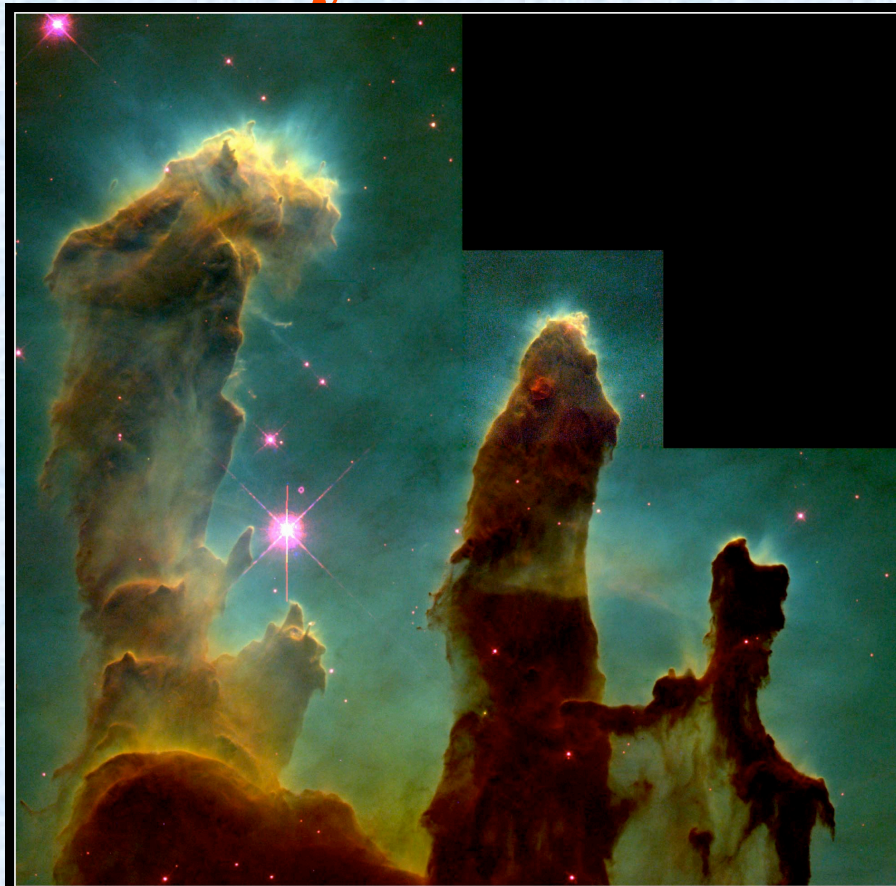


Astronomy 1 – Winter 2011



Gaseous Pillars in M16 • Eagle Nebula
Hubble Space Telescope • WFPC2

PRC95-44a • ST ScI OPO • November 2, 1995 • J. Hester and P. Scowen (AZ State Univ.), NASA

Lecture 16; February 11 2011

Previously on Astro-1

- **Jupiter and Saturn**
 - **Size and composition; Atmosphere & interior**
 - **The rings of Saturn**

Stargazing Events

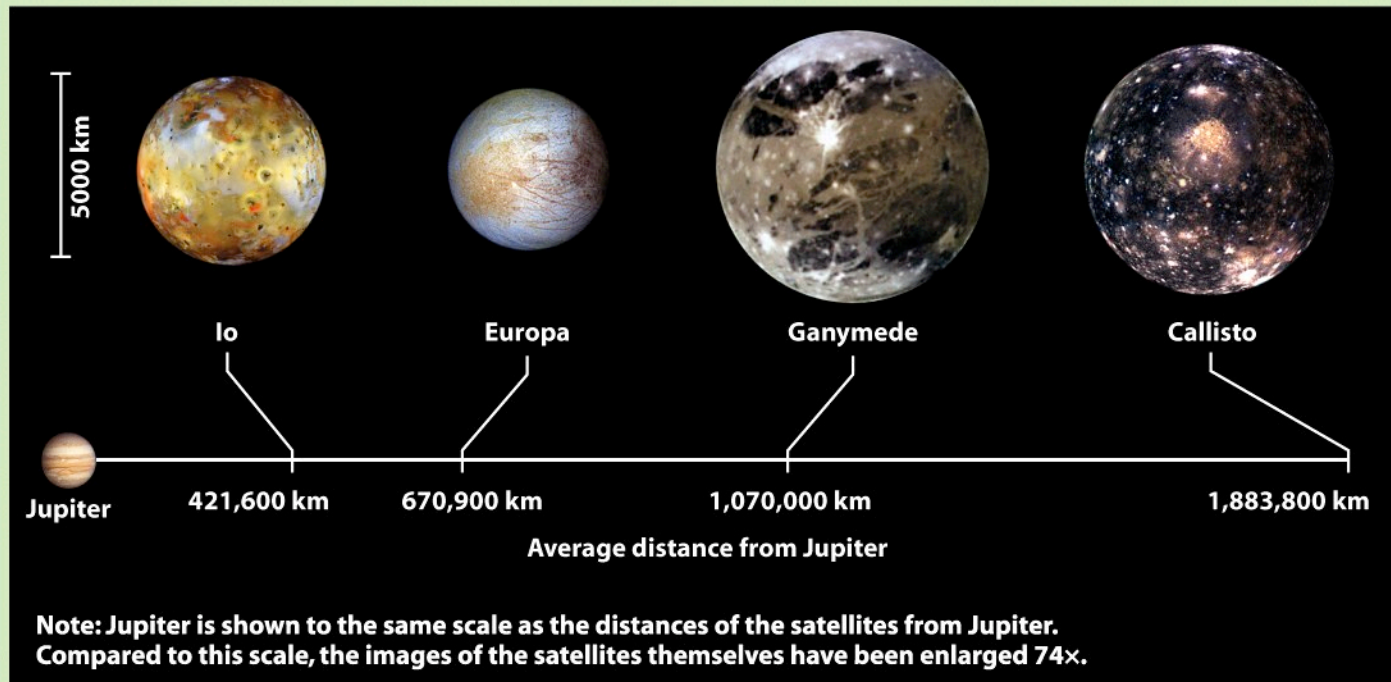
- Santa Barbara Museum of Natural History
 - Feb 12, this Saturday. 7PM
 - March 12. 7PM
 - Ticket is \$2
 - 2% credit if you sign your name at the museum
- Broida Hall
 - March 7/8
 - 2% credit, first come first served basis, register with TA. Instructions to be given later (-2% if you register and don't show up!)
- **YOU CAN ONLY GET CREDIT FOR ONE EVENT**

Today on Astro-1

- **The satellites of Jupiter and Saturn. A wonderful microcosm of the solar system**
 - **Jupiter's giant satellites**
 - **Crusts and cores**
 - **Volcanism and internal activity**

Table 13-1 Jupiter's Galilean Satellites Compared with the Moon, Mercury, and Mars

	Average distance from Jupiter (km)	Orbital period (days)	Diameter (km)	Mass		Average density	
				(kg)	(Moon = 1)	(kg/m ³)	Albedo
Io	421,600	1.769	3642	8.932×10^{22}	1.22	3529	0.63
Europa	670,900	3.551	3120	4.791×10^{22}	0.65	3018	0.64
Ganymede	1,070,000	7.155	5268	1.482×10^{23}	2.02	1936	0.43
Callisto	1,883,000	16.689	4800	1.077×10^{23}	1.47	1851	0.17
Moon	—	—	3476	7.349×10^{22}	1.00	3344	0.11
Mercury	—	—	4880	3.302×10^{23}	4.49	5430	0.12
Mars	—	—	6794	6.419×10^{23}	8.73	3934	0.15



Note: Jupiter is shown to the same scale as the distances of the satellites from Jupiter. Compared to this scale, the images of the satellites themselves have been enlarged 74x.

R I  U X G
(NASA/JPL)

Table 13-1

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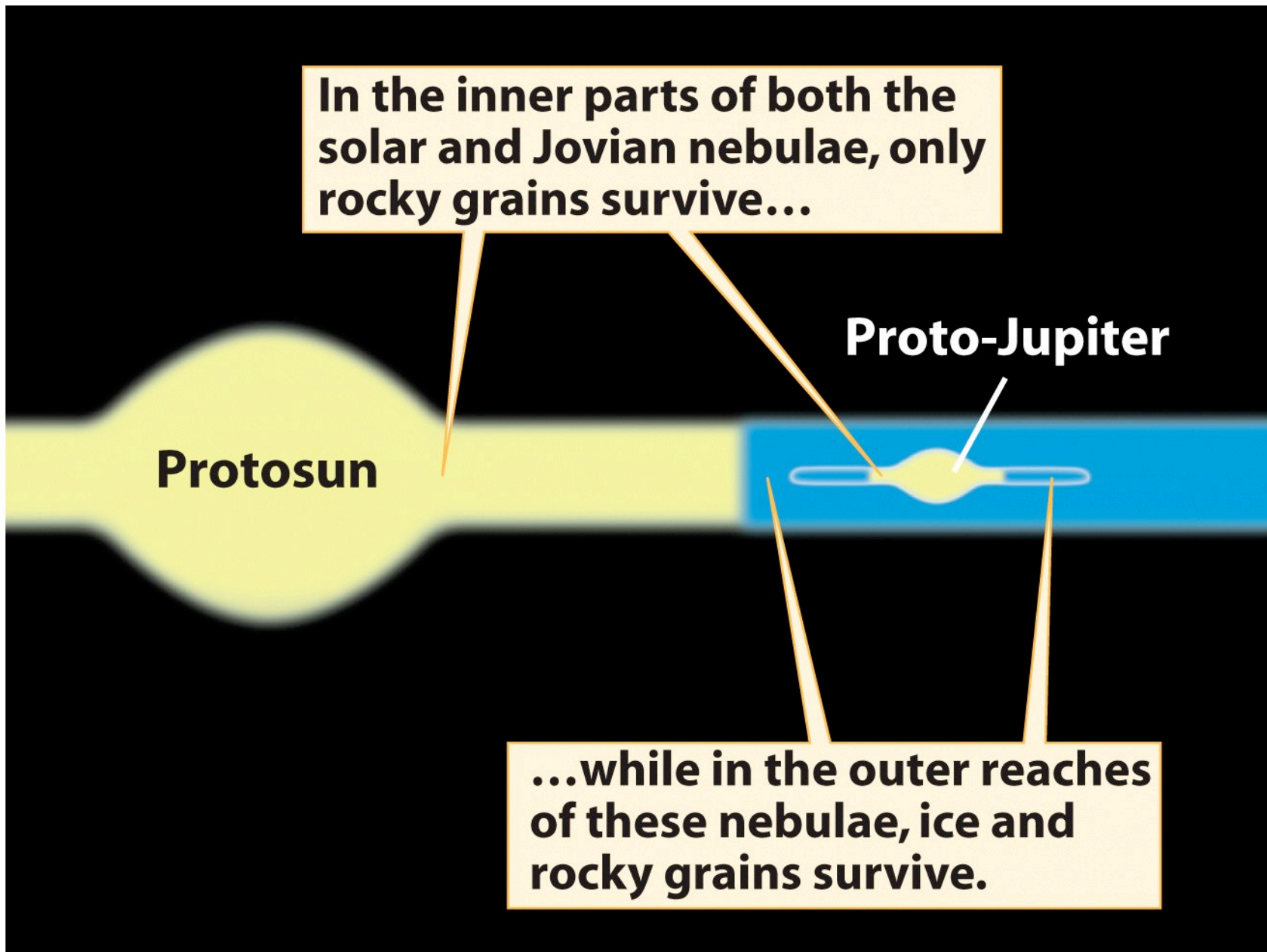
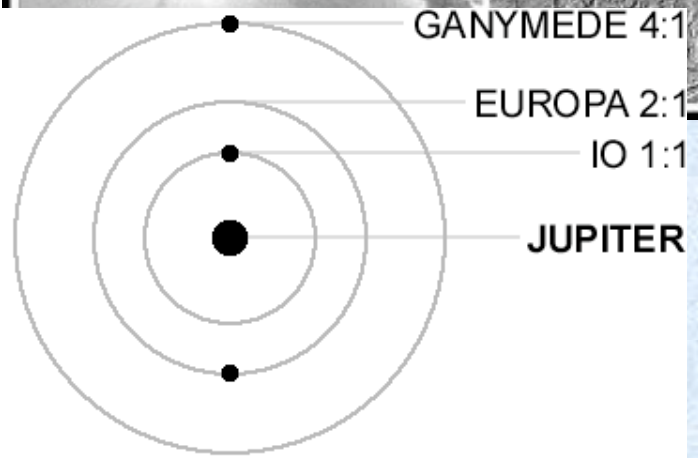
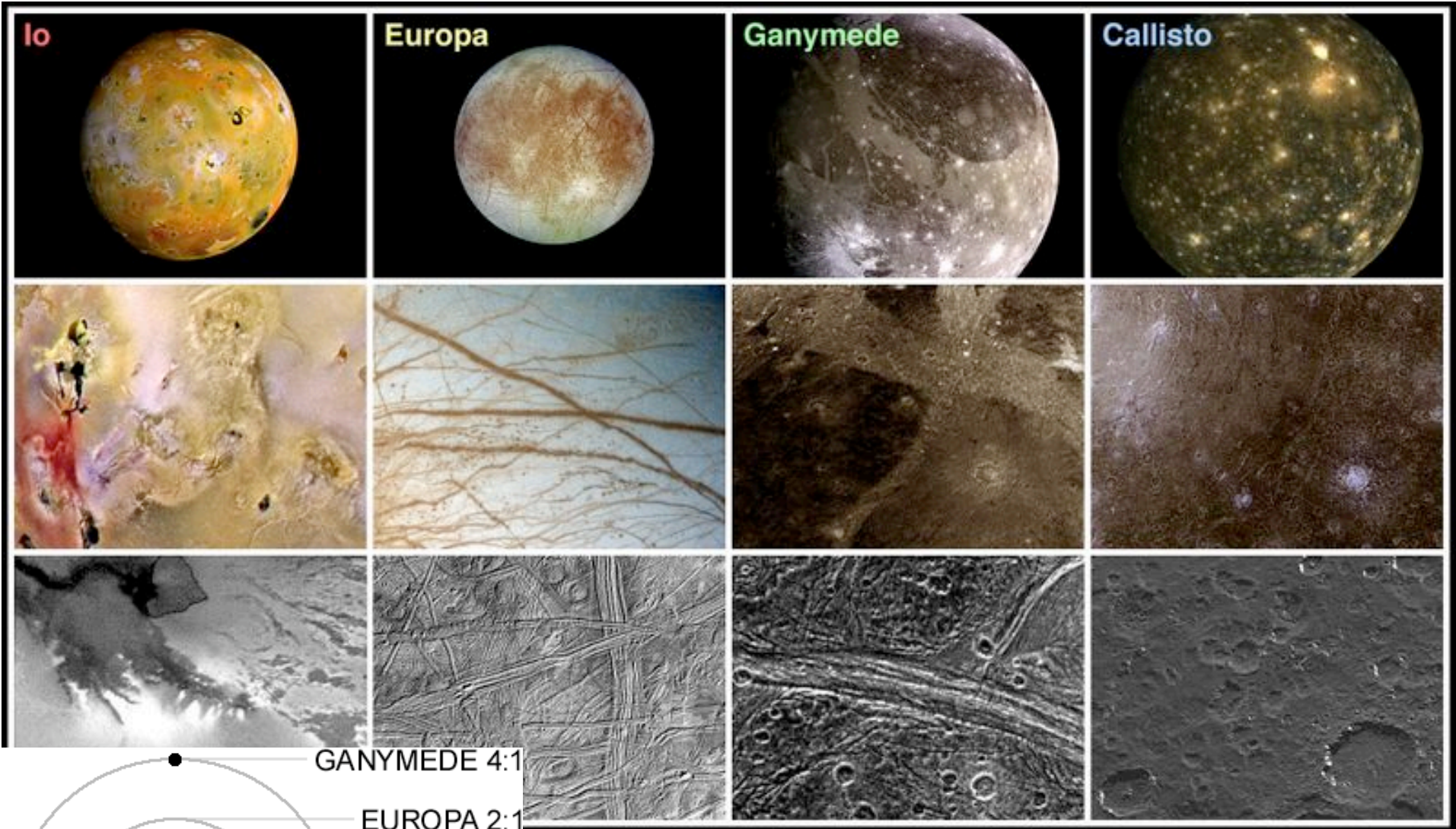


Figure 13-3
Universe, Eighth Edition
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Jupiter's Galilean Moons

Io and Jupiter



Io false color (Jupiter looks blue behind it)



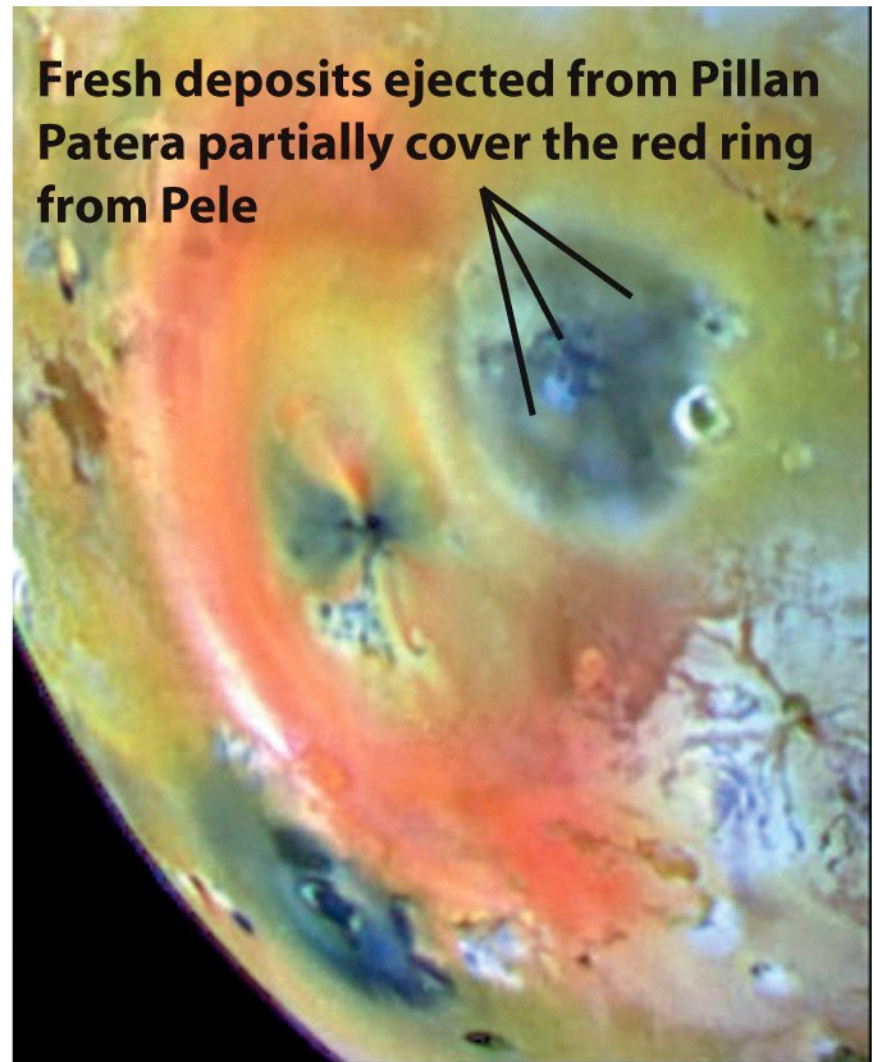
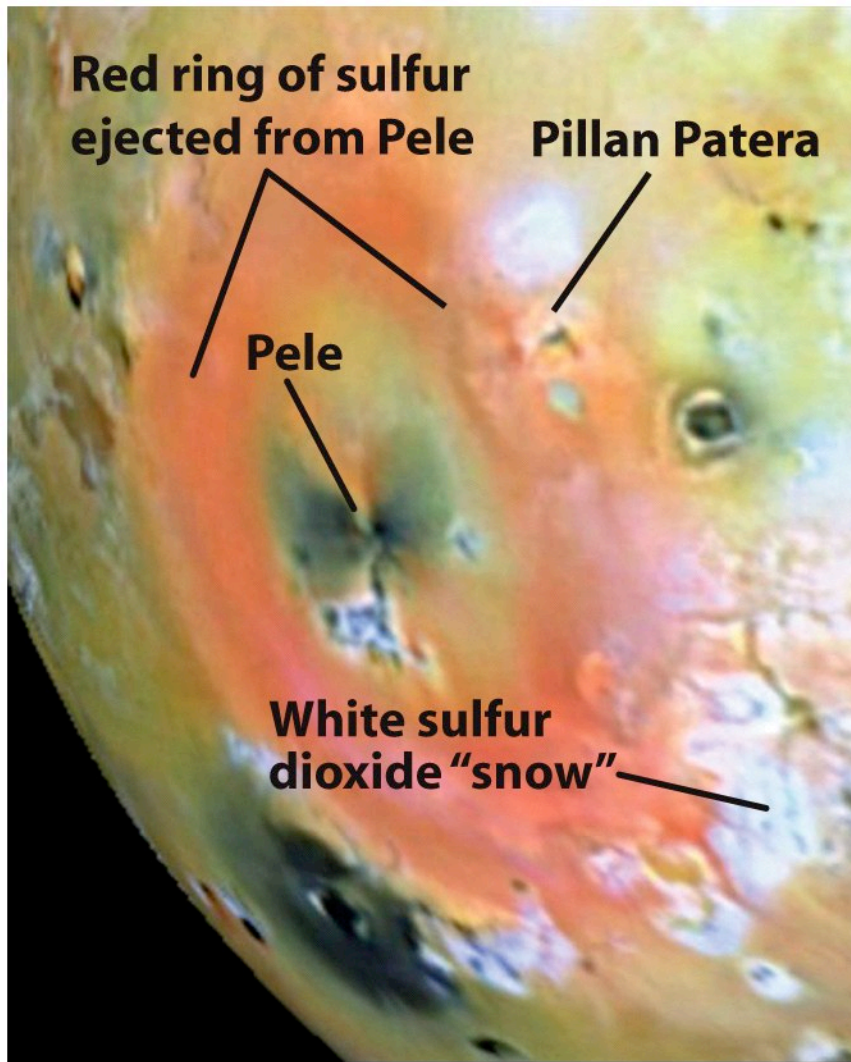


