

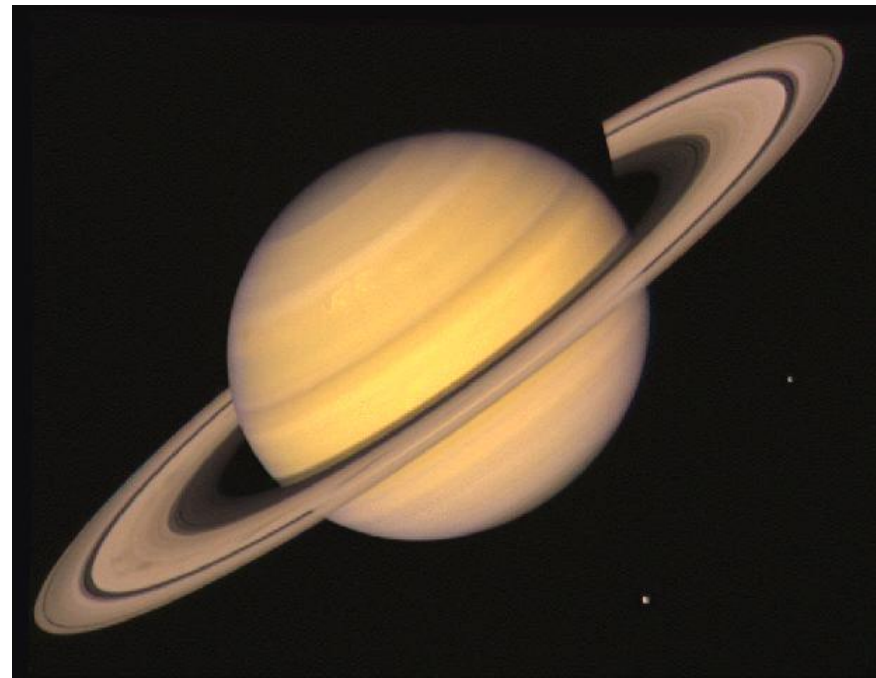
# The Essential Cosmic Perspective

Lecture 12  
The Rings and Moons  
of the Outer Planets  
**October 15, 2018**

Bennett  
Donahue  
Schneider  
Voit

# Rings of Outer Planets

- Rings are not solid but are fragments of material
  - Saturn: Ice and ice-coated rock (bright)
  - Others: Dusty ice, rocky material (dark)
- Very thin
  - Saturn rings ~0.05 km thick!
- Rings can have many gaps due to small satellites
  - Saturn and Uranus



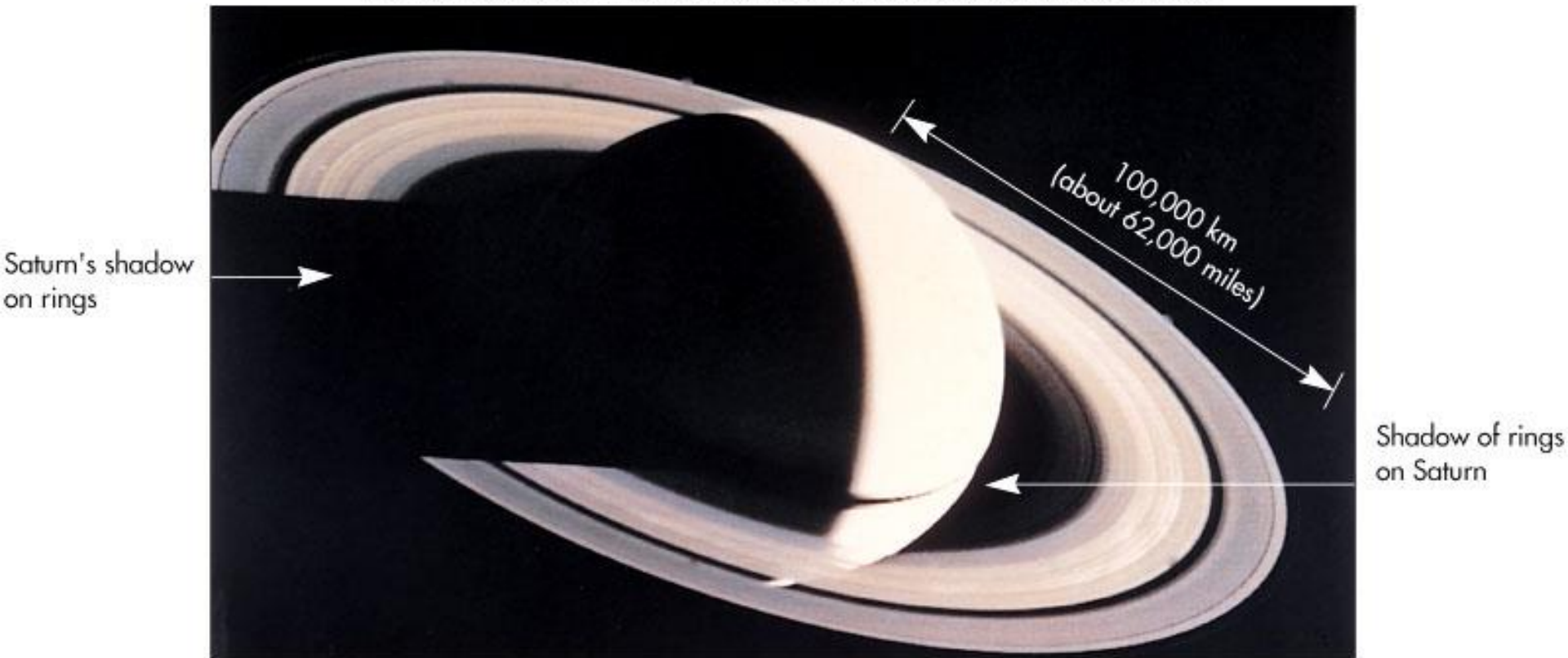
# Rings of Jupiter

- Very thin and made of small, dark particles.



# Rings of Saturn

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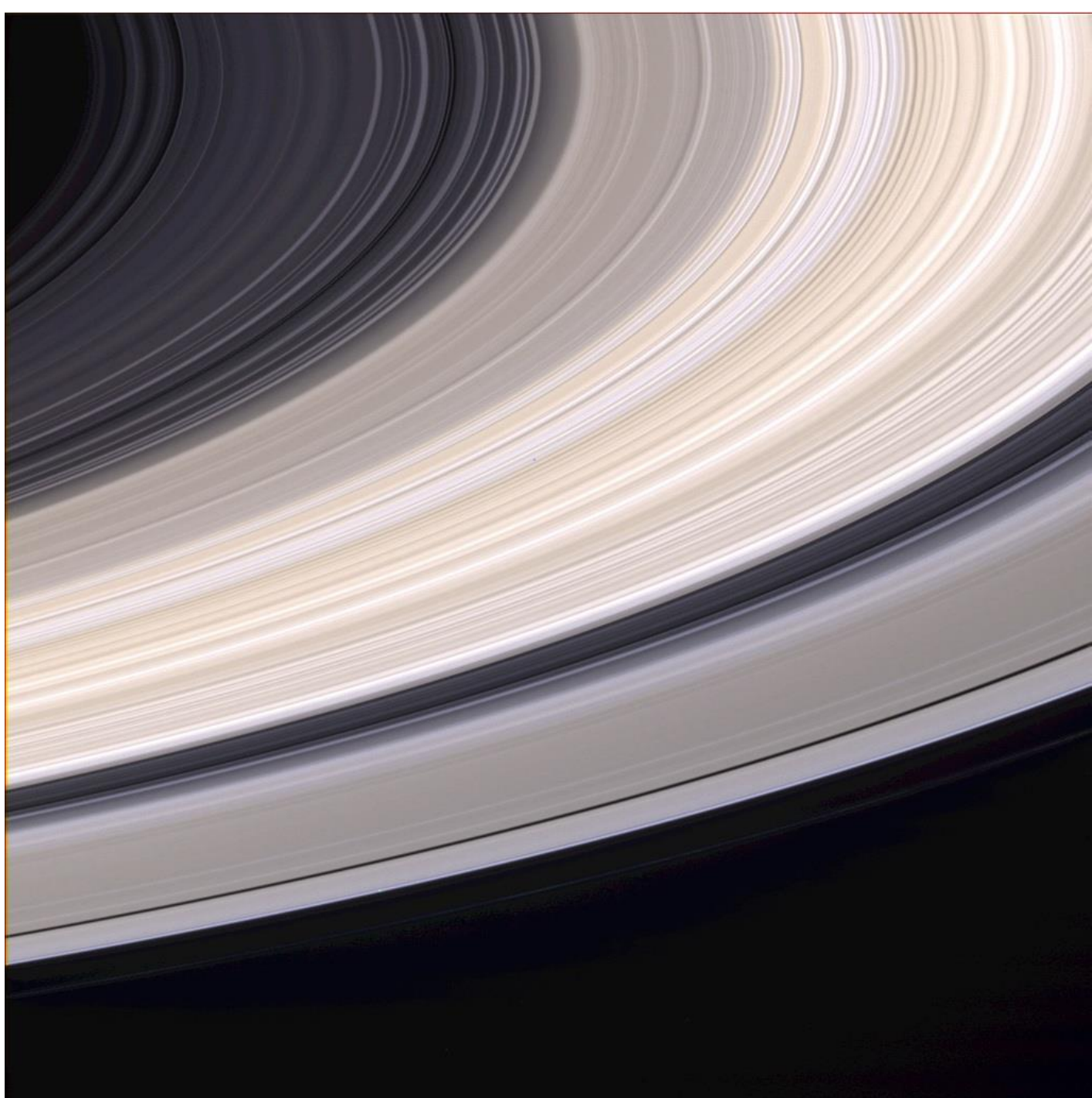


[Flash movie](#)



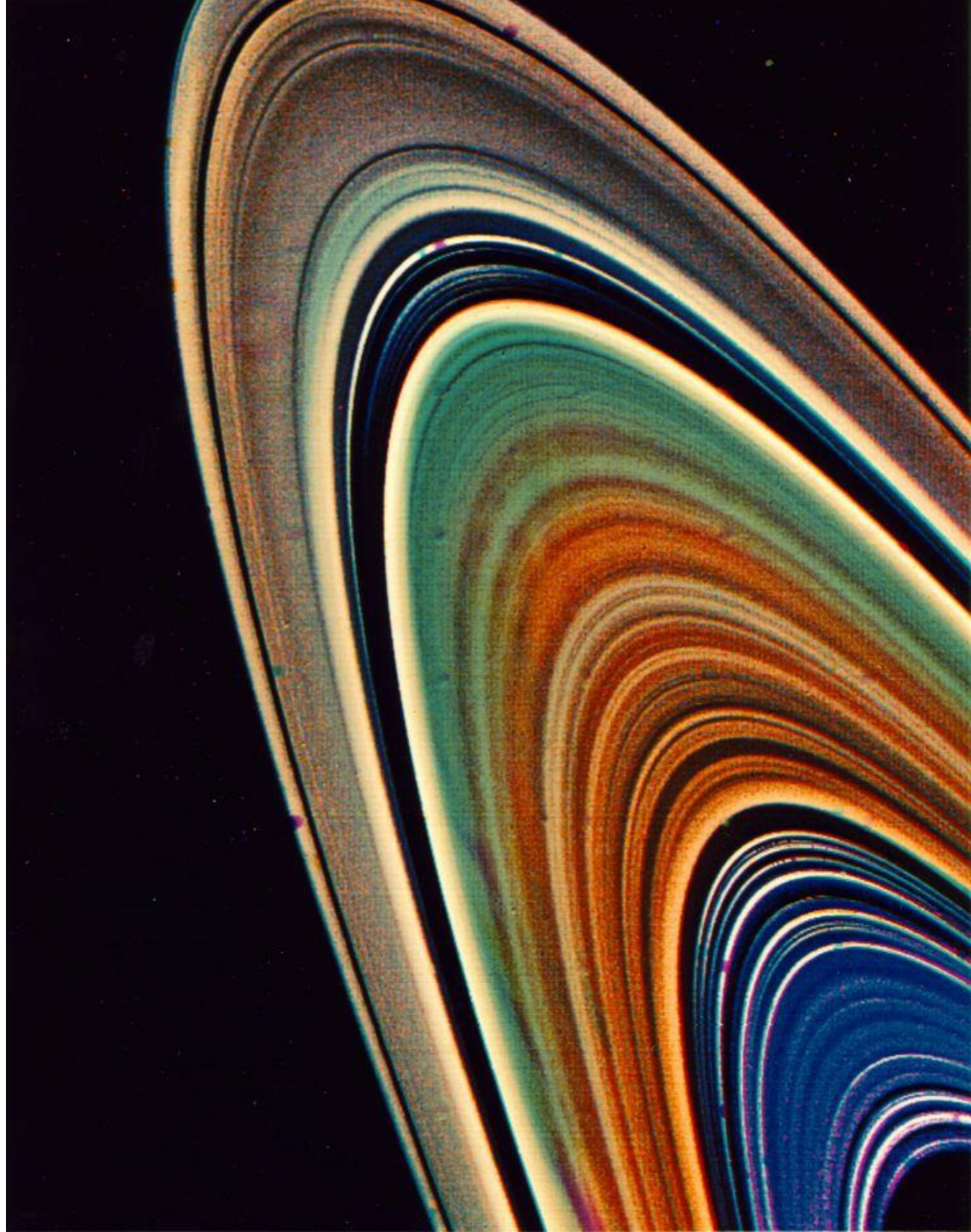
# Saturn's Rings

Ring structure in natural color, photographed by Cassini probe July 23, 2004. Click on image for Astronomy Picture of the Day site, or [here for JPL information](#)

