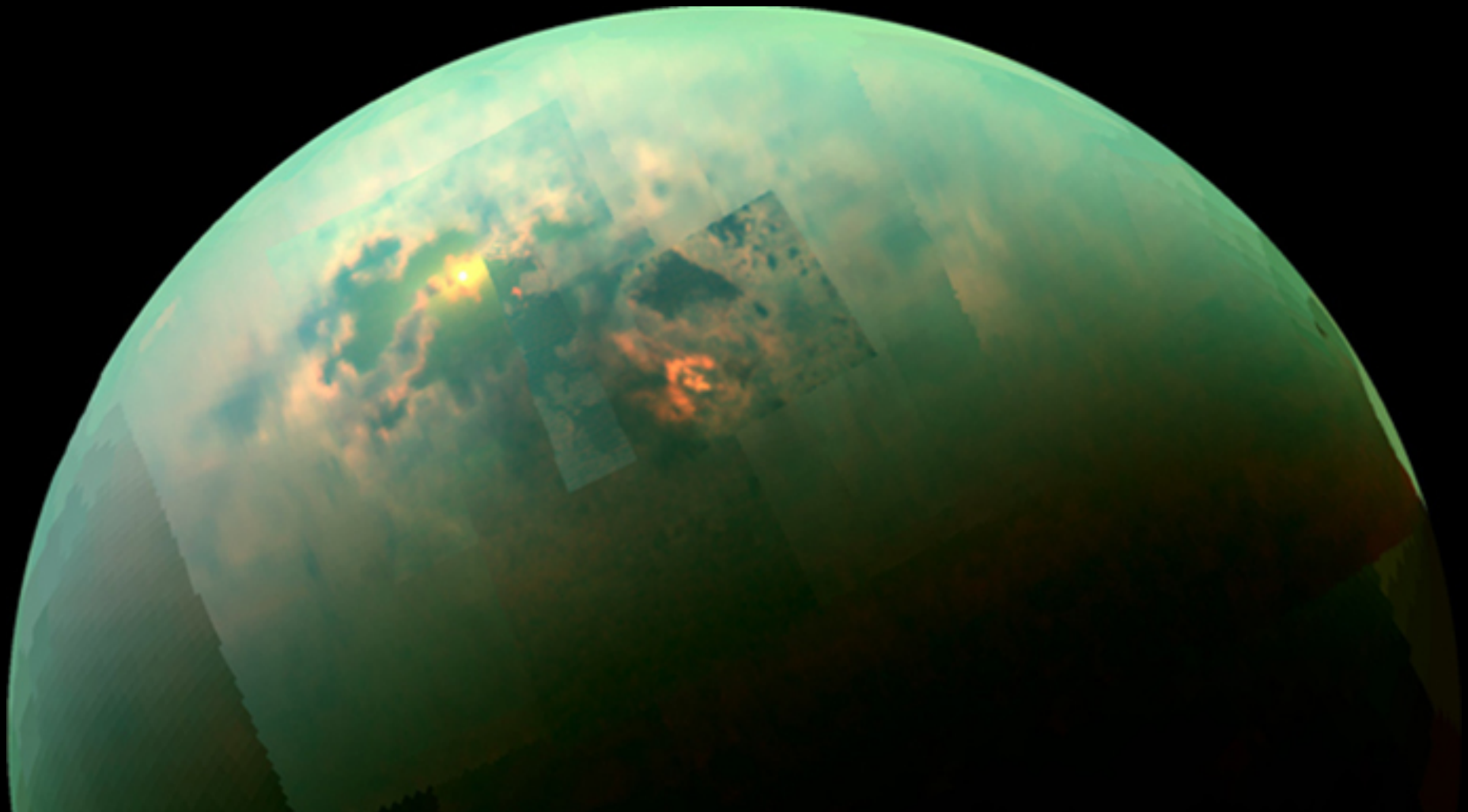
atmospheric haze
in optical light

Underneath the atmosphere is terrain, including seas of liquid hydrocarbons

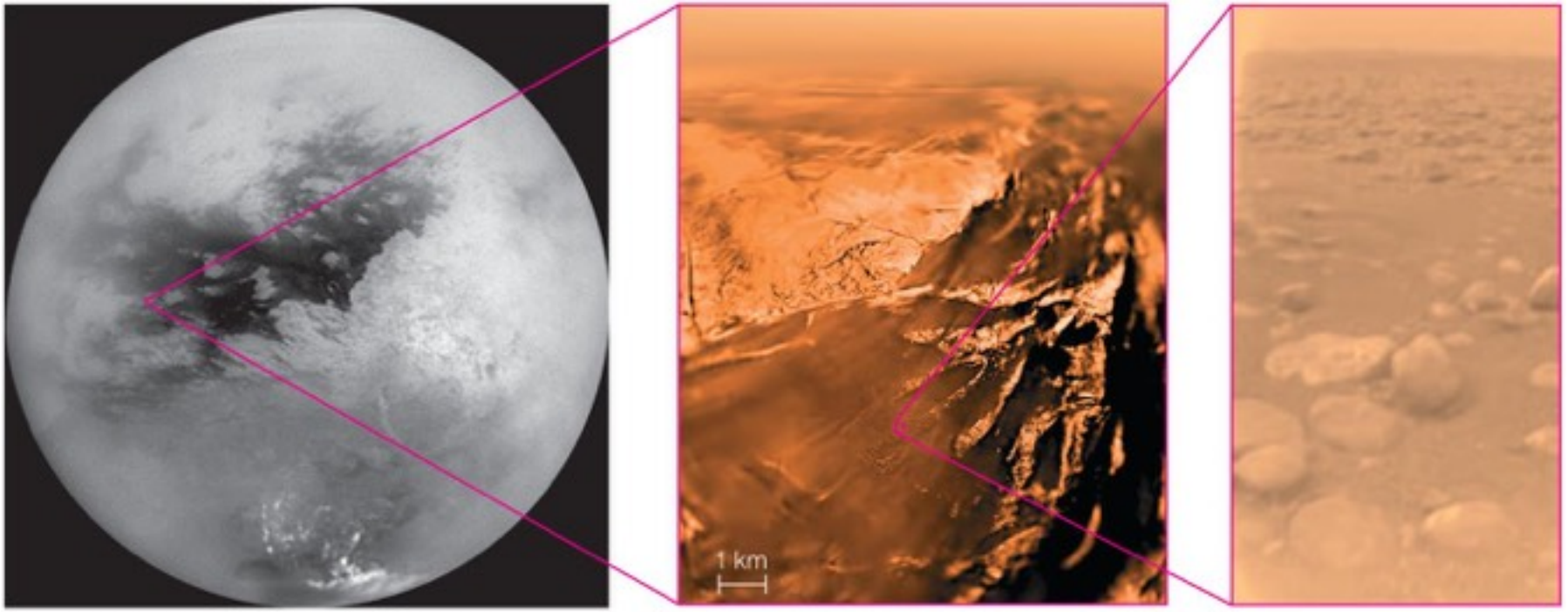



solid surface
liquid
methane