Figure 13-6
Universe, Eighth Edition
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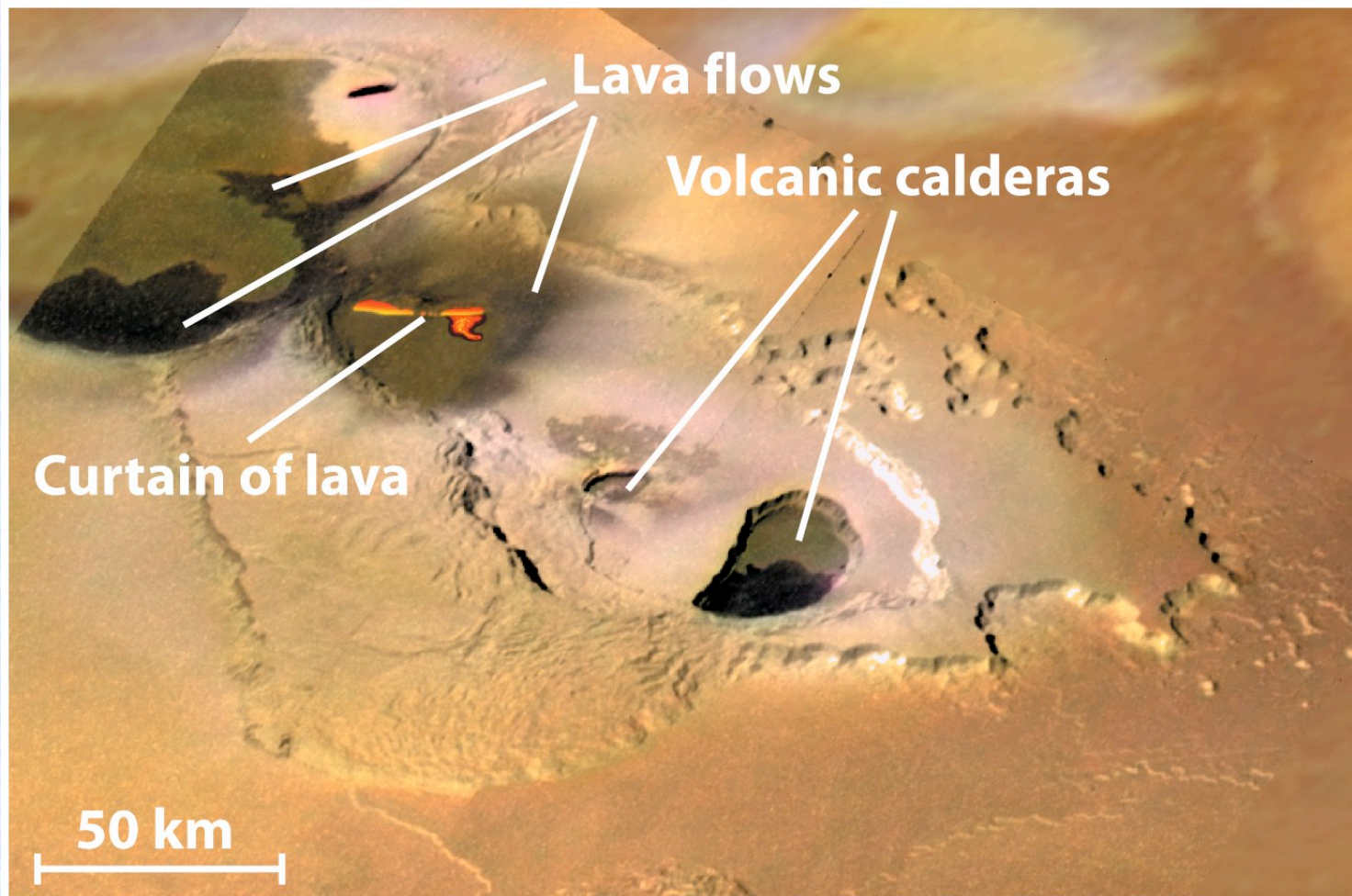
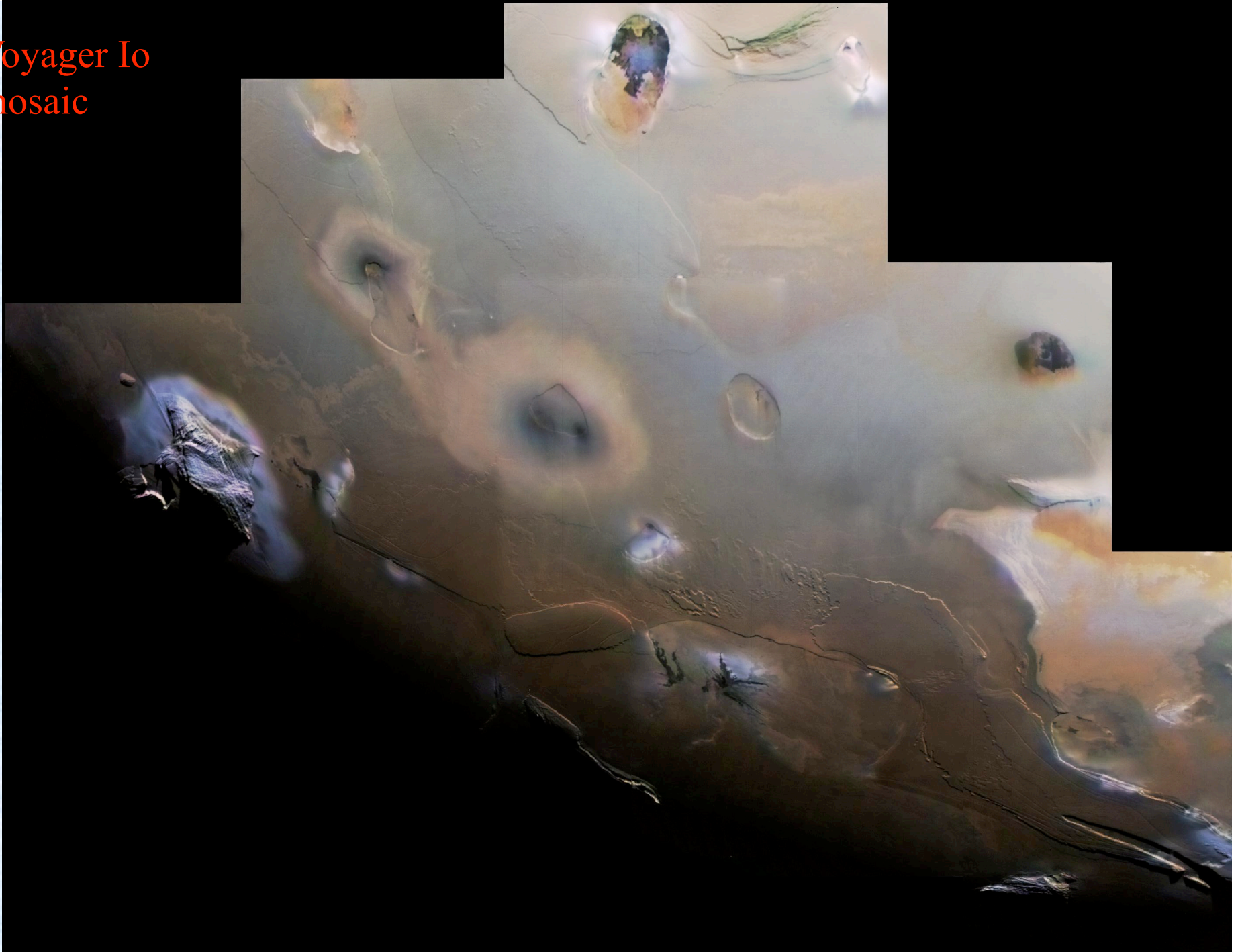


Figure 13-7
Universe, Eighth Edition
© 2008 W. H. Freeman and Company

Io's Lava: *Galileo* images show a nested chain of volcanic calderas (pits) with black lava flows. The red streak at upper left is a fissure in the surface about 40 km (25 mi) long, through which lava is erupting upward in a vertical sheet or curtain.

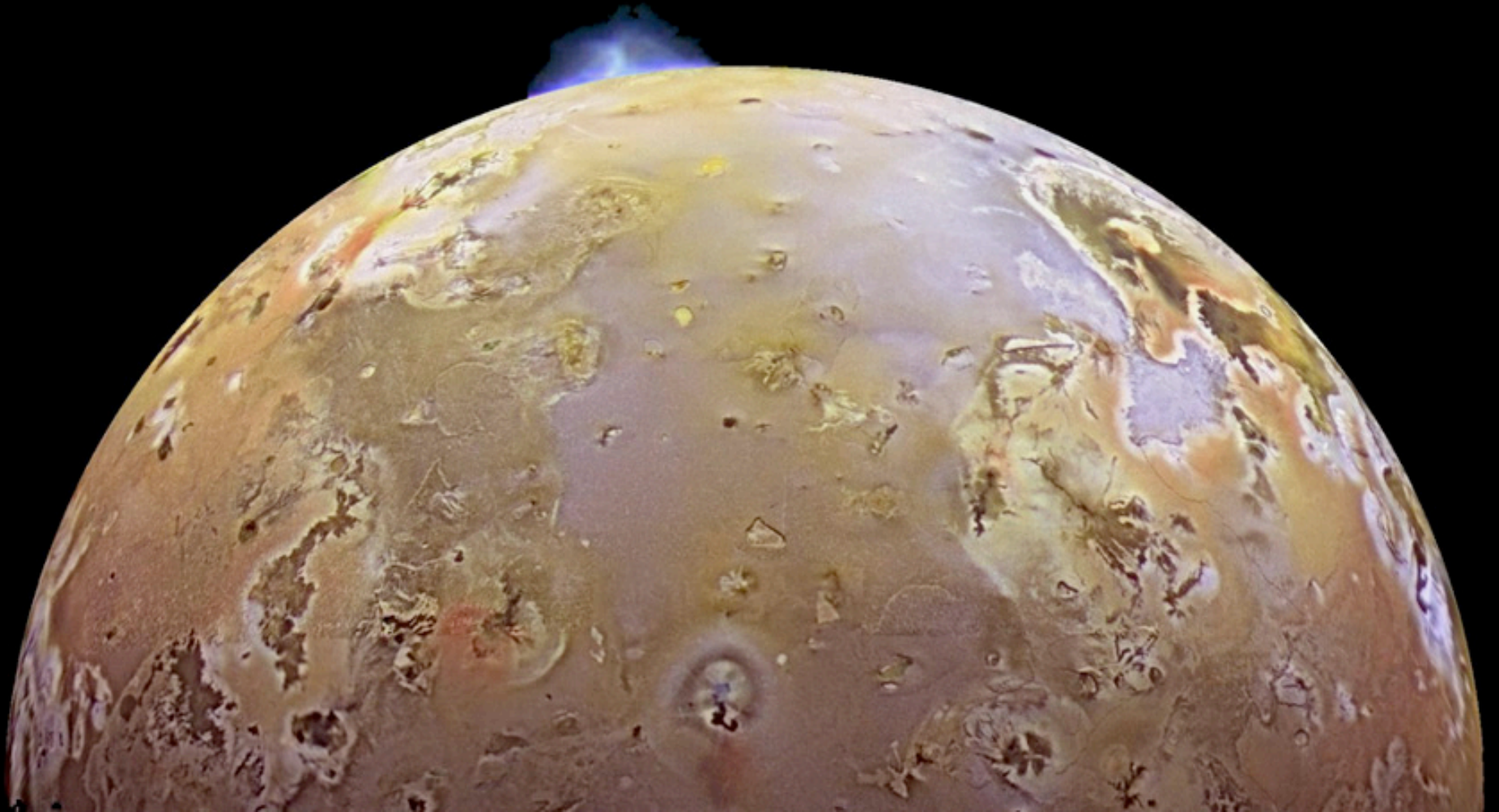
Voyager Io
mosaic



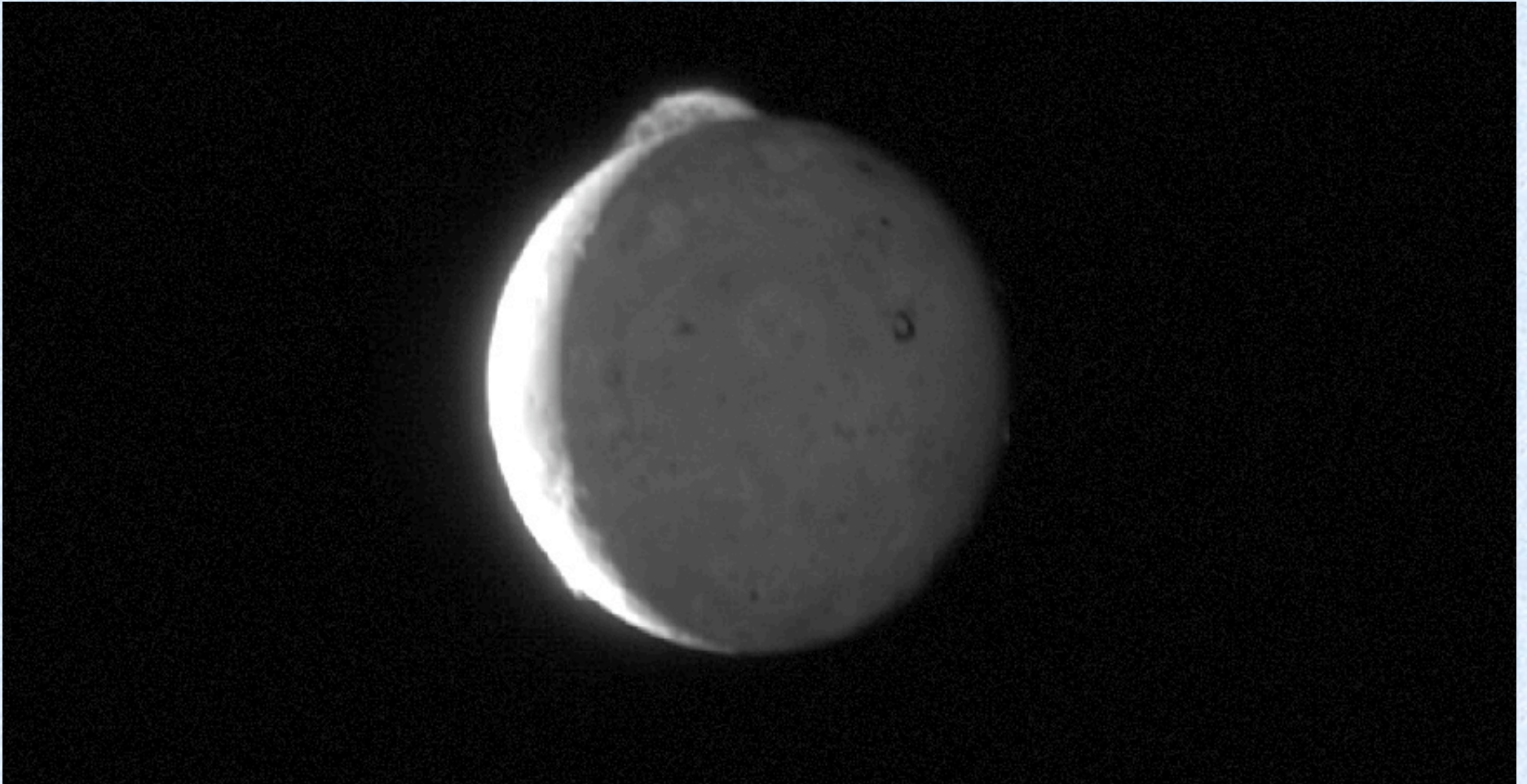
Io



Volcano on Io



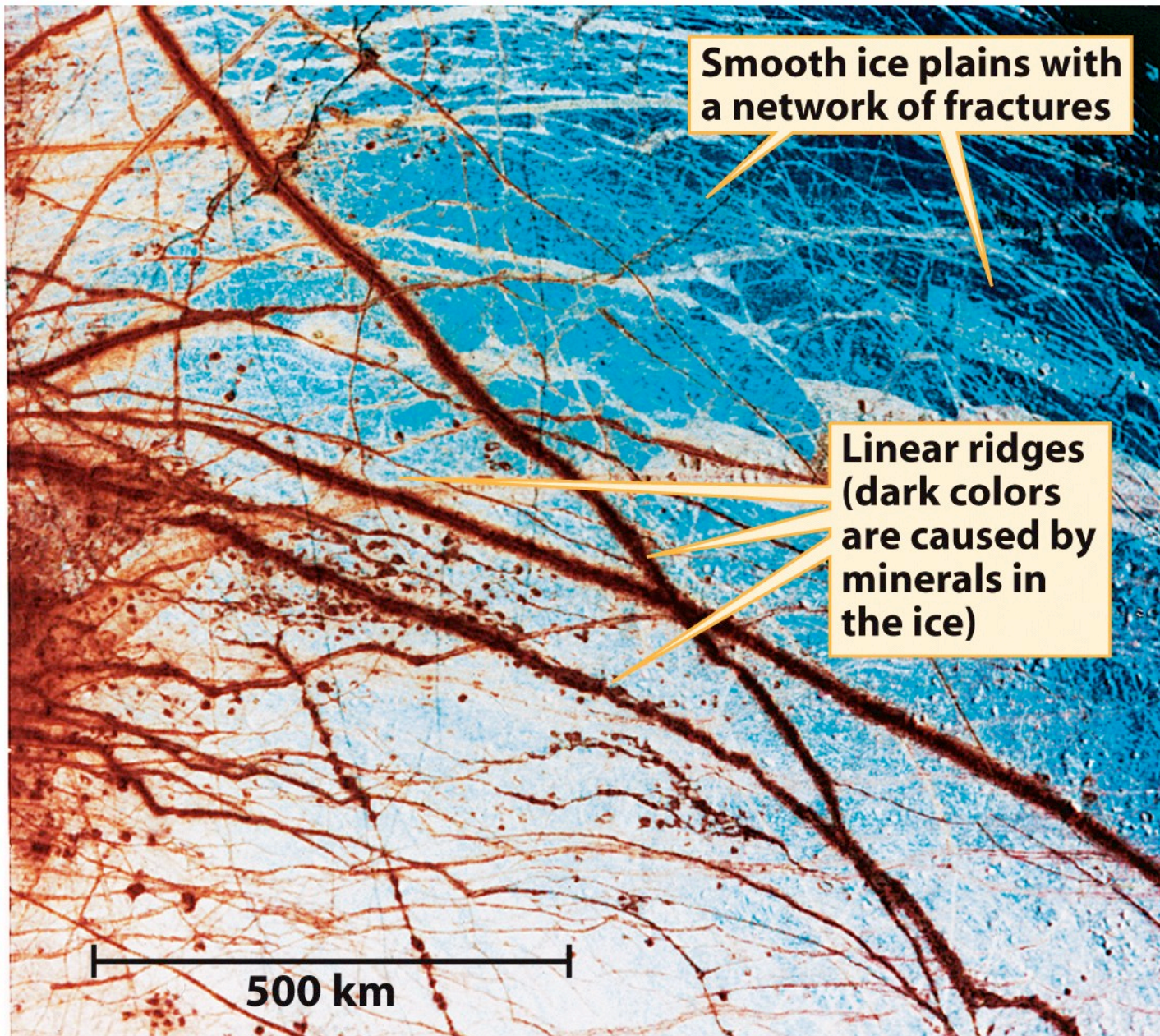
Io volcano



Europa



A thin oxygen atmosphere, made by destroyed water molecules



Smooth ice plains with a network of fractures

Linear ridges (dark colors are caused by minerals in the ice)

