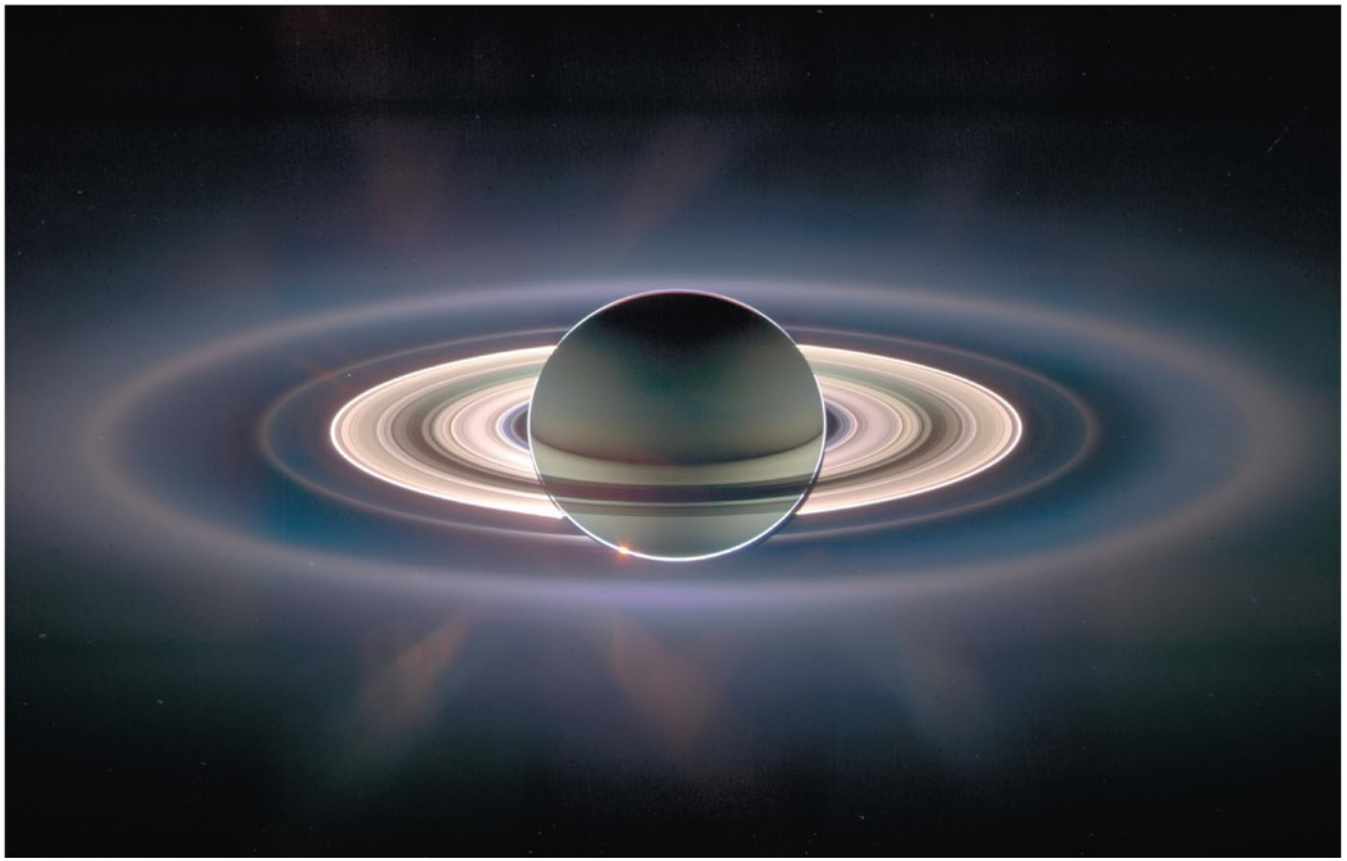
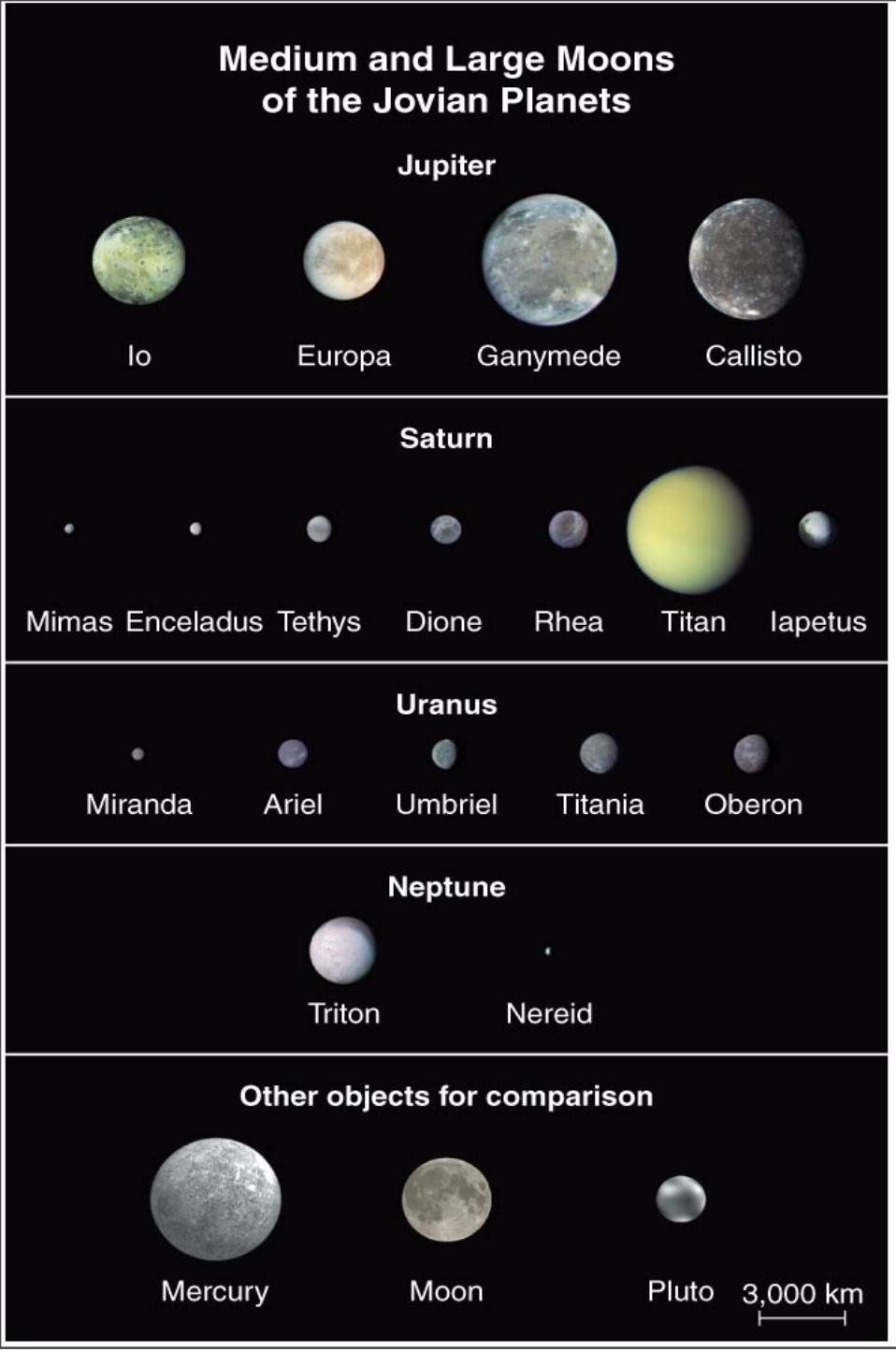
Astronomy Picture of the Day

Surface of Saturn's moon Enceladus. Enormous ice jets are erupting. Giant plumes of ice have been photographed in dramatic fashion by the robotic Cassini spacecraft during this past weekend's flyby of Saturn's moon Enceladus. Pictured above, numerous plumes are seen rising from long tiger-stripe canyons across Enceladus' craggy surface. Several ice jets are even visible in the shadowed region of crescent Enceladus as they reach high enough to scatter sunlight. Other plumes, near the top of the above image, appear visible just over the moon's sunlit edge. That Enceladus vents fountains of ice was first discovered on Cassini images in 2005, and has been under close study ever since. Continued study of the ice plumes may yield further clues as to whether underground oceans, candidates for containing life, exist on this distant ice world.