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



Titan's Surface

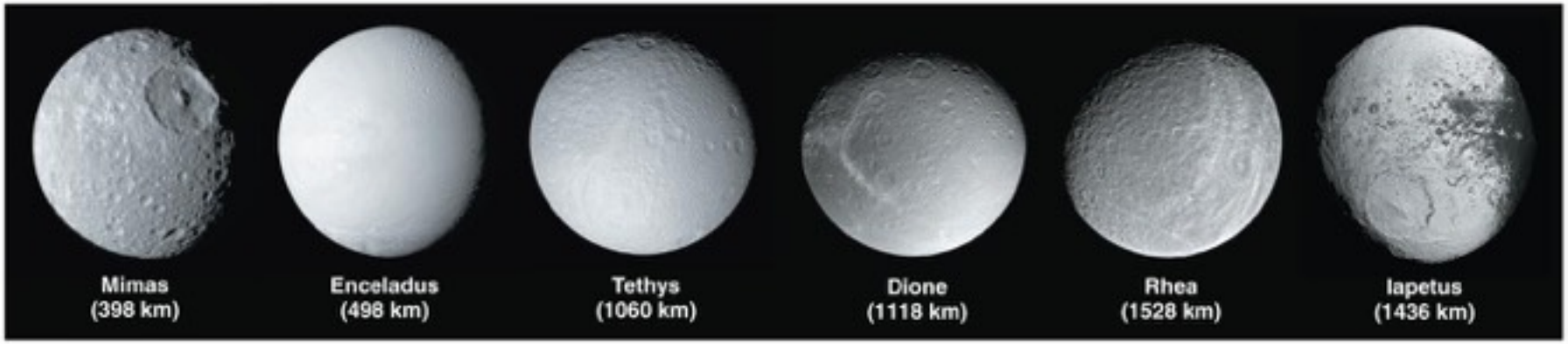


- The *Huygens* probe provided a first look at Titan's surface in early 2005.
- It had liquid methane, "rocks" made of ice.