500 km

Figure 13-11
Universe, Eighth Edition
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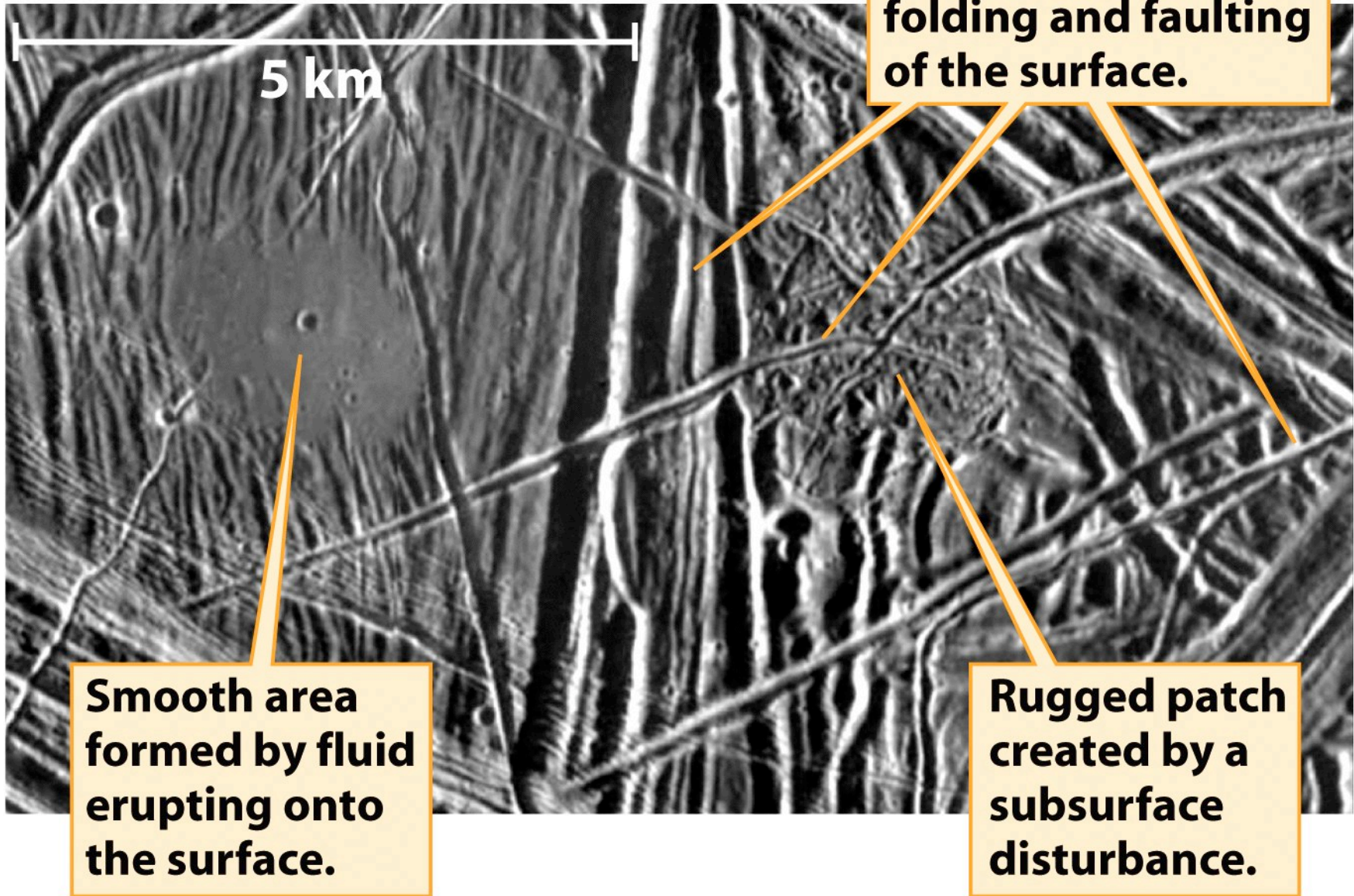
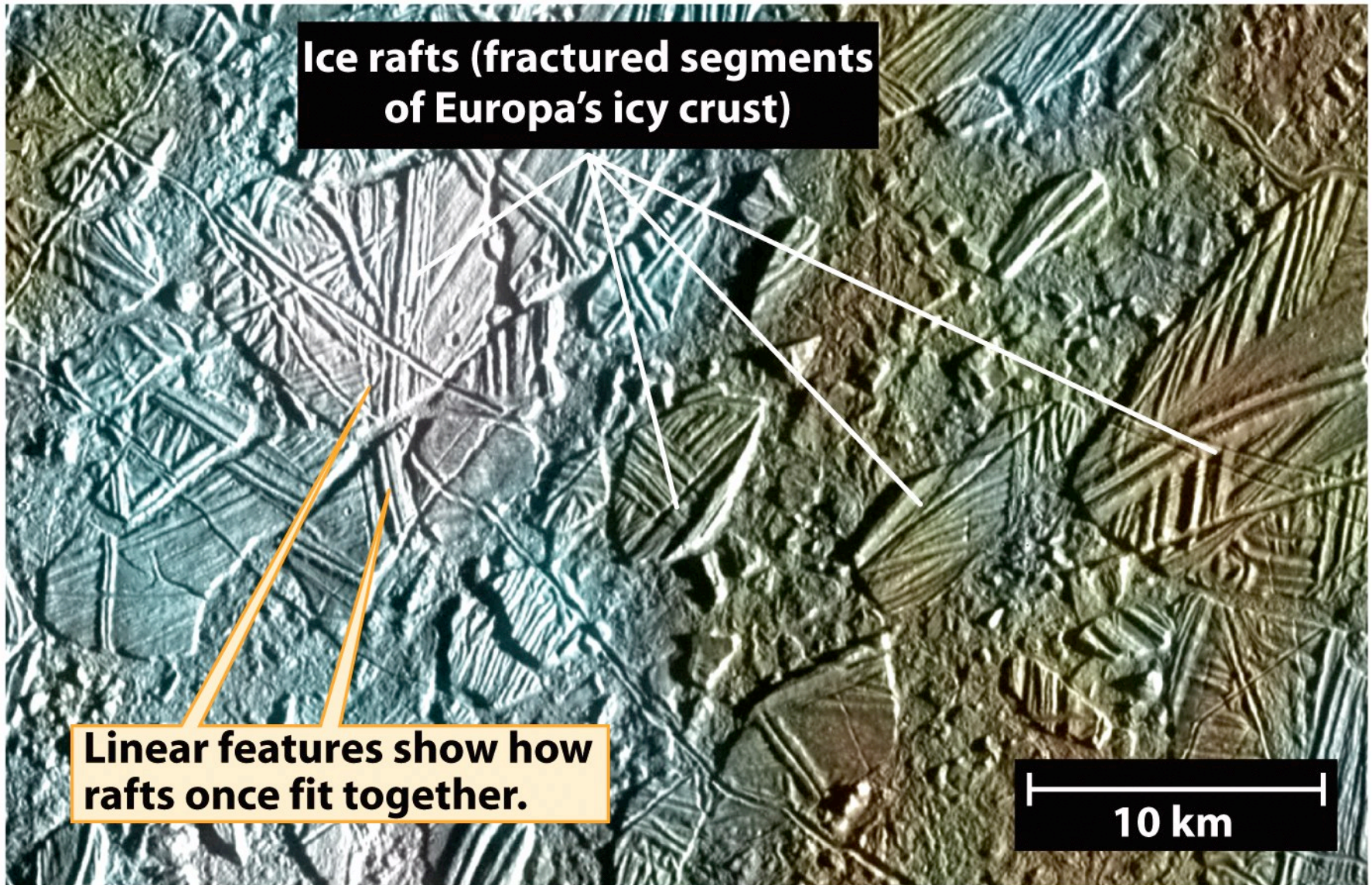


Figure 13-12
Universe, Eighth Edition
© 2008 W. H. Freeman and Company

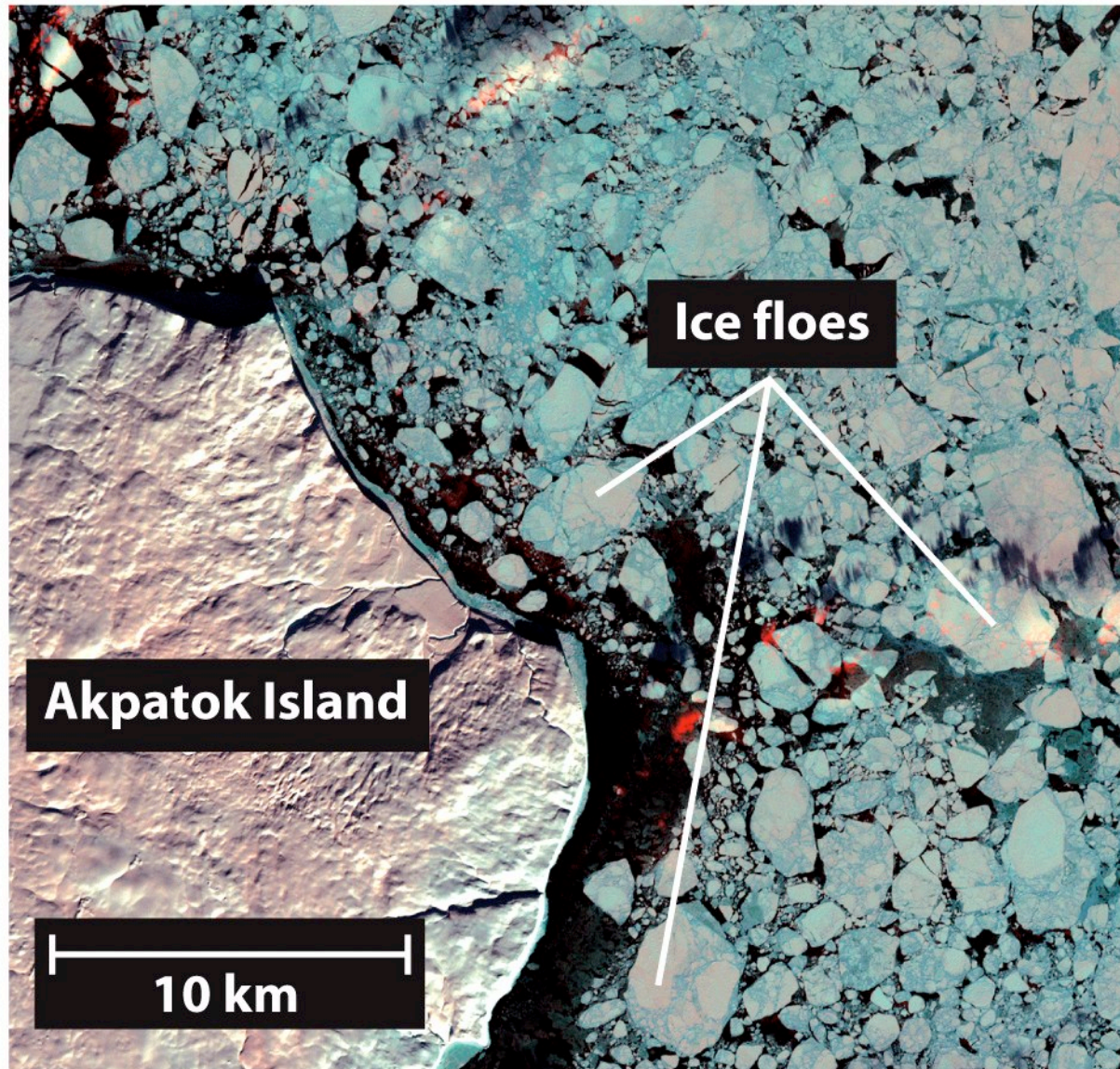


Ice rafts on Europa

Figure 13-13a

Universe, Eighth Edition

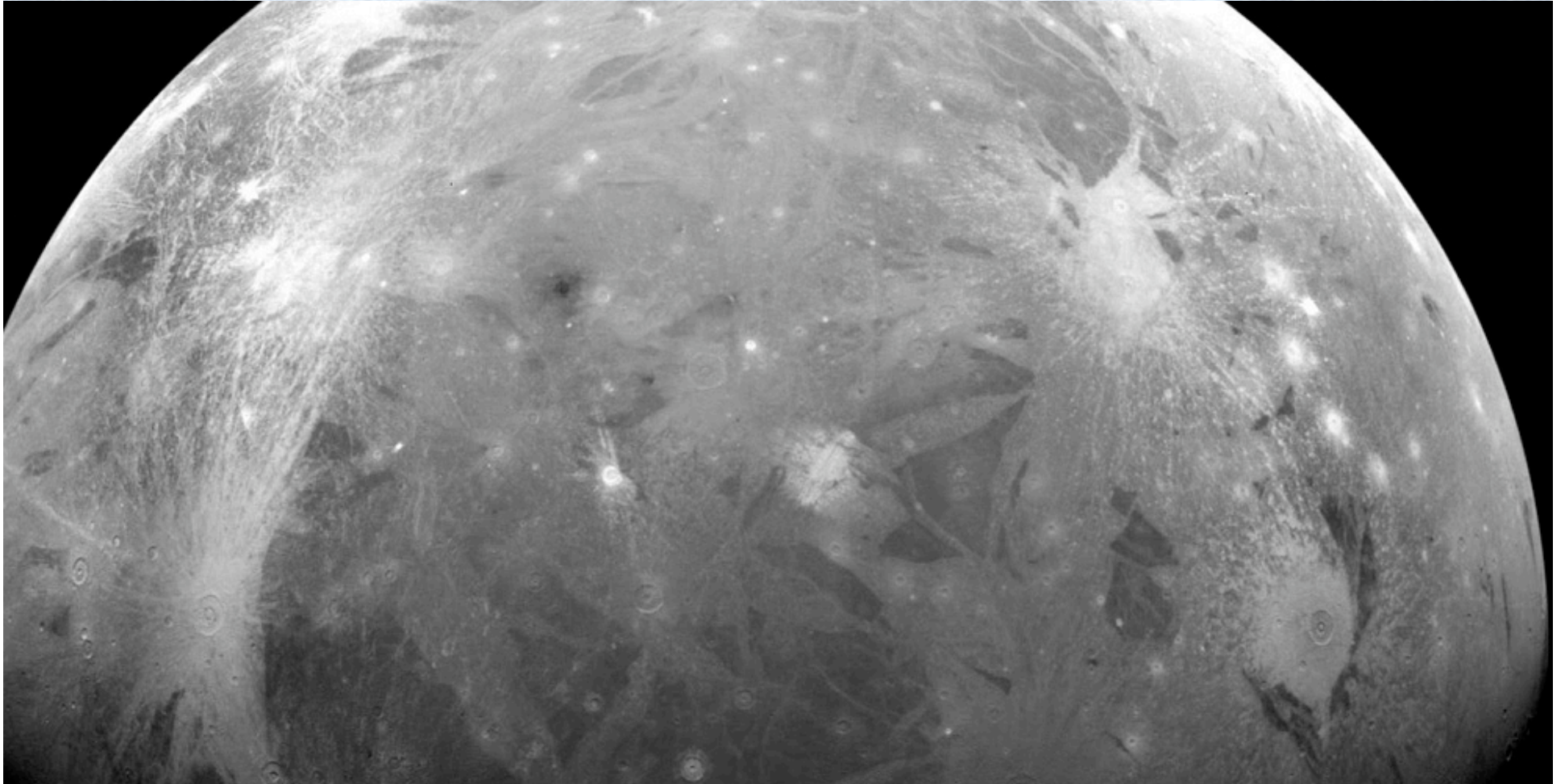
© 2008 W. H. Freeman and Company



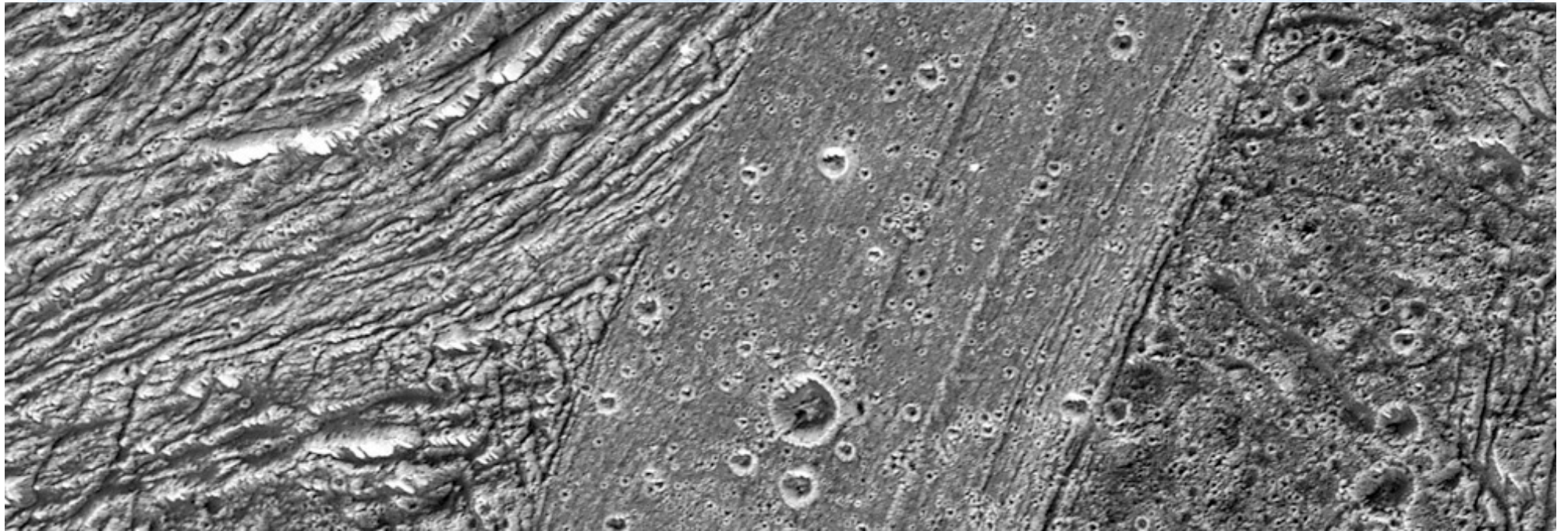
Ice floes on Earth

Figure 13-13b
Universe, Eighth Edition
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Ganymede

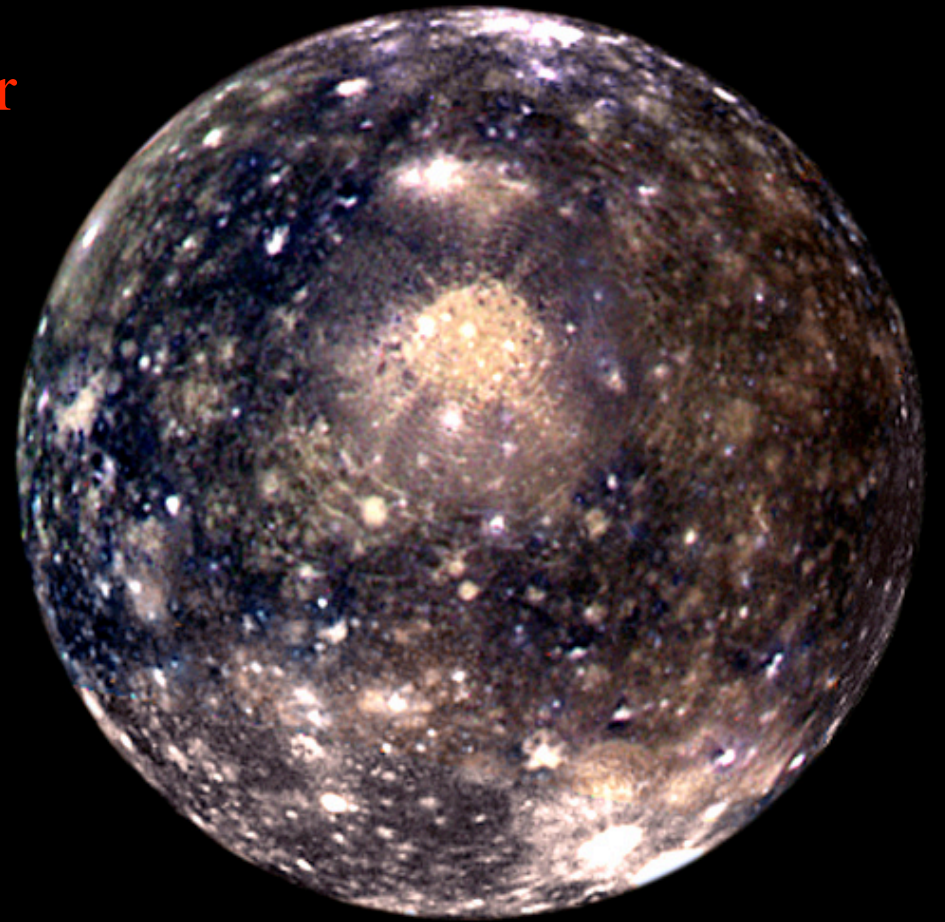


Ganymede



The icy Galilean moons of Jupiter

Ganymede



Callisto

Craters are bright – excavate fresh ice. Callisto has more → older surface, geologically dead.