http://www.nasa.gov/mission_pages/cassini/main/index.html

Chapter 11
Jovian Planet Systems

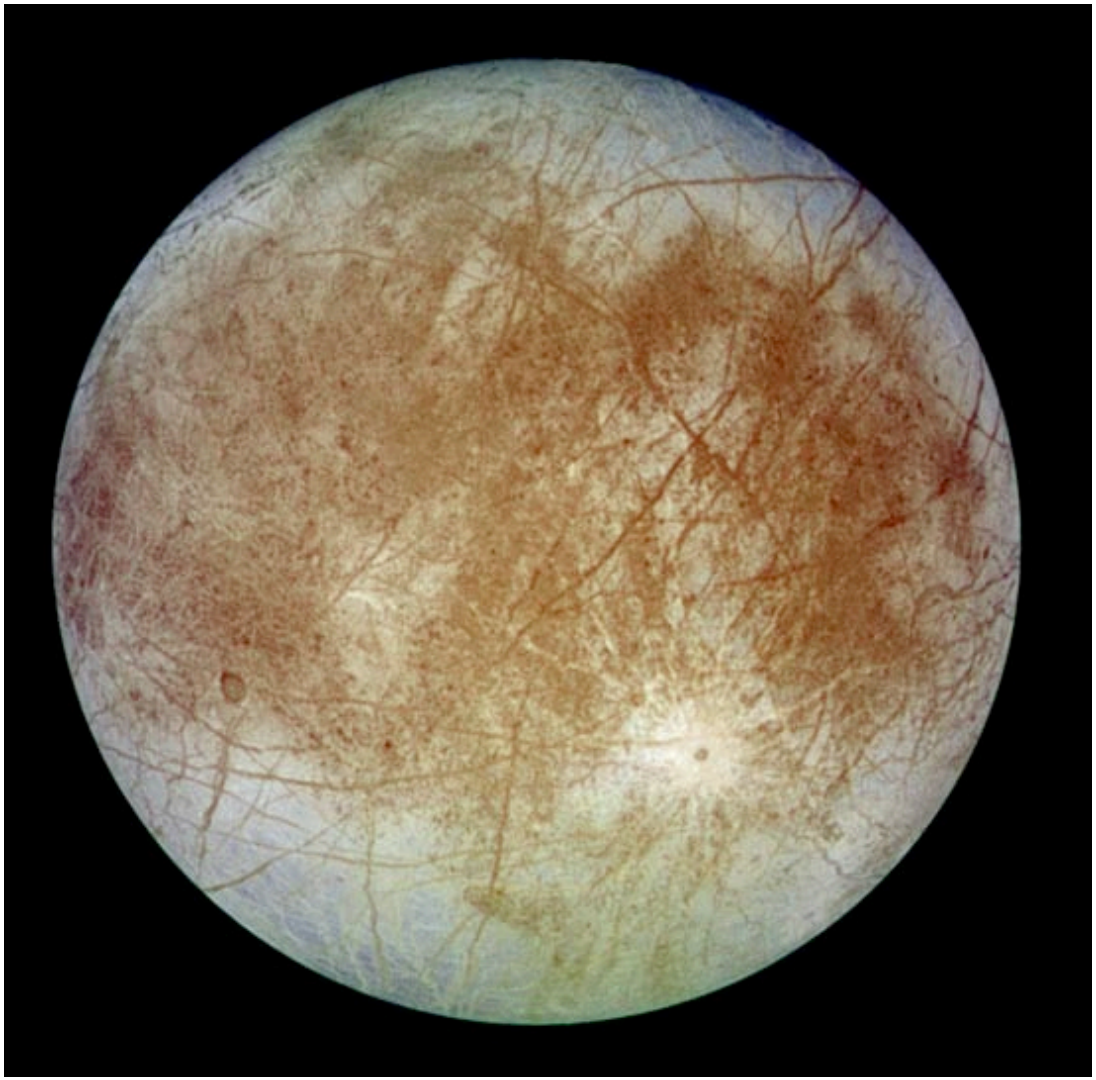




Medium & Large Moons

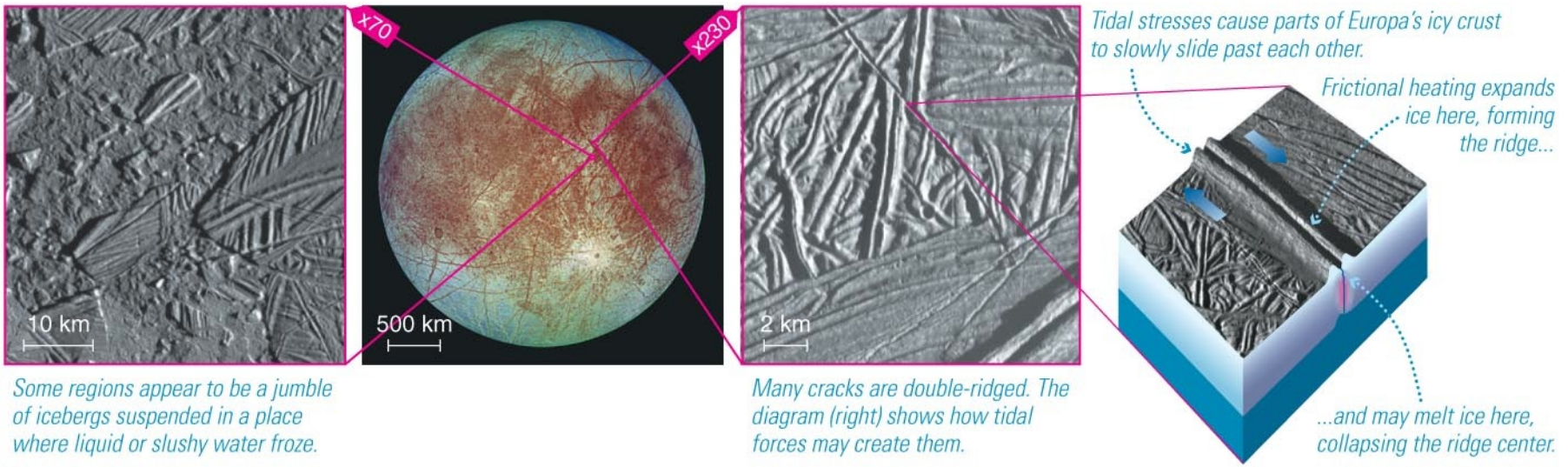
- Enough **self-gravity** to be **spherical**
- Have substantial amounts of **ice**.
- Formed in orbit around jovian planets.
- Circular orbits in same direction as planet rotation.

Europa's Ocean: Waterworld?



Covered with water ice.

Tidal stresses crack Europa's surface ice.

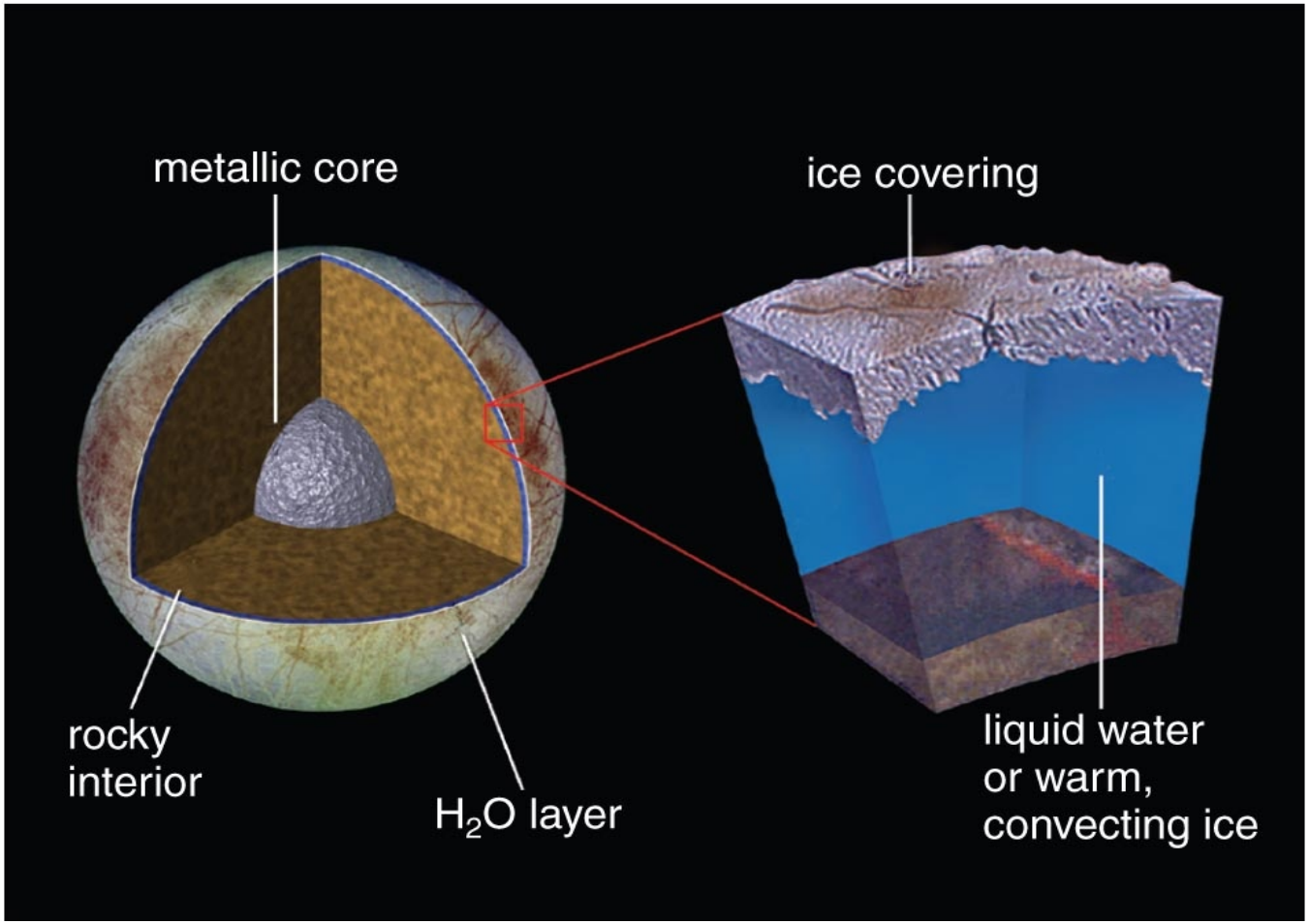


Some regions appear to be a jumble of icebergs suspended in a place where liquid or slushy water froze.

Many cracks are double-ridged. The diagram (right) shows how tidal forces may create them.

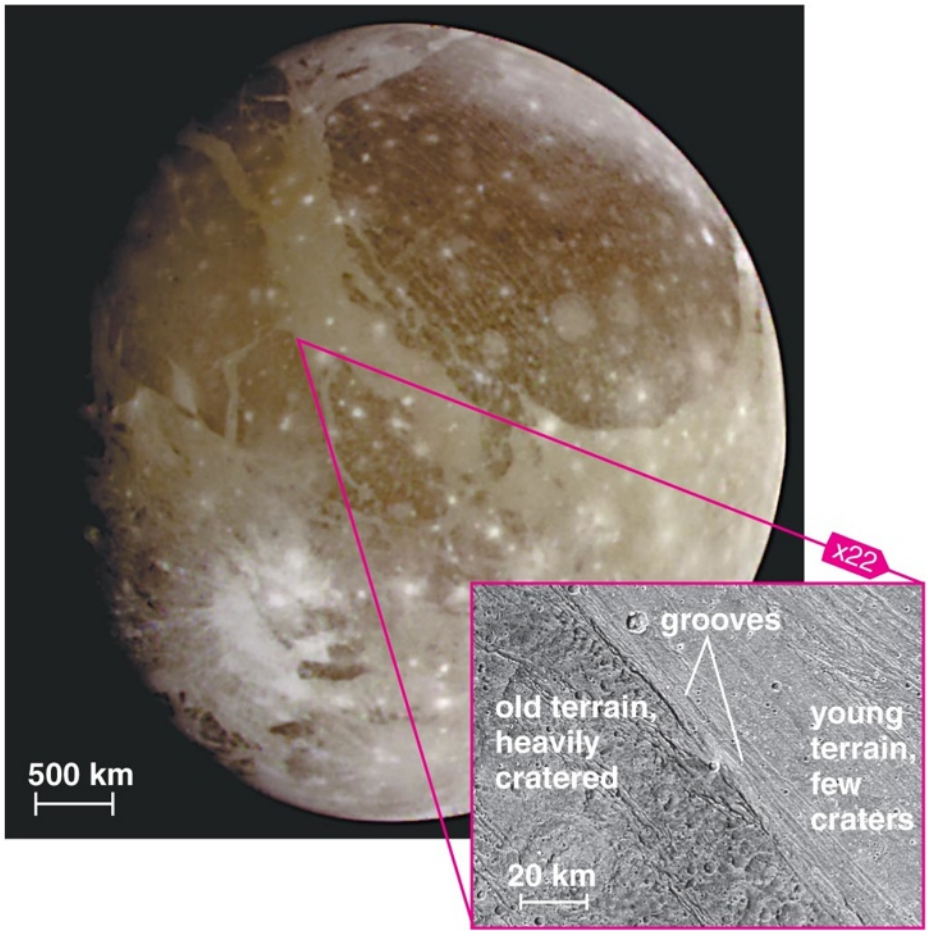
Water is the agent of change on Europa's surface: either liquid water rising up from beneath the icy crust, or interior ice that is just warm enough to undergo convection that allows some of it to rise up and flow across the surface.