Huygens descent movie

https://www.youtube.com/watch?v=HtYDPj6eFLc

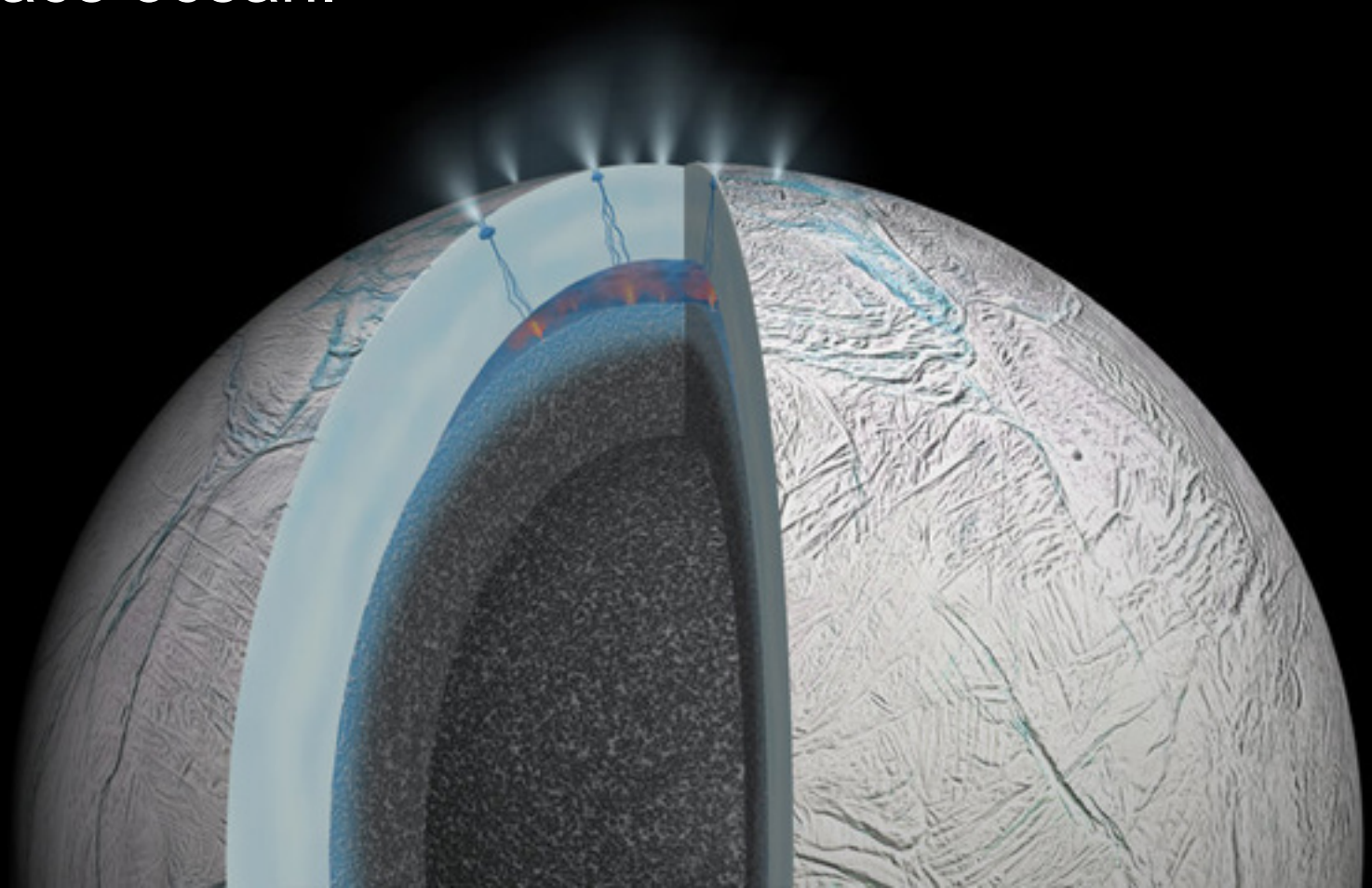
Medium Moons of Saturn



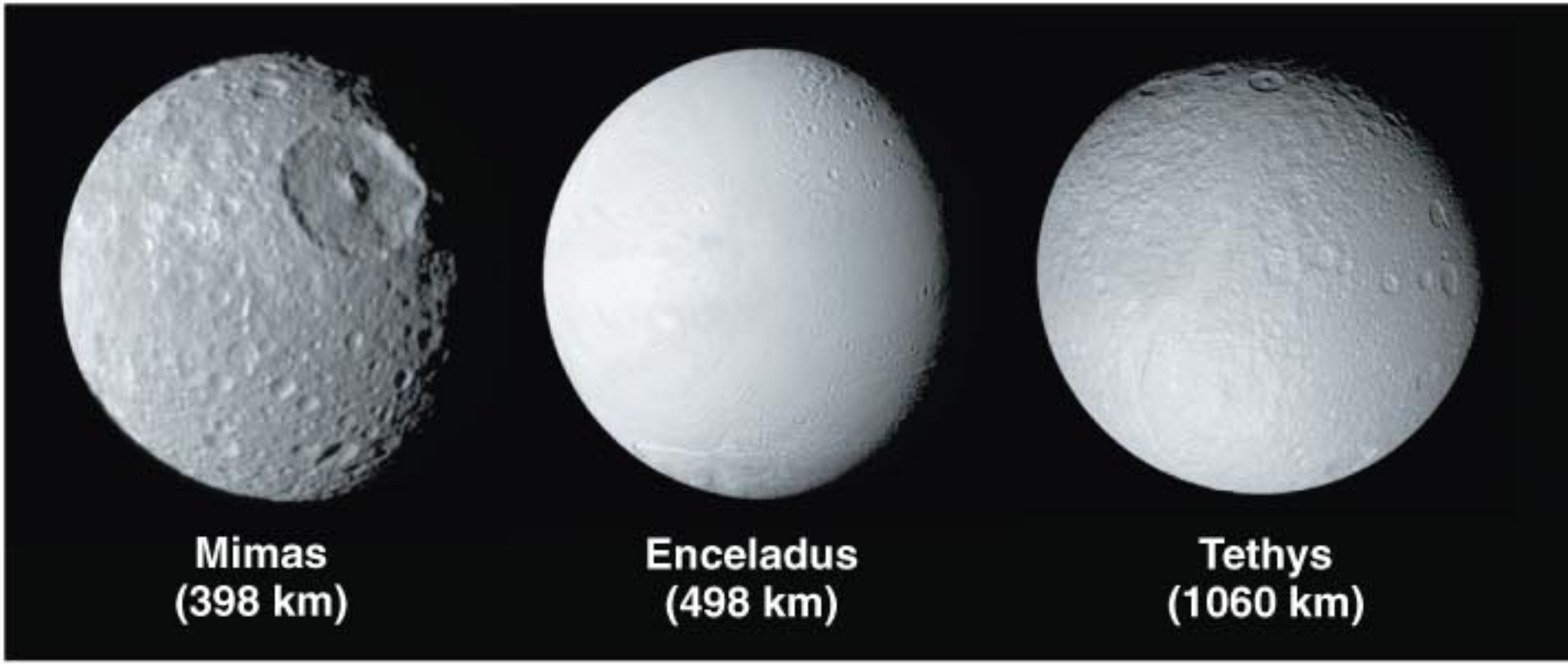
- Almost all of them show evidence of past volcanism and/or tectonics.

Medium Moons of Saturn

- Ice fountains of Enceladus suggest it may have a subsurface ocean.