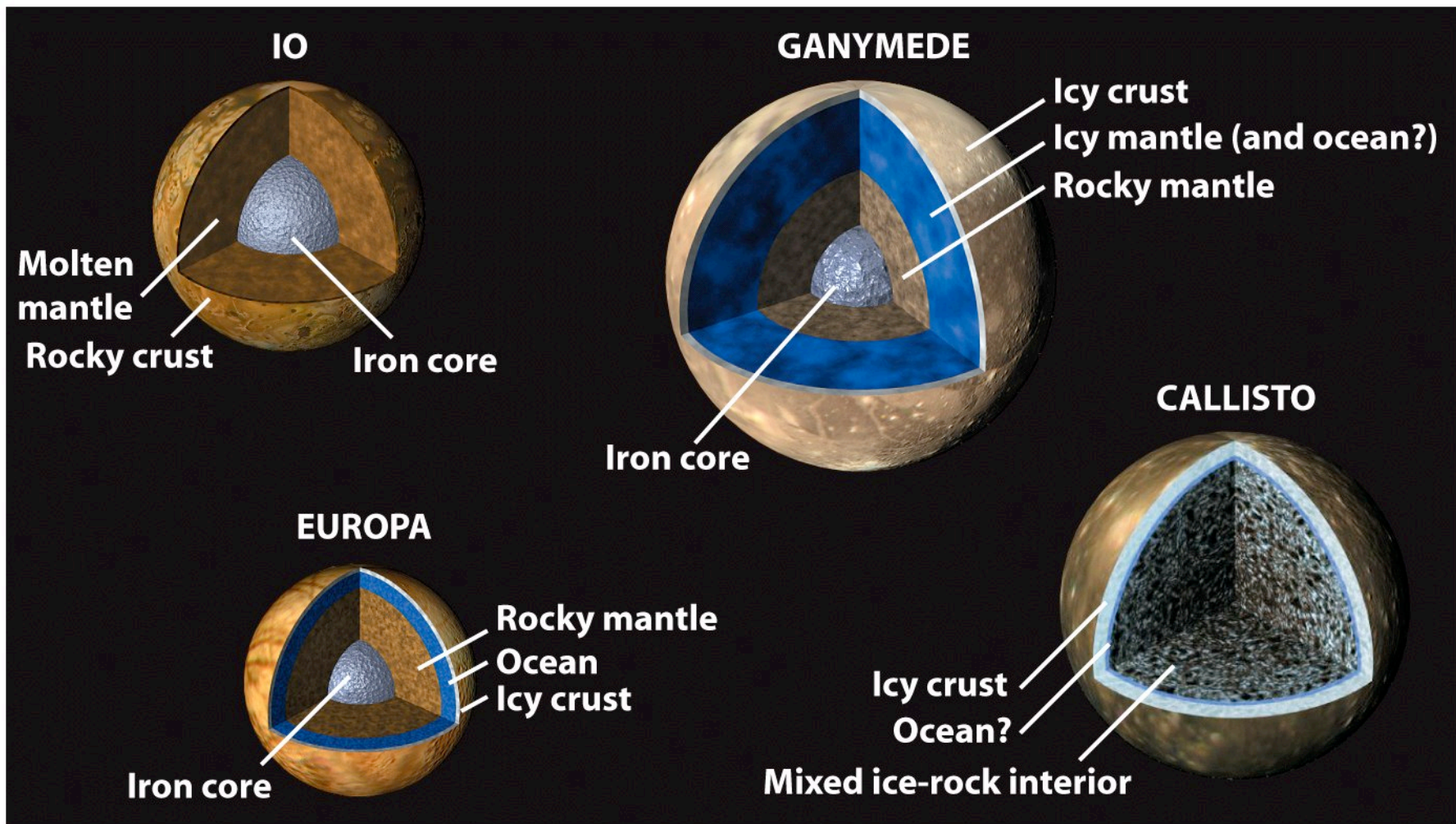


Figure 13-17
Universe, Eighth Edition
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Question 16.1 (iclickers!)

• Jupiter's mass is more than 300 times the mass of Earth, and Saturn has almost 100 times Earth's mass. These masses were determined by

- A) Watching carefully the orbits of these planets around the Sun
- B) Measuring the deviations of other planets from their expected orbits around the Sun
- C) Measuring the deflection of Halley's comet from its orbit when it is near Jupiter and Saturn
- D) Measuring the orbits of the satellites of these planets

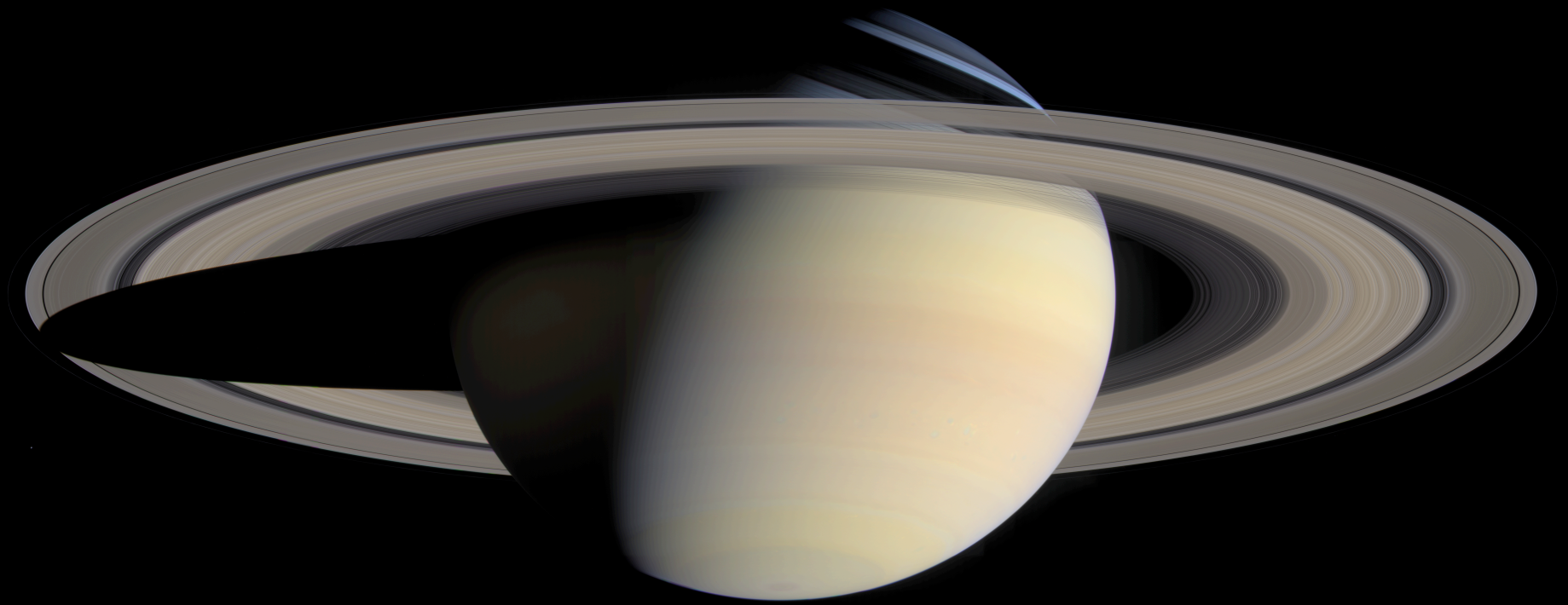
Question 16.2 (iclickers!)

- The source of energy powering Io's continuous and intense volcanic activity is
 - A) Tidal flexion and distortion, caused by Jupiter and the other large moons
 - B) Frictional heating as the solar wind impacts on the moon surface
 - C) Solar UV and visible radiation
 - D) Heat released by continuous shrinkage after creation, transforming potential gravitational energy to heat.

Jupiter's rings (image taken when Jupiter was eclipsing the Sun).