Europa's interior also warmed by tidal heating



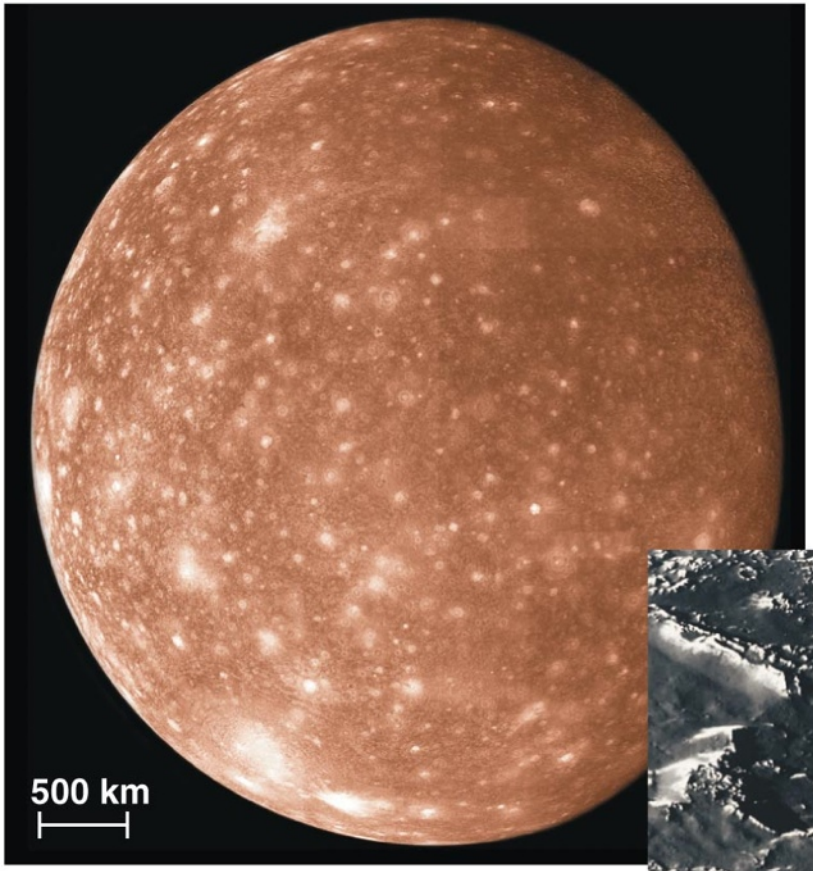
- Upper 5-25 km should be solidly frozen.
- Enough water to make water layer of ~100 km thick (salty ocean!) -- life?
- Magnetic data from *Galileo* strongly suggests liquid water layer.

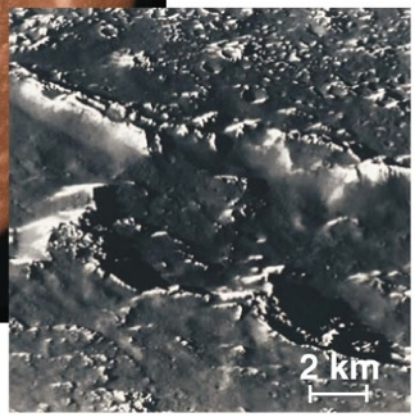
Ganymede



- Largest moon in the solar system
- Clear evidence of geological activity on the surface of water ice
- Both young and old terrain
- Tidal heating plus heat from radio-active decay?

Callisto





Callisto is heavily cratered, indicating an old surface that nonetheless may

- Outer most Galilean moon
- "Classic" cratered iceball.
- No tidal heating, no orbital resonances.

Bright patches, because large impacts blasts out "clean" ice from deep underground; dark powdery substance in low-lying areas may be debris left behind when ice sublimates into gas.

Quiz

What shape are moons?

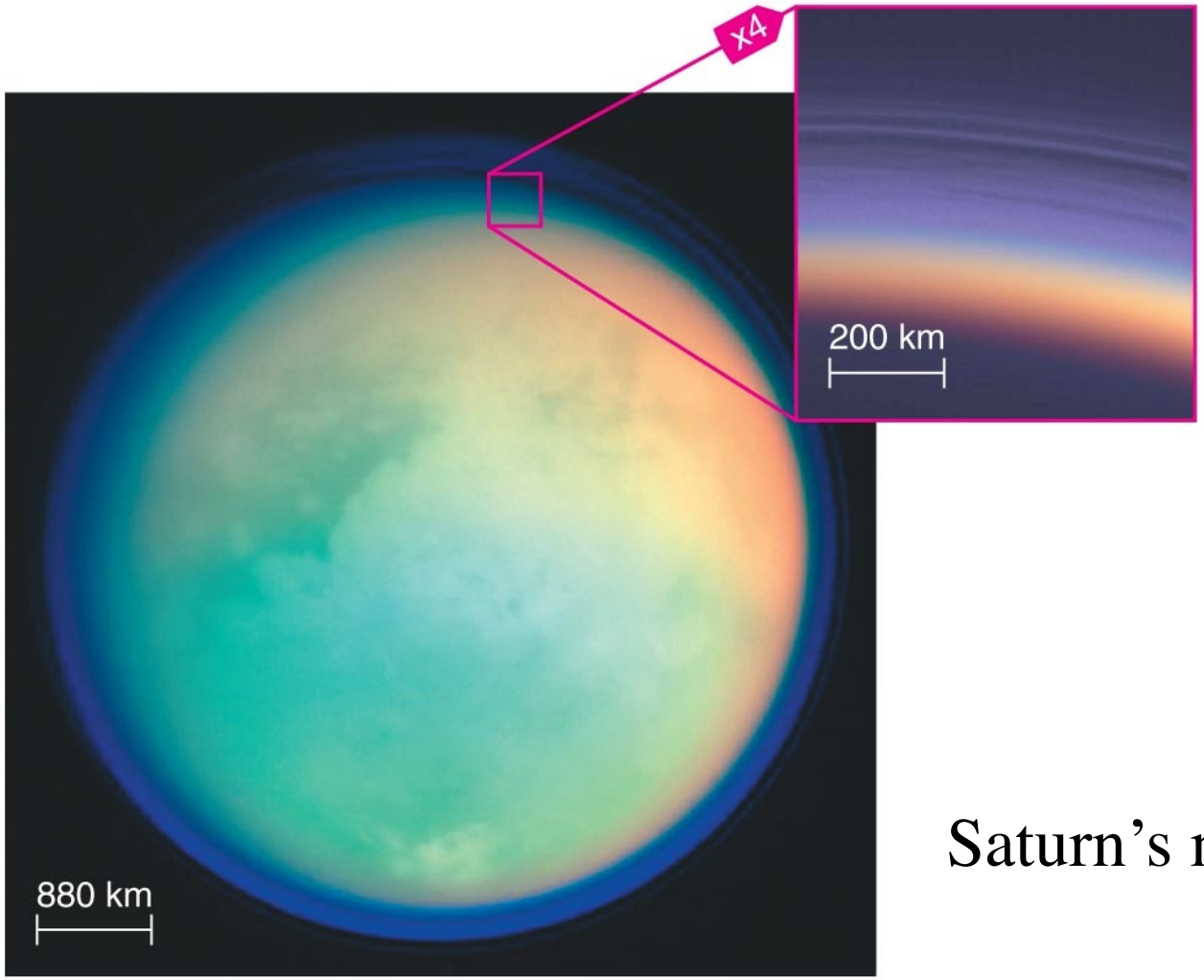
A. They are all spherical
B. Large ones are spherical, small ones irregular
C. It depends on which planet they orbit.

Quiz

Why is Io more volcanically active than our moon?

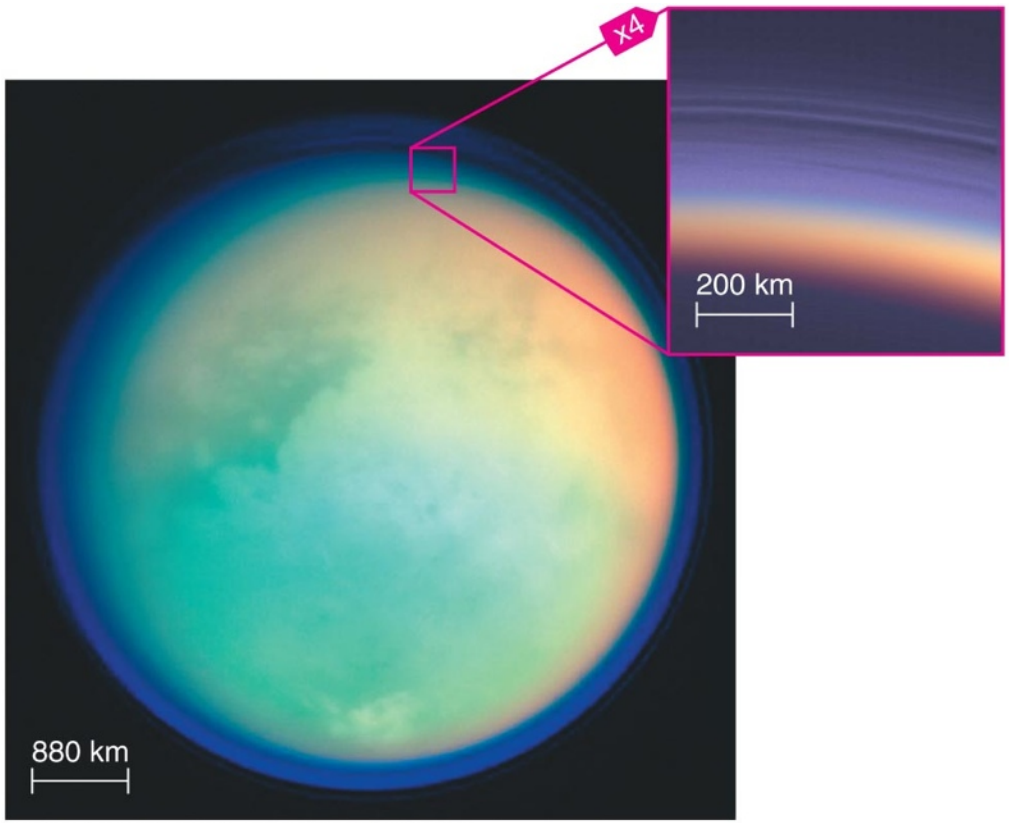
A. Io is much larger.
B. Io has a higher concentration of radioactive elements.
C. Io is heated by tidal heating mechanism.

What is remarkable about **Titan** and other major moons of the outer solar system?



Saturn's moon

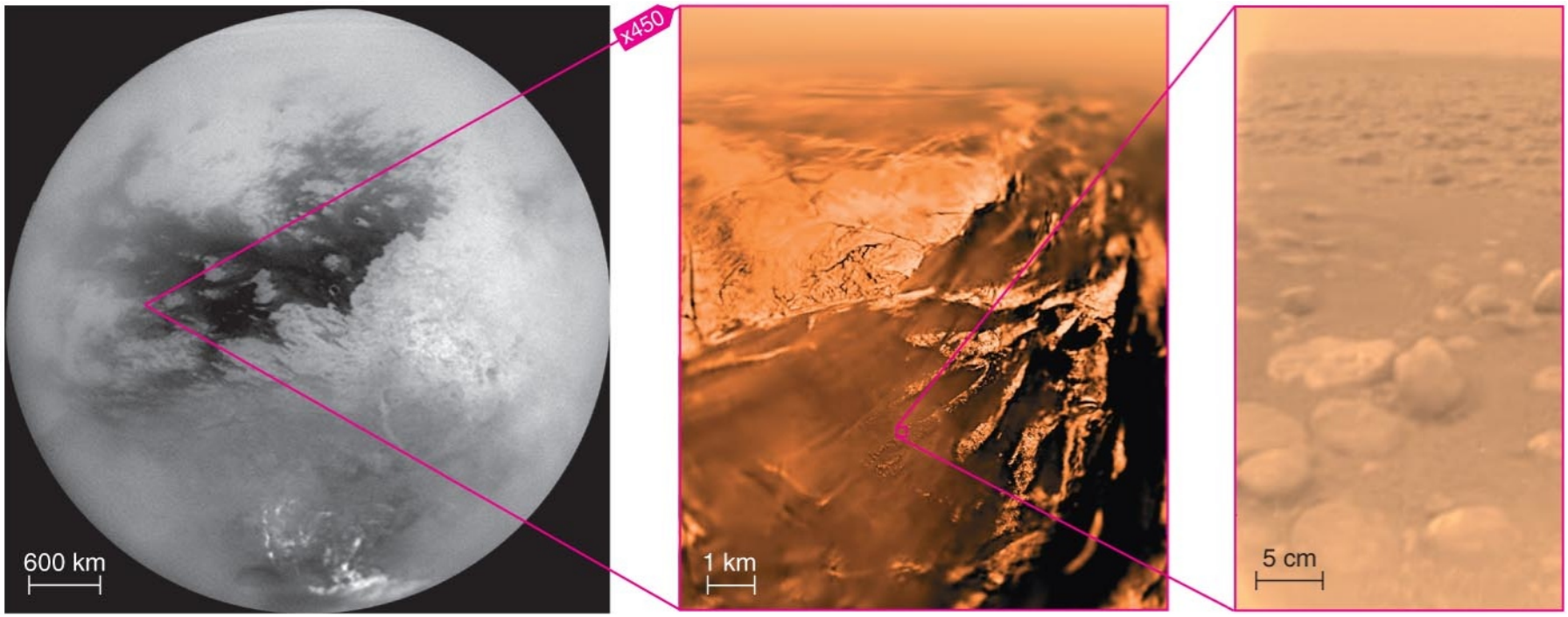
Titan's Atmosphere



Many organic molecules -- may teach us on the conditions on the early days of Earth formation.