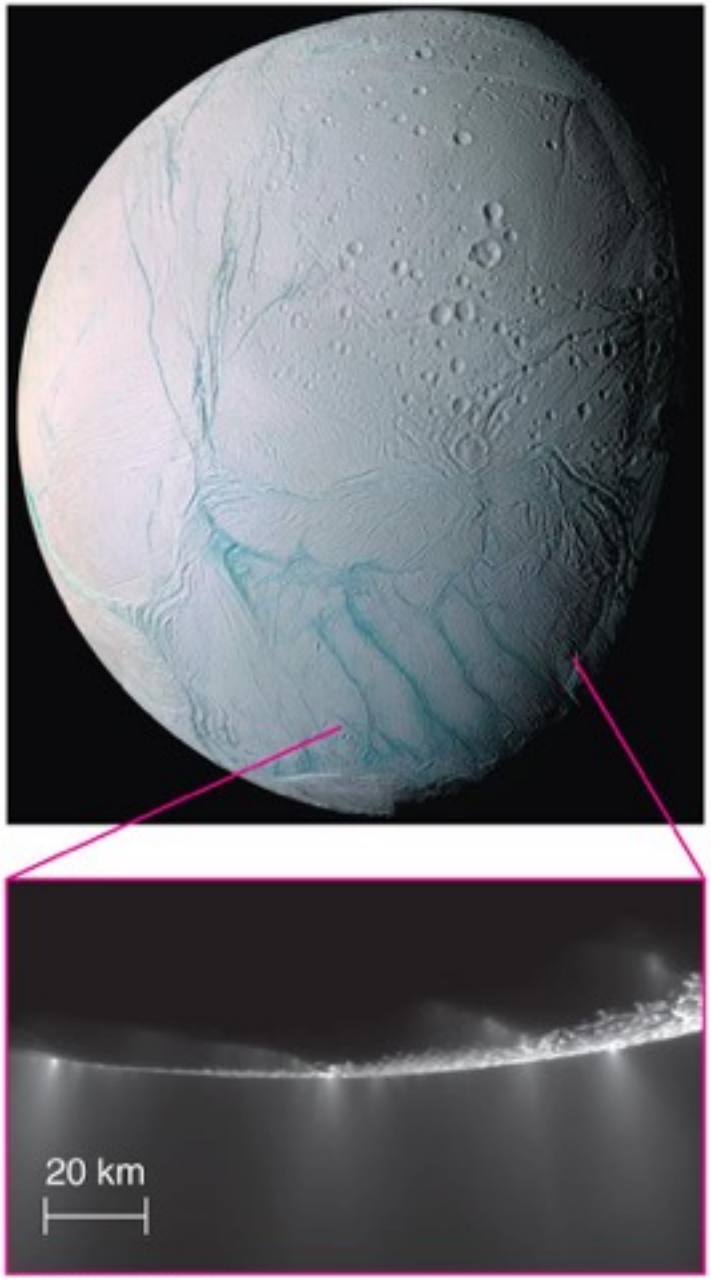
Medium Moons of Saturn



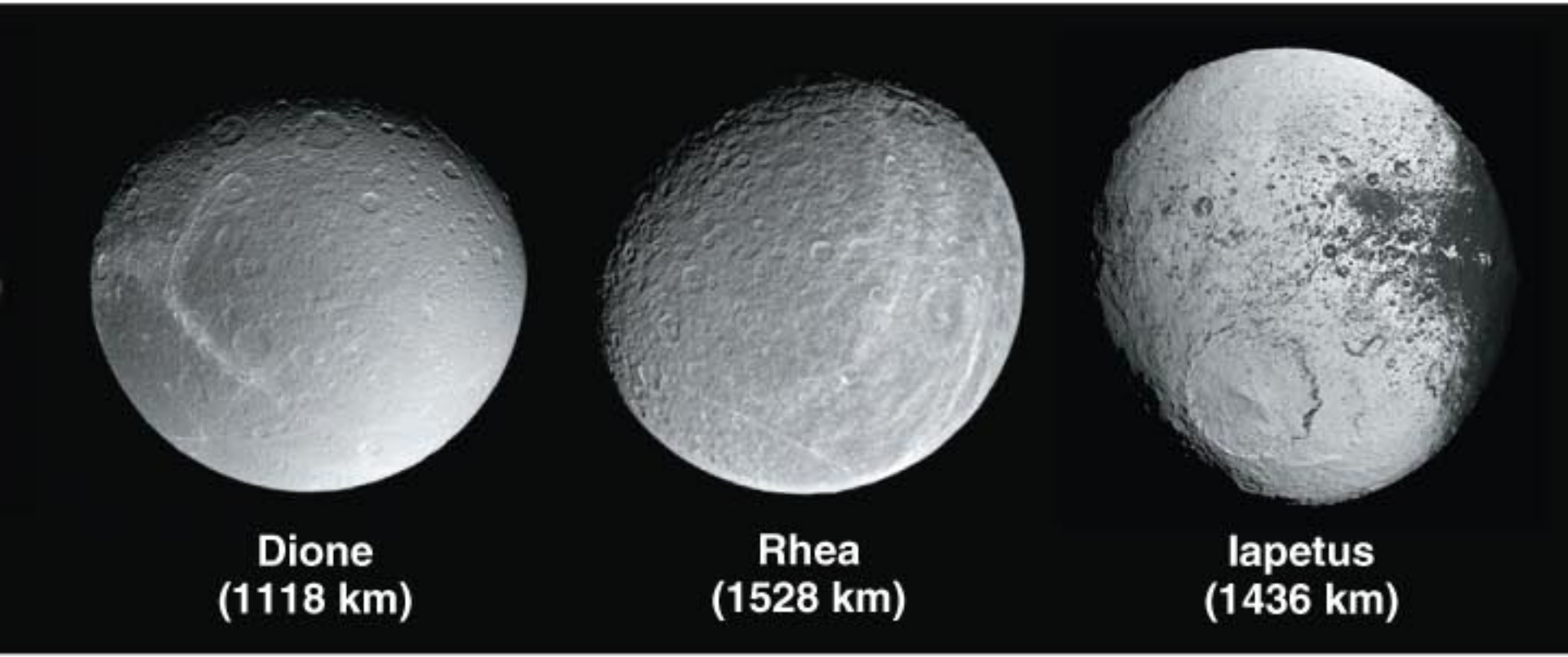
- Mimas has a big crater that makes it look like the Death Star.

Medium Moons of Saturn

- Ice fountains of Enceladus suggest it may have a subsurface ocean.