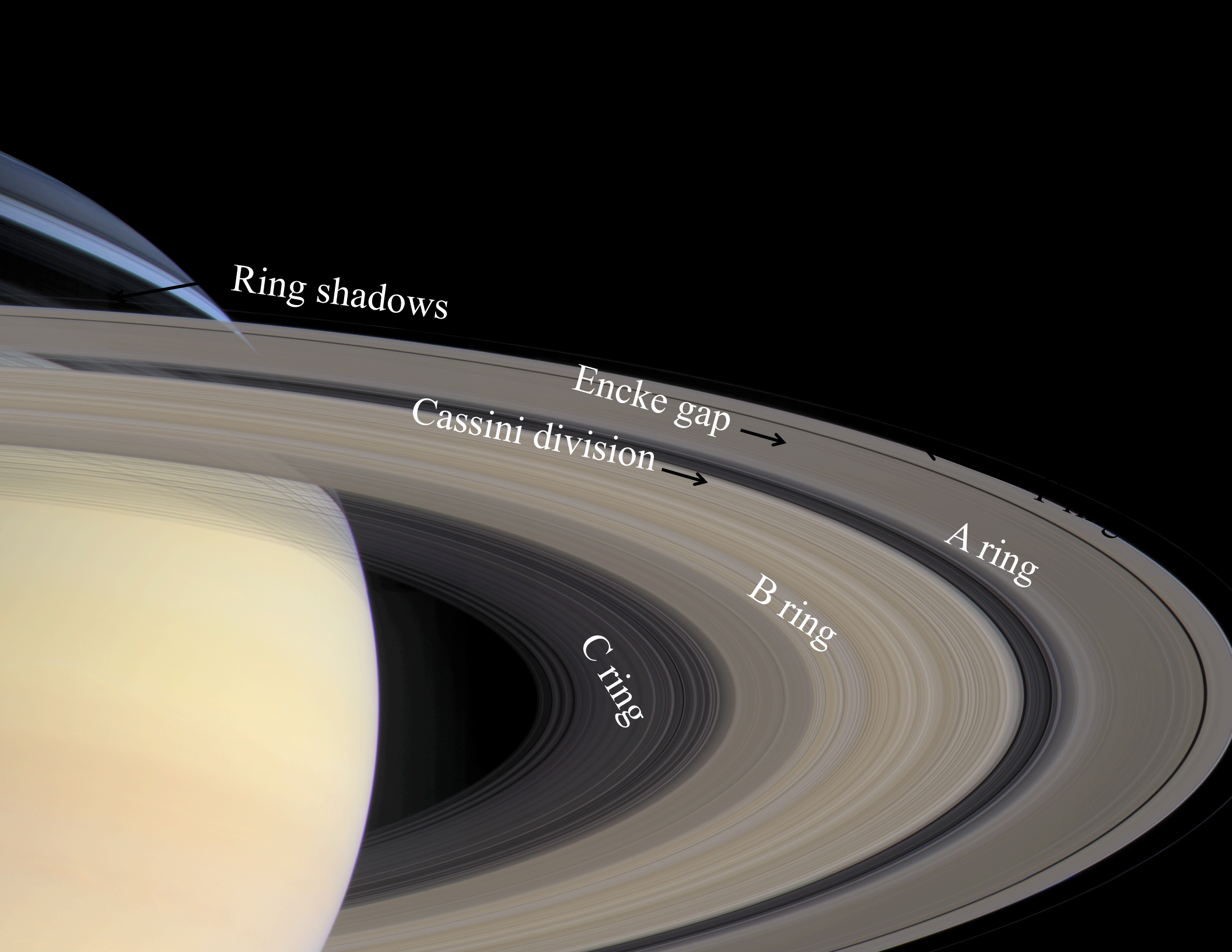


Saturn natural color composite from Cassini



Mimas and Saturn





Ring shadows

Encke gap

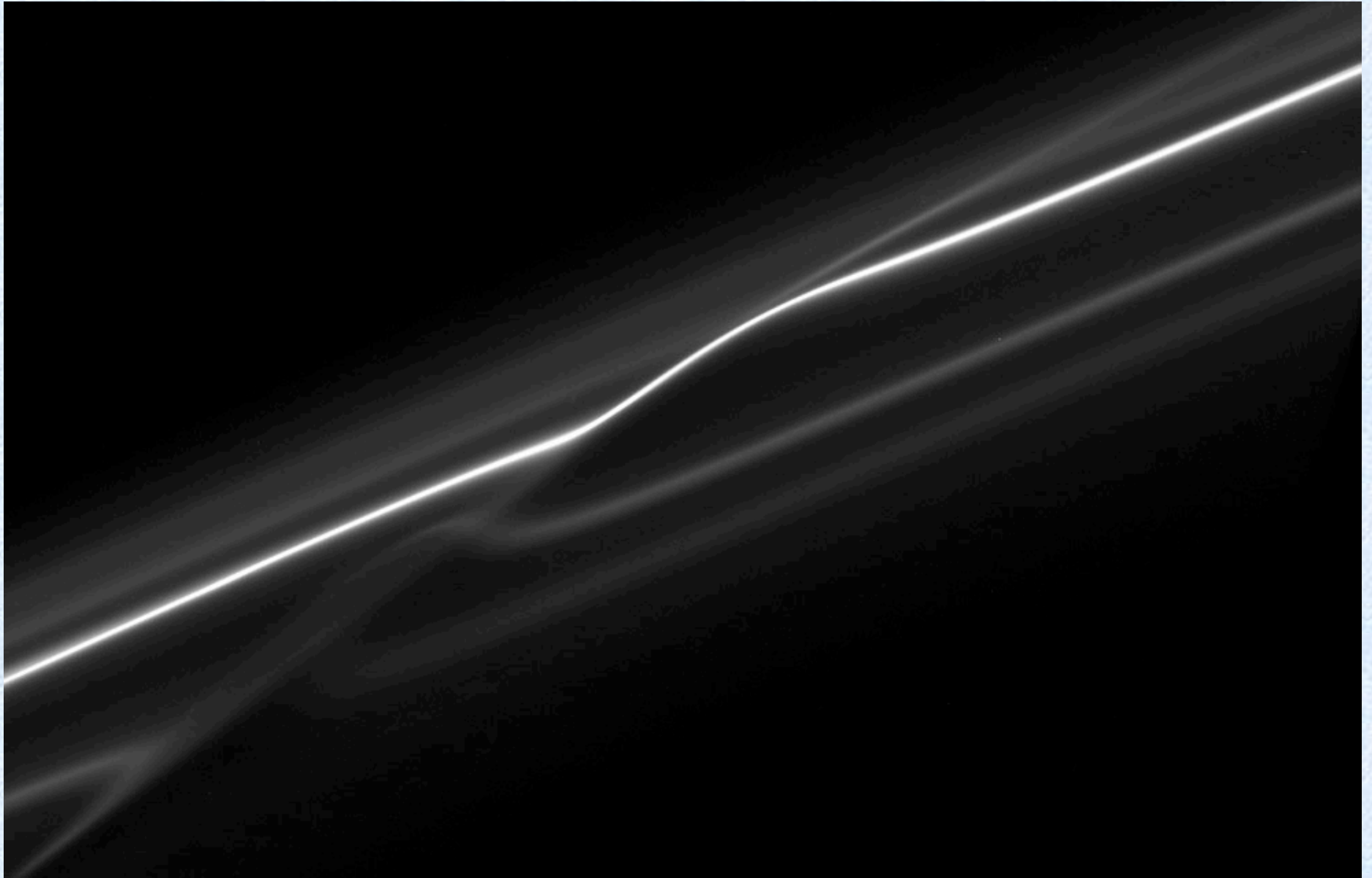
Cassini division

A ring

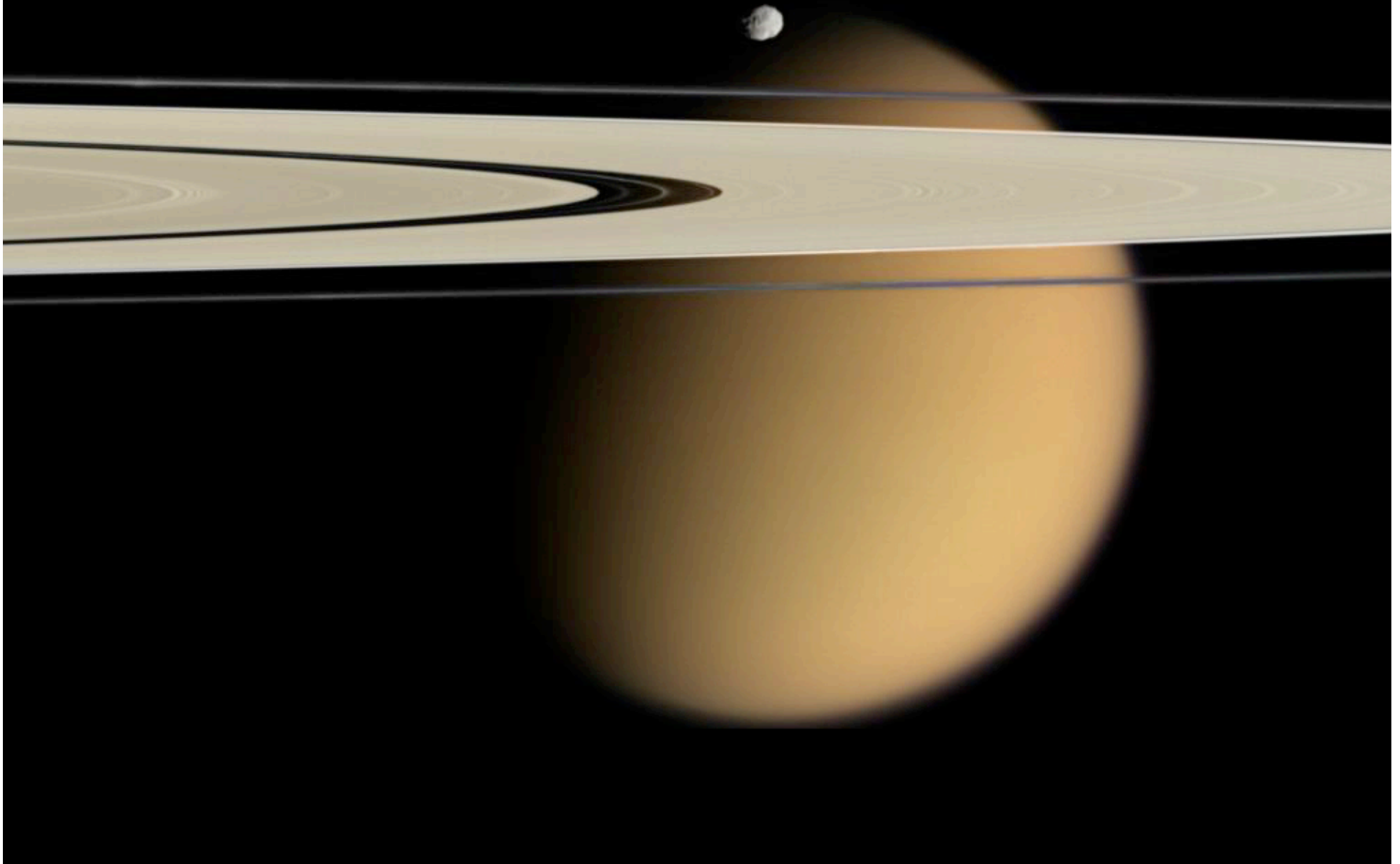
B ring

C ring

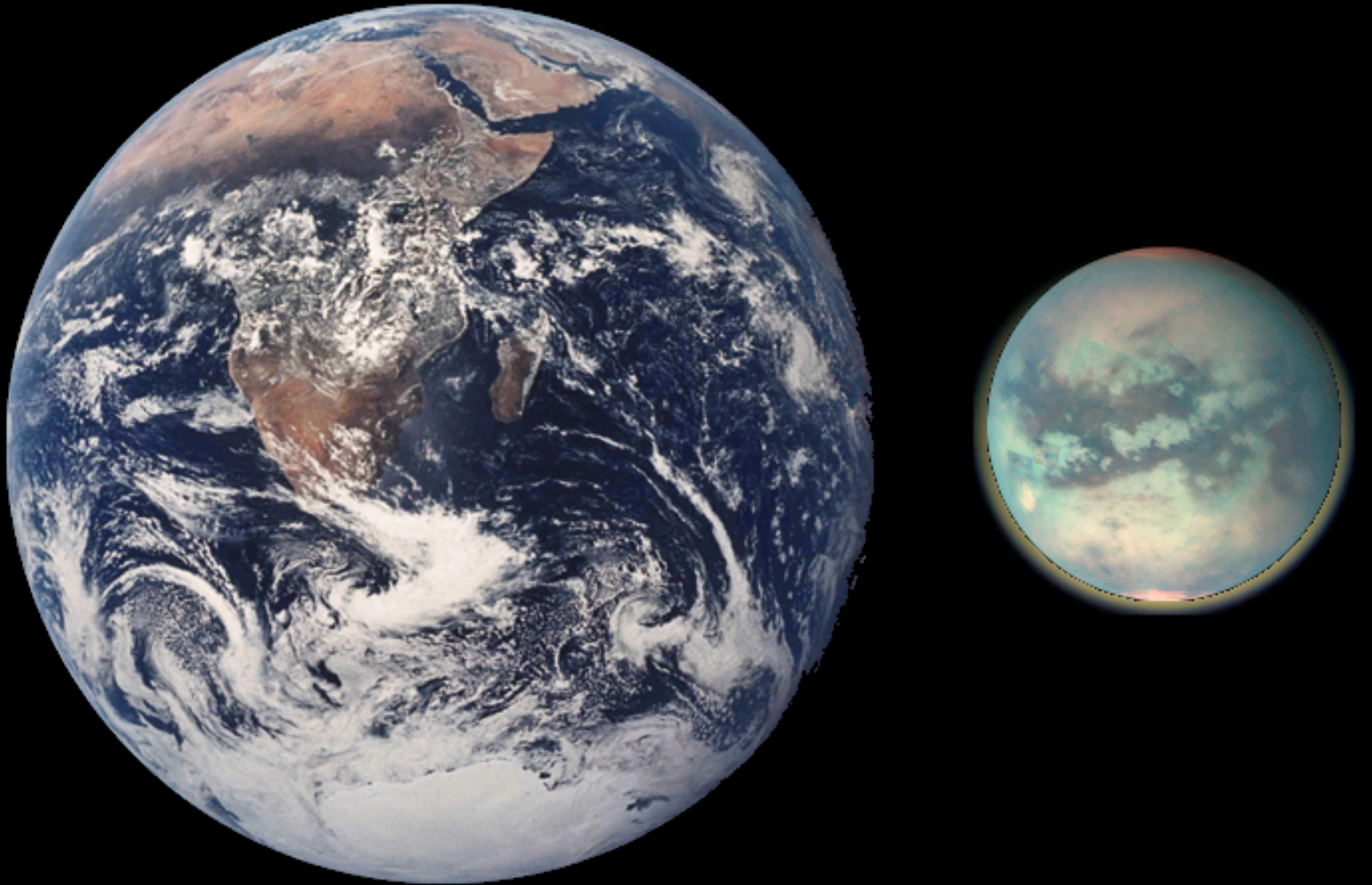
Saturn F ring after the passage of Prometheus



Epimetheus and Titan

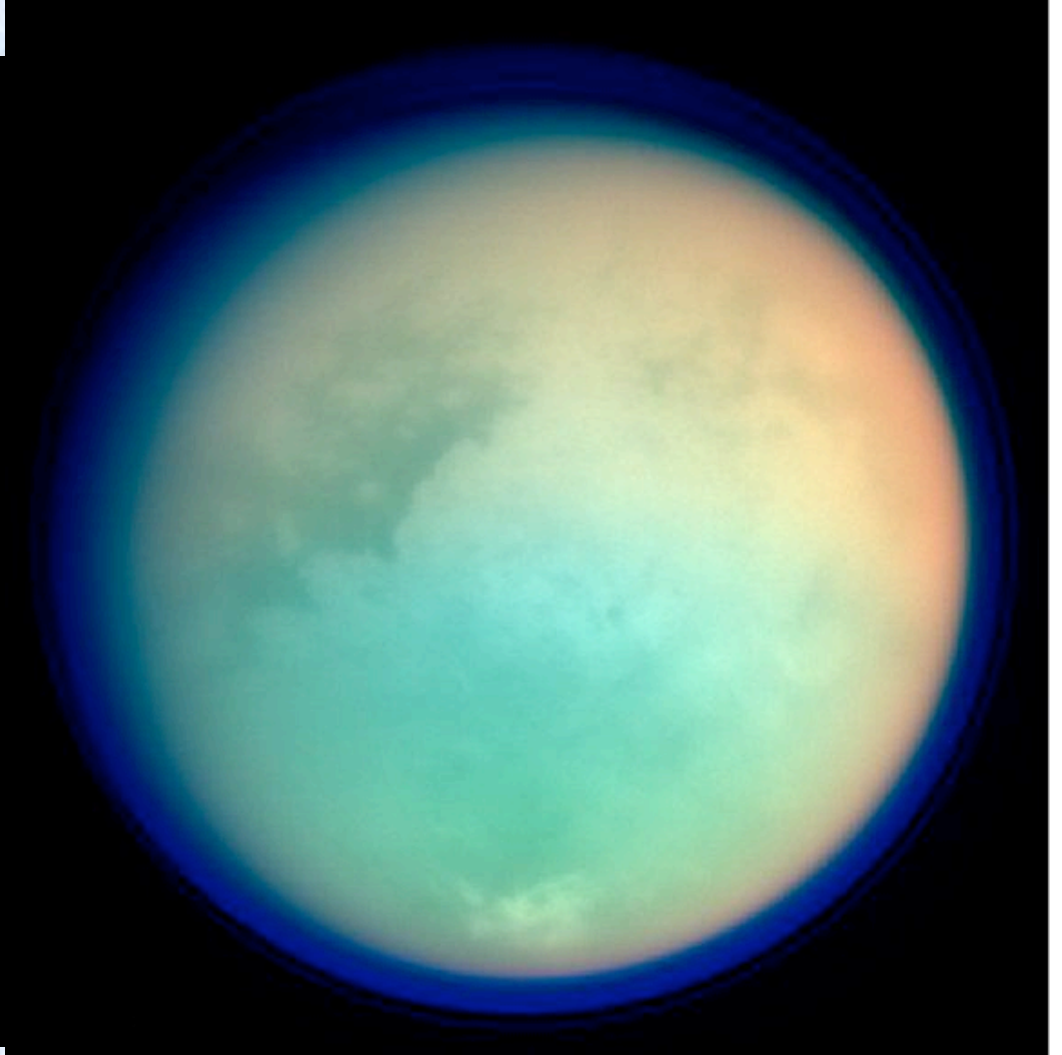
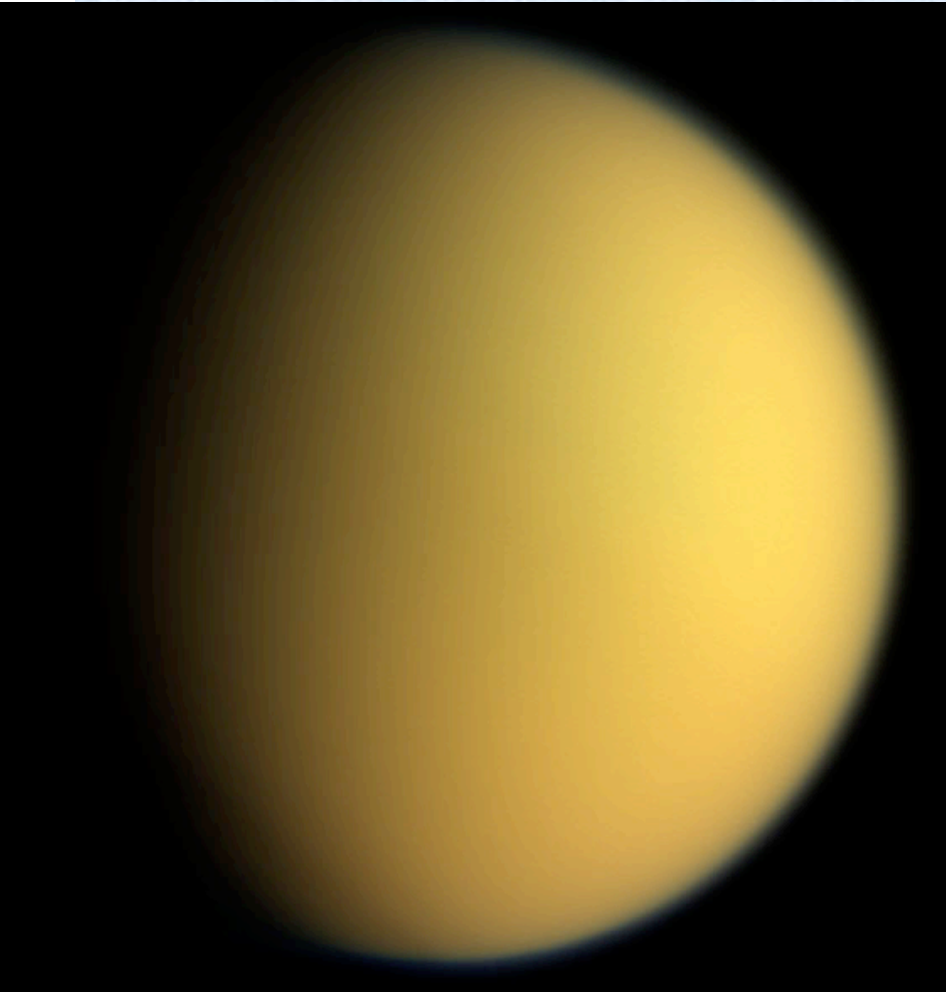


Titan beneath the clouds, size compared to Earth



Titan, visible light

Titan in infrared, can see beneath the haze

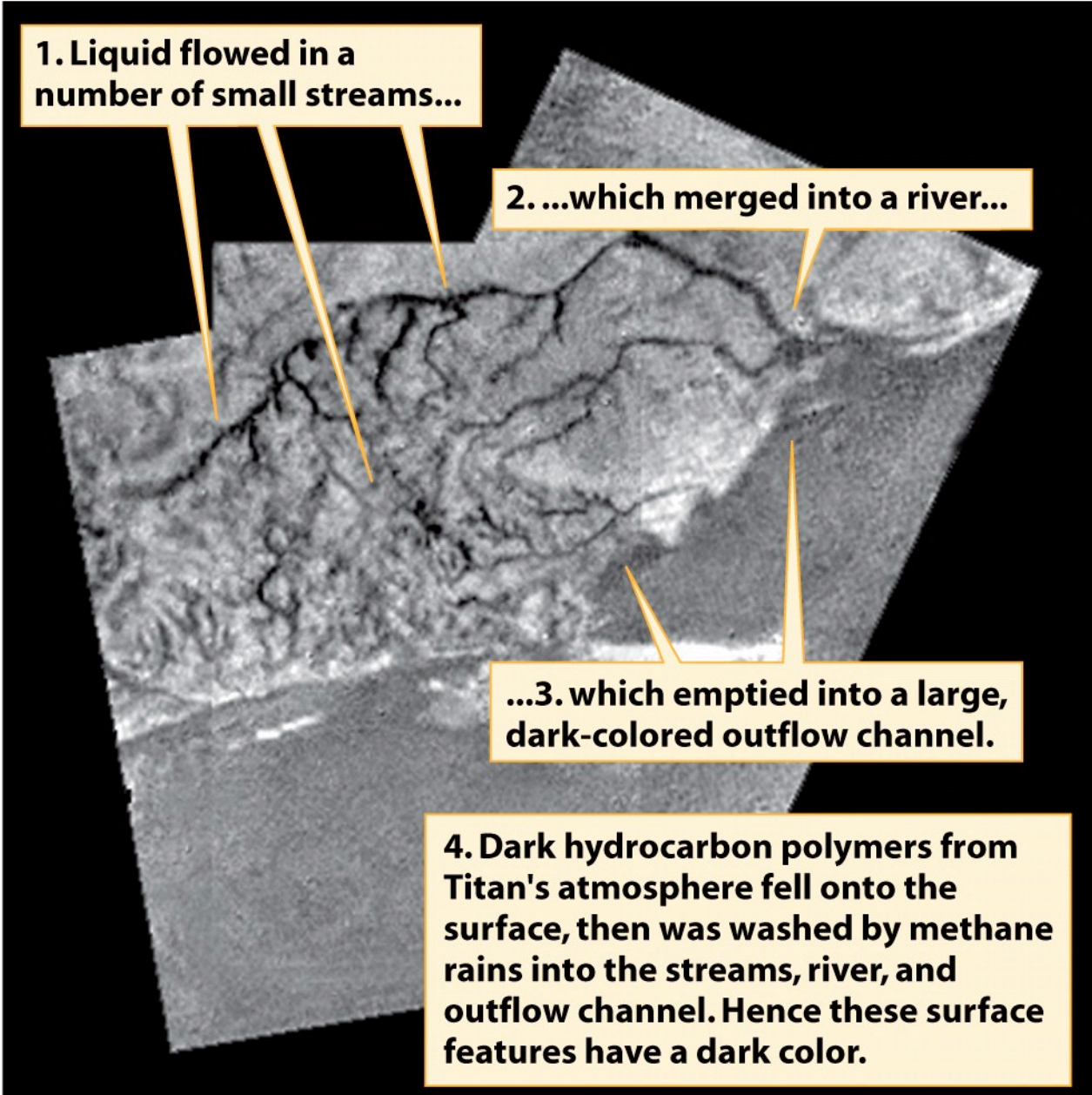


Titan is the only moon in the Solar System with a real atmosphere. Atmosphere is about 1.5x the atmospheric pressure of Earth's, and is 98.4% nitrogen. It might be like the primitive Earth, but colder (-180°C).

True color picture of the haze in Titan's atmosphere







1. Liquid flowed in a number of small streams...

2. ...which merged into a river...

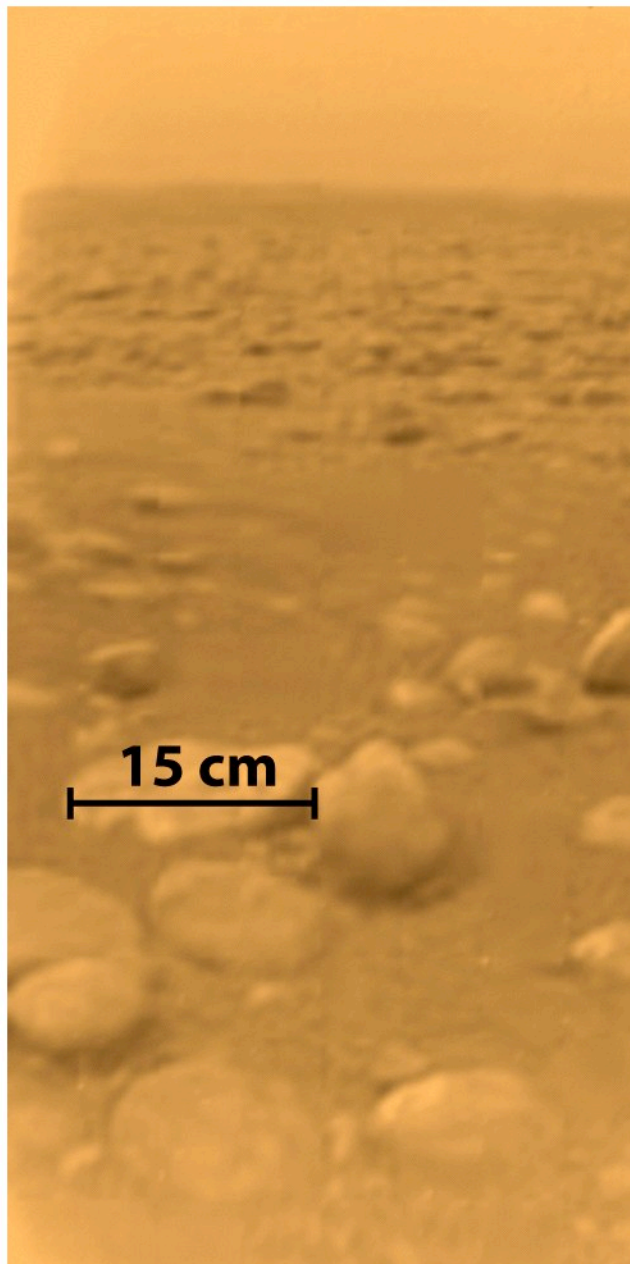
...3. which emptied into a large, dark-colored outflow channel.

4. Dark hydrocarbon polymers from Titan's atmosphere fell onto the surface, then was washed by methane rains into the streams, river, and outflow channel. Hence these surface features have a dark color.

Figure 13-19b

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This nearly true-color *Huygens* image shows the view from Titan's surface. The 15-cm (6-in.) wide "rock" is about 85 cm (33 in.) from the camera. Unlike Earth rocks, Titan "rocks" are chunks of water ice

Figure 13-19c
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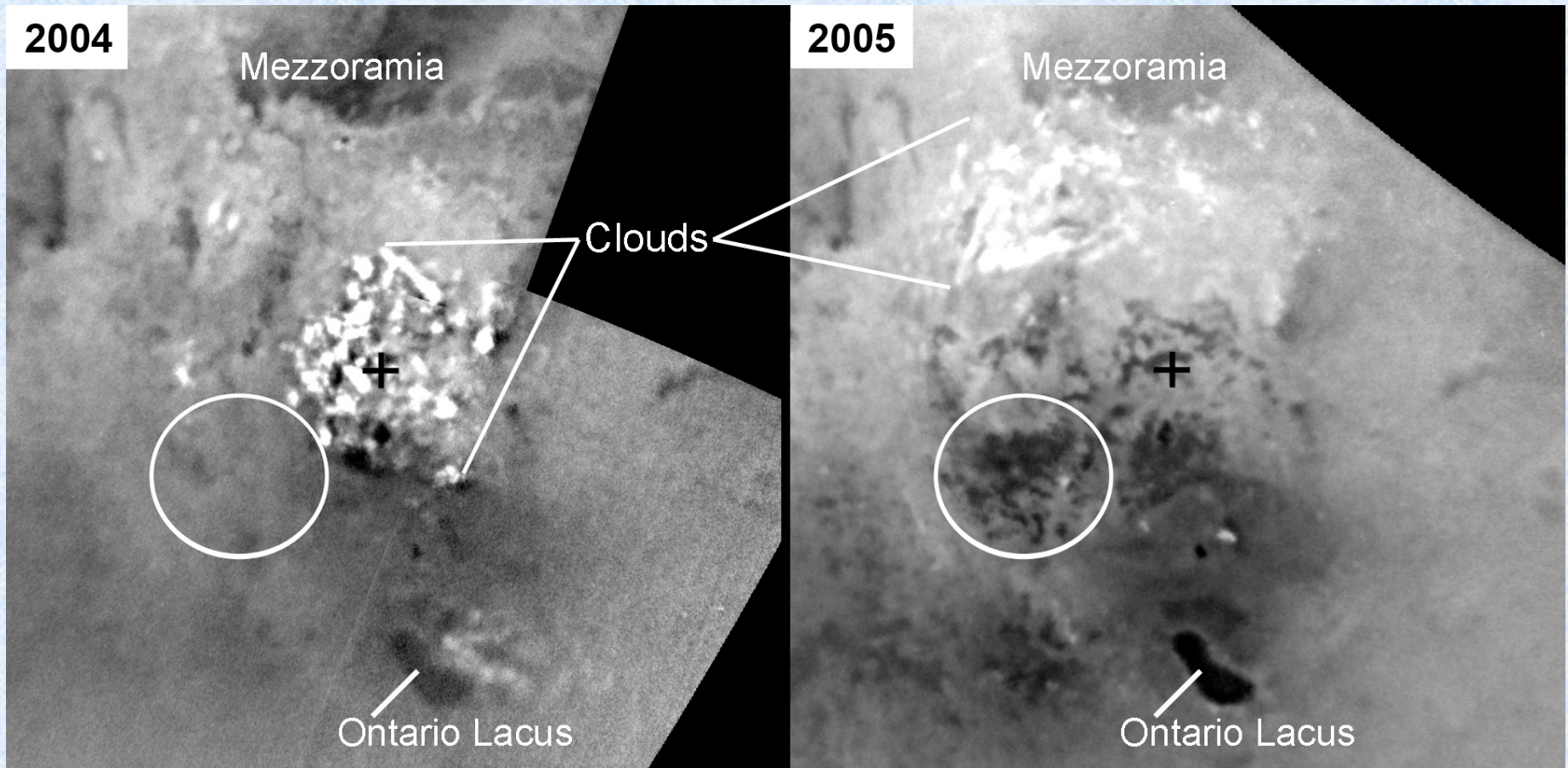
The View from Huygens on January 14, 2005