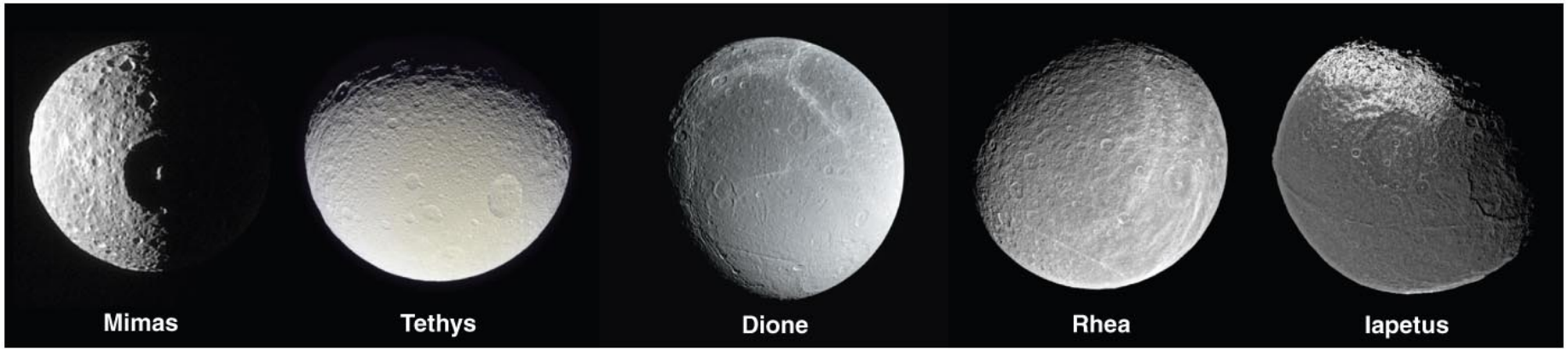
- Titan is the only moon in the solar system to have a thick ***atmosphere***
- 99% **nitrogen** (77% on Earth) with some argon, methane, and ethane
- Icy composition supplies methane and ammonia gas through sublimation
- **Nitrogen** is made after the solar UV radiation breaks ammonia, and ethane is made from methane
- Greenhouse effect makes it warm, but still -180°C
- Pressure is x1.5 the sea level pressure on Earth

Titan's Surface



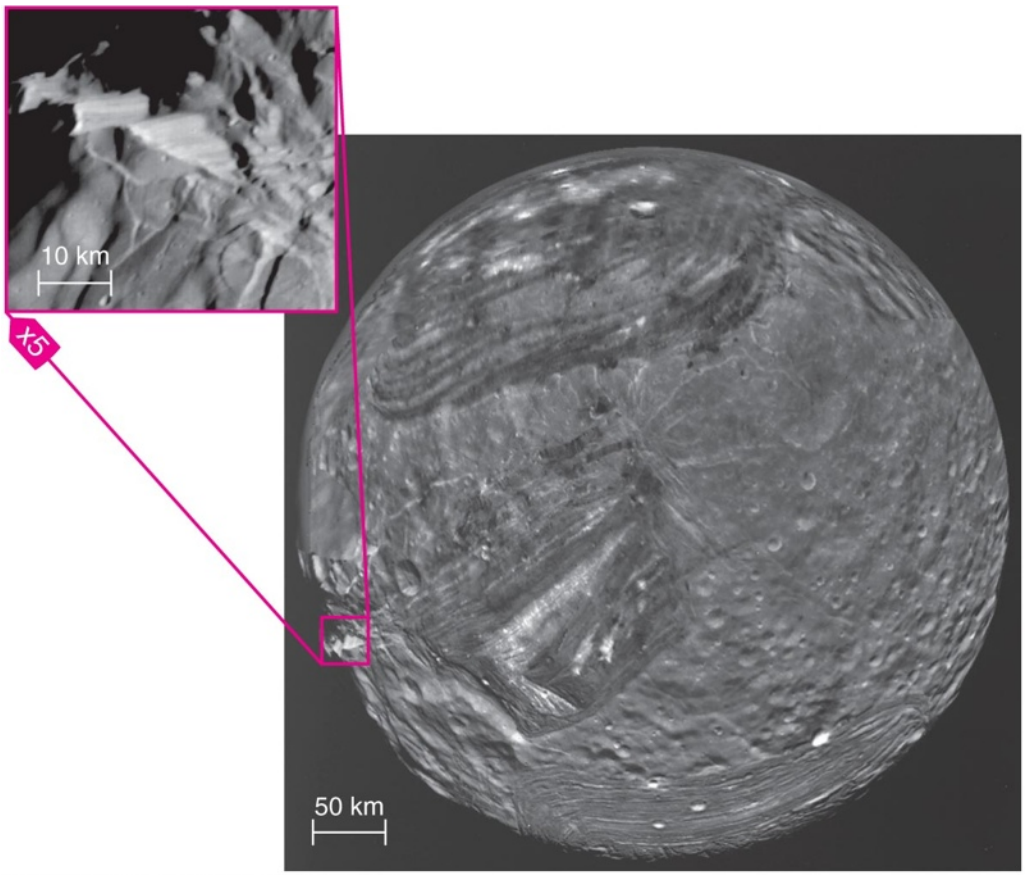
- ***Huygens*** probe provided first look at Titan's surface in early 2005
- Liquid methane, "ice boulders" rounded by erosion -- similar to Earth
- Instead of liquid water, Titan has liquid methane and ethane; Instead of rocks, Titan has ice. Instead of molten lava, Titan has a slush of water

Medium Moons of Saturn



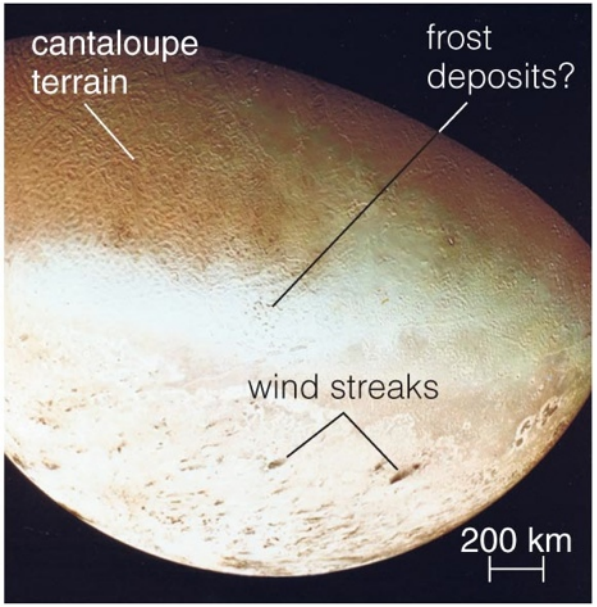
- Images taken by the *Cassini* mission (until 2010)
- Almost all show evidence of past volcanism and/or tectonics, but no geological activity today.
- "Darth Crater" on Mimas -- **"Death Star"??!**
- Astonishing ridge that span more than a quarter of Iapetus' circumference

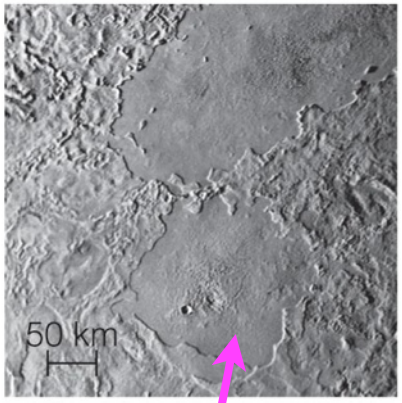
Medium Moons of Uranus



- Made largely of **ice**, just like other jovian moons
- Varying amounts of geological activity
- Moon **Miranda** has large tectonic features and few craters (episode of tidal heating in past?)