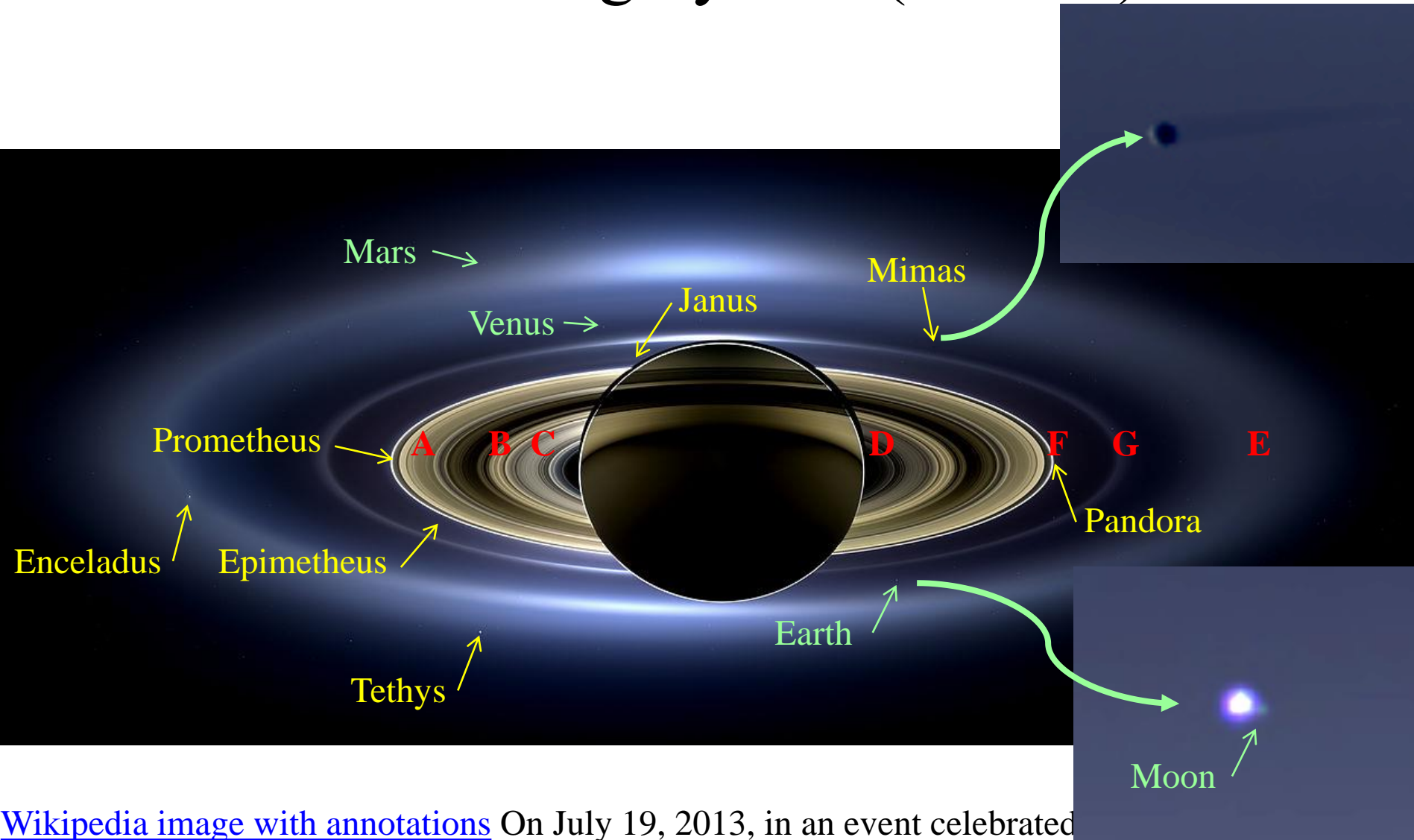


# Saturn's Rings (false color)

Photo taken by Voyager 2  
on August 17, 1981.  
[Click on image for more  
information](#)



# Saturn's Ring System (Cassini)

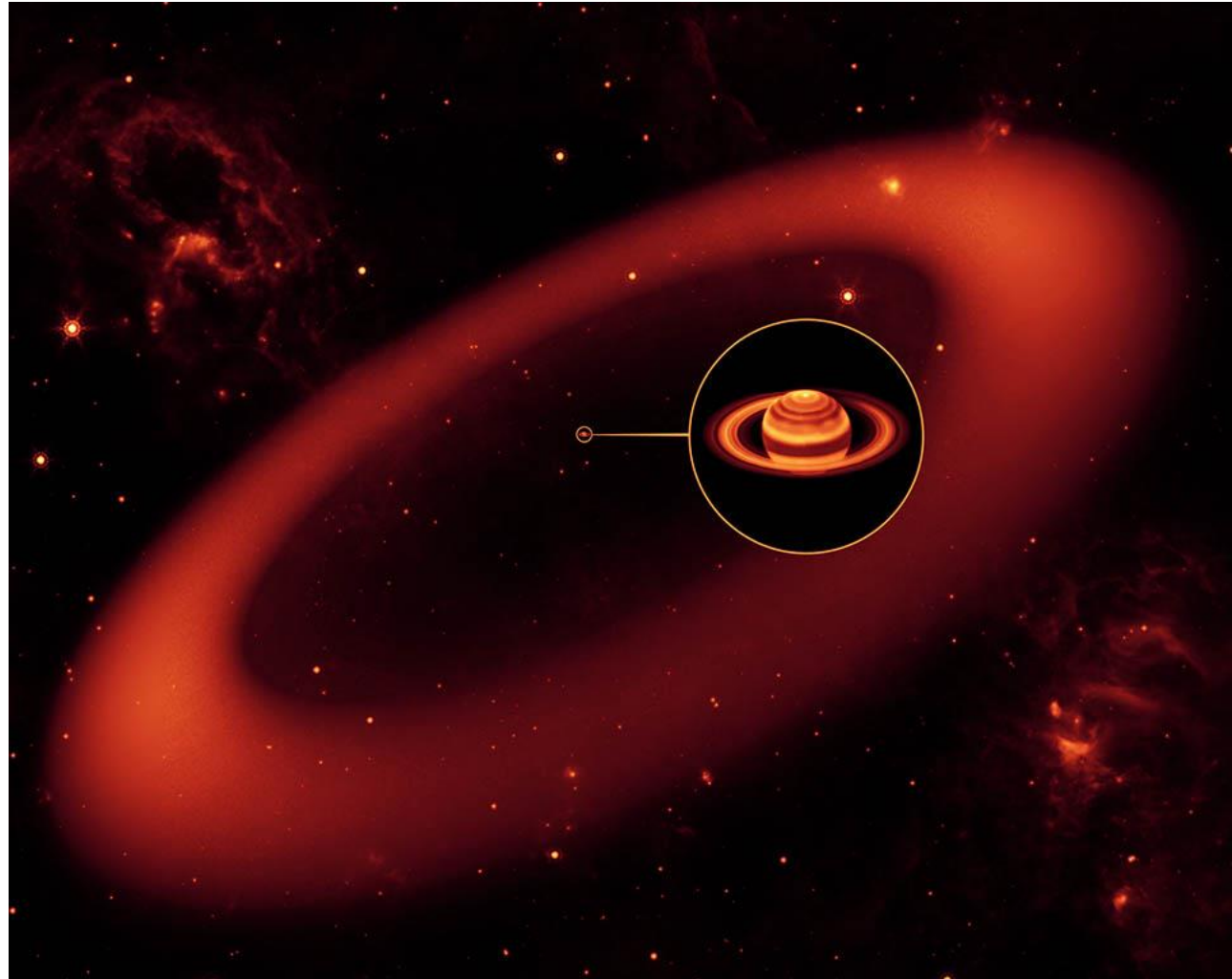


[Wikipedia image with annotations](#) On July 19, 2013, in an event celebrated NASA's Cassini spacecraft slipped into Saturn's shadow and turned to image the planet, seven of its moons, its inner rings -- and, in the background, our home planet, Earth.



# Newly Discovered Saturnian Ring

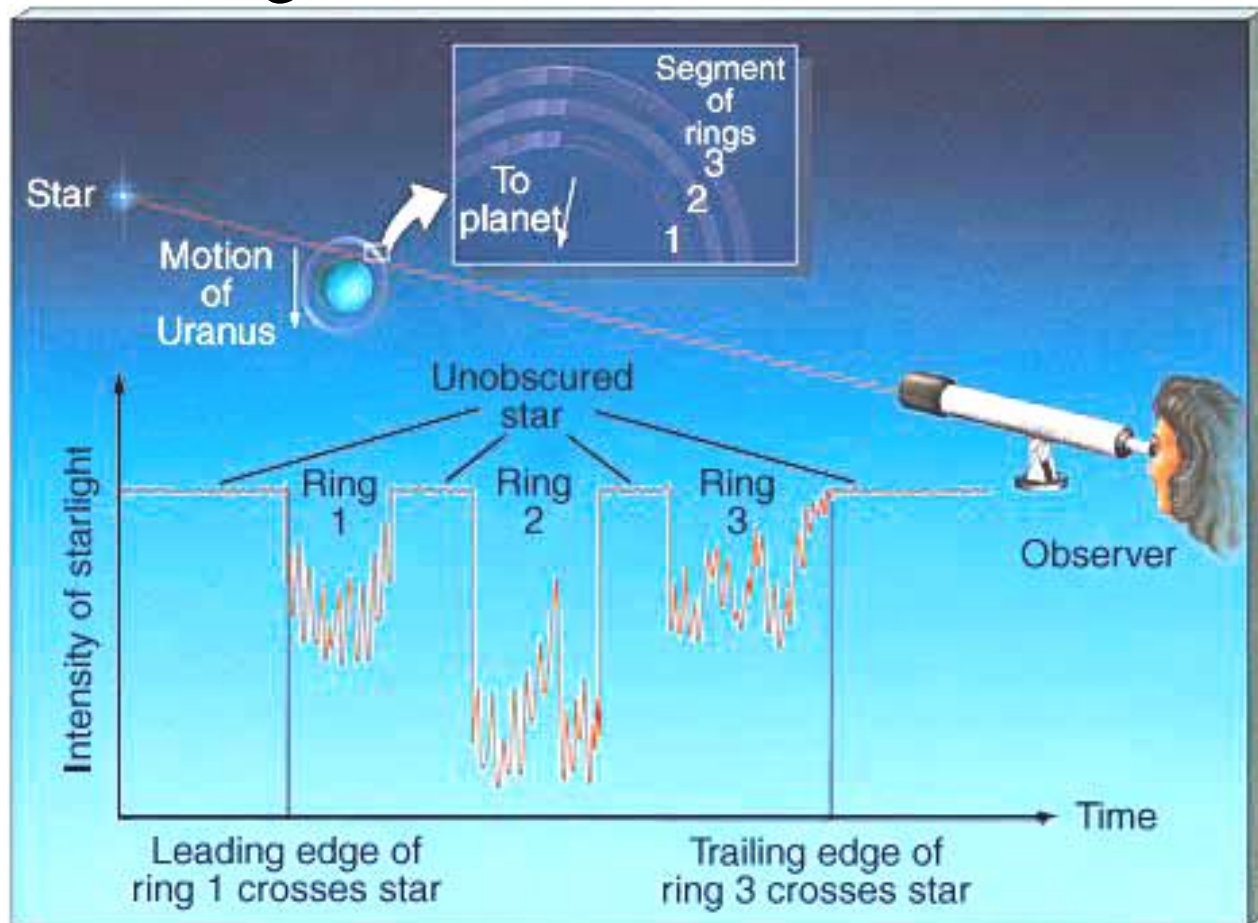
- Nearly invisible ring in the plane of the moon Pheobe's orbit, tilted  $27^\circ$  from Saturn's equatorial plane
- Discovered by the infrared Spitzer Space Telescope and [announced 6 October 2009](#)
- Extends from 128 to 207 Saturnian radii and is about 40 radii thick
- Contributes to the [two-tone coloring](#) of the moon Iapetus
- [Click here](#) for more info about the artist's rendering





# Rings of Uranus

- Uranus -- rings discovered through **stellar occultation**
  - Rings block light from star as Uranus moves by.