A Simulation Made Possible by the
Descent **I**mager / **S**pectral **R**adiometer

Erich Karkoschka, the DISR Team, NASA, ESA

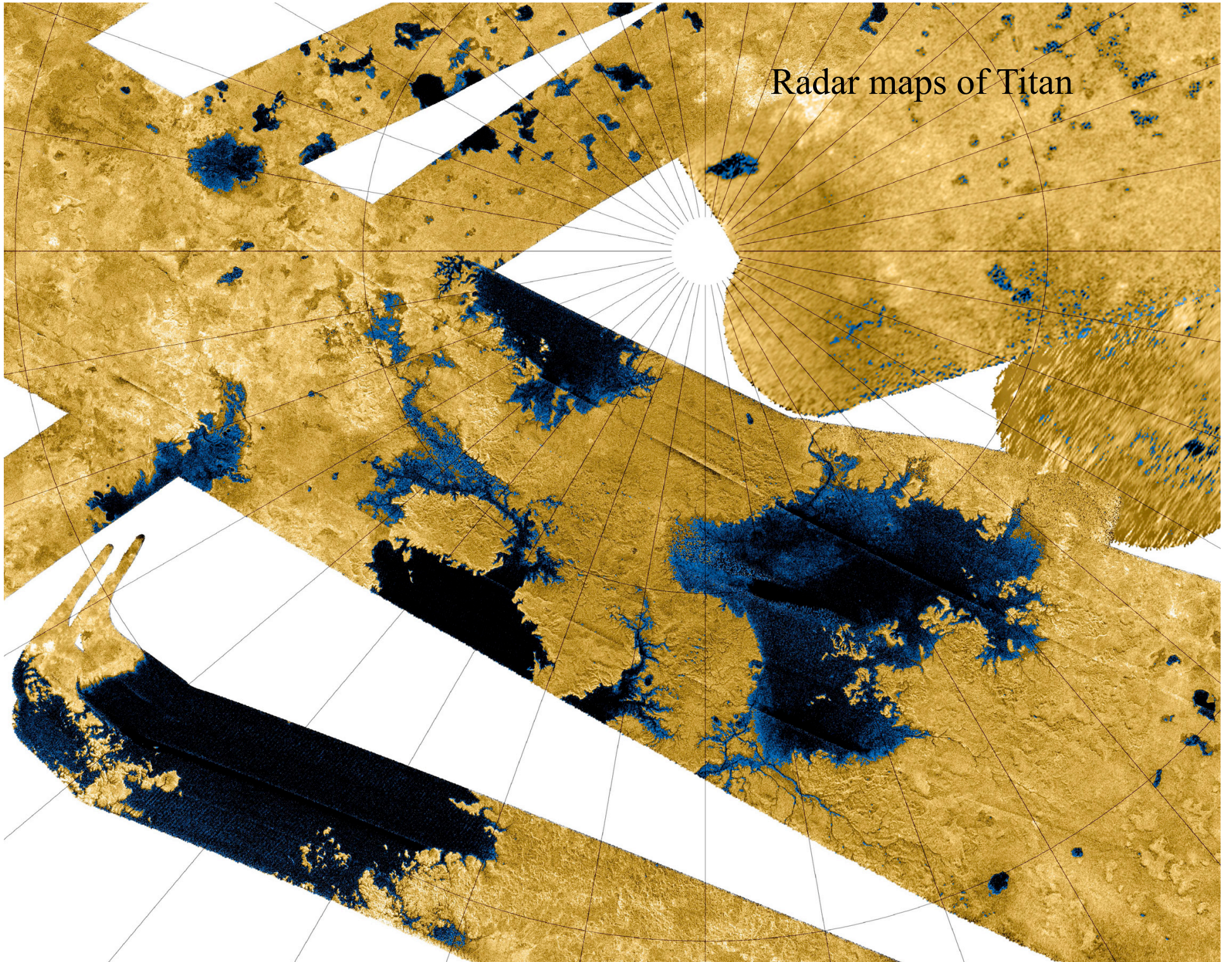
Version 2

© 2006 University of Arizona



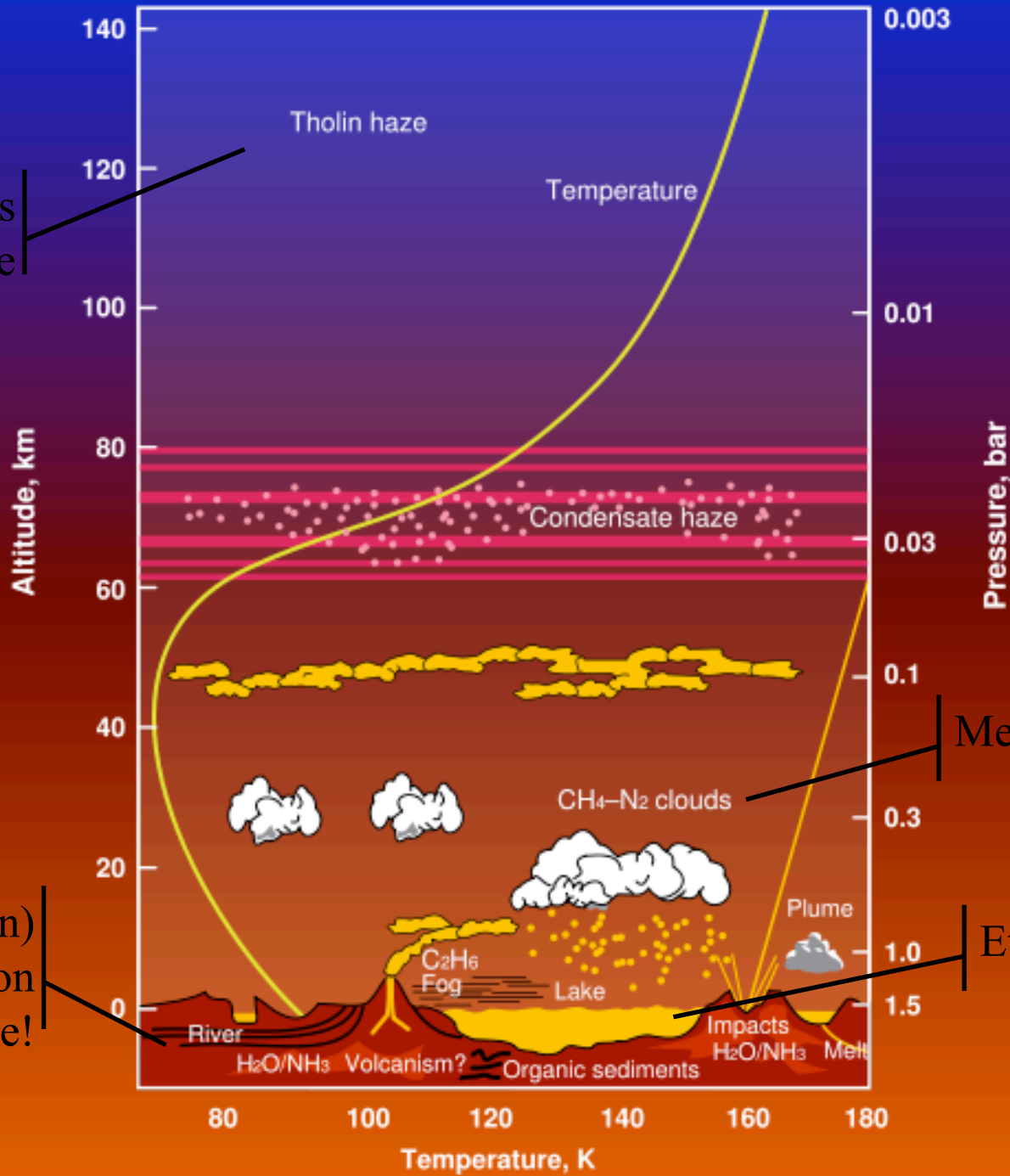
Seasonal hydrocarbon lakes on Titan of ethane (C_2H_6) and methane (CH_4) -- the two primary components of natural gas. These are located near the poles where the hydrocarbons condense in winter (natural gas “rain” or drizzle?).

Radar maps of Titan



Titan climate

Tarlike substances
make haze

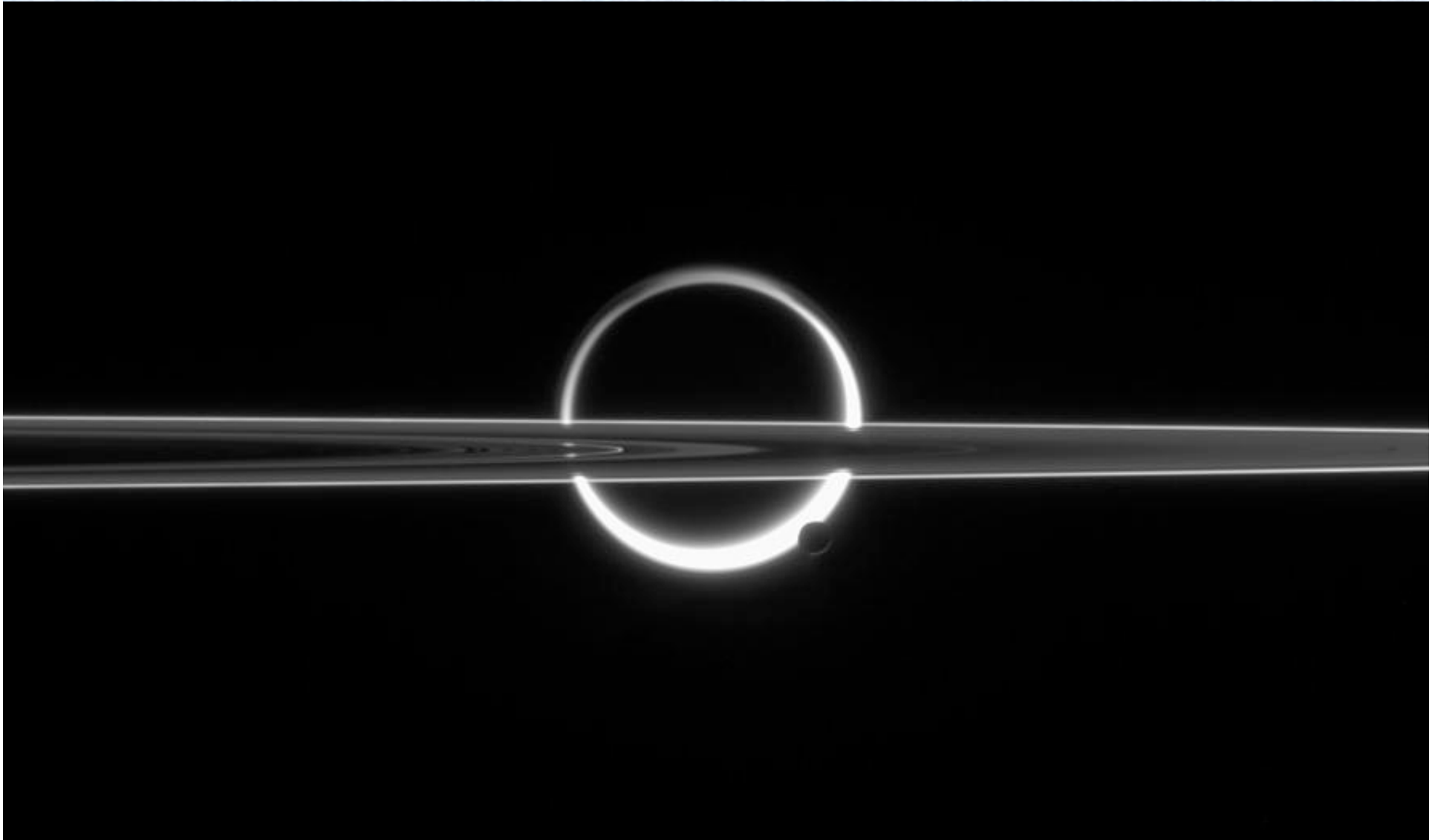


Organic (carbon)
compounds on
surface!