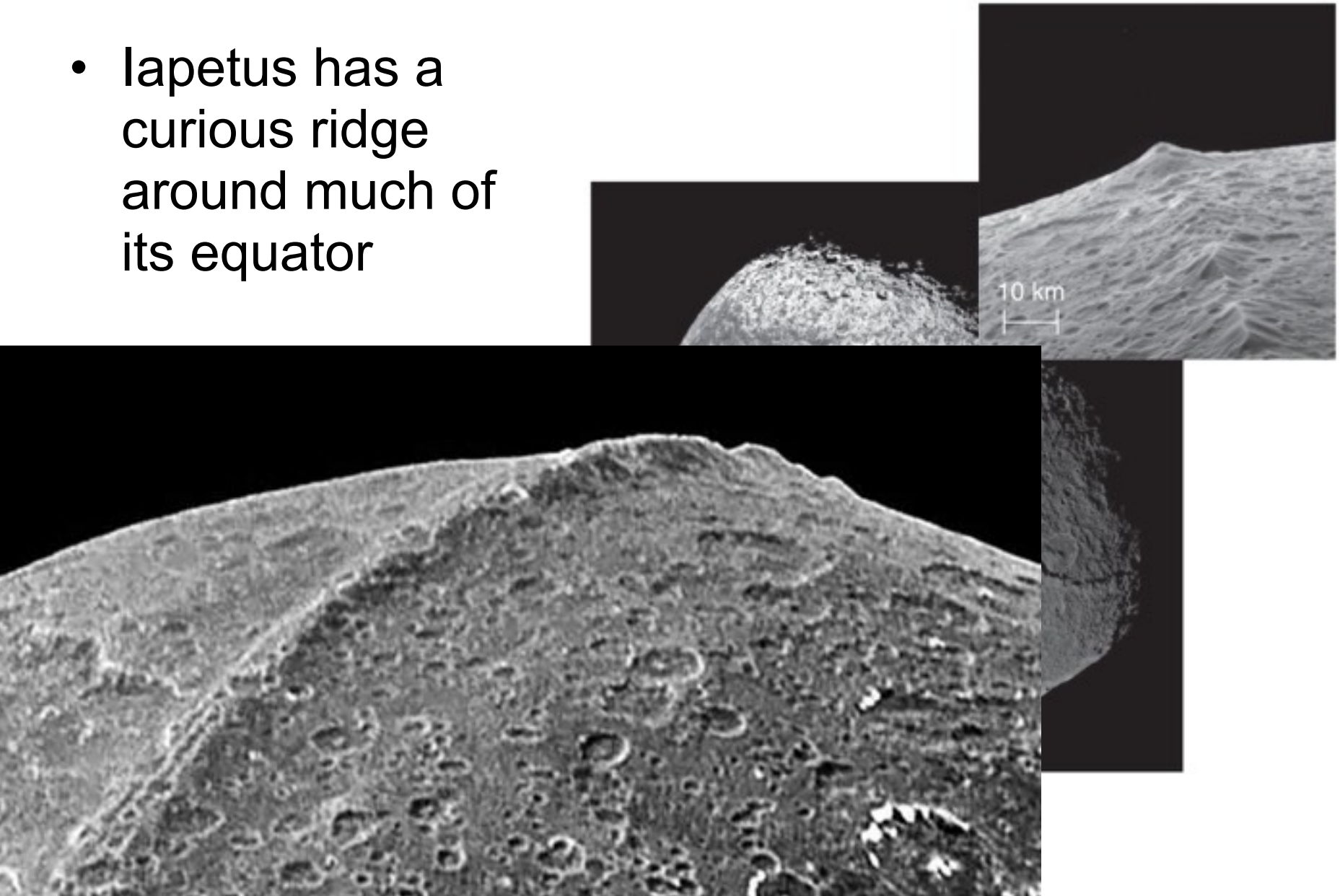
Medium Moons of Saturn



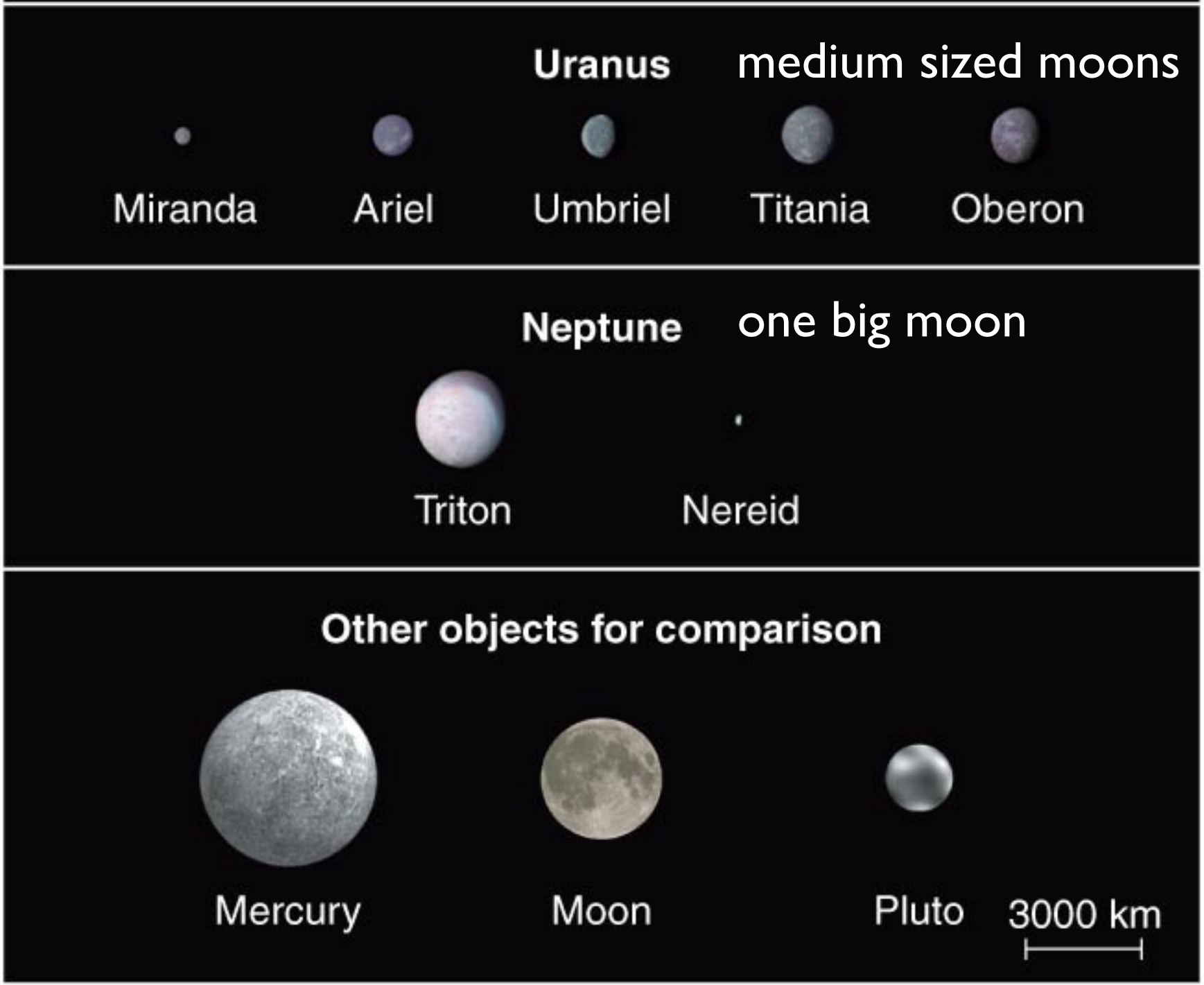
- Iapetus is dark on one side & bright on the other. It seems to have collected a goo of space debris emitted by Phoebe on the leading (dark) side of