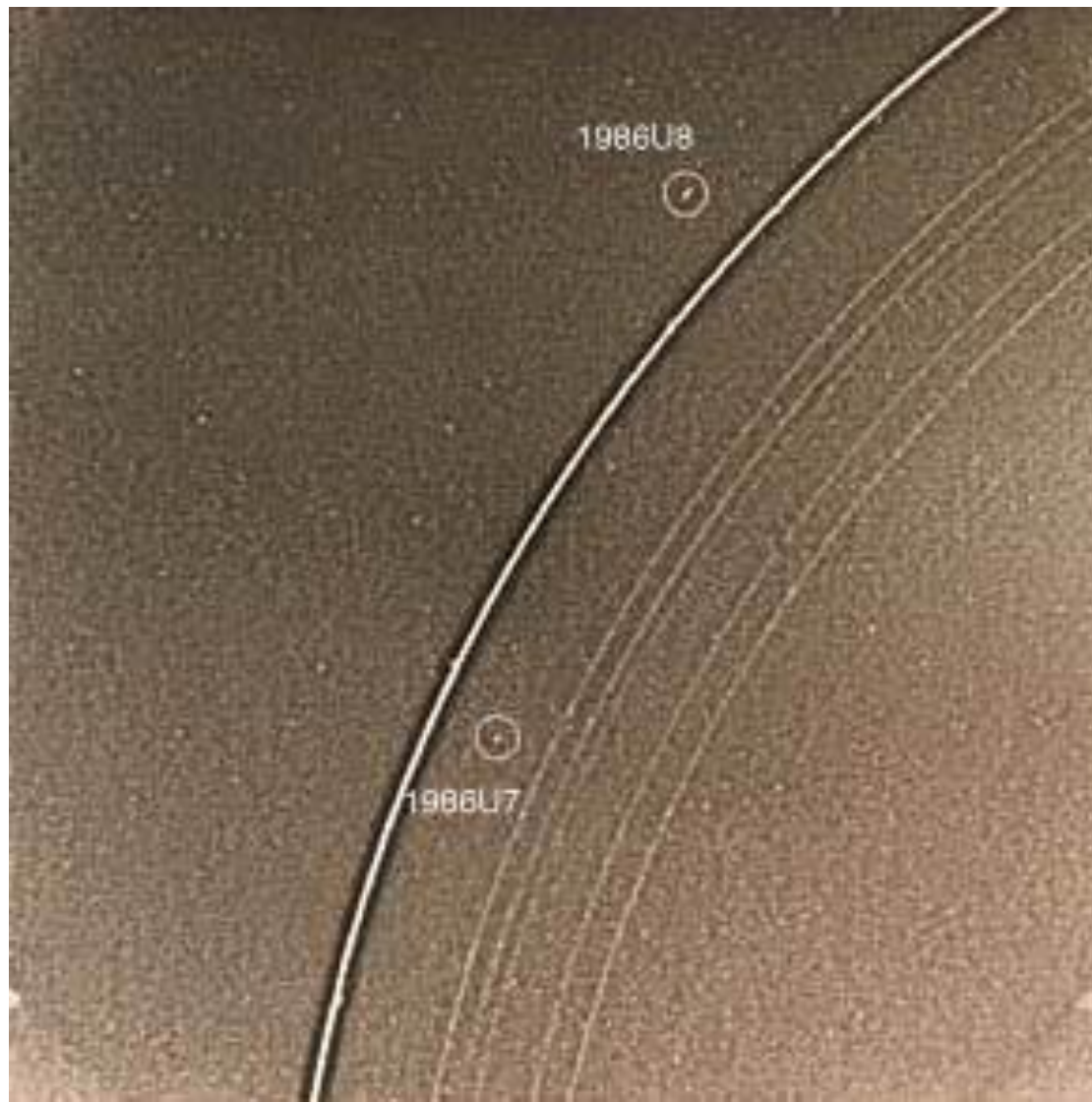


# Rings of Uranus

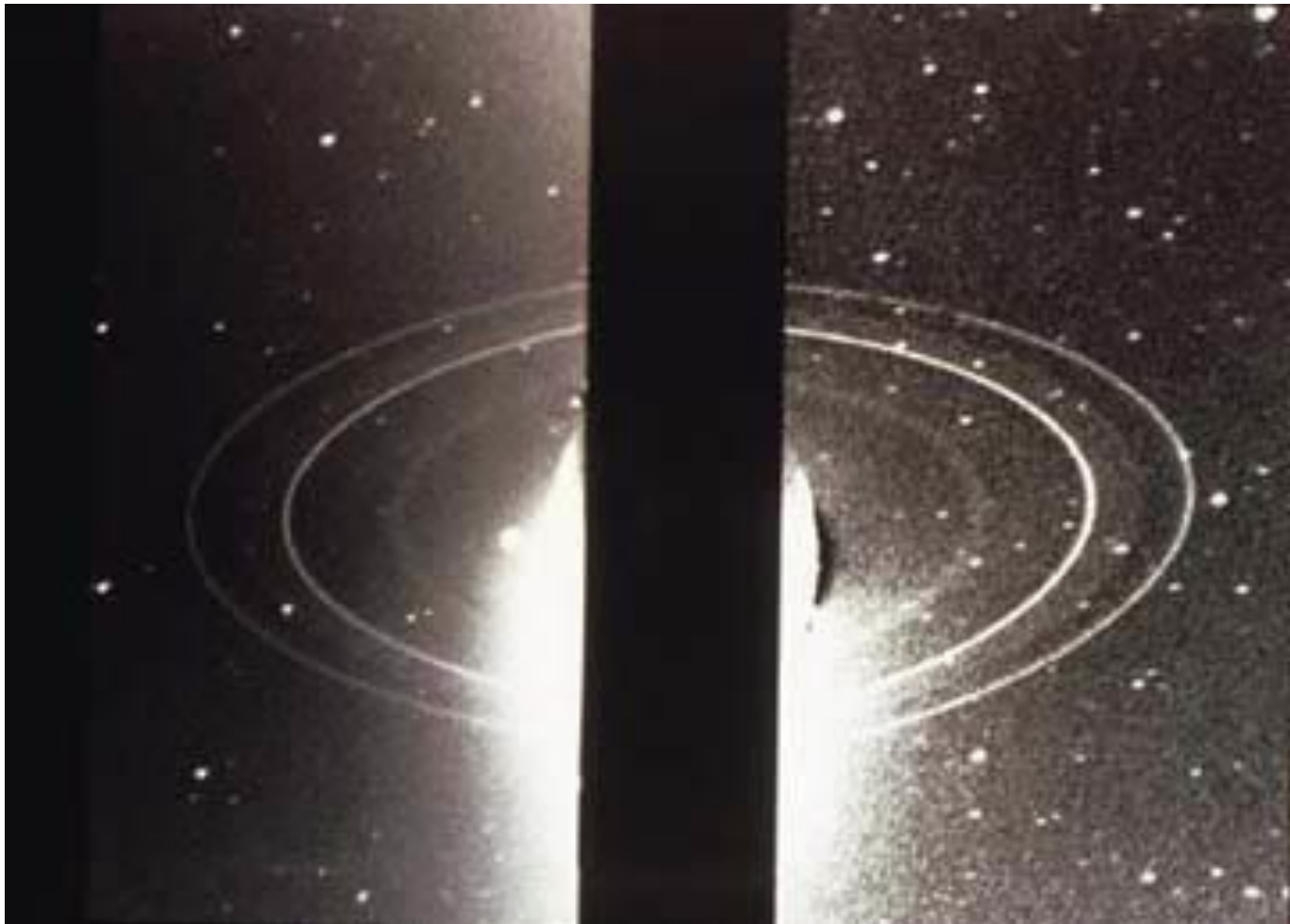
## Shepherd satellites

keep rings thin by means of small gravitational forces.

- Inner moon: tugs forward on ring particles, boosting them to larger orbit
- Outer moon: tugs backward on ring particles, slowing them to smaller orbit.



# Rings of Neptune



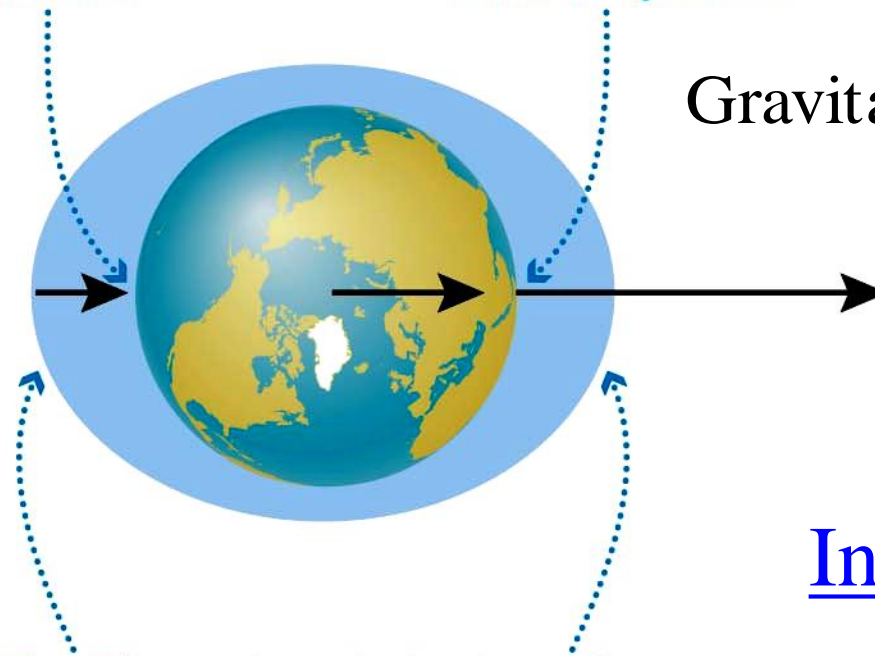


# Tidal Forces – Earth & Moon

- Gravity of Moon pulls on Earth
- Force on near side stronger than far side

*The gravitational attraction to the Moon is weakest here...*

*...and strongest here.*



$$\text{Gravitational Force} = \frac{Gm_1m_2}{r^2}$$



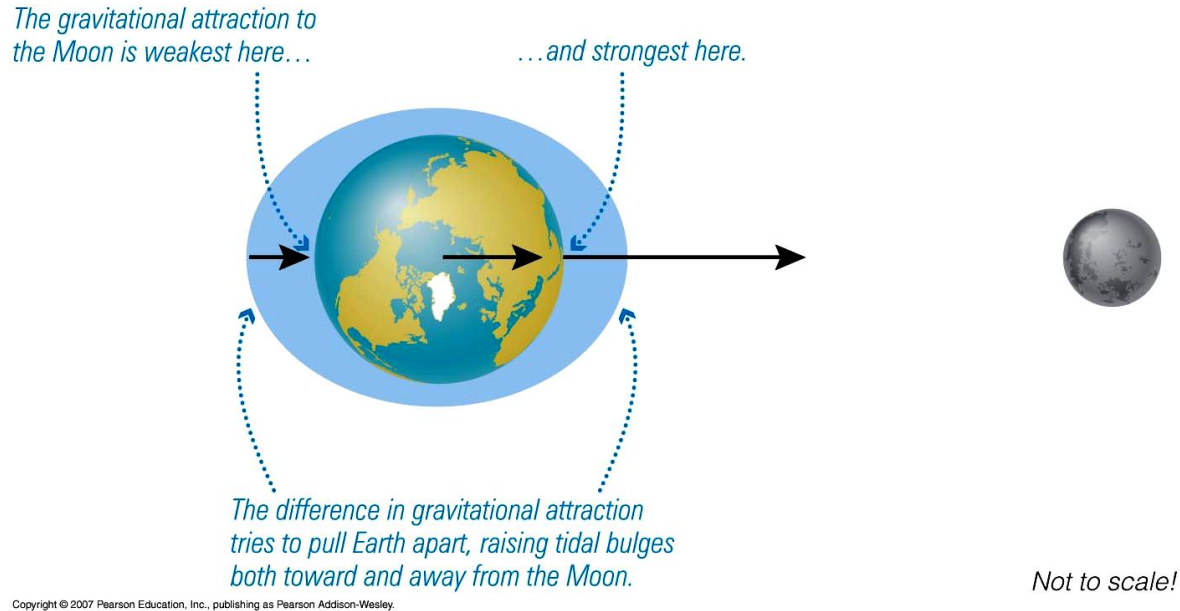
[Interactive Applet](#)

*The difference in gravitational attraction tries to pull Earth apart, raising tidal bulges both toward and away from the Moon.*

*Not to scale!*

# Tidal Forces

- Net result is to pull object apart.



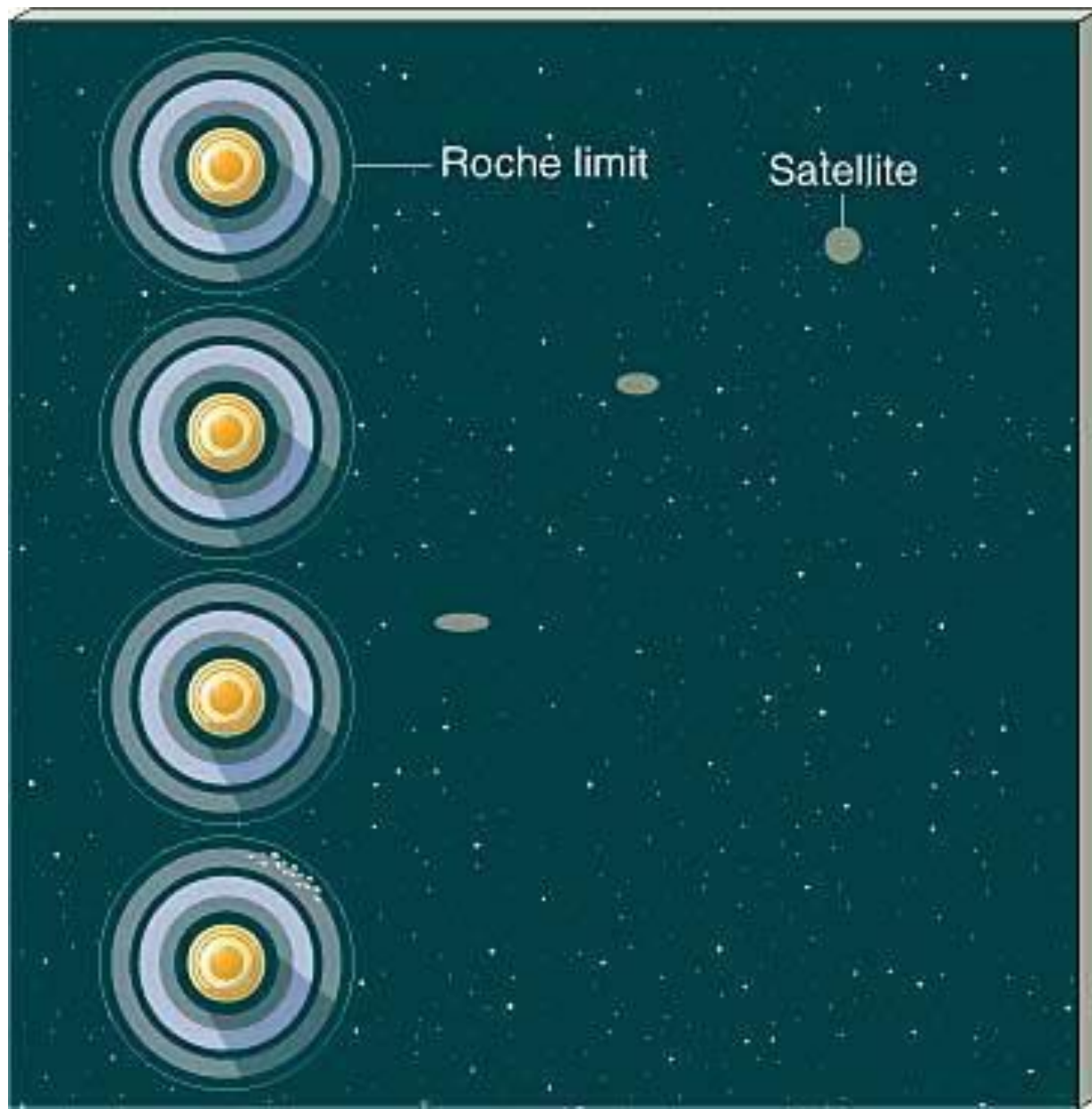
- Difference in forces on far and near side is the **tidal force**
  - Causes bulge in water on Earth.
  - Earth also slightly distorted

# How are Rings Formed?

- **Tidal forces** increase the closer one gets to the planet.
- If the moon is too close, tidal force can break apart moon
- **Roche limit** = distance from planet where tidal forces are equal to internal forces
  - Rings form inside Roche limit
  - Moons form outside Roche limit
  - Only small objects can form inside Roche limit



# Roche Limit

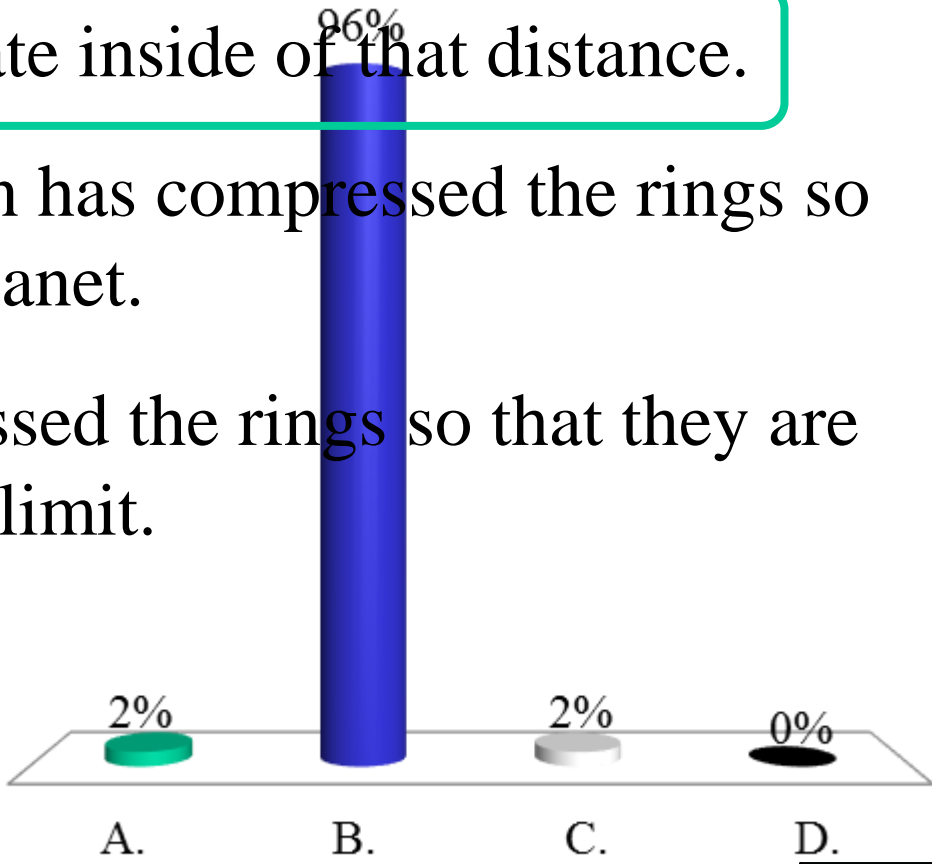


# How Old are Saturn's Rings?

- Rings are likely recent.
- Modeling shows rings of Saturn cannot remain stable for billions of years.
- Likely that a small moon or comet strayed into Roche limit of Saturn and was destroyed ~50 million years ago.