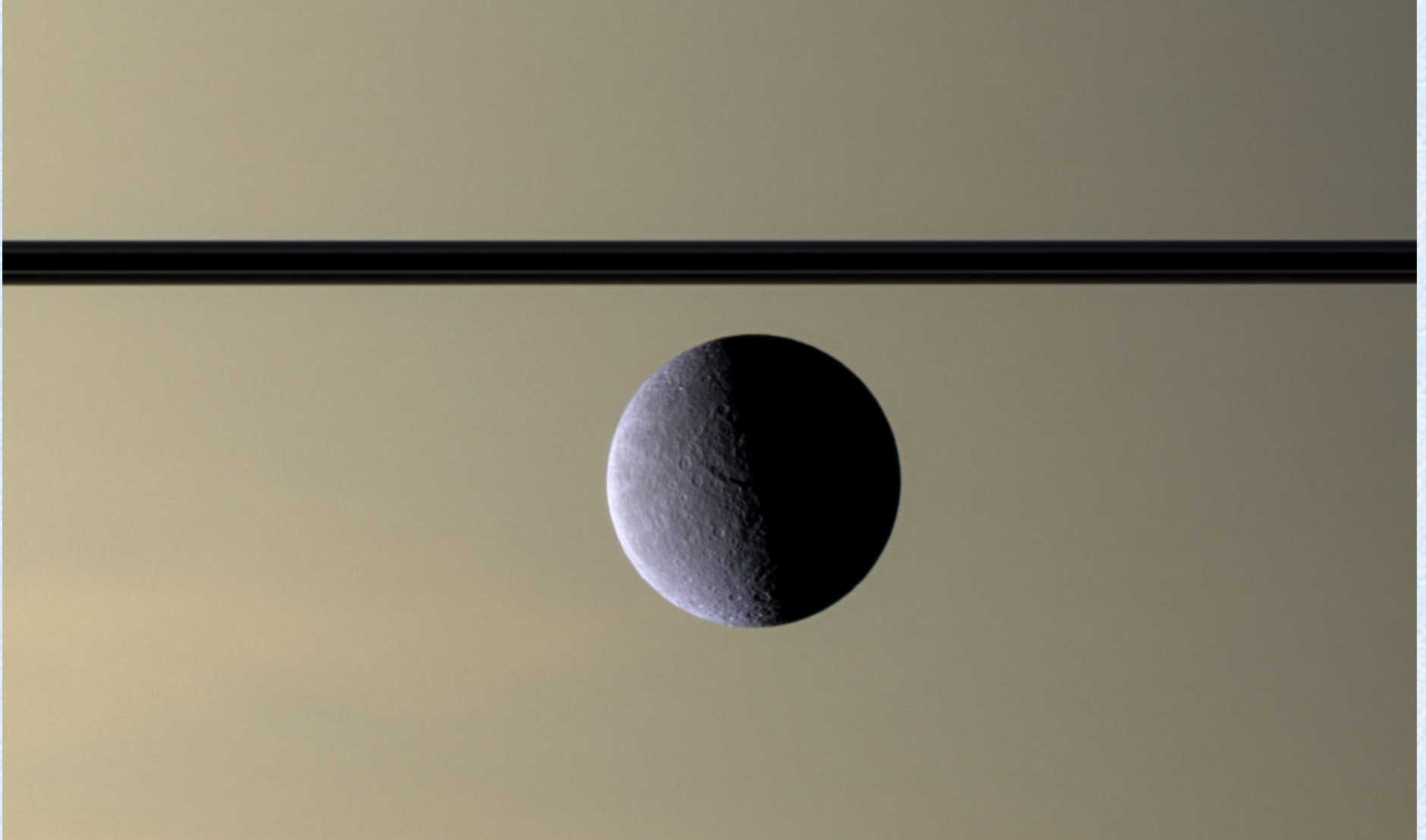
Methane clouds

Ethane lakes

Titan backlit by the sun from Cassini



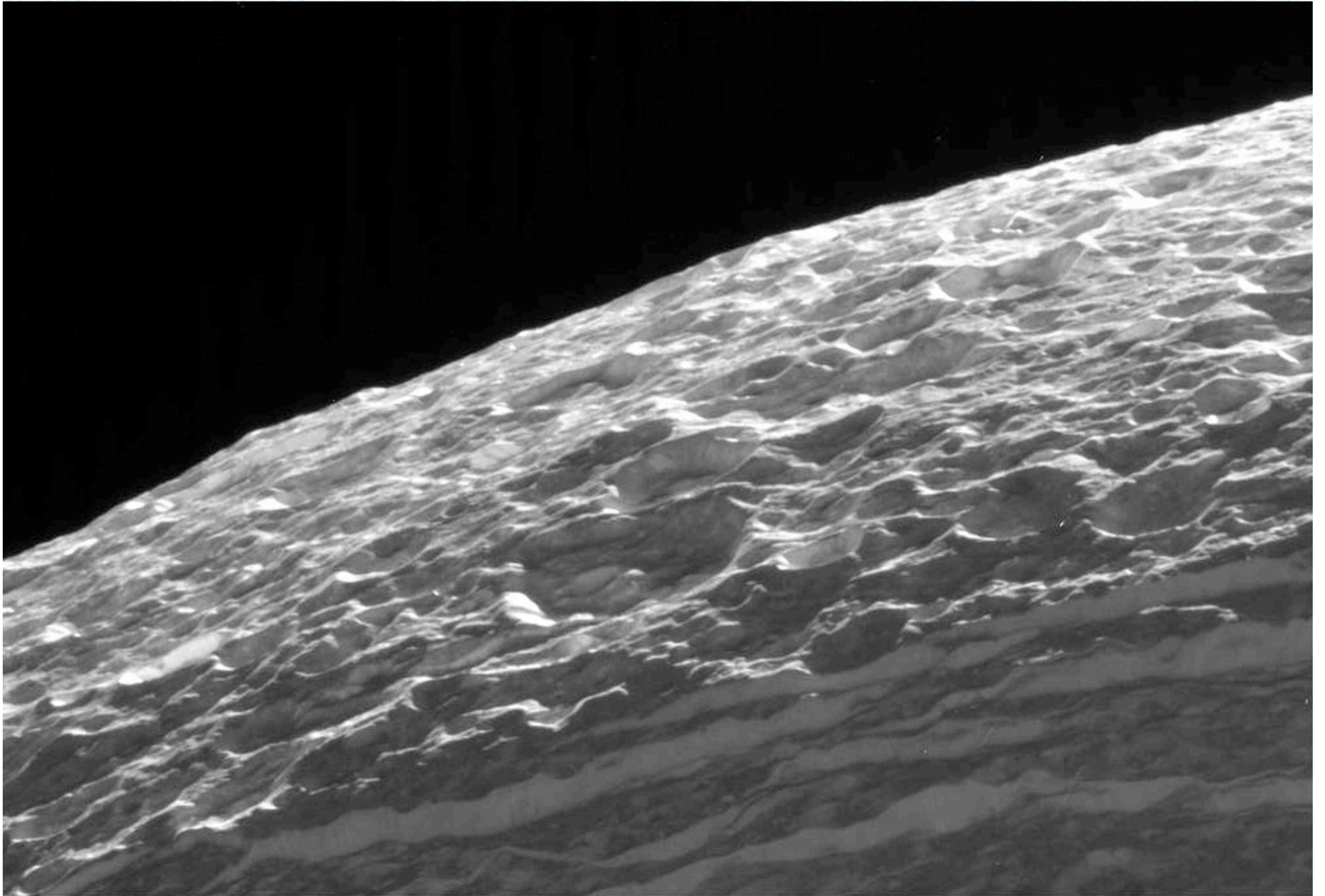
Rhea and Saturn



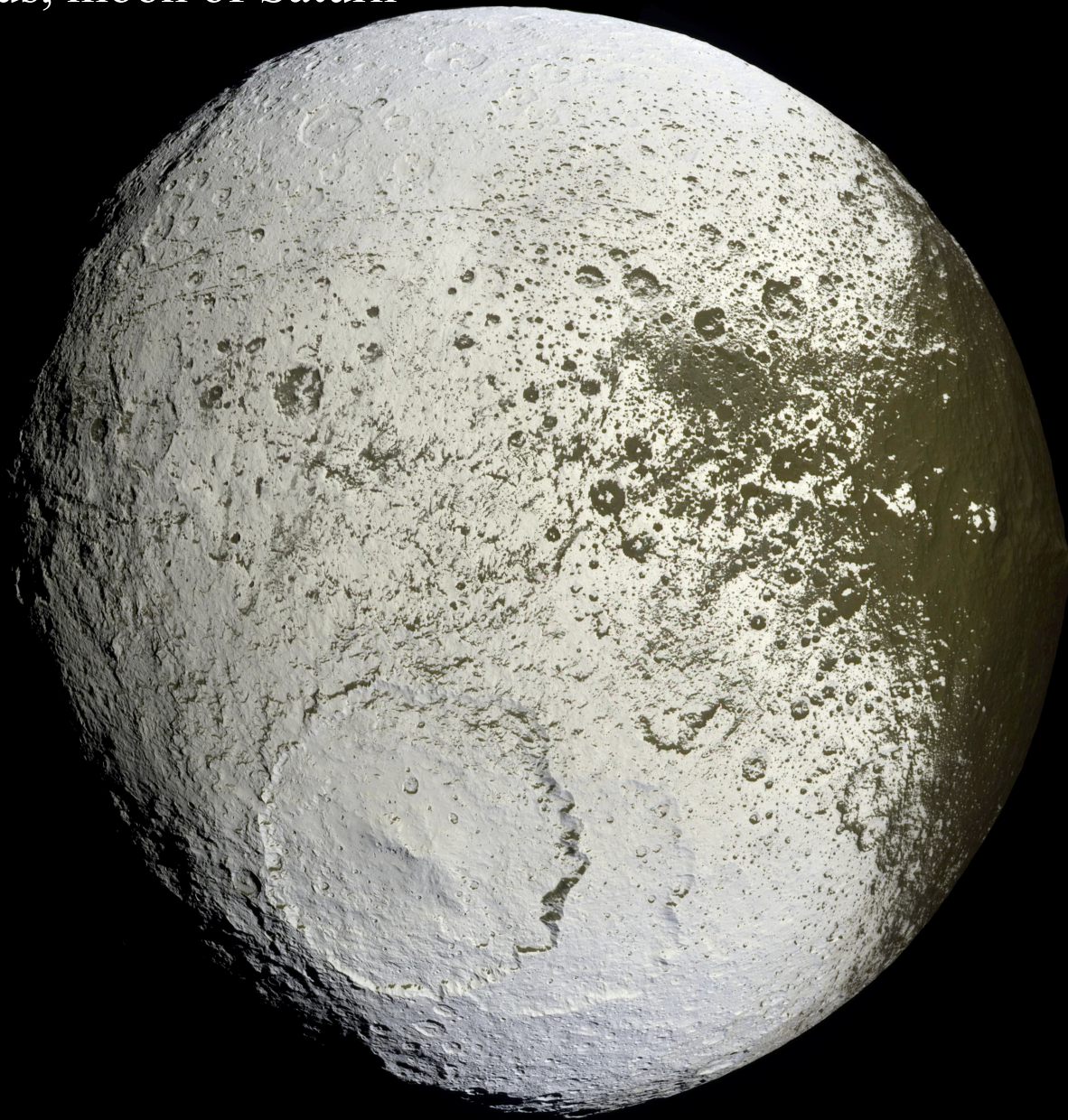
Dione from Cassini



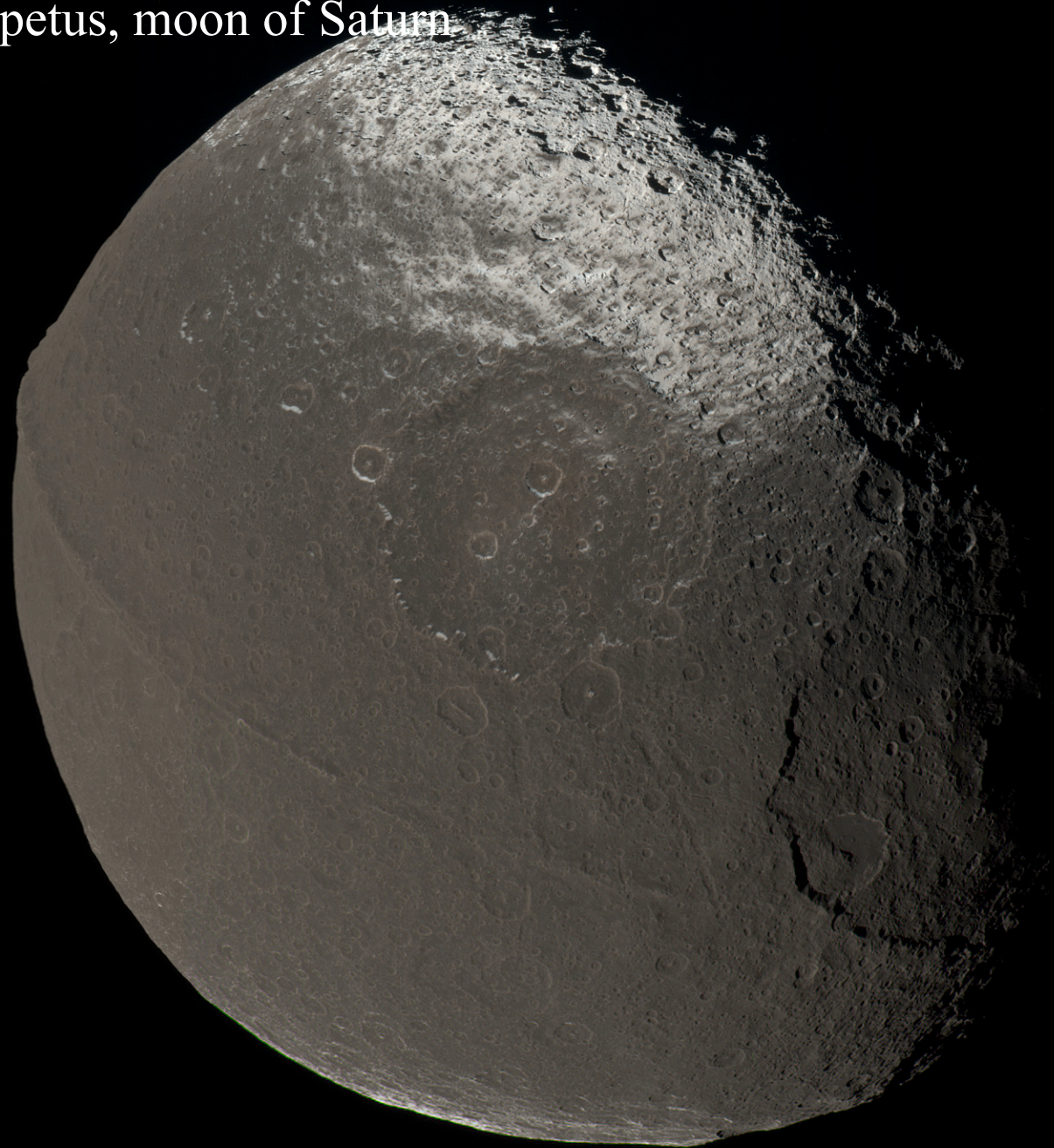
Dione from Cassini



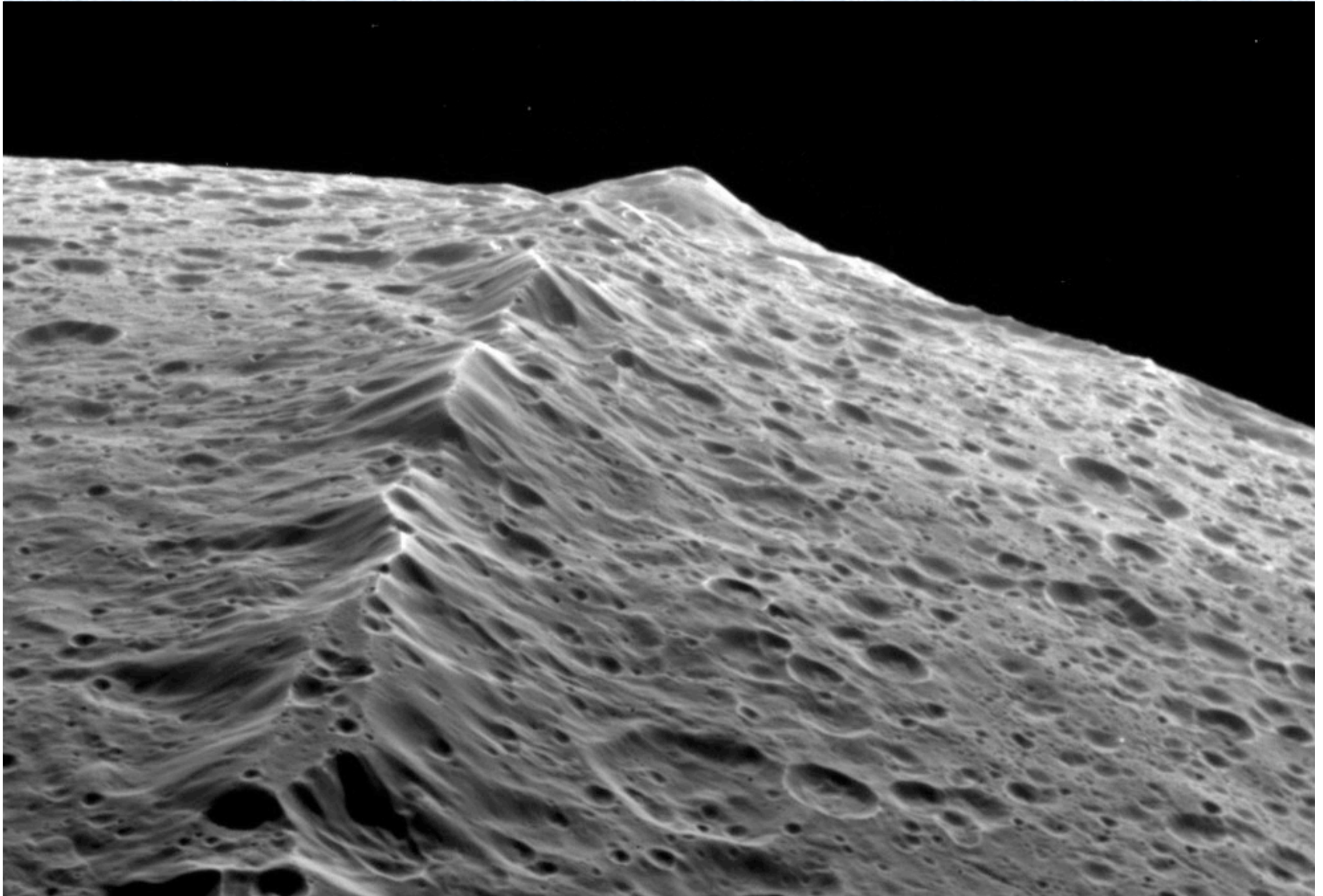
Iapetus, moon of Saturn



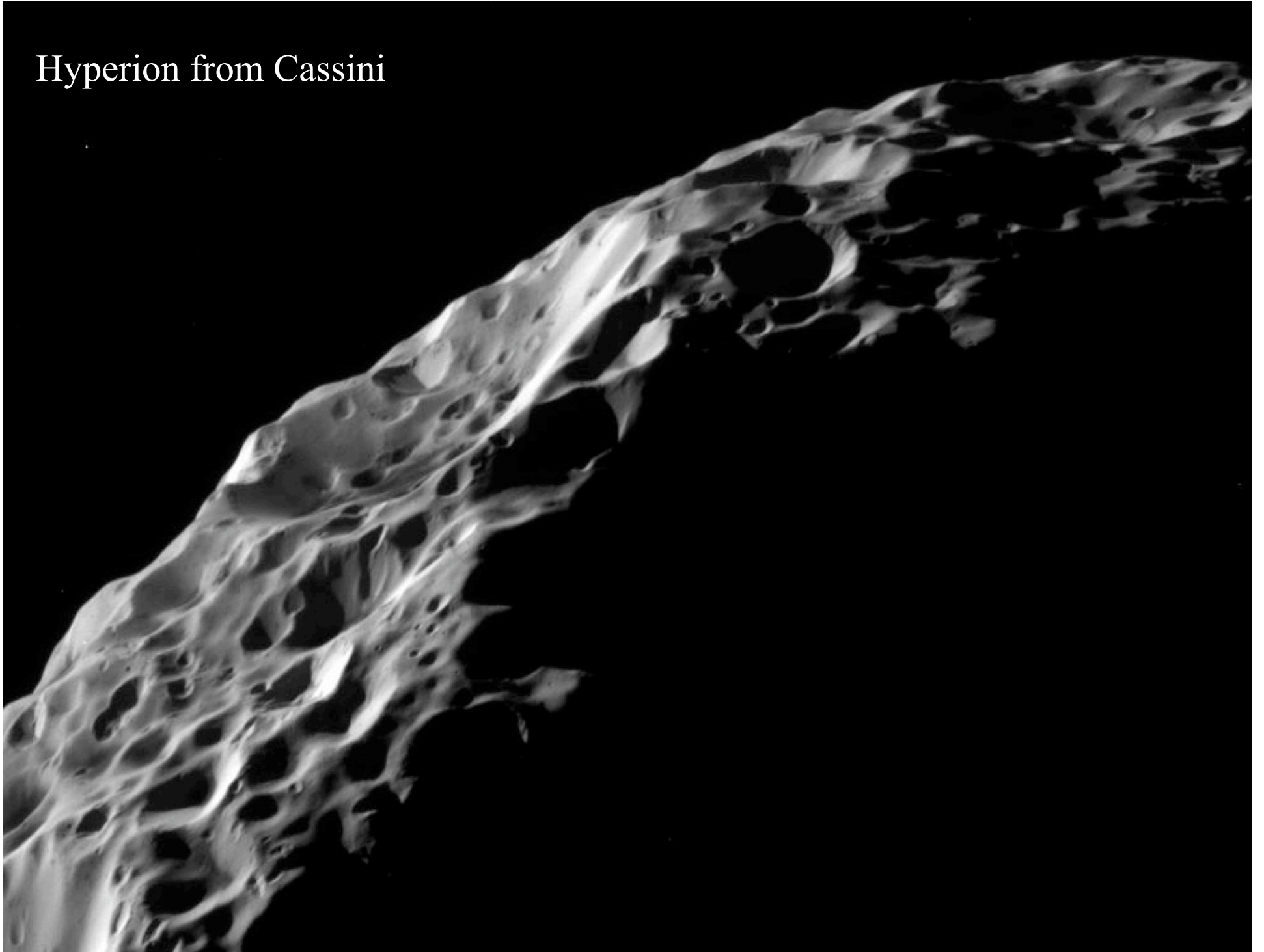
Iapetus, moon of Saturn



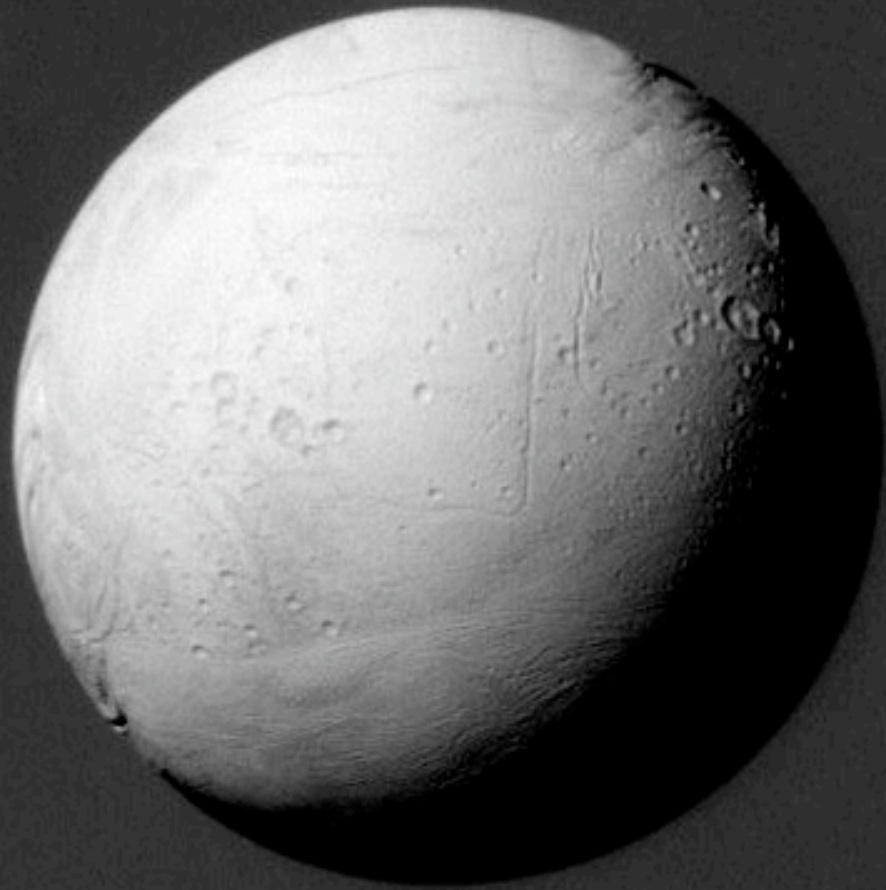
Iapetus, moon of Saturn



Hyperion from Cassini



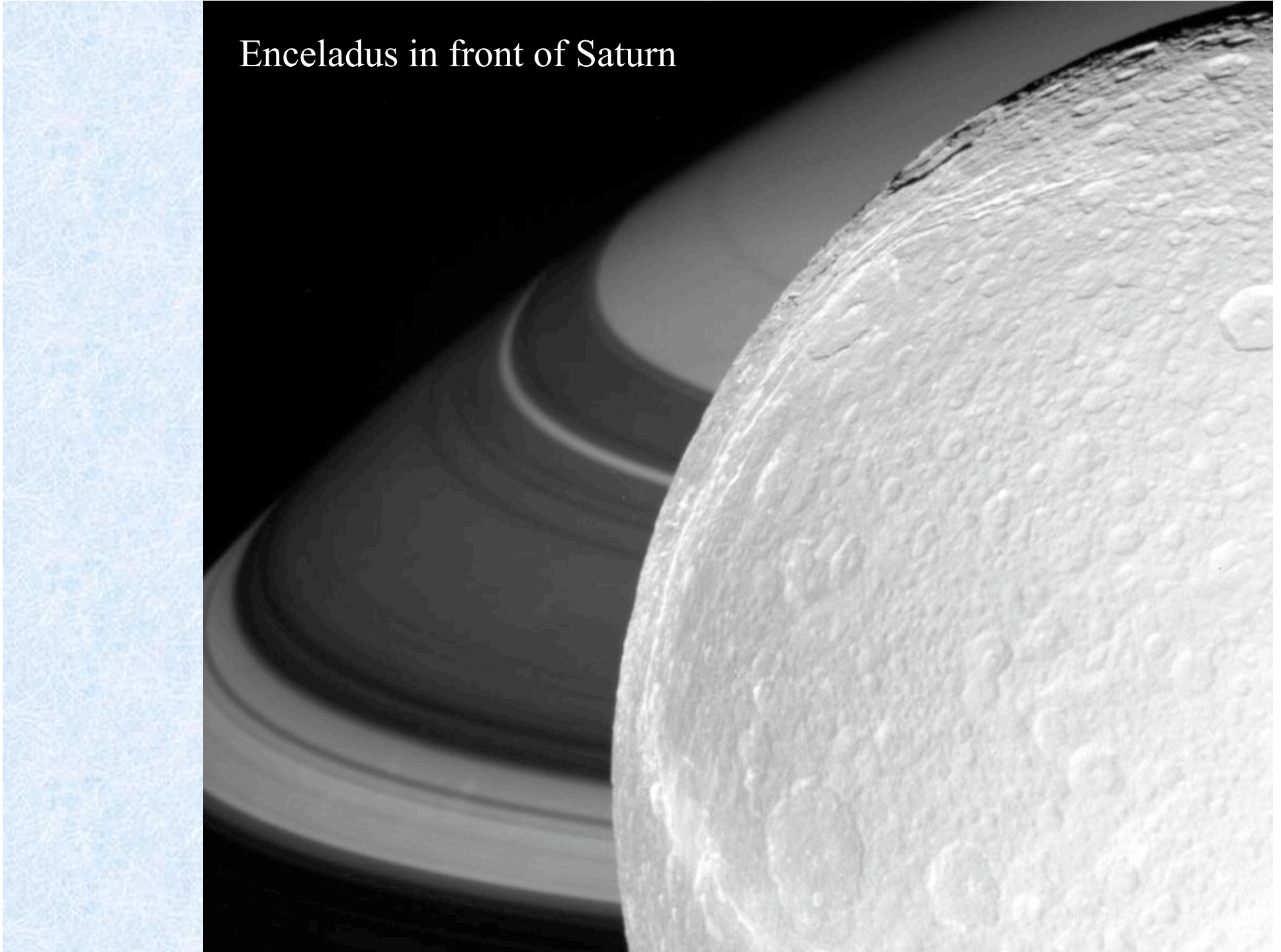
Enceladus in front of Saturn