Medium Moons of Saturn

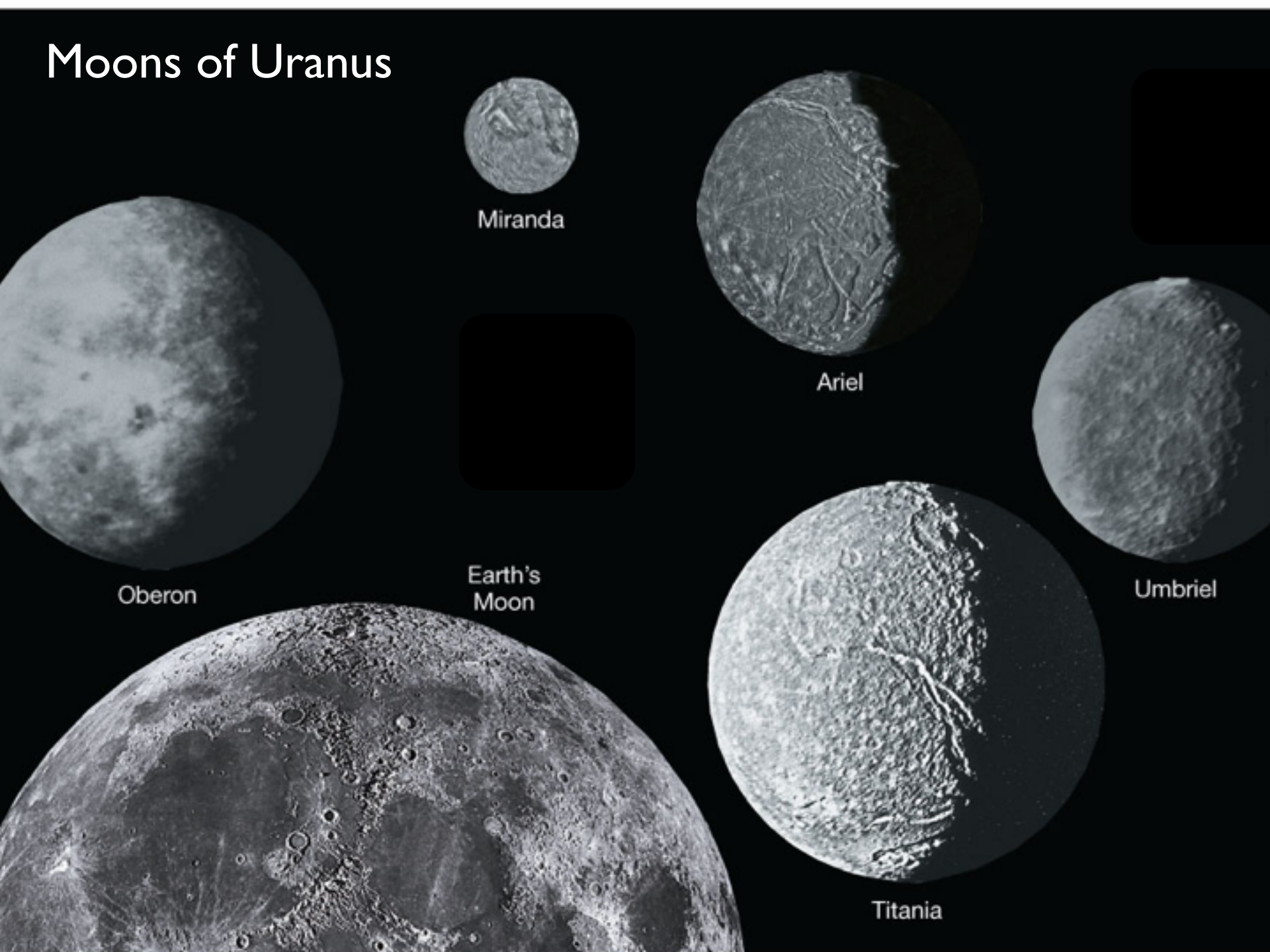
- Iapetus has a curious ridge around much of its equator



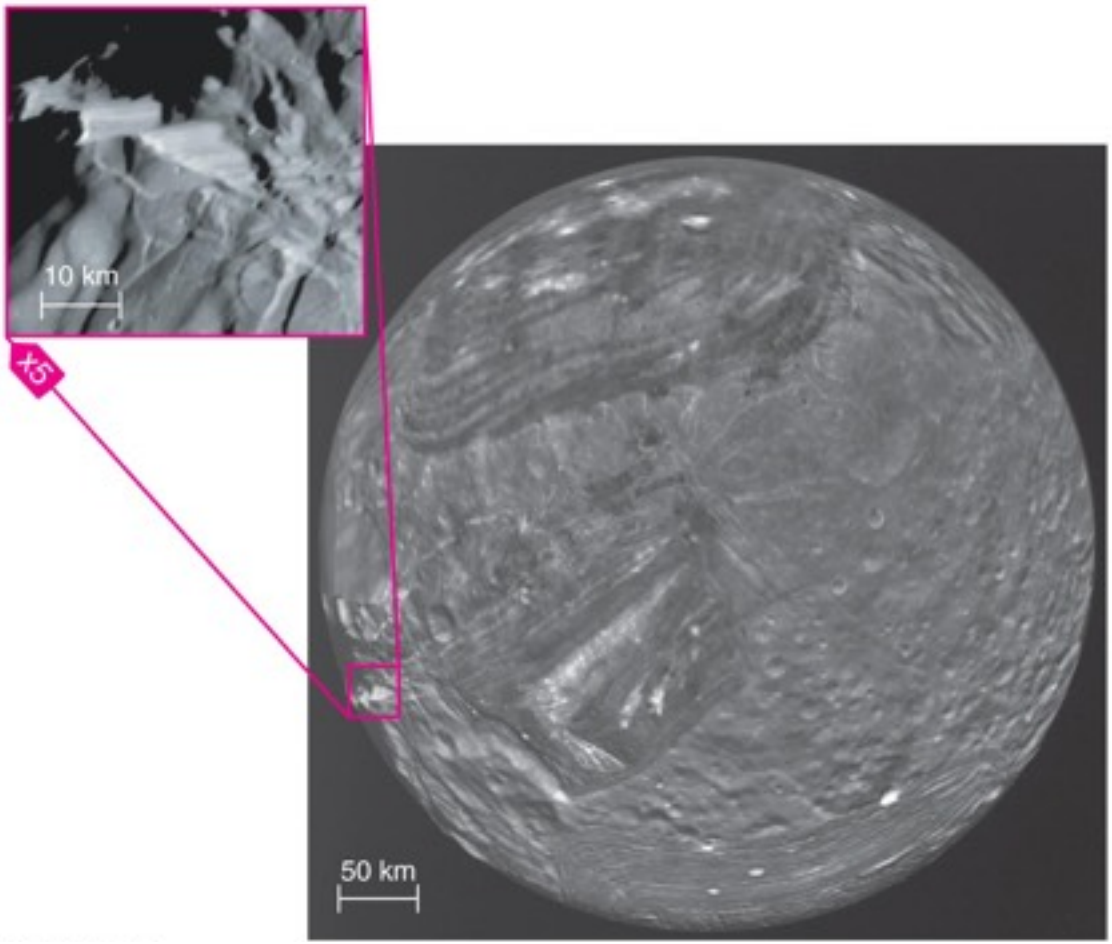
Small moons can also be weird. Hyperion looks like a sponge.


Uranus
medium sized moons
Miranda
Ariel
Umbriel
Titania
Oberon
Neptune
one big moon
Triton
Nereid
Other objects for comparison
Mercury
Moon
Pluto
3000 km