The rings of Saturn are mostly located within the Roche limit because

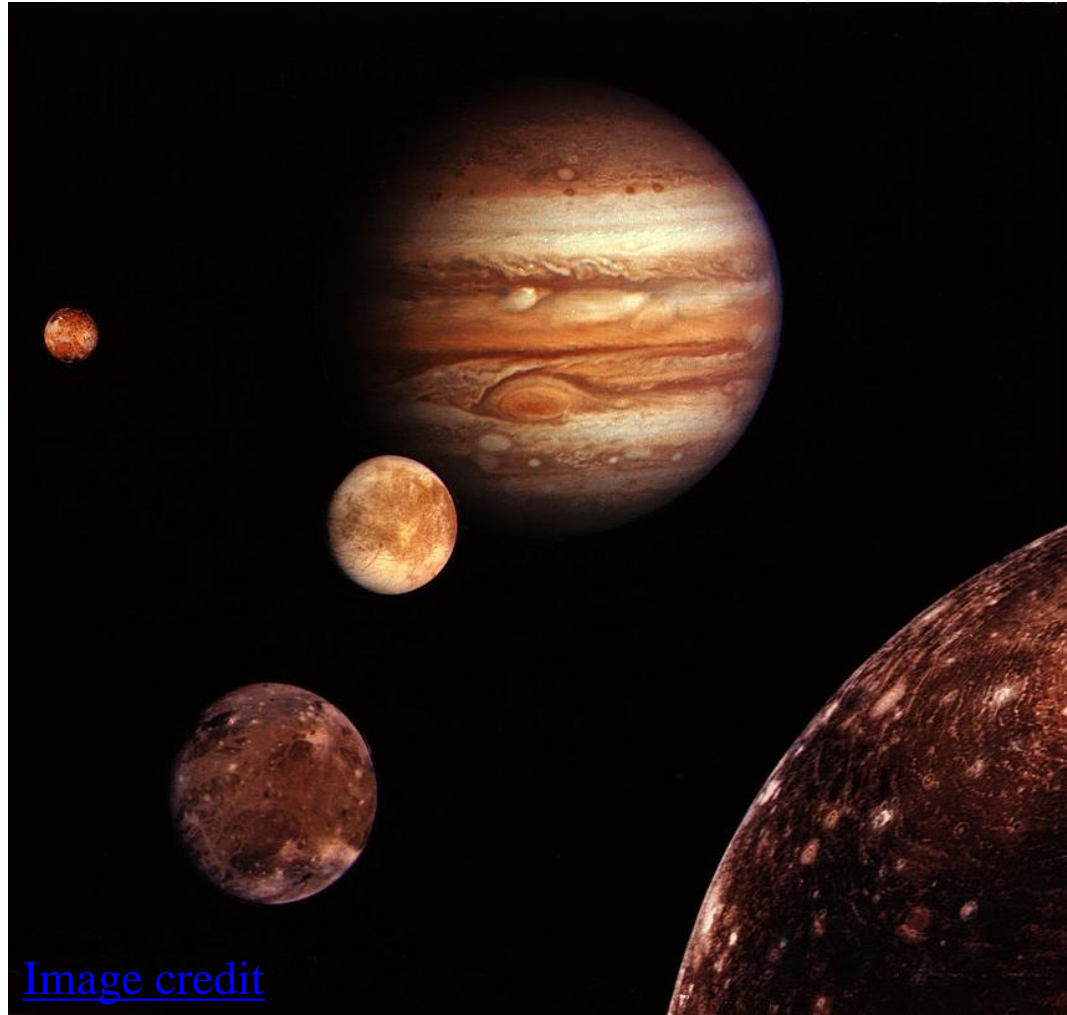
- A. particles outside the Roche limit can escape Saturn.
- B. no large moon can aggregate inside of that distance.
- C. the strong gravity of Saturn has compressed the rings so that they are close to the planet.
- D. the solar wind has compressed the rings so that they are almost entirely within this limit.





# Moons of Jupiter

- 79 known moons
  - 4 large moons -- Galilean Moons
- 
- Provide look at mini-solar system
  - Density decreases outward. (3570-1865 kg/m<sup>3</sup>)
  - All have synchronous rotation



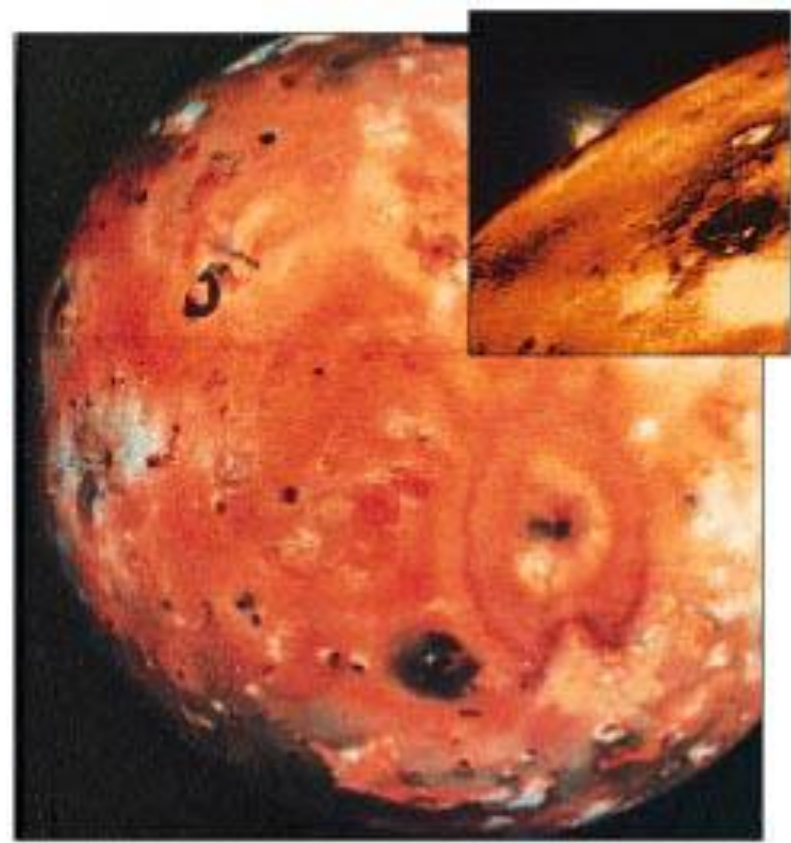
[Image credit](#)

# Basic Information on Galilean Moons

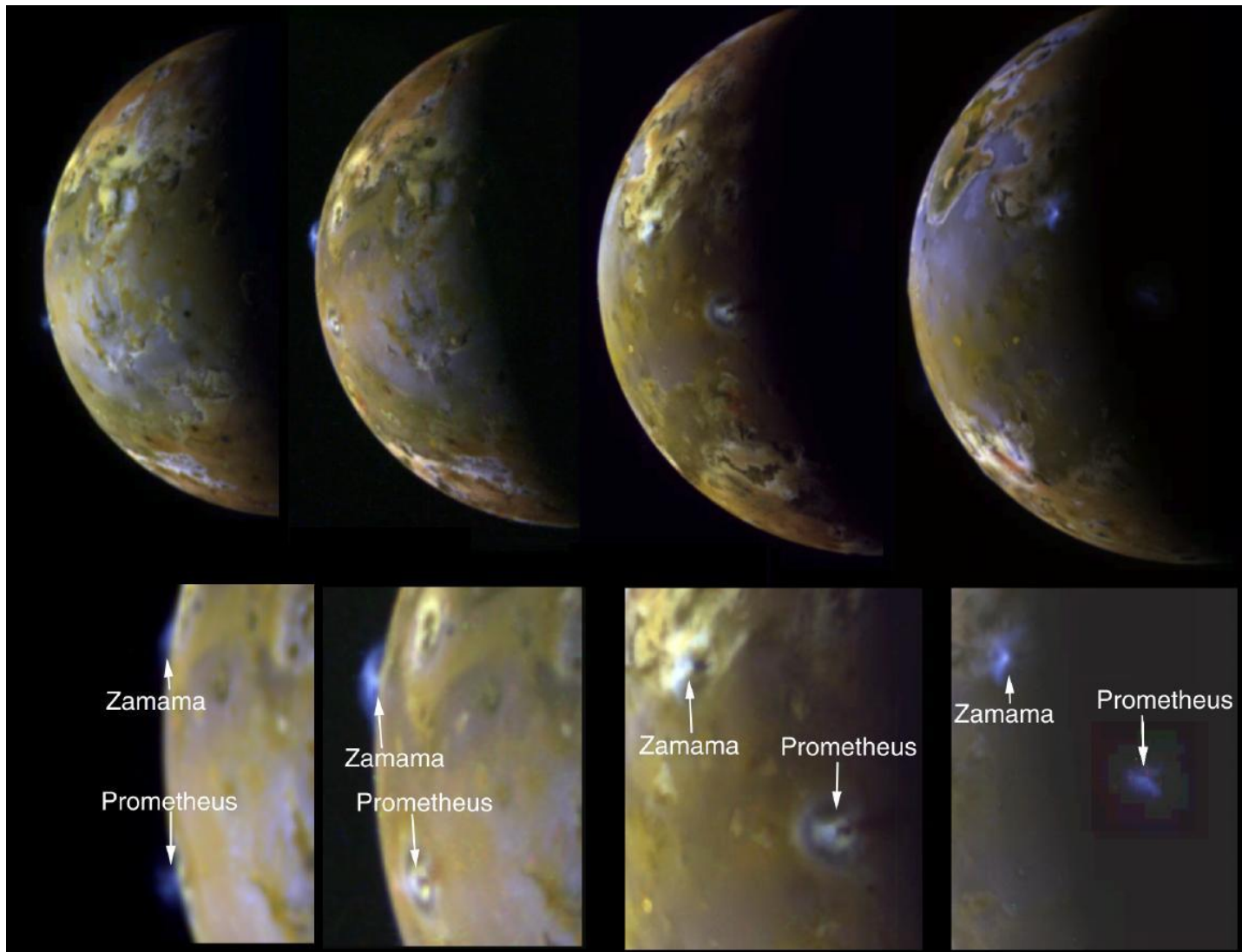
Moon	Radius	Mass	Density (kg/m <sup>3</sup> )	Dist (M km)
Io	1815 km 1.04 $R_{\text{moon}}$	1.22 $M_{\text{moon}}$	3570	0.4
Europa	1569 km 0.9 $R_{\text{moon}}$	0.65 $M_{\text{moon}}$	2967	0.7
Ganymede	2631 km 1.5 $R_{\text{moon}}$	2.01 $M_{\text{moon}}$	1940	1
Callisto	2400 km 1.4 $R_{\text{moon}}$	1.47 $M_{\text{moon}}$	1865	1.8

# Io

- Densest
- Sulfur compounds give surface orange color.
- Extremely volcanically active
- Few craters
- Why so active?
  - Orbit not circular but elliptical.
  - tidal forces continually changing, flexing interior of Io.
  - Flexing produces large amounts of heat, melting the interior.



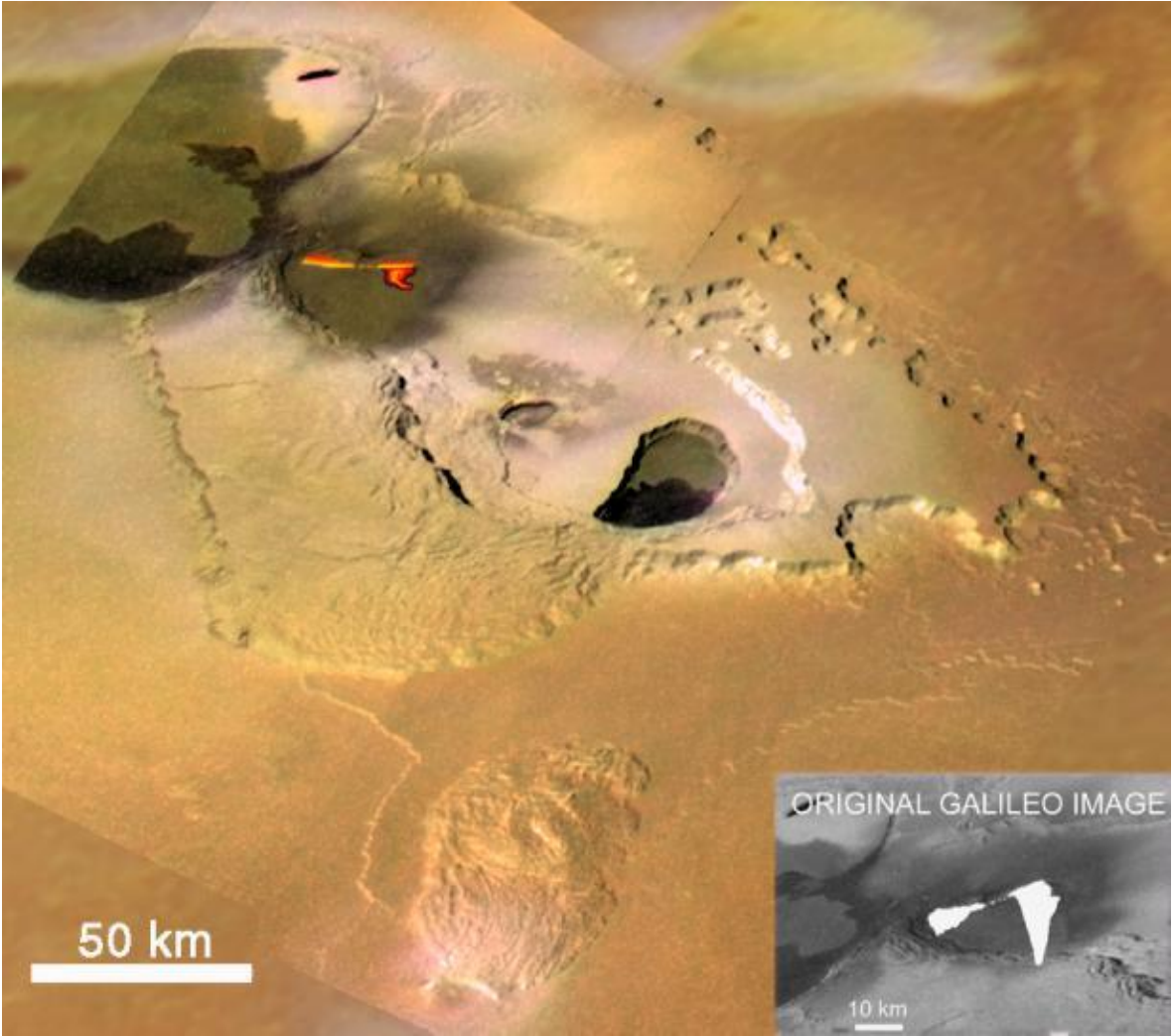
# Volcanic Plumes on Io - Galileo



<http://photojournal.jpl.nasa.gov/catalog/PIA01652>



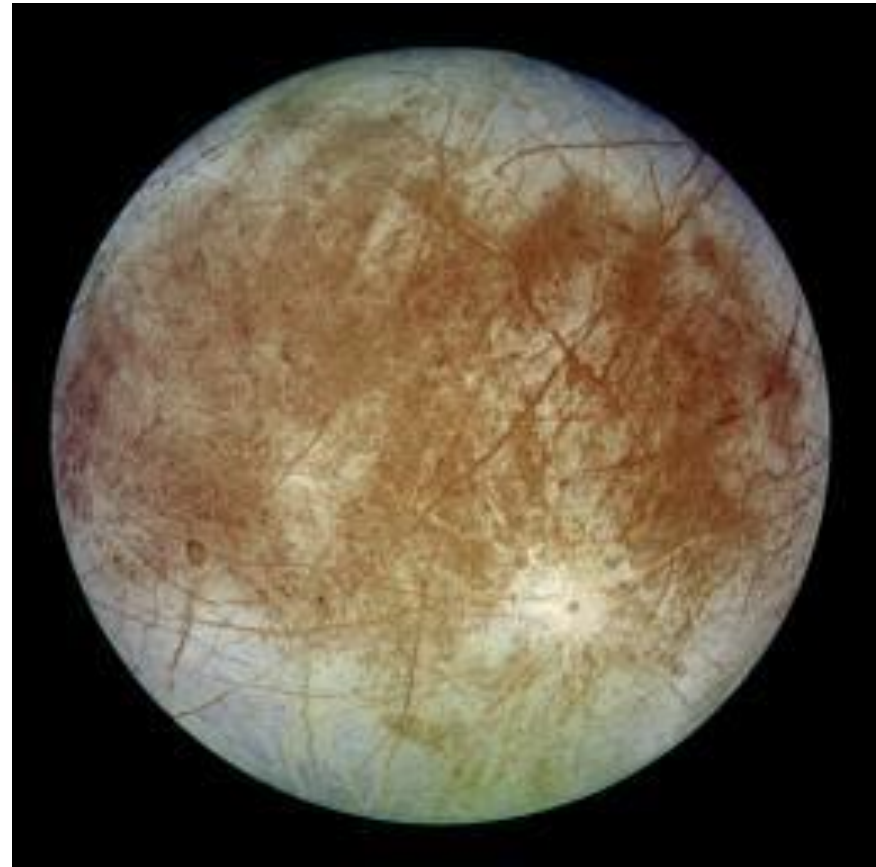
# Eruption at Tvashtar Catena, Io - Galileo