Enceladus over Saturn's rings

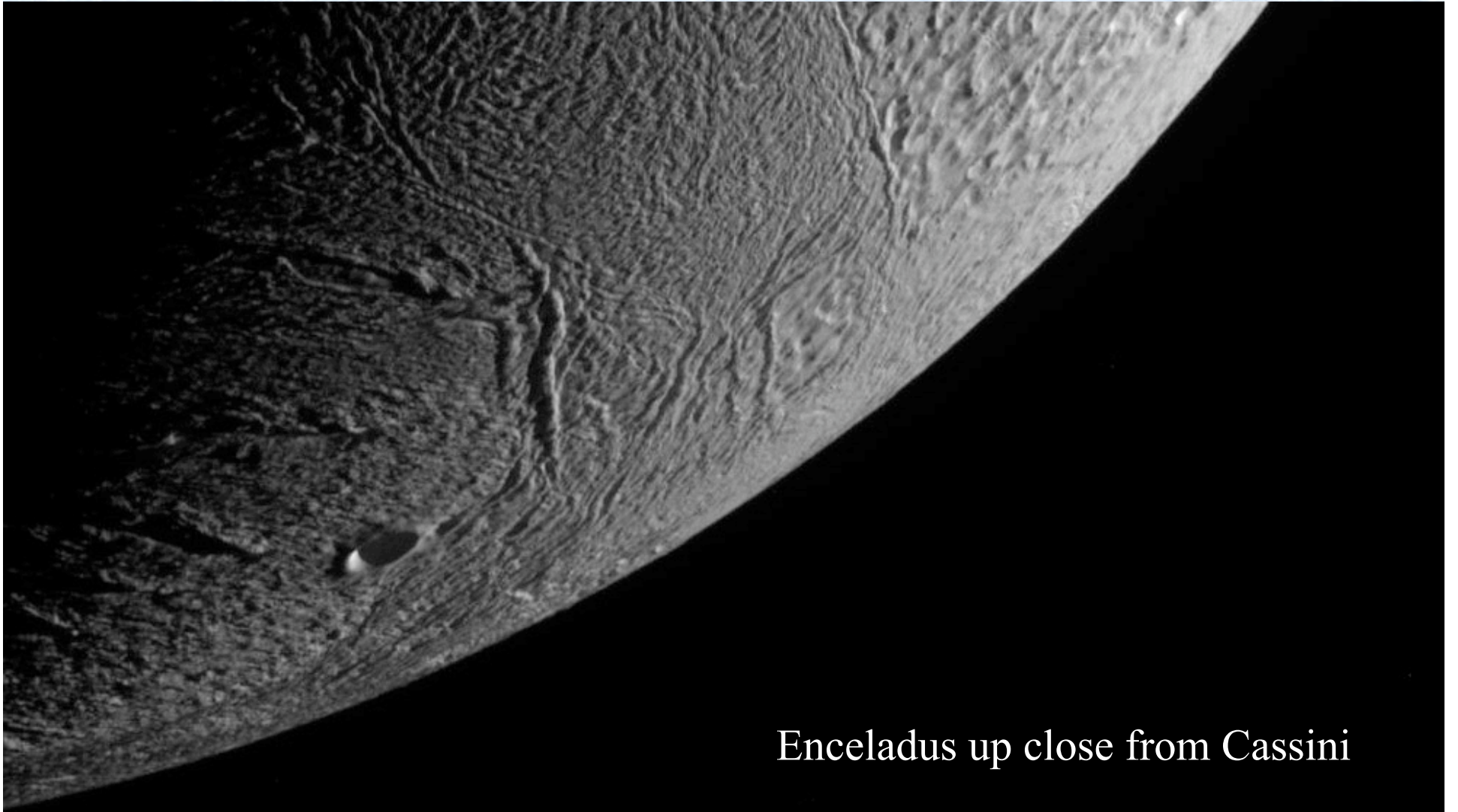


Enceladus in front of Saturn



Enceladus in front of Saturn



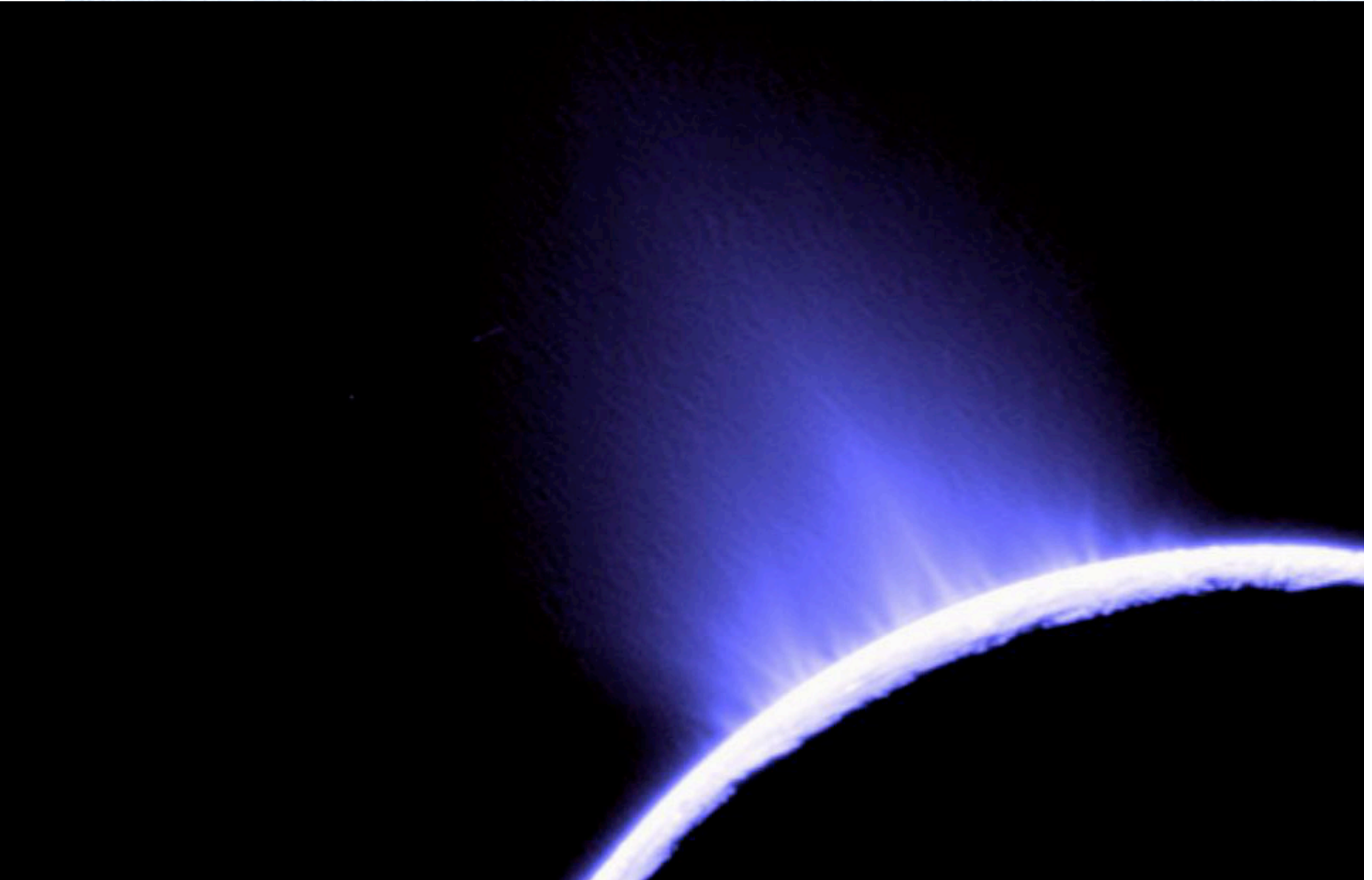


Enceladus up close from Cassini

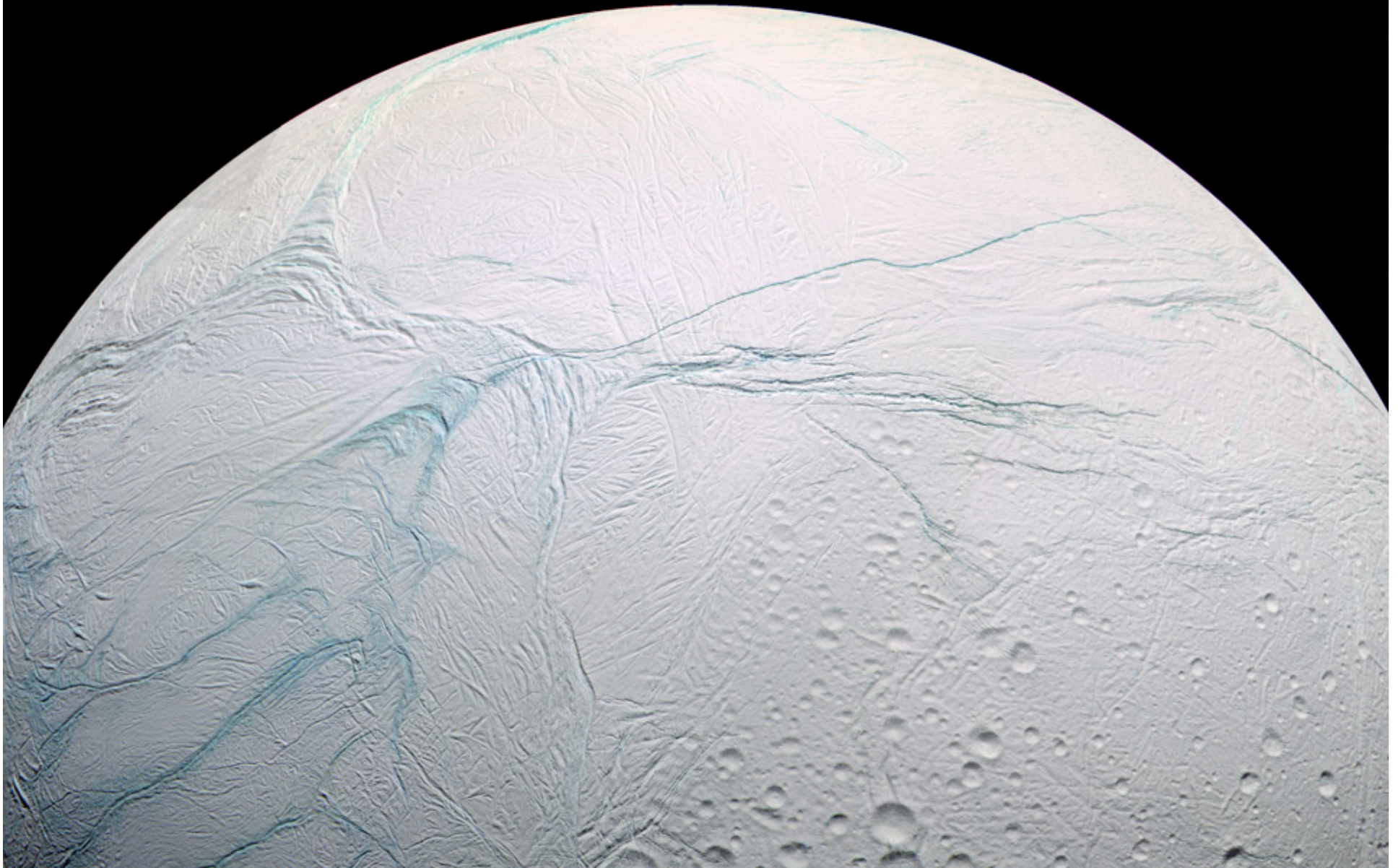
Water ice geysers on Enceladus



Processed and colored image of the ice geysers of Enceladus



Enceladus

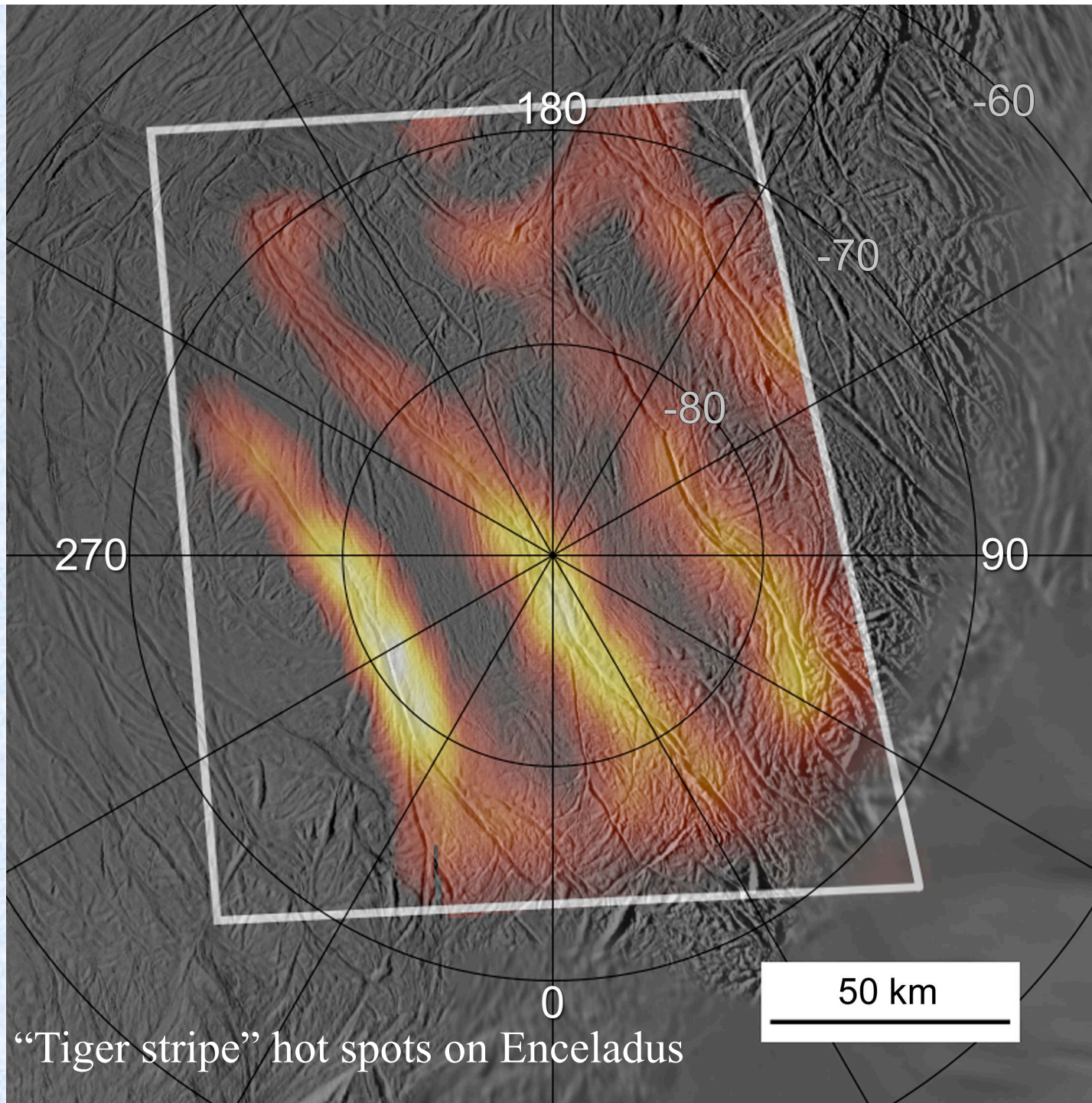


Enceladus up close from Cassini

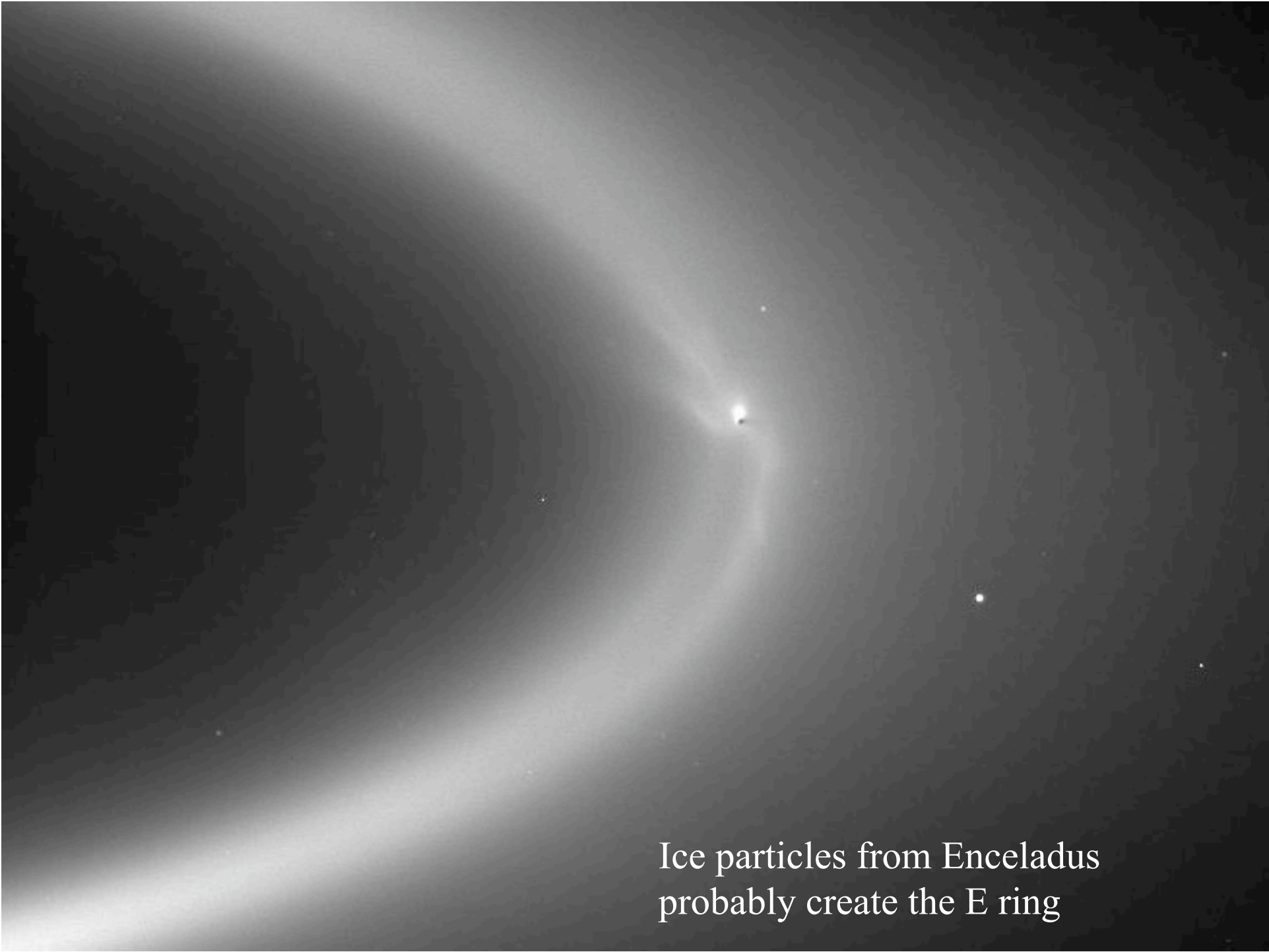


Enceladus up close from Cassini



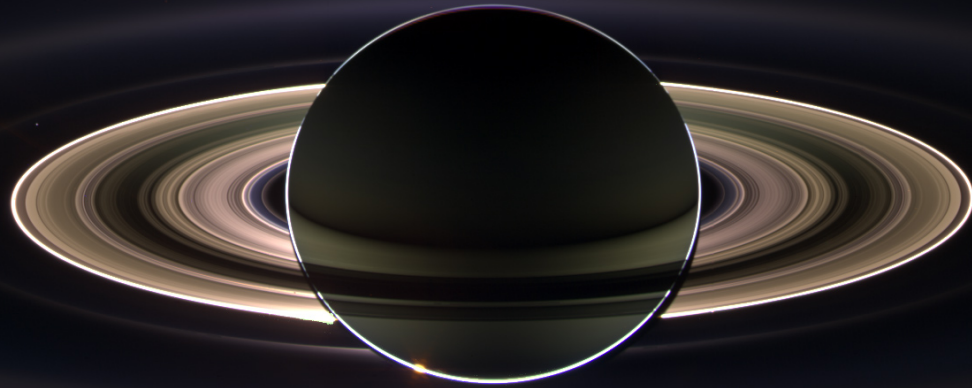


“Tiger stripe” hot spots on Enceladus