Moons of Uranus



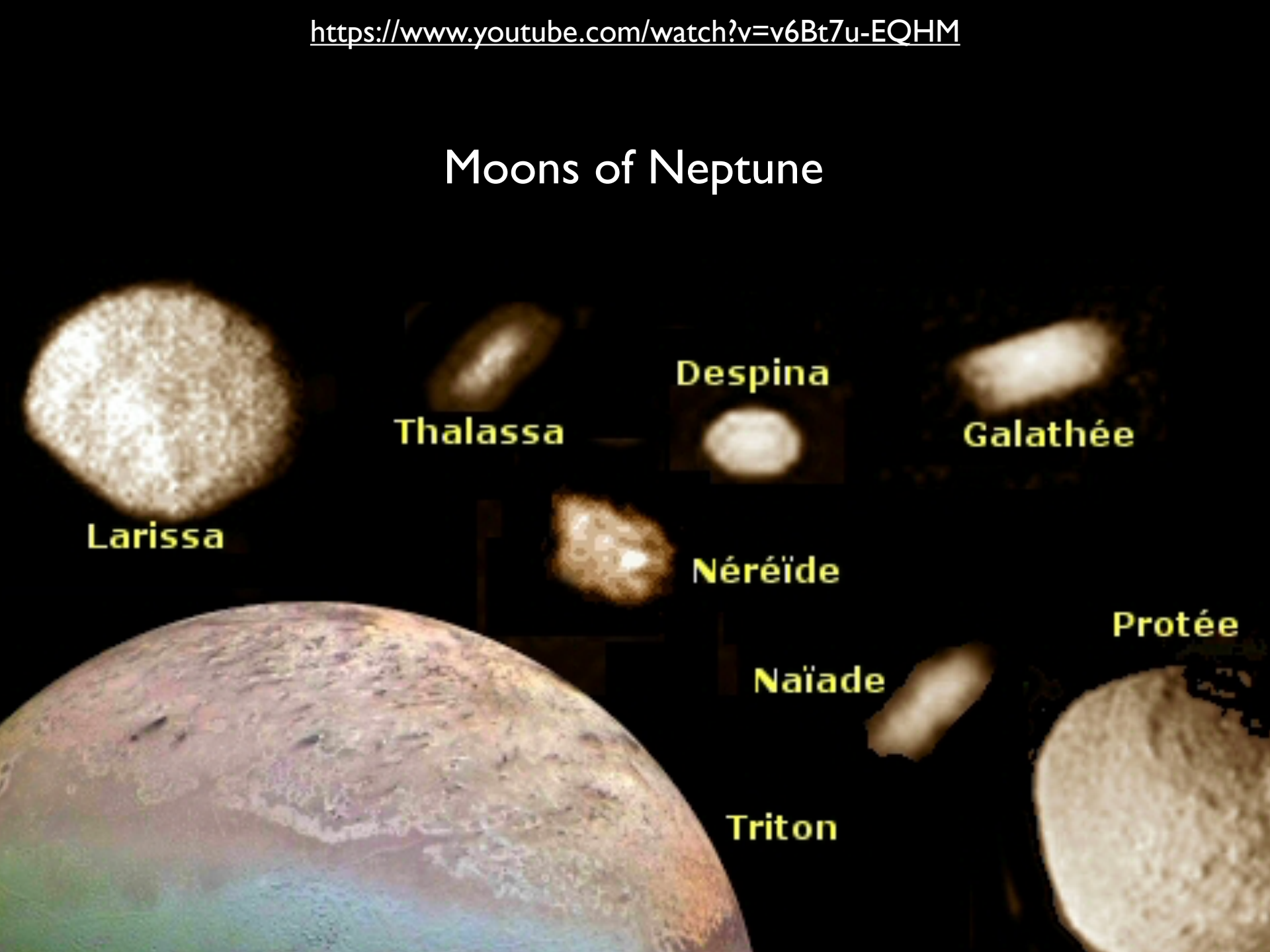
Medium Moons of Uranus

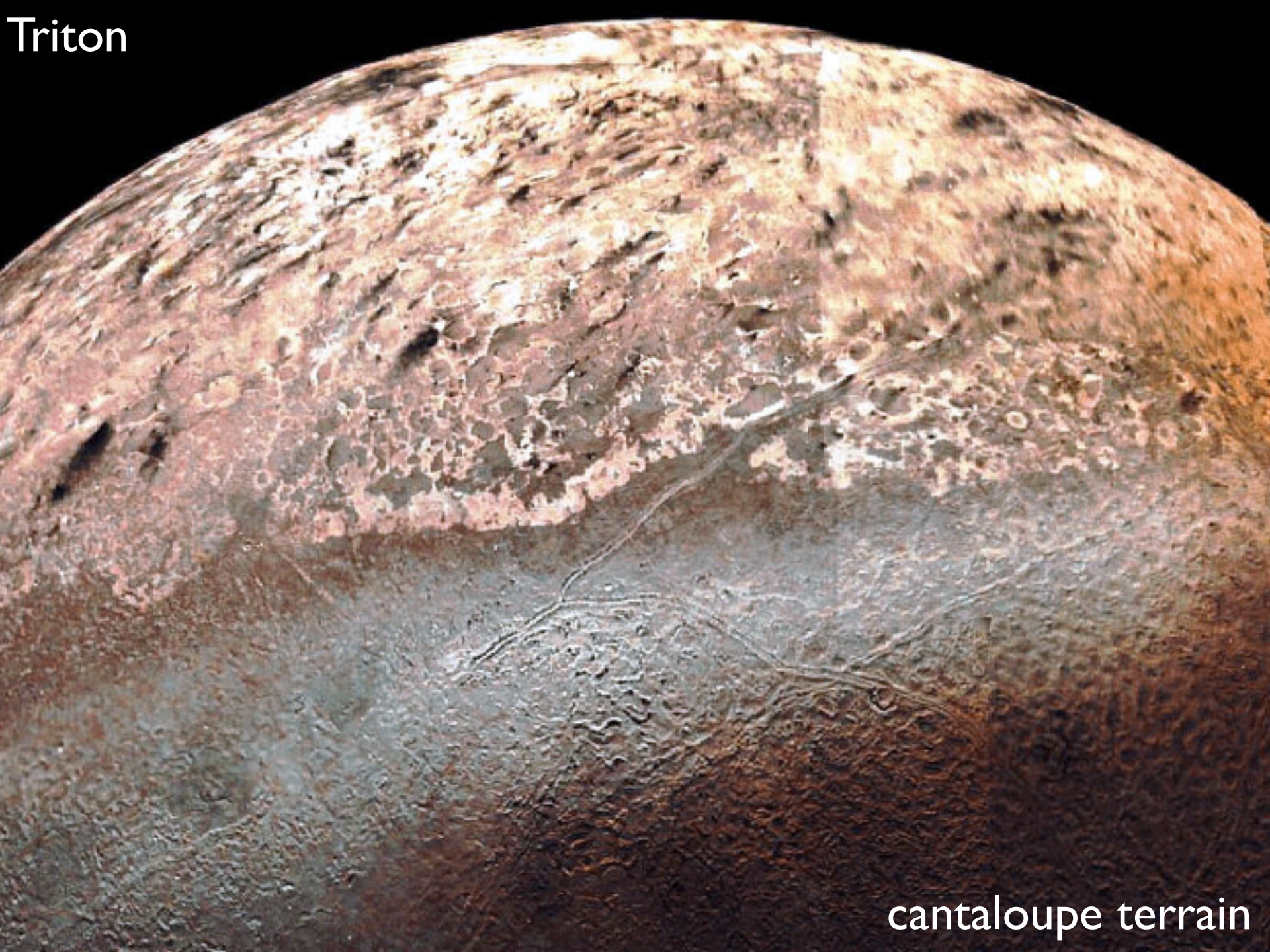


- They have varying amounts of geological activity.
- Miranda has large tectonic features and few craters (possibly indicating an episode of tidal heating in past).