Neptune's Moon **Triton**

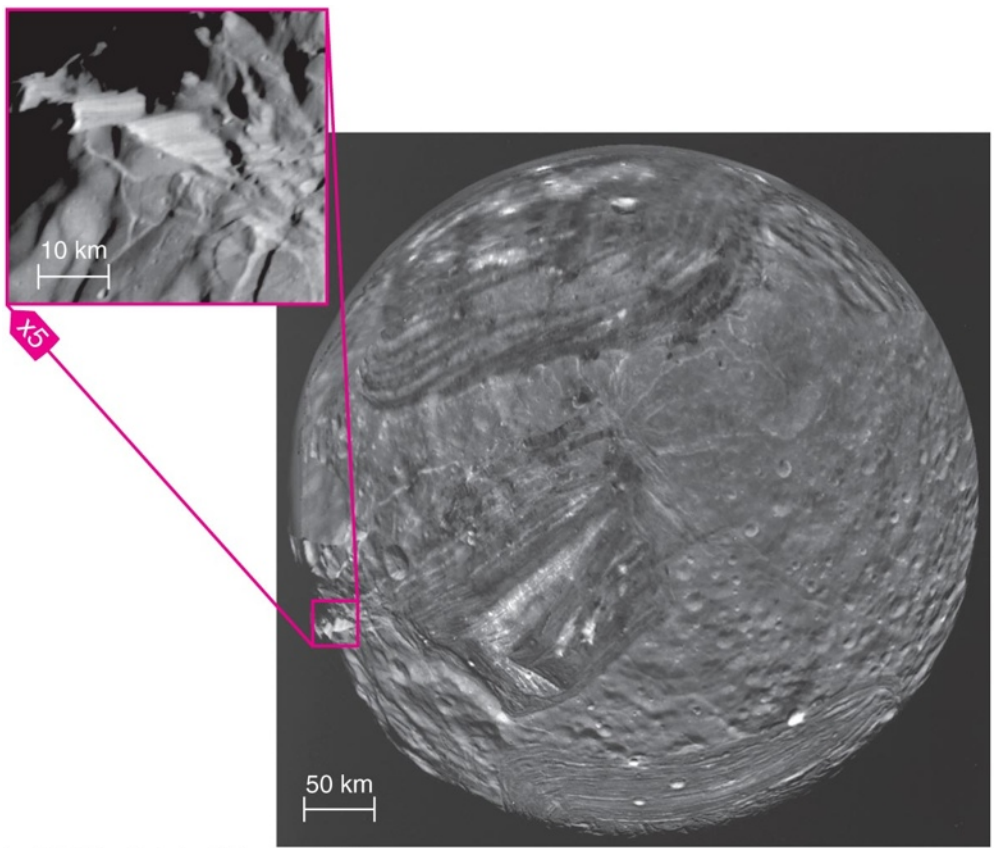




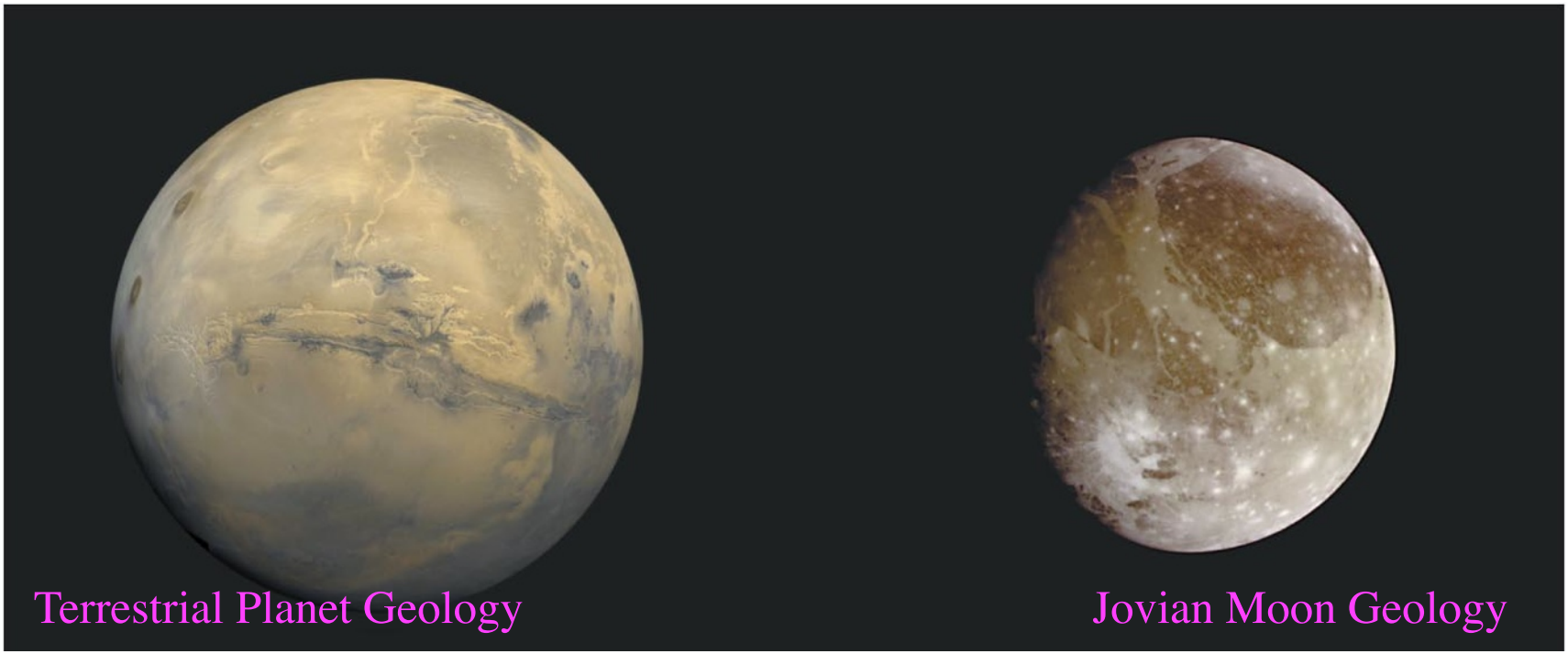
- Similar to Pluto, but larger
- Coldest world in the solar system
- Evidence for past geological activity
- Perhaps a captured satellite

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

OK, so.....Why are small icy moons more geologically active than small rocky planets?



Rocky Planets vs. Icy Moons



- Rock melts at higher temperatures
- Internal heat mostly from **radioactivity**
- Only large rocky planets have enough heat for activity

- Ice melts at lower temperatures
- **Tidal heating** can melt internal ice, driving geological activity

What have we learned?

- What kinds of moons orbit jovian planets?
  - Moons of many sizes
  - Level of geological activity depends on size
- Why are Jupiter's Galilean moons so geologically active?
  - Tidal heating drives activity, leading to Io's volcanoes and ice geology on other moons

What have we learned?

- What is special about Titan and other major moons of the solar system?
  - Titan is only moon with thick atmosphere
  - Many other major moons show signs of geological activity
- Why are small icy moons more geologically active than small rocky planets?
  - Ice melts and deforms at lower temperatures enabling tidal heating to drive activity

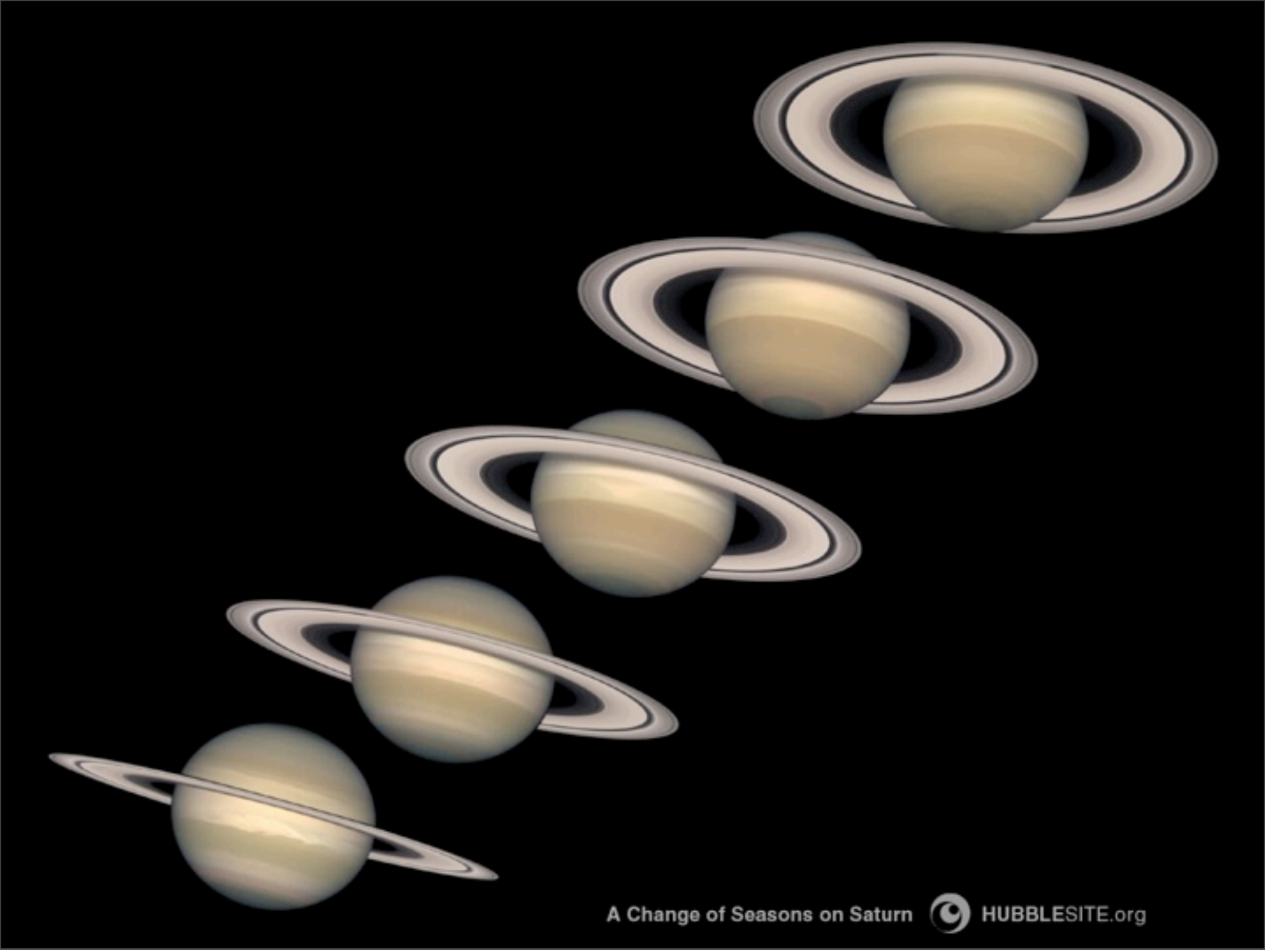
11.3 Jovian Planet Rings

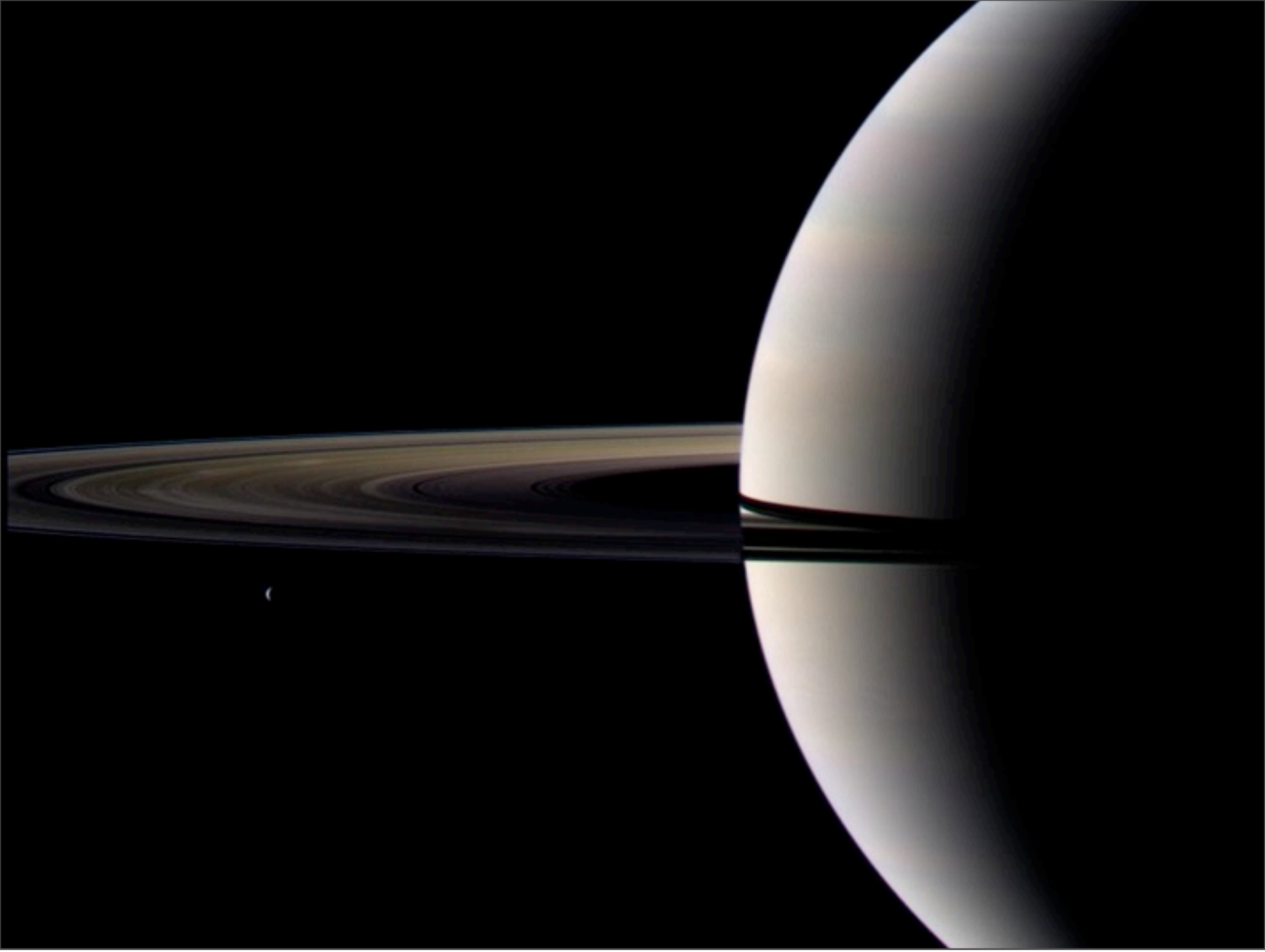
Our goals for learning:

- What are Saturn's rings like?
- How do other jovian ring systems compare to Saturn's?
- Why do the jovian planets have rings?

What are Saturn's rings like?

Earth-based view

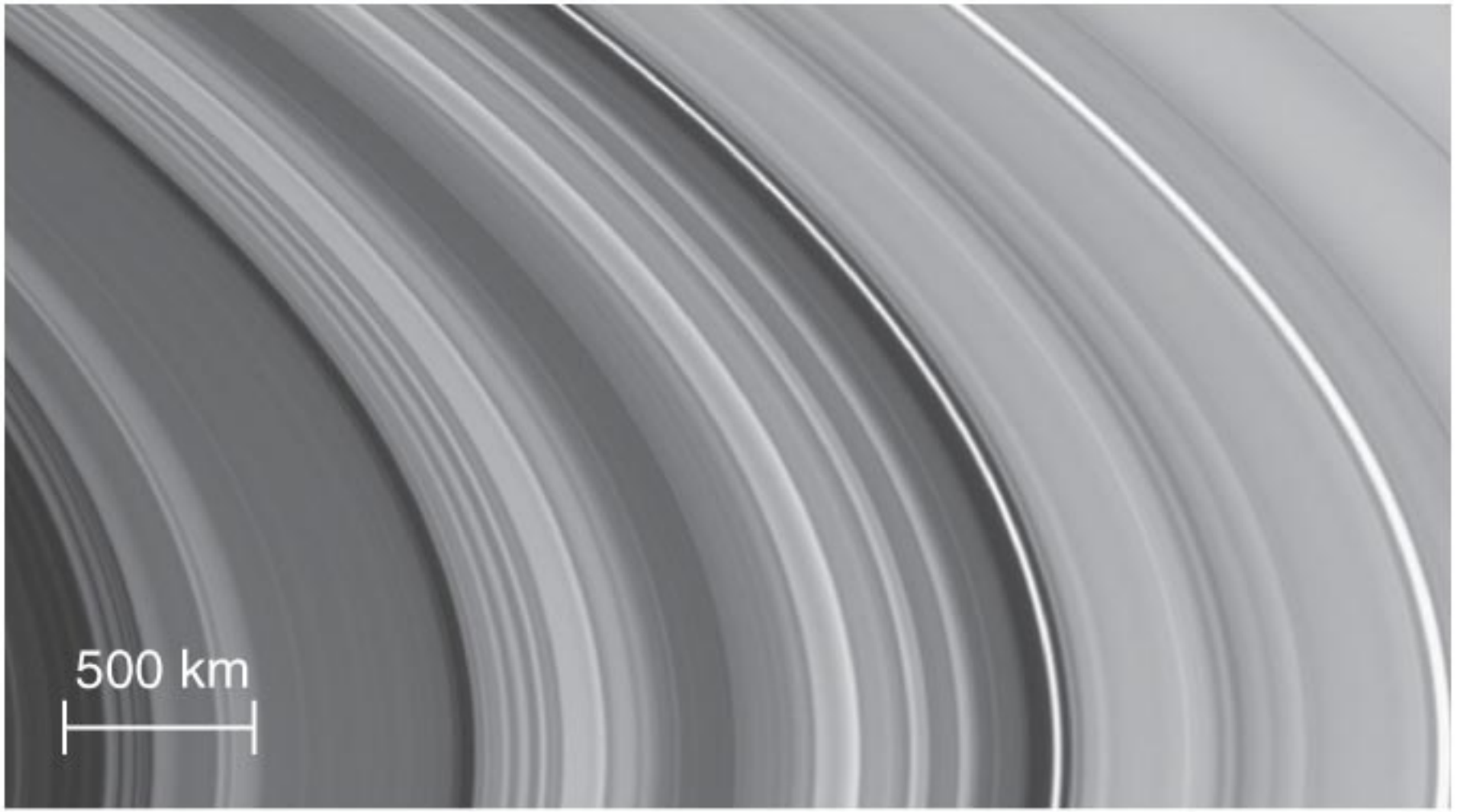

A Change of Seasons on Saturn
HUBBLESITE.org



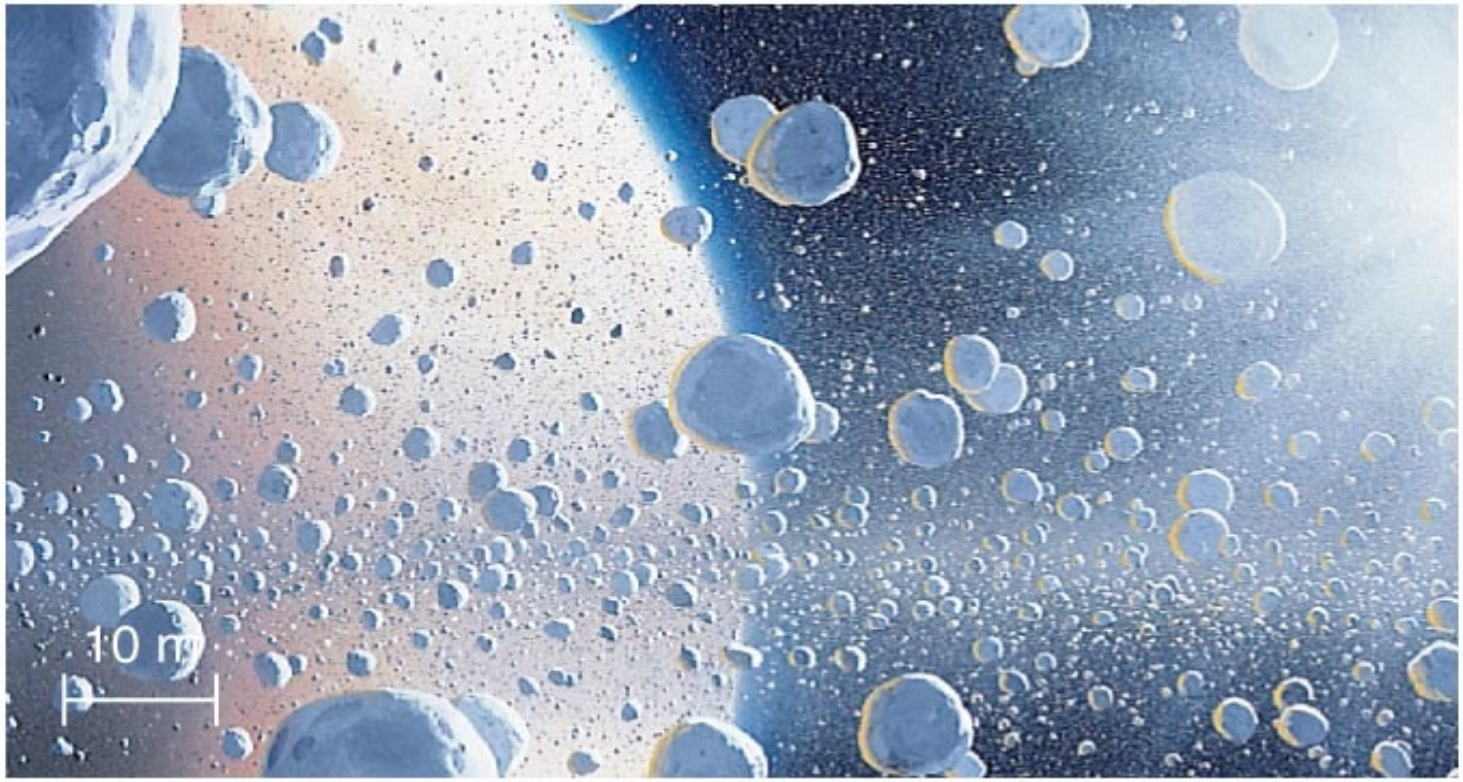
What are Saturn's rings like?

- Earth-based view makes them appear to be continuous, concentric sheets of material separated by a large gap (called the *Cassini Division*)
- But they are made up of countless **icy particles** ranging in size from dust grains to large boulders; much like myriad tiny moons
- They orbit over Saturn's equator
- They are very thin --- diameter is 270,000 km, but only a few tens of *meters* thick

Spacecraft view of ring gaps

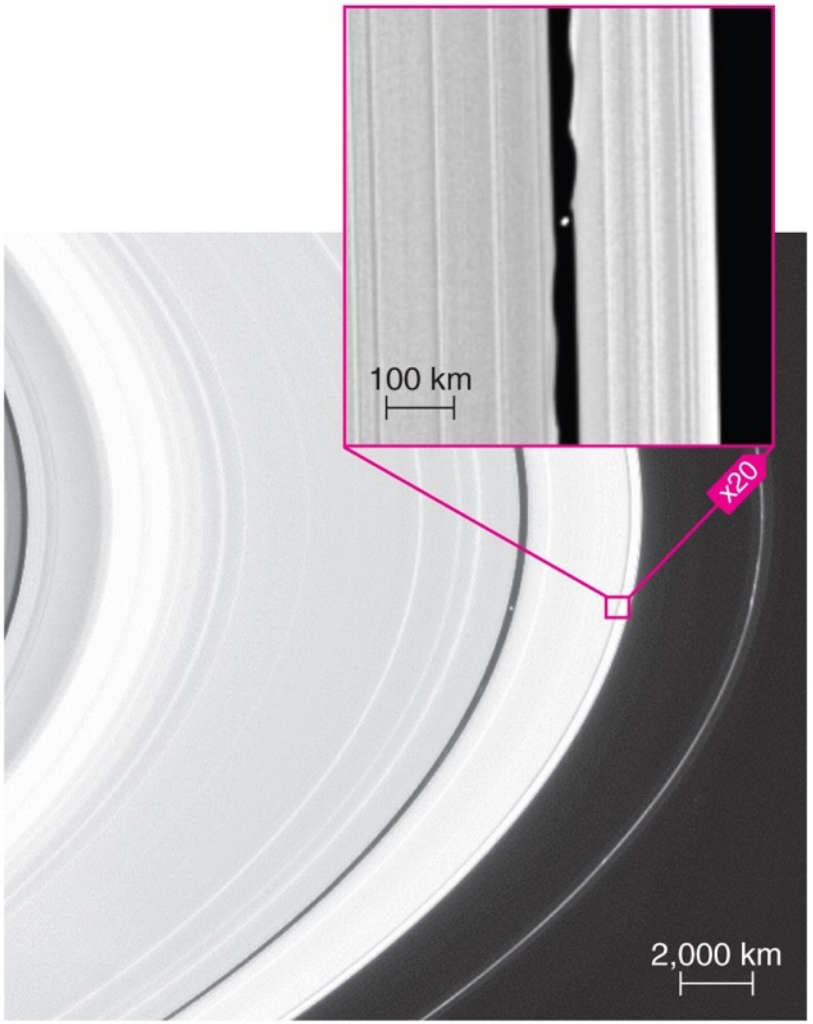


Artist's conception of close-up



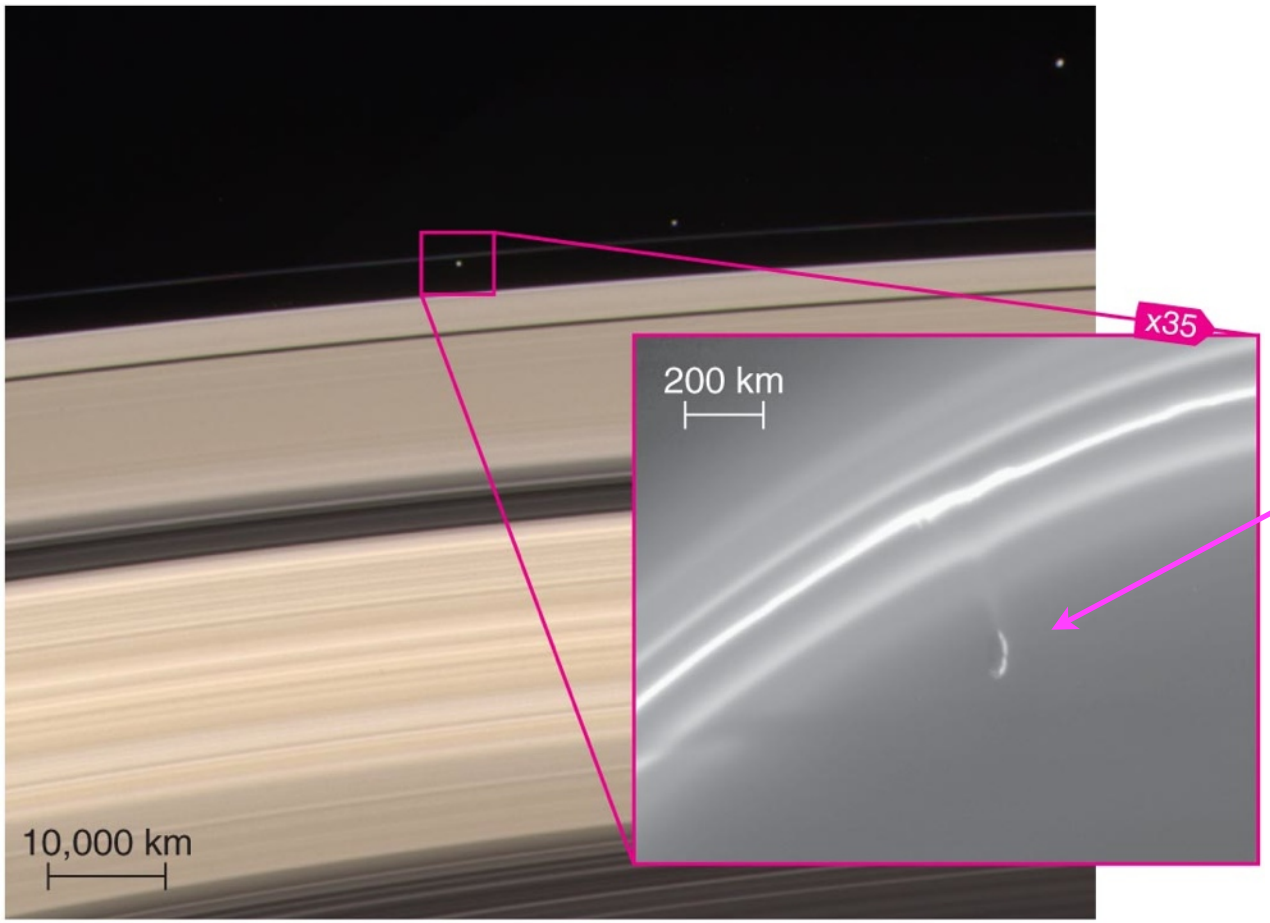
- Spectroscopy reveals that they are made of relatively **reflective water ice**.
- They collide frequently, every few hours, but the collisions are gentle.
- Frequent collisions explain why they are so thin -- any particle that move away from the narrow ring plane is soon brought back within it

Gap Moons



- Some small moons create gaps within rings **-- Gap moons**
- Particles bunch up when gravity nudges the orbits of rings in some particular way
- Gap moons create ripples as its gravity nudges particles

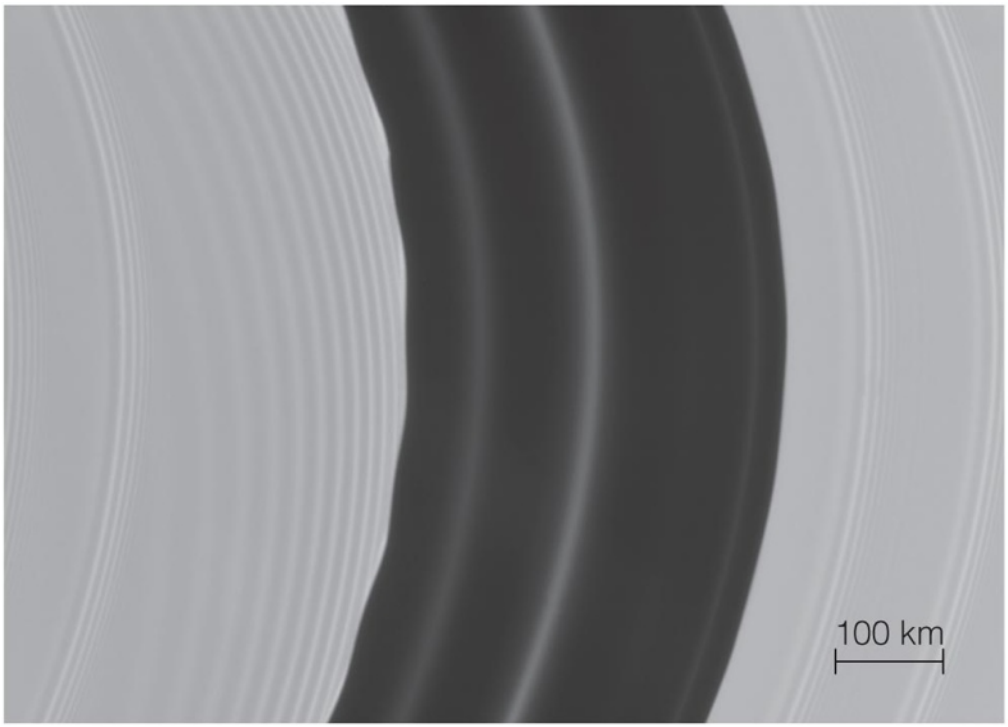
Shepherd Moons



The 100 km wide moon might be supplying or attracting ring material.

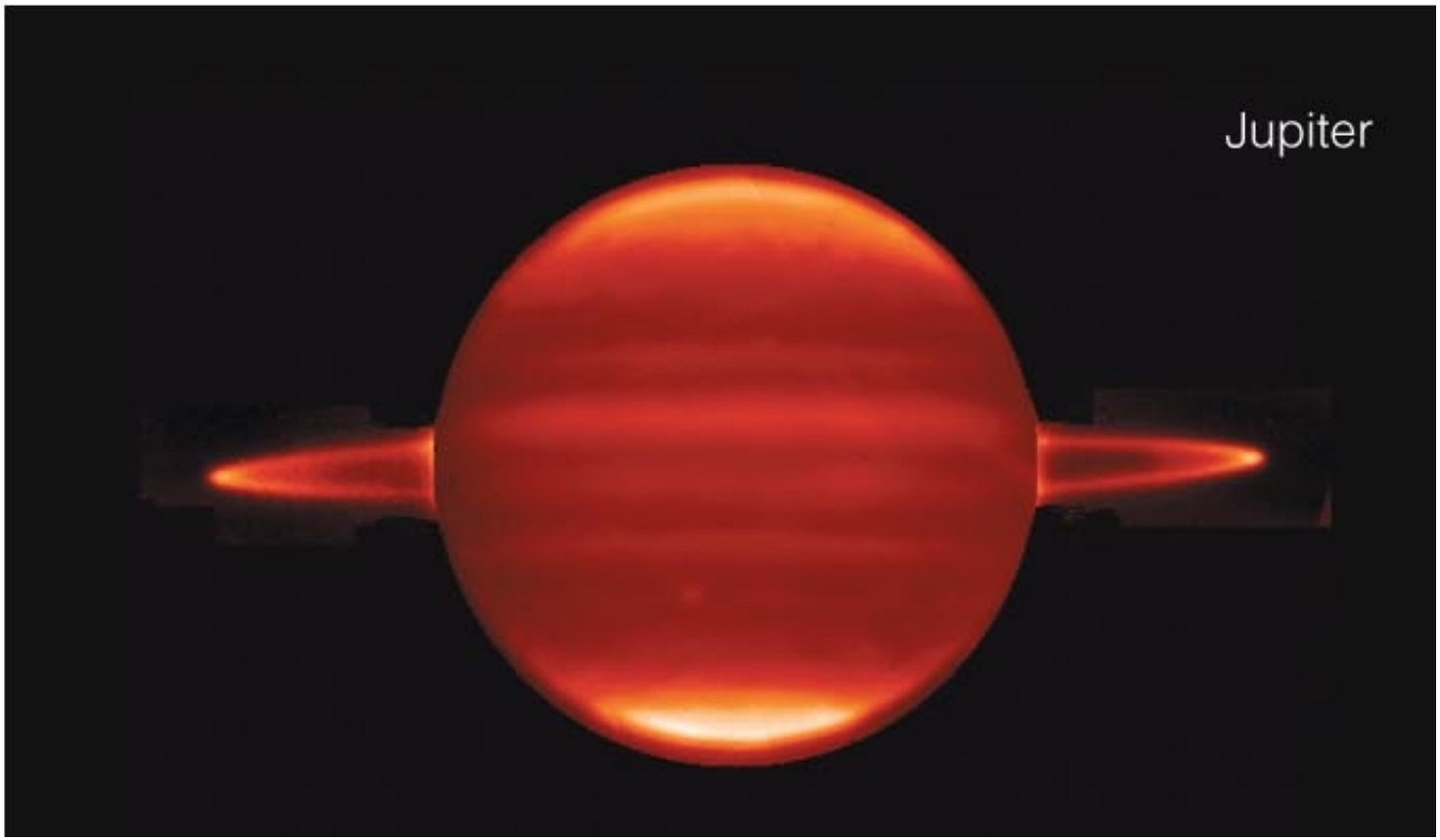
- Pair of small moons can force particles into a narrow ring