<http://photojournal.jpl.nasa.gov/catalog/PIA02545>

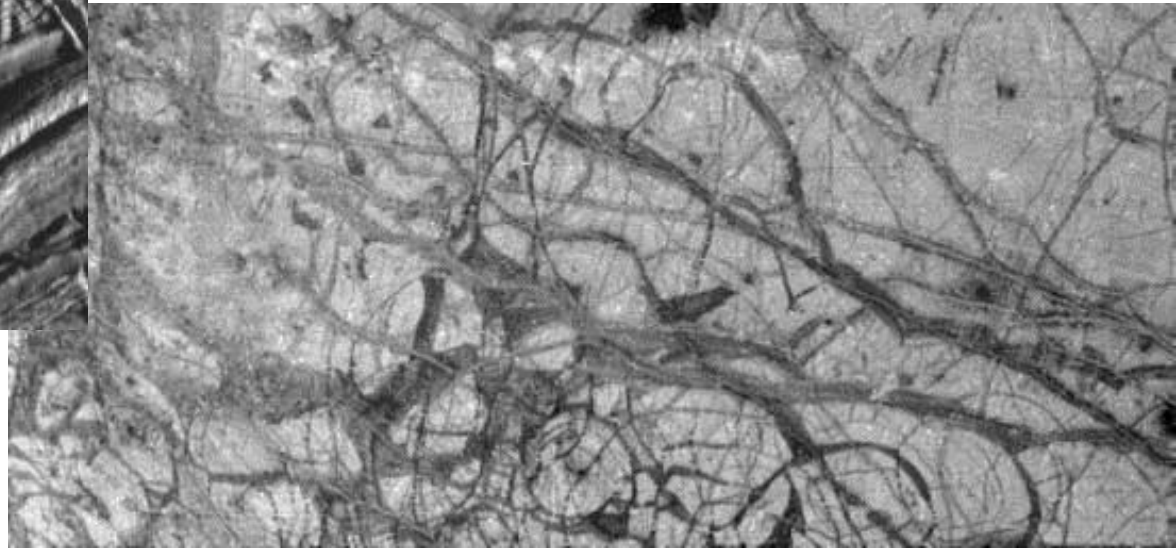
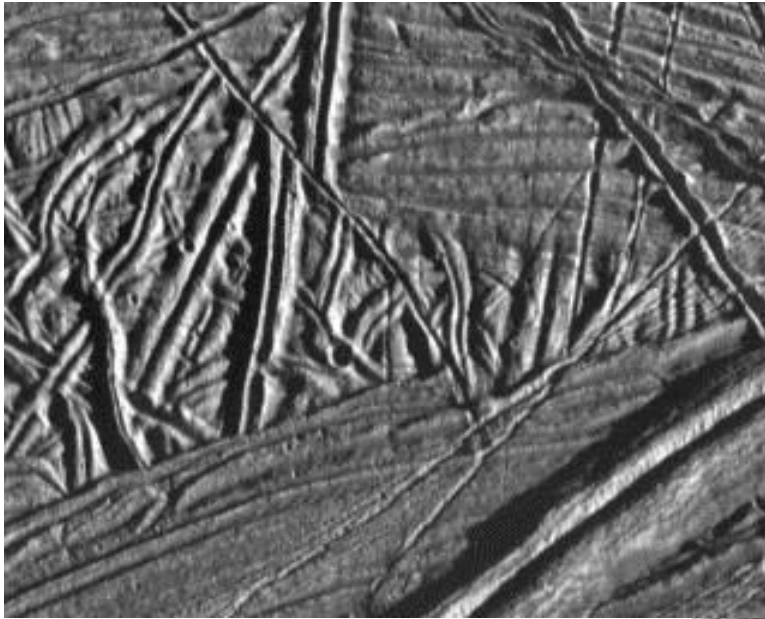
# Europa

- Smooth, icy surface with cracks similar to polar regions on Earth.
- Few craters.
- Thin, oxygen atmosphere
- Tidal forces acting on Europa may have melted water under ice creating liquid ocean under the surface ice.
- Rocky core (from density).



<http://photojournal.jpl.nasa.gov/catalog/PIA00502>

# Europa - Galileo



<http://photojournal.jpl.nasa.gov/catalog/PIA00291>

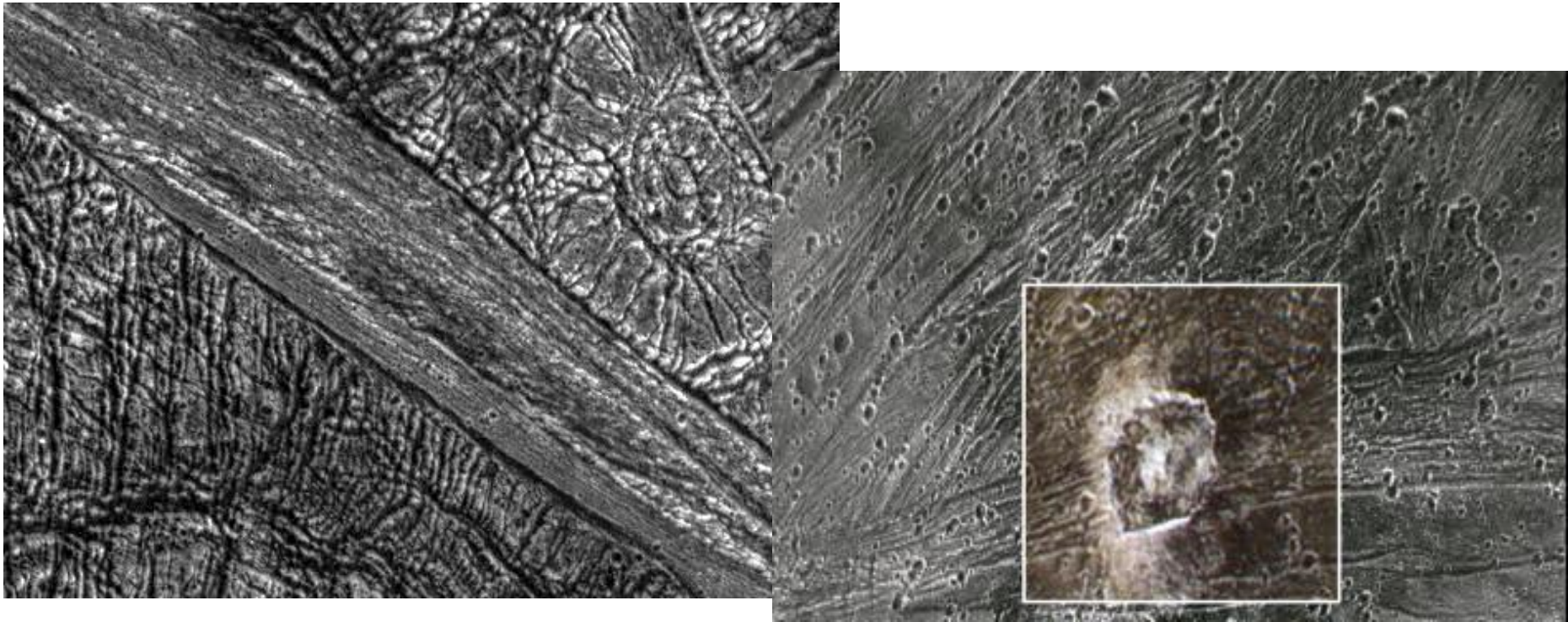
# Ganymede

- Largest satellite (larger than Mercury or Pluto)
- Low density = mainly ice.
- Many craters.
- Surface is dust-covered ice.
- Grooves and ridges may be due to crustal motion
- Magnetic field
- Possible sub-surface ocean





# Grooved Terrain on Ganymede - Galileo



<http://photojournal.jpl.nasa.gov/catalog/PIA01616>

<http://photojournal.jpl.nasa.gov/catalog/PIA01611>



# Callisto

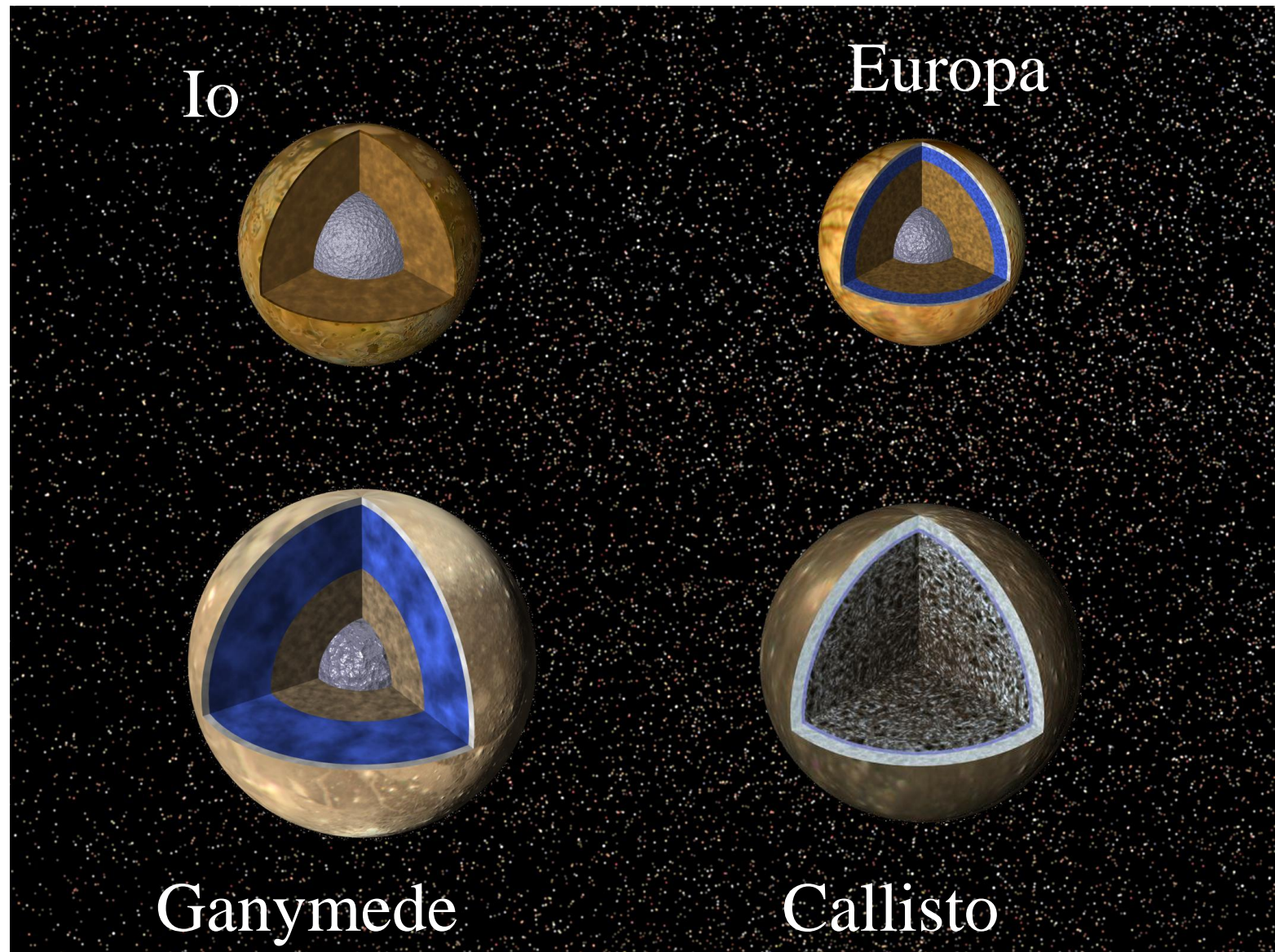
- Many craters
- No recent geologic activity.
- Frozen ice and some rock.
- Magnetic field
- Possible sub-surface ocean.



<http://photojournal.jpl.nasa.gov/catalog/PIA03456>

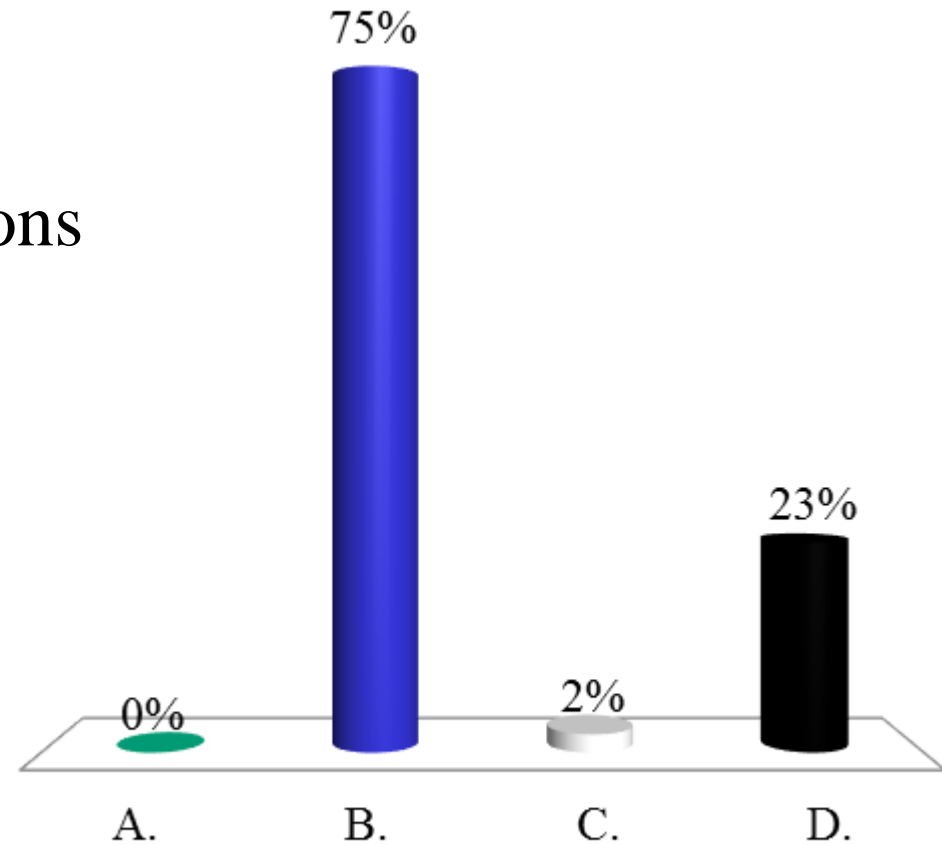
<http://photojournal.jpl.nasa.gov/catalog/PIA00745>

# Possible Interiors of the Galilean Moons



# What energy source powers Io's active volcanoes?

- A. Chemical reactions
- B. Tidal forces
- C. Roche energy
- D. Thermonuclear reactions