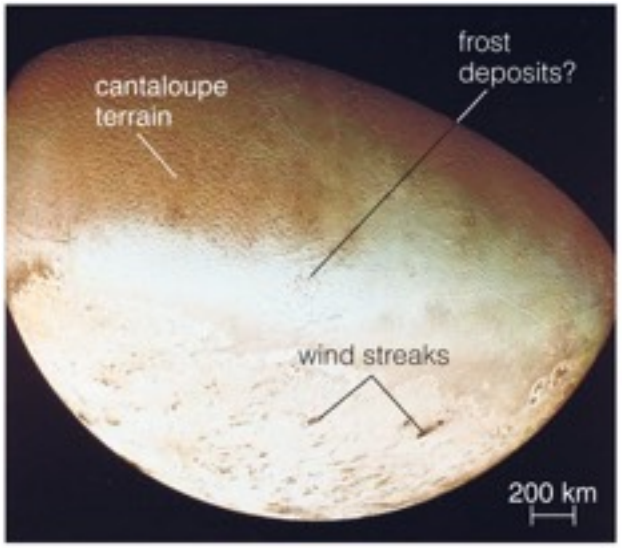
https://www.youtube.com/watch?v=v6Bt7u-EQHM

Moons of Neptune

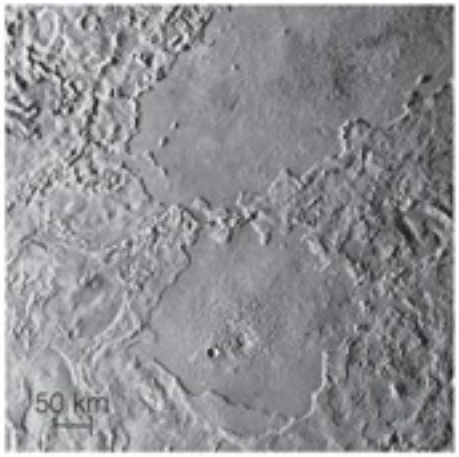



Triton
cantaloupe terrain

Neptune's Moon Triton



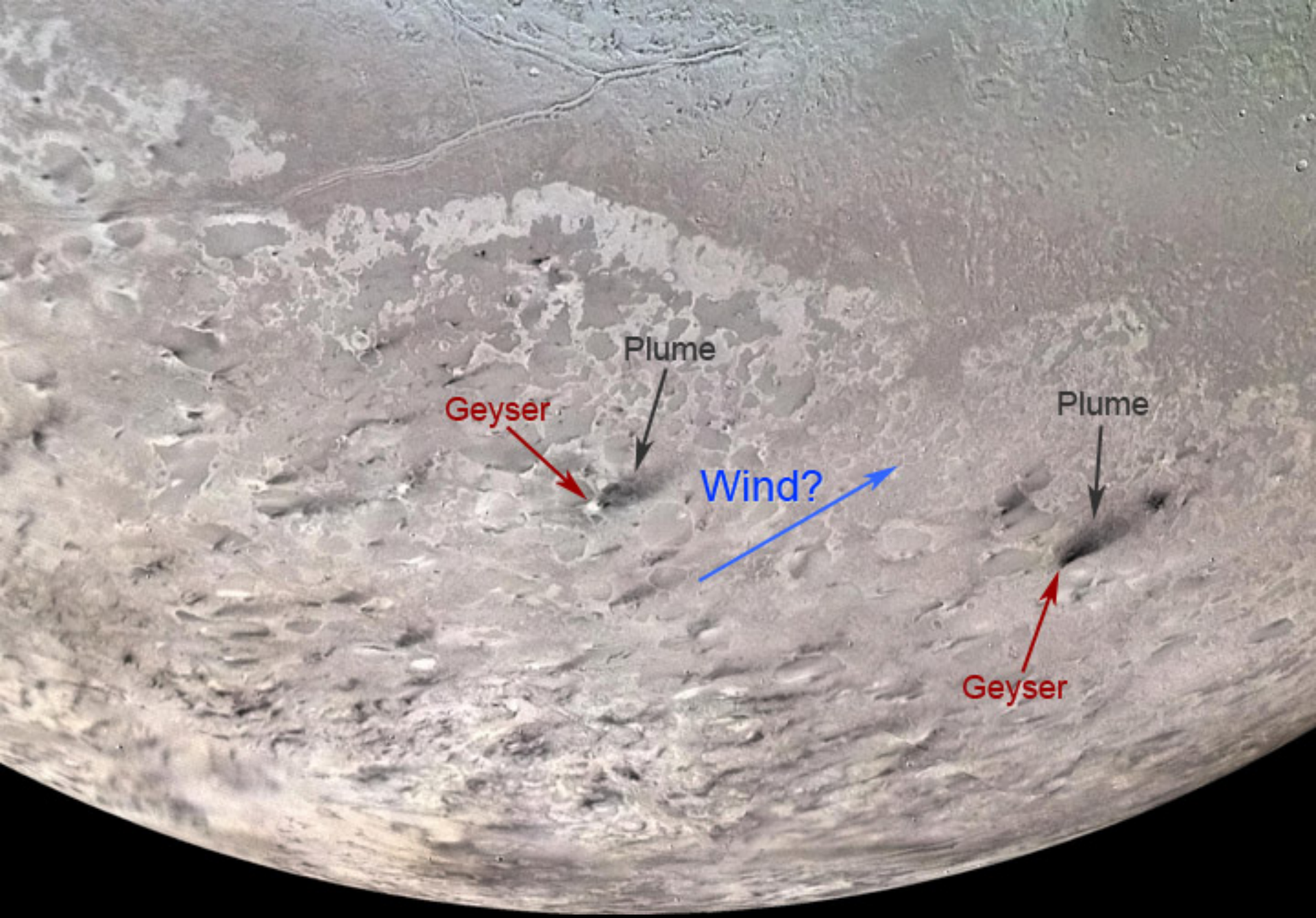
Triton's southern hemisphere as seen by *Voyager 2*.



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

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

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



geysers