Resonance Gaps

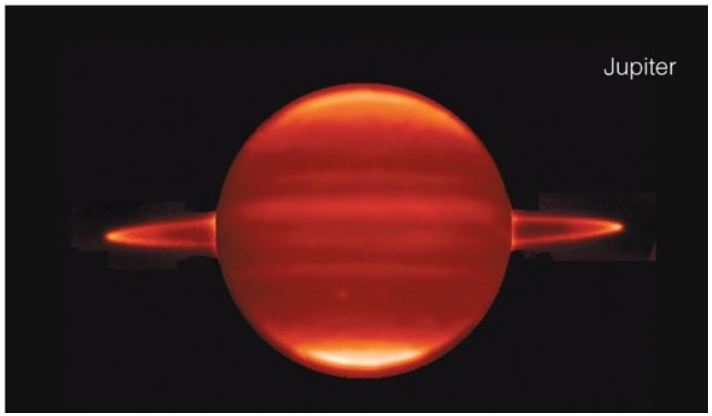


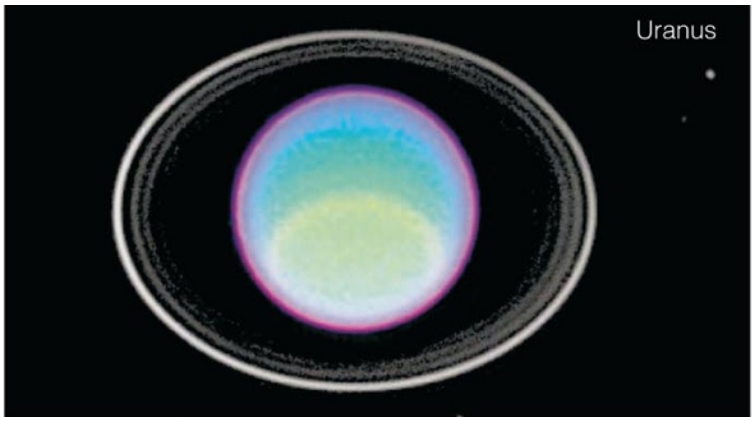
- ***Orbital resonance*** with a larger moon can also produce a gap

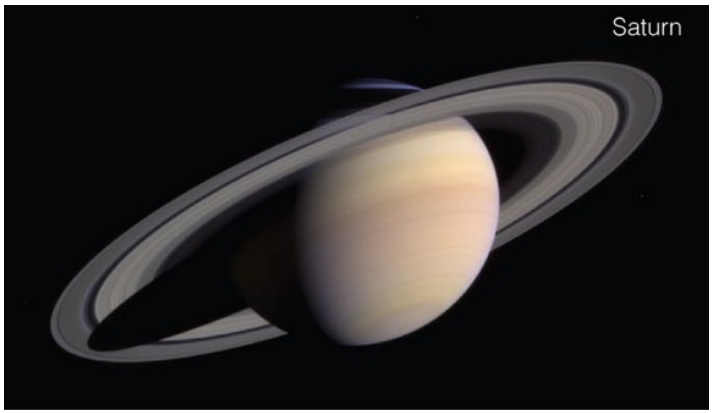
How do other jovian ring systems compare to Saturn's?

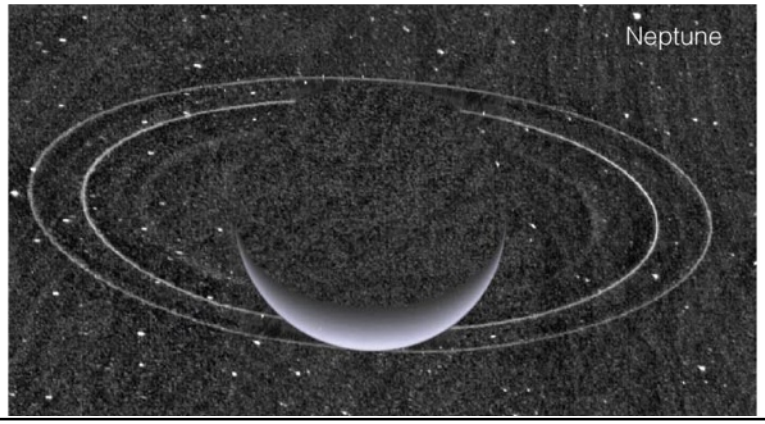


Jovian Ring Systems



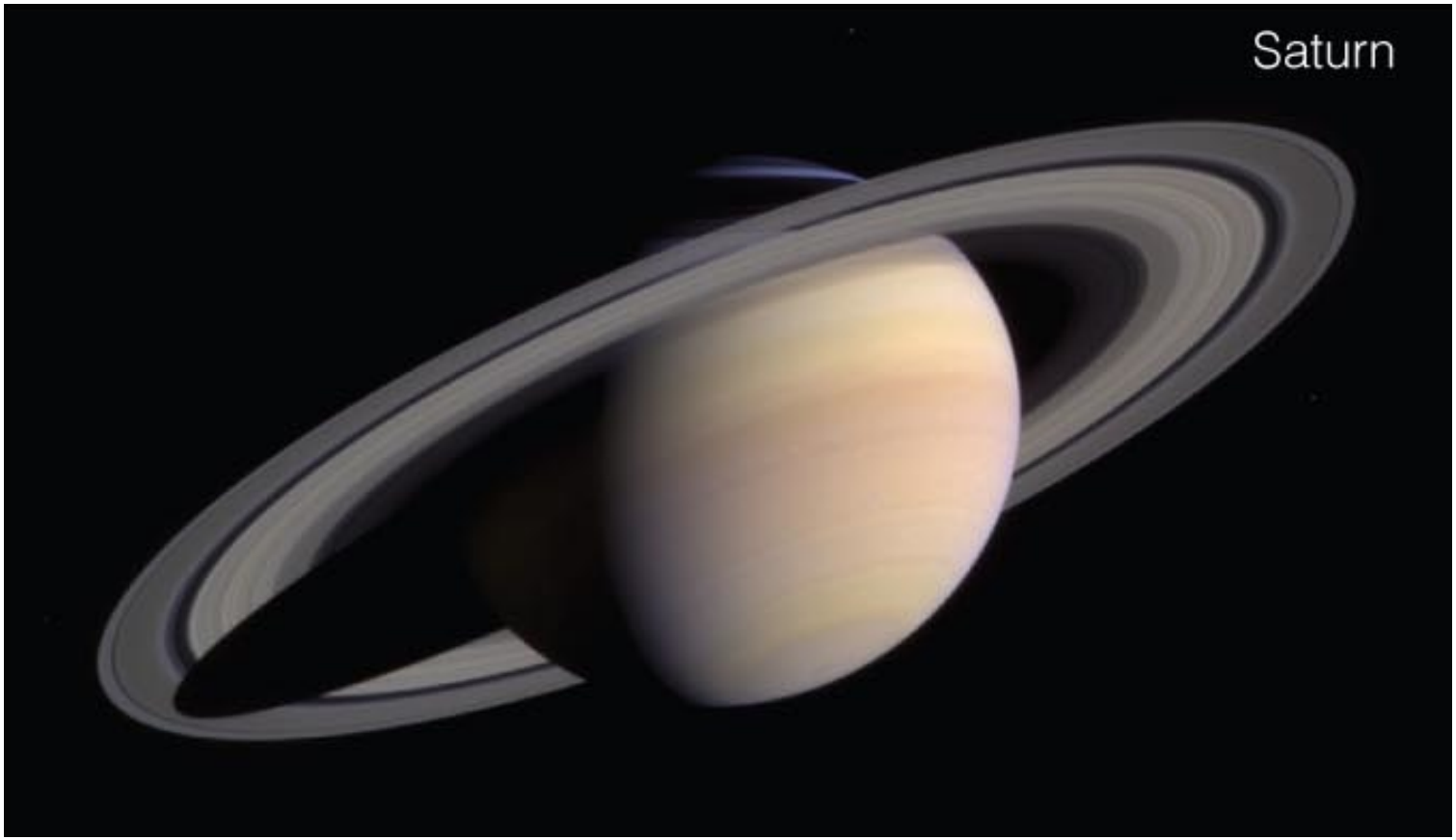






- All four jovian planets have ring systems
- Others have smaller, darker ring particles than Saturn
- Jupiter ring: 1979 *Voyager* Uranus ring: 1986 *Voyager 2*
- Neptune ring: 1989 *Voyager 2* -- partial ring; gap filled with dust

Why do the jovian planets have rings?



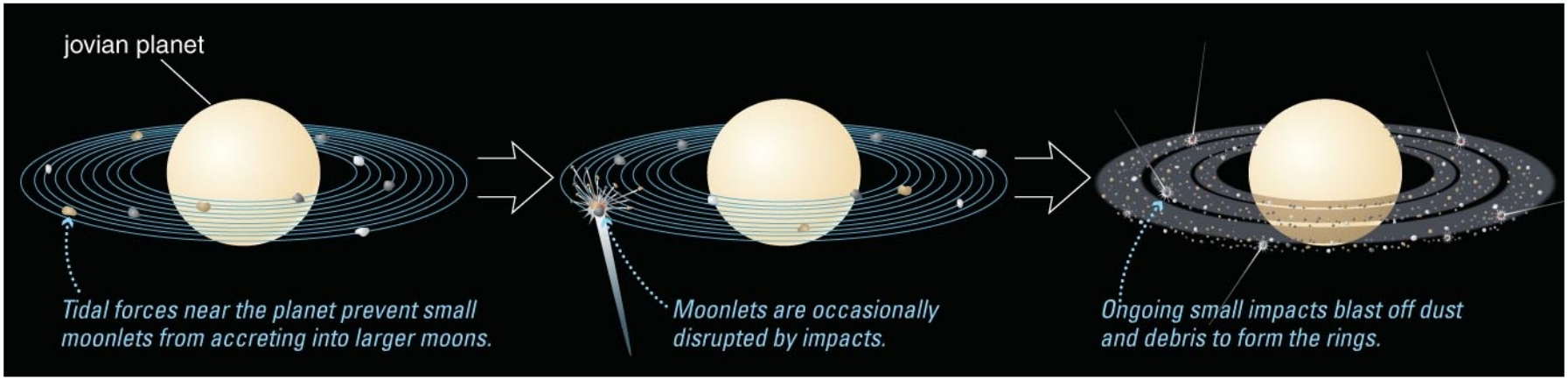
Why do the jovian planets have rings?

- Rings lie close to their planet in a region where tidal forces are very strong
- Any large moon would be ripped apart by tidal forces in the region of rings; also small particles would gradually spiral slowly into the planet
- So the rings cannot be the leftover chunks of rock and ice that condensed in the disk of gas when the planet was young

Why do the jovian planets have rings?

- So they must have formed from dust created in impacts on moons orbiting those planets
- There must be a continuous replacement of tiny particles.
- The most likely source is numerous small moons -- tiny impacts are gradually grinding away these small moons
- In summary, the dust- to boulder-size particles in rings all ultimately come from the gradual dismantling of small moons that formed during the birth of the solar system

Ring Formation



- Jovian planets all have rings because they possess many small moons close-in
- Impacts on these moons are random -- the numbers and sizes of particles in any particular ring system must vary dramatically over millions of years
- Saturn's incredible rings may be an "accident" of our time

Quiz

Why do Jupiter, Saturn, Uranus, and Neptune <u>all</u> have rings?

A. Rings were left over from solar system formation
B. They all captured particles
C. All have small moons and small orbiting particles that constantly collide and make rings

Quiz

Saturn's many moons affect the rings through

A. tidal forces
B. orbital resonances
C. magnetic field interactions

Quiz

Saturn's rings

A. have looked basically the same since they formed along with Saturn.
B. were created long ago when tidal forces tore apart a large moon.
C. are continually supplied by impacts with small moons.

What have we learned?

- What are Saturn's rings like?
  - Made up of countless individual ice particles
  - Extremely thin with many gaps
- How do other jovian ring systems compare to Saturn's?
  - Much fainter ring systems with smaller, darker, less numerous particles
- Why do the jovian planets have rings?
  - Ring particles are probably debris from moons