# Moons of Saturn

- 62 known moons
- Most are small and irregular.
- Some spherical moons.
- Largest moon = Titan



# Titan

- Largest of 61 moons of Saturn
- Second largest moon in Solar System
- Dense nitrogen atmosphere
- Featureless clouds and purple-blue haze
- Organic compounds found in atmosphere

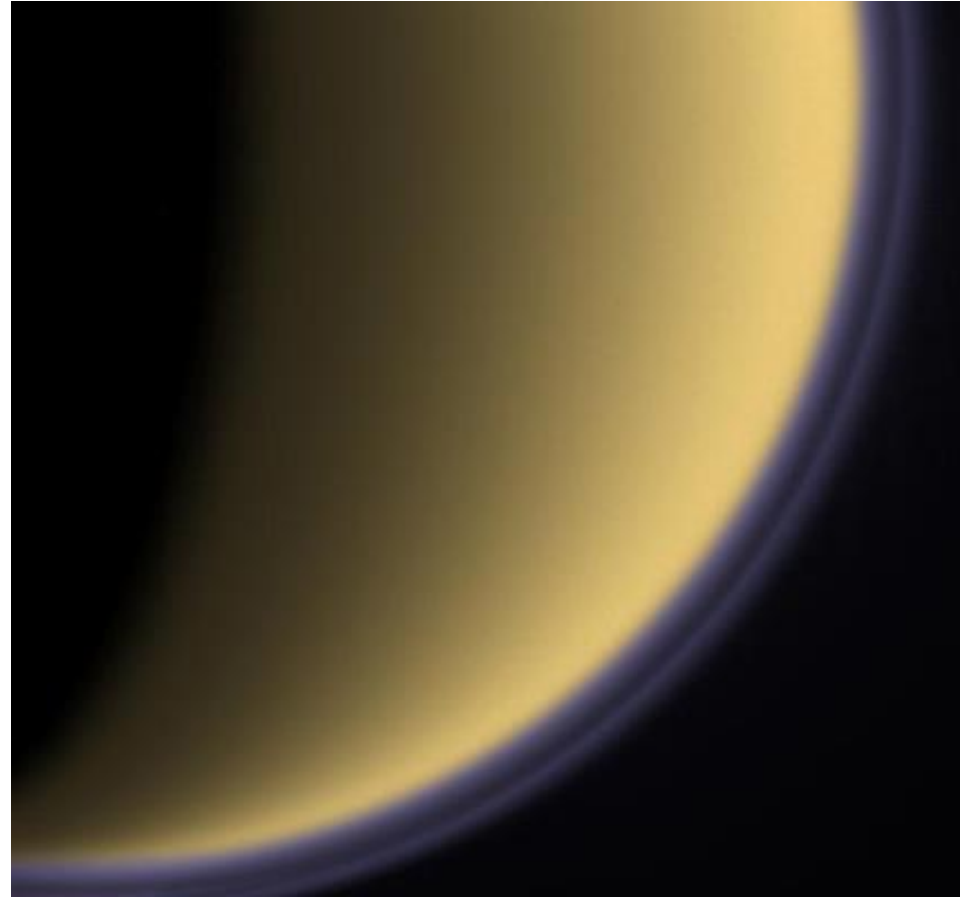


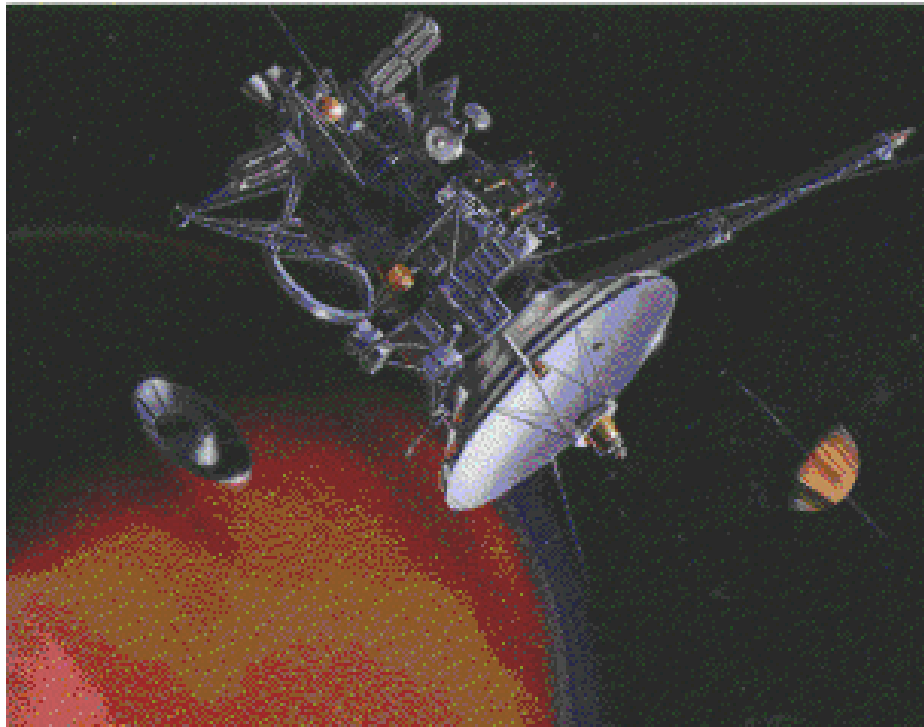
Image courtesy of NASA. Click on image for more information.



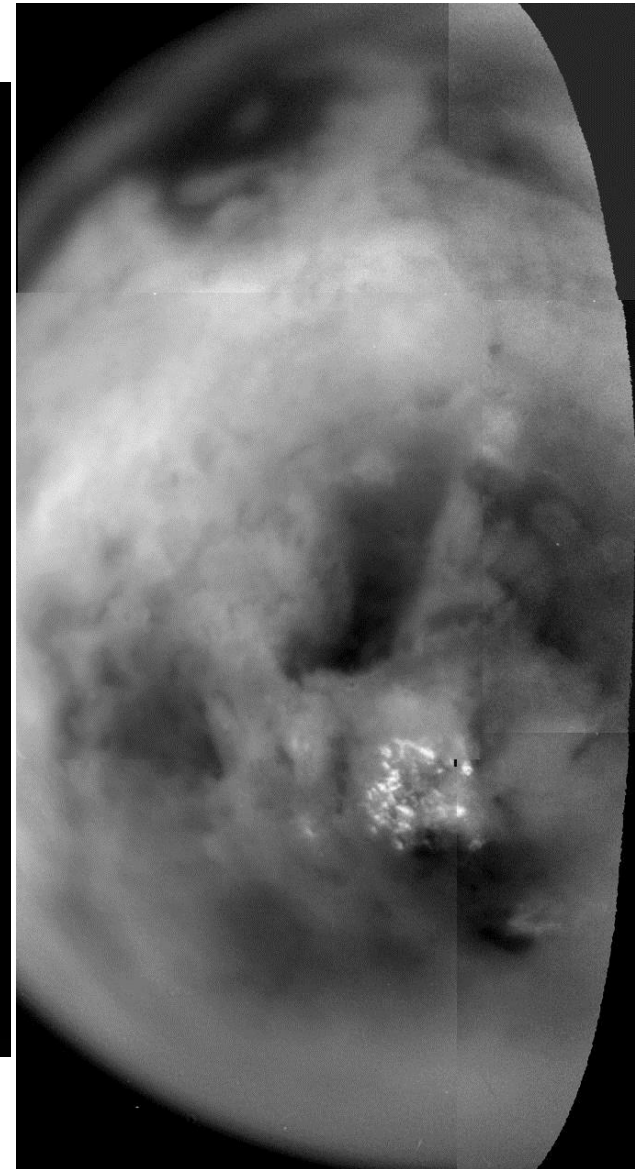
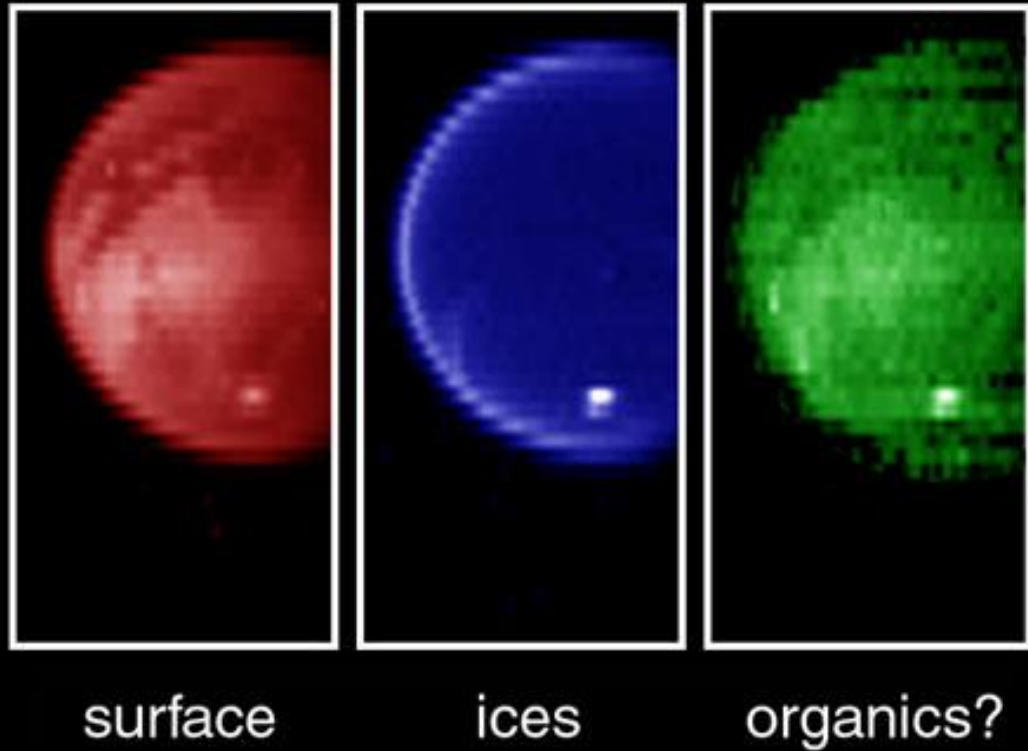
# Basic Information on Titan

- Mass =  $1.8 M_{\text{moon}}$
- Radius = 2575 km ( $1.48 R_{\text{moon}}$ )
- Density =  $1880 \text{ kg/m}^3$
- Distance = 1.2 million km

# Cassini - Huygens



# Near-Infrared Views of Titan from Cassini



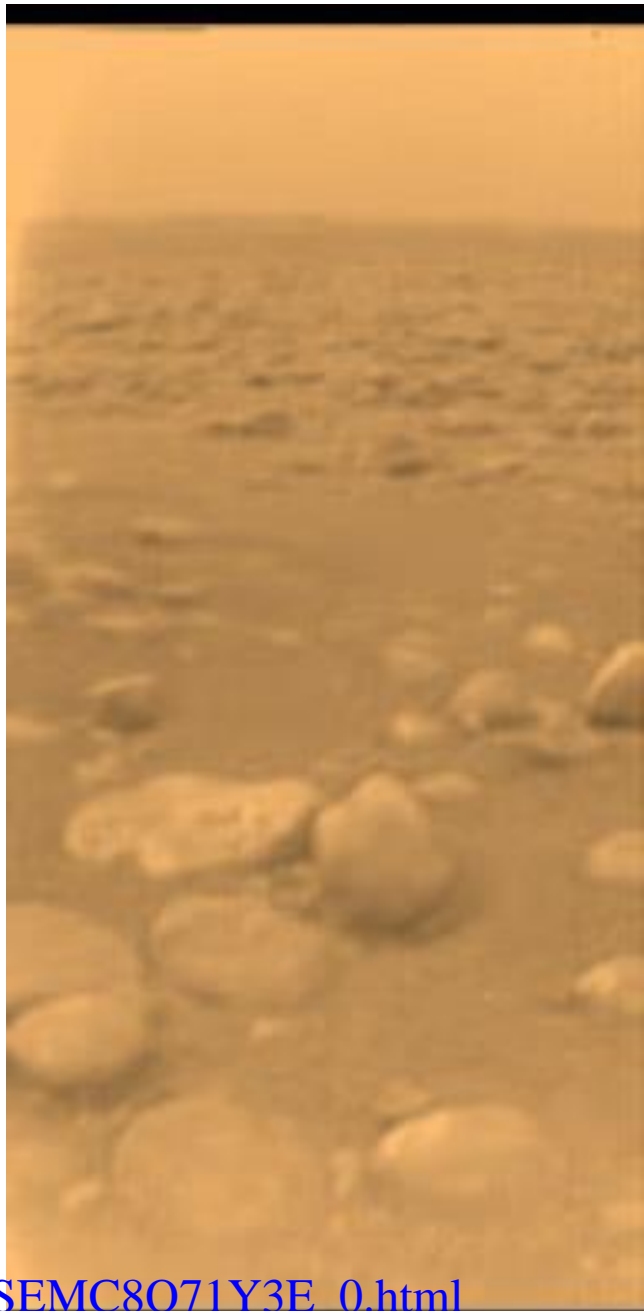
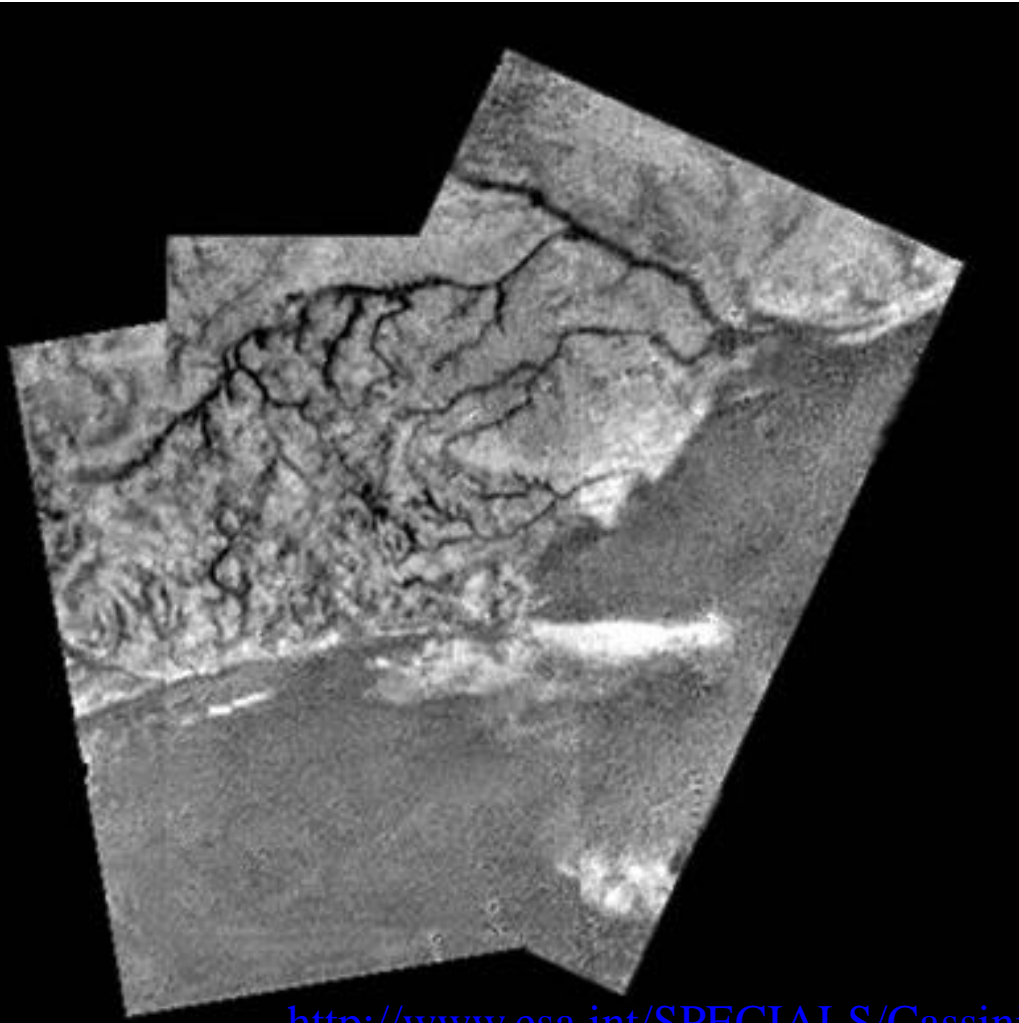
<http://photojournal.jpl.nasa.gov/catalog/PIA06405>

<http://photojournal.jpl.nasa.gov/catalog/PIA06109>

# Methane Oceans and Streams on Titan

[Best guess of landing spot](#)    [Mosaic of Huygens Images](#)

[Interactive Figure](#)



# Mimas

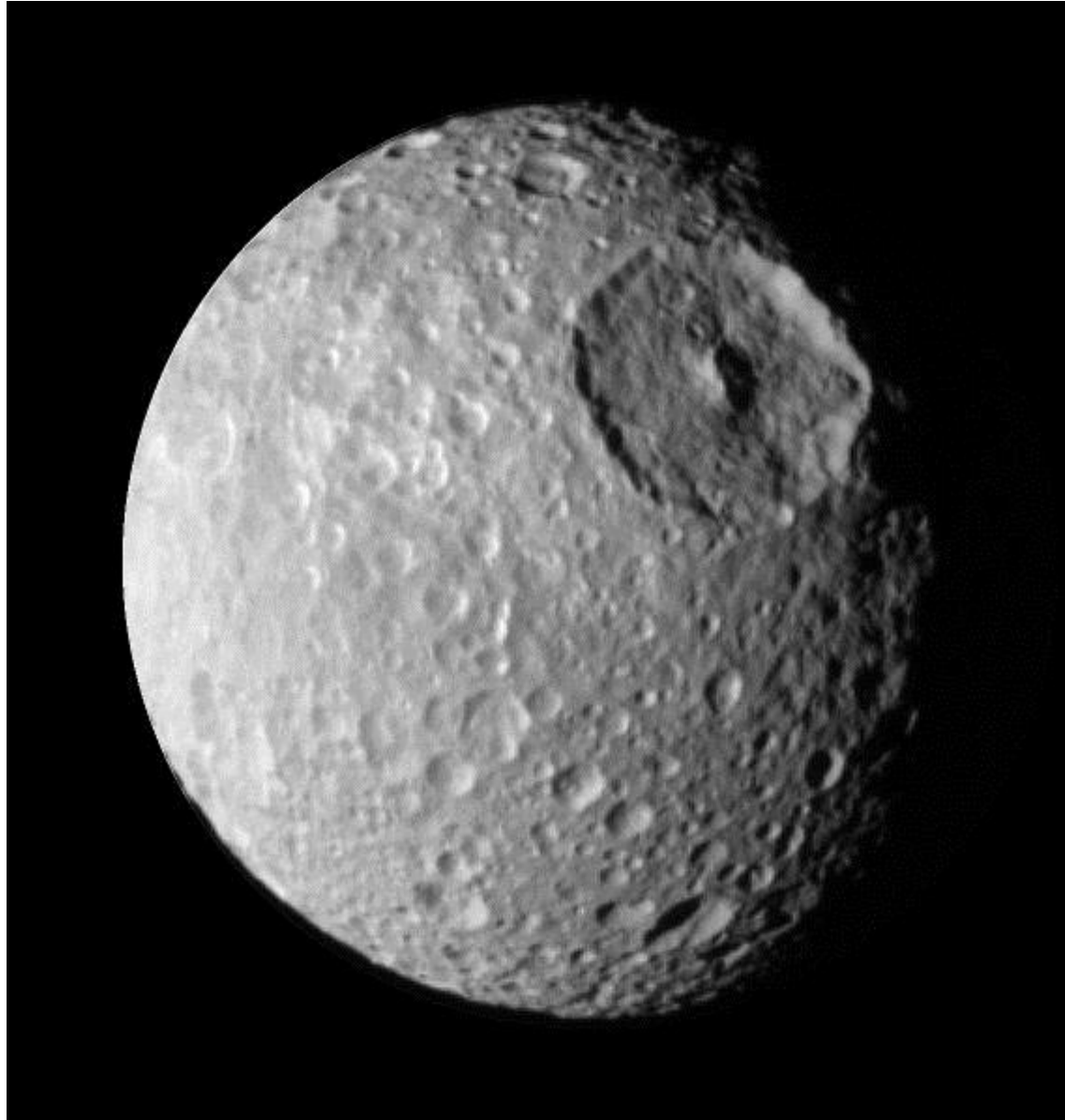
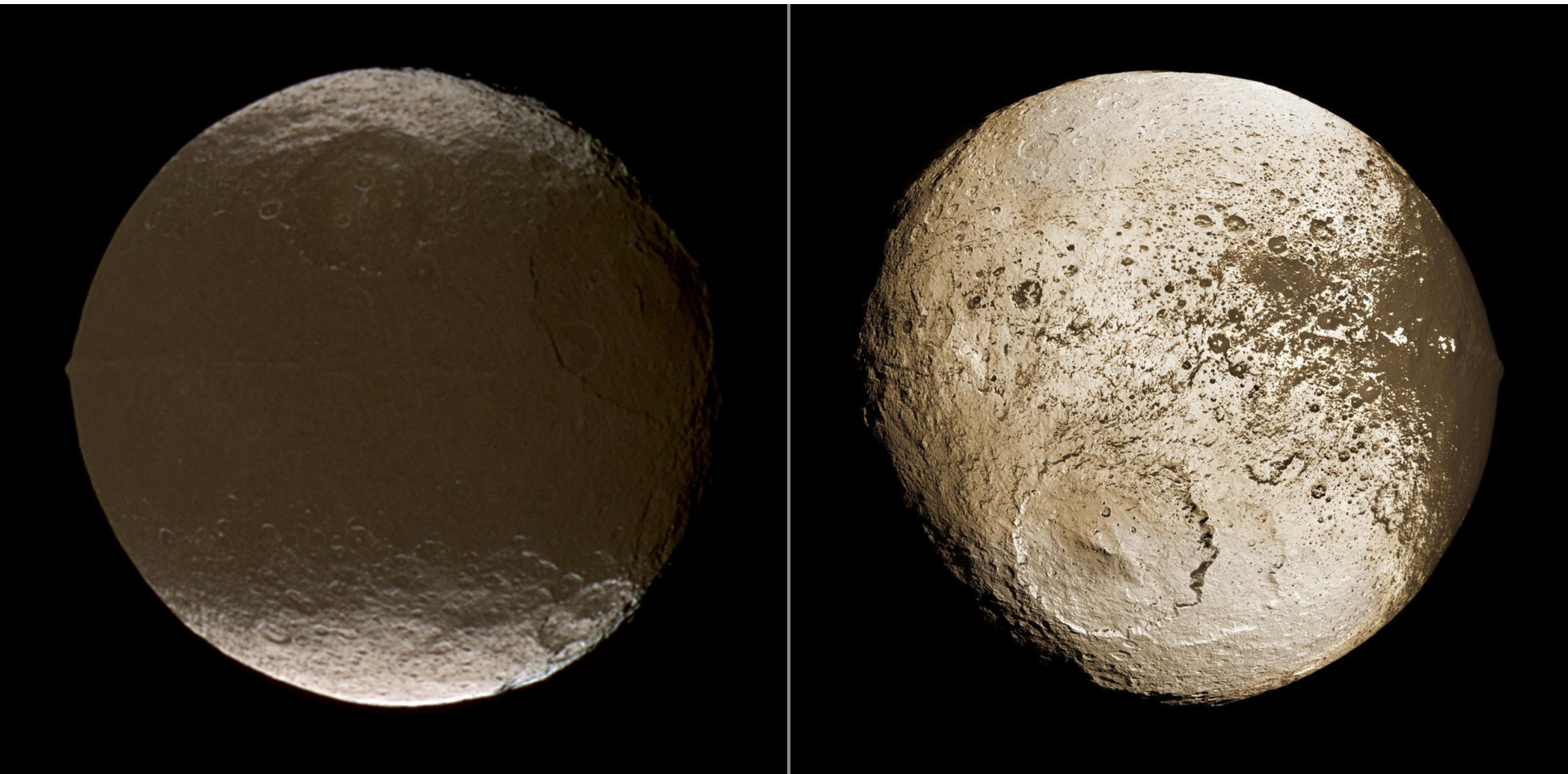


Image taken by  
Cassini spacecraft  
August 2, 2005.  
[Click here](#) for more  
information



# Iapetus

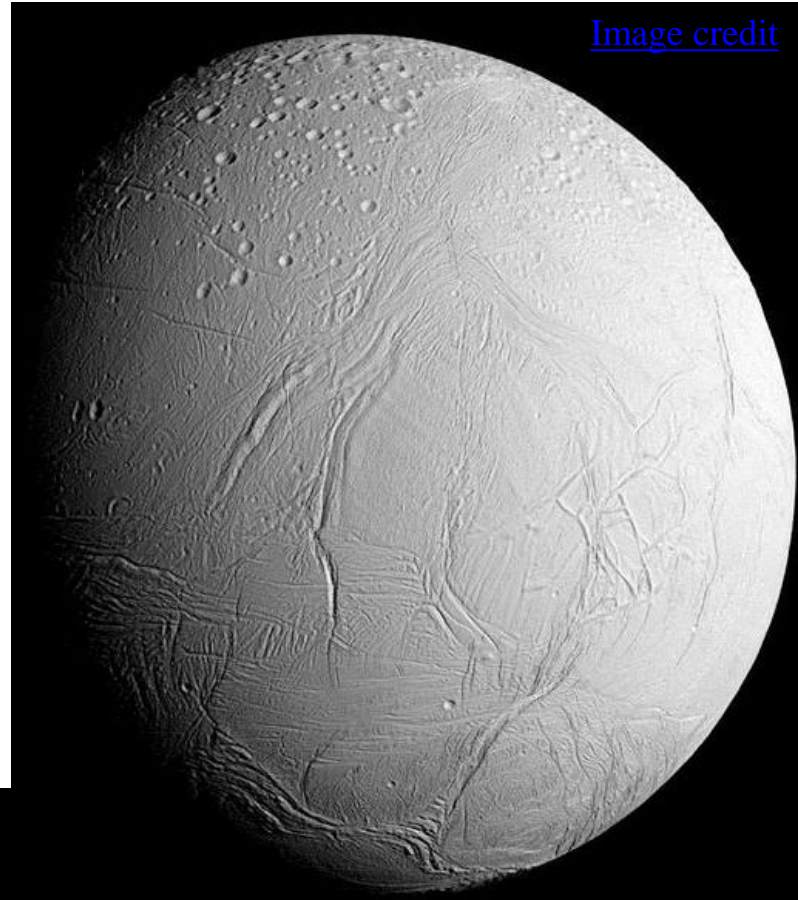


These two global images of Iapetus show the extreme brightness dichotomy on the surface of Iapetus, possibly created by dust from Phoebe and ice sublimation. Images taken by Cassini spacecraft December 27, 2004 (left panel) and September 10, 2007. [Click here](#) for more information.

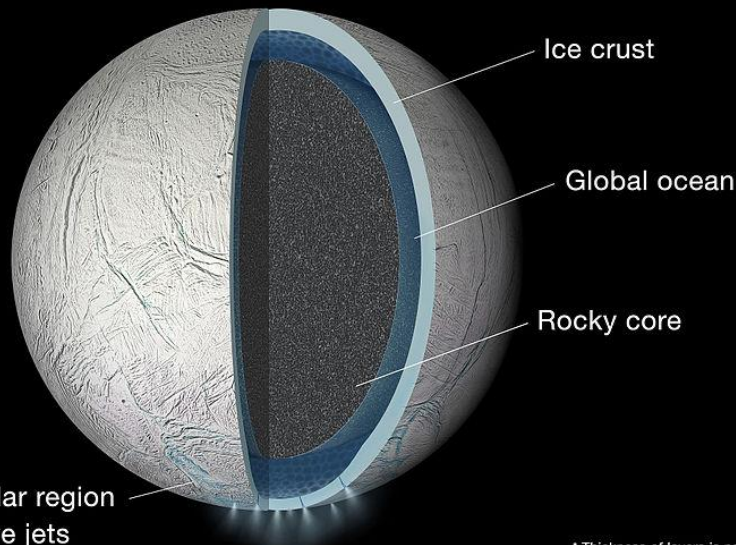
# Enceladus

- Smaller than Colorado, but geologically active
- South pole is venting huge clouds of water vapor, ice crystals, and some salt
- Subsurface ocean could harbor life?

[Image credit](#)



Global Ocean on  
Saturn's Moon  
ENCELADUS



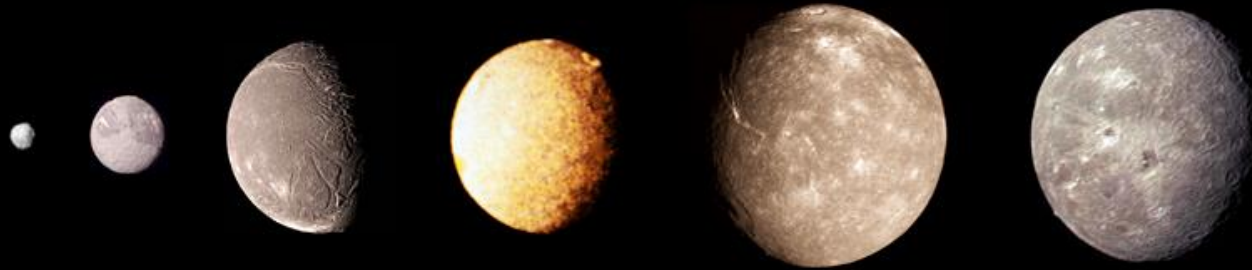
[Image credit](#)



[Image credit](#)

# Moons of Uranus

- 27 known moons
- Most smaller, mainly made of ice
- Heavily cratered, dirty surface
- Some have cracks due to possible past activity (Miranda)



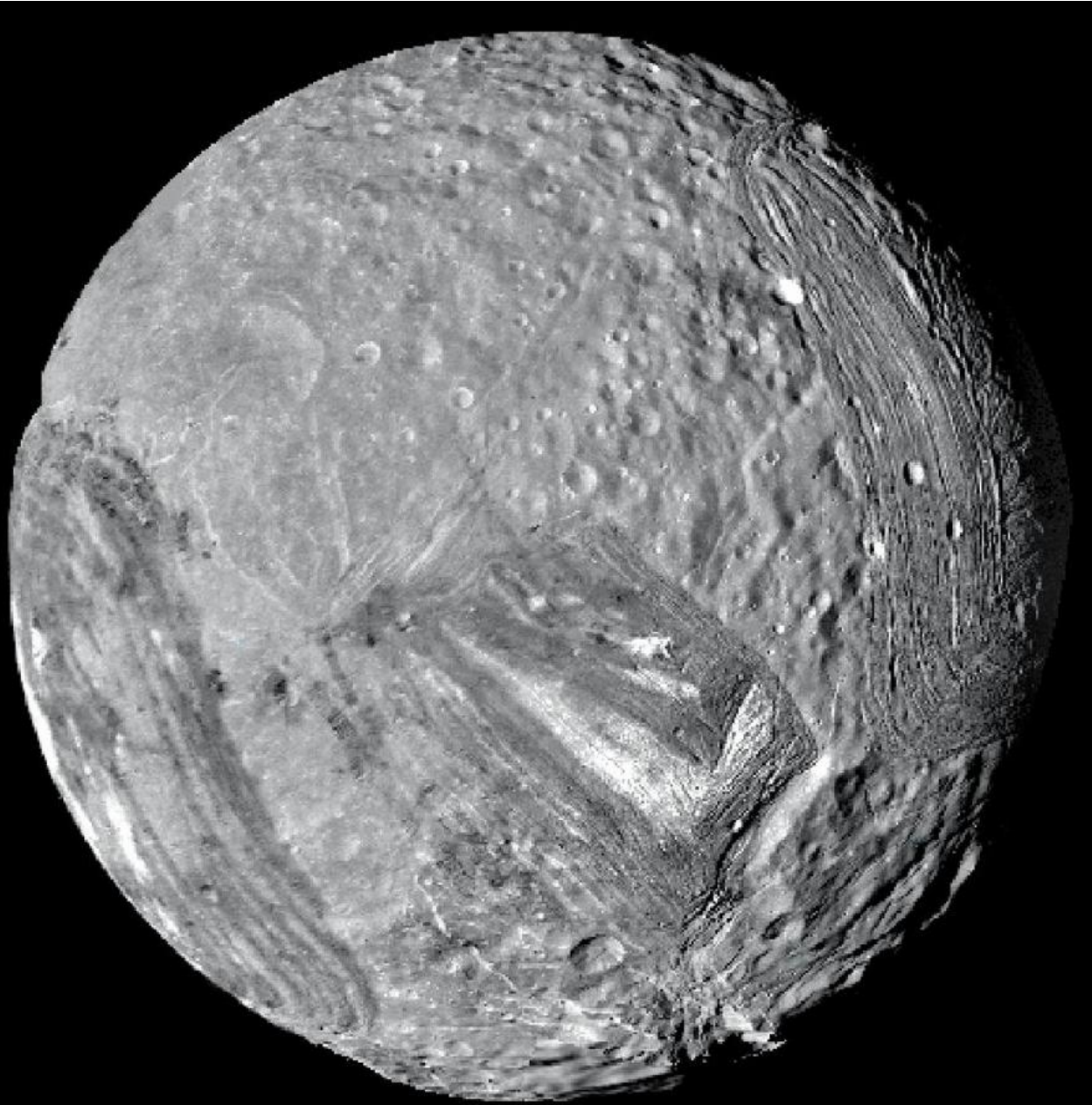


# Titania and Oberon (Uranus)



Images courtesy of NASA. Click on images for more information

# Miranda



One of 27 moons of Uranus

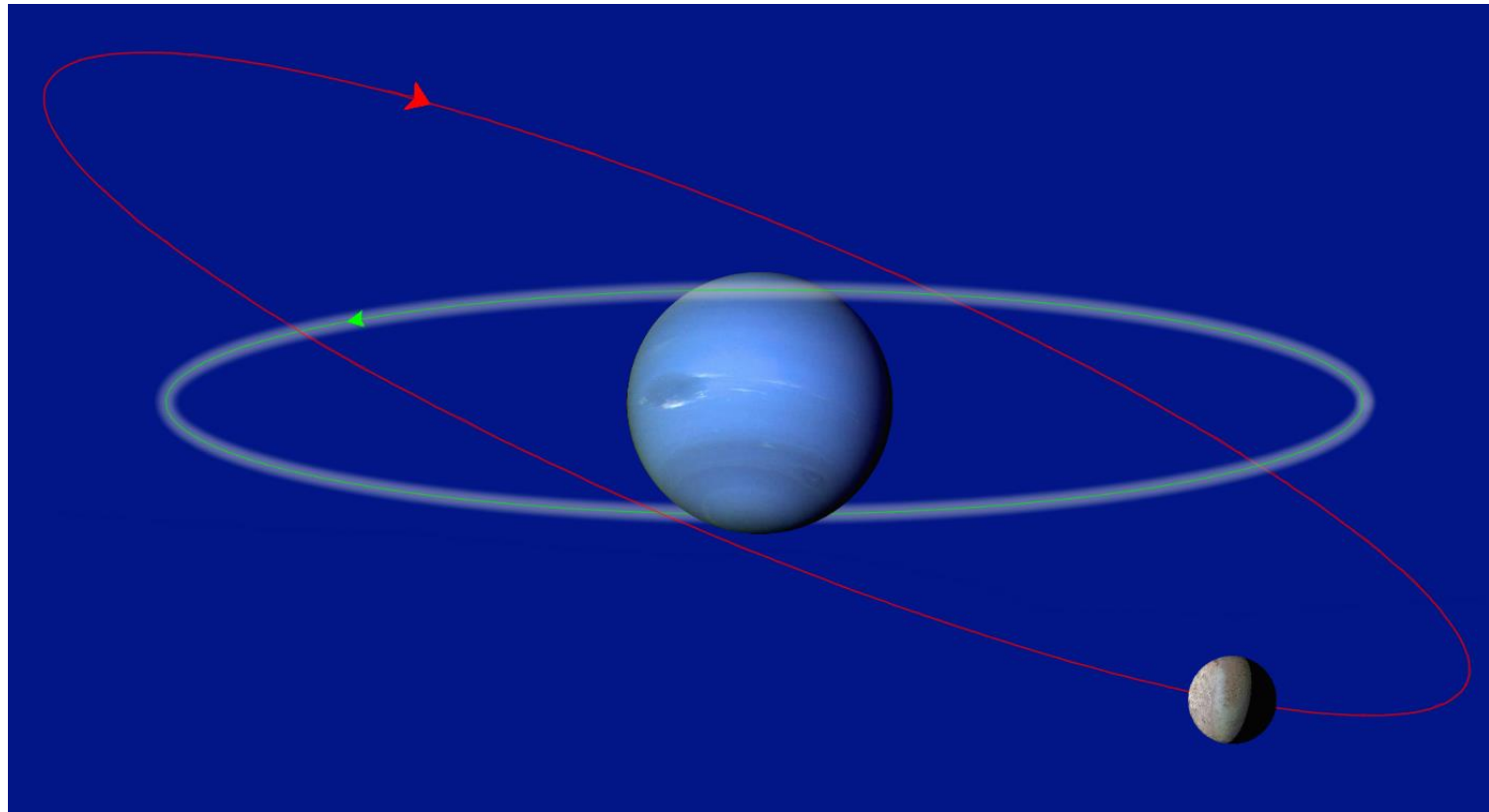
Although smallest among the five main satellites of Uranus, Miranda's bizarre surface makes it the most interesting and memorable.

Astronomers can only guess at the violent events that led to the unusual wrinkles and bands.



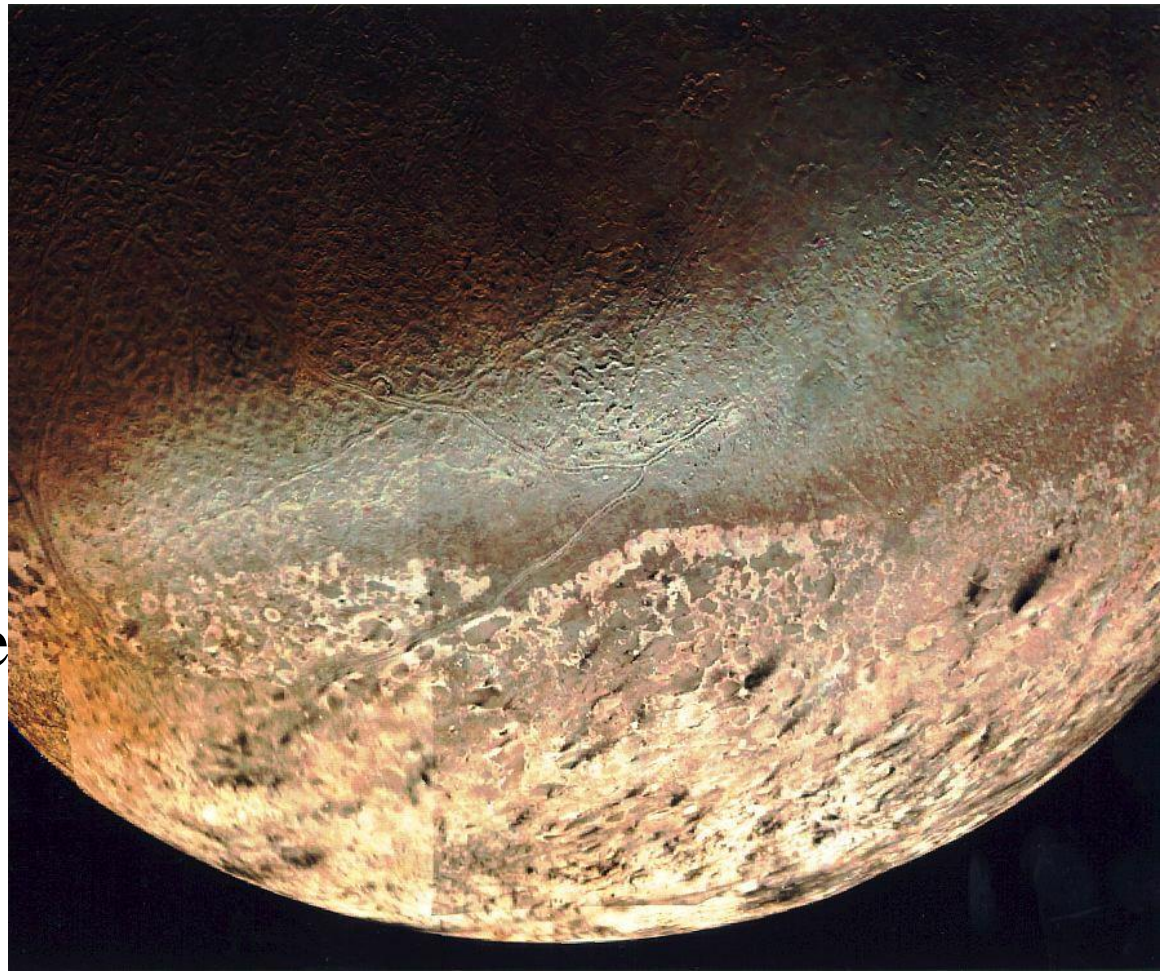
# Moons of Neptune

- There are 14 known moons
- Most smaller, mainly made of ice
- Largest is Triton



# Triton

- Moon of Neptune, discovered October 10, 1846, just 17 days after Neptune.
- Orbits retrograde (possibly captured?)
- Thin nitrogen atmosphere
- Young frozen nitrogen and water ice surface
- Jets of nitrogen erupting from surface were observed by Voyager 2



# Basic Information on Triton

- Mass =  $0.29 M_{\text{moon}}$
- Radius = 1350 km ( $0.78 R_{\text{moon}}$ )
- Density =  $2070 \text{ kg/m}^3$
- Distance = 0.35 million km
- Only slightly larger than Pluto and nearly identical in composition... the two likely share the same origin.

# Triton – Nitrogen Geysers

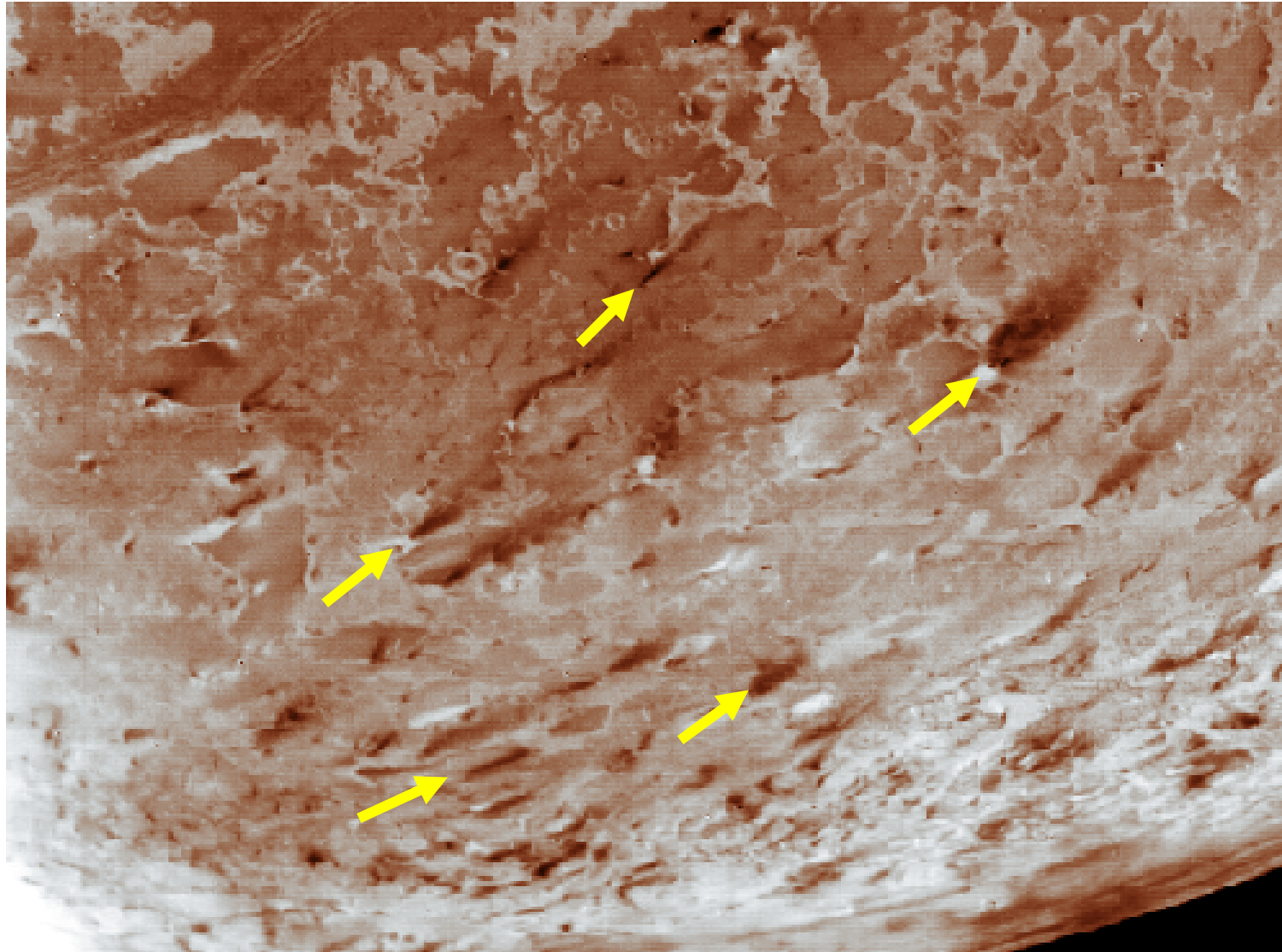


Image taken by  
Voyager 2 in  
August 1989.  
Click on image for  
more information.

[Additional view](#)



Triton, the giant moon of Neptune, differs from all other major moons of planets in that

- A. it has a nitrogen atmosphere.
- B. it emits plumes of gas from its surface.
- C. it has a retrograde orbit.
- D. its orbit lies inside the rings of Neptune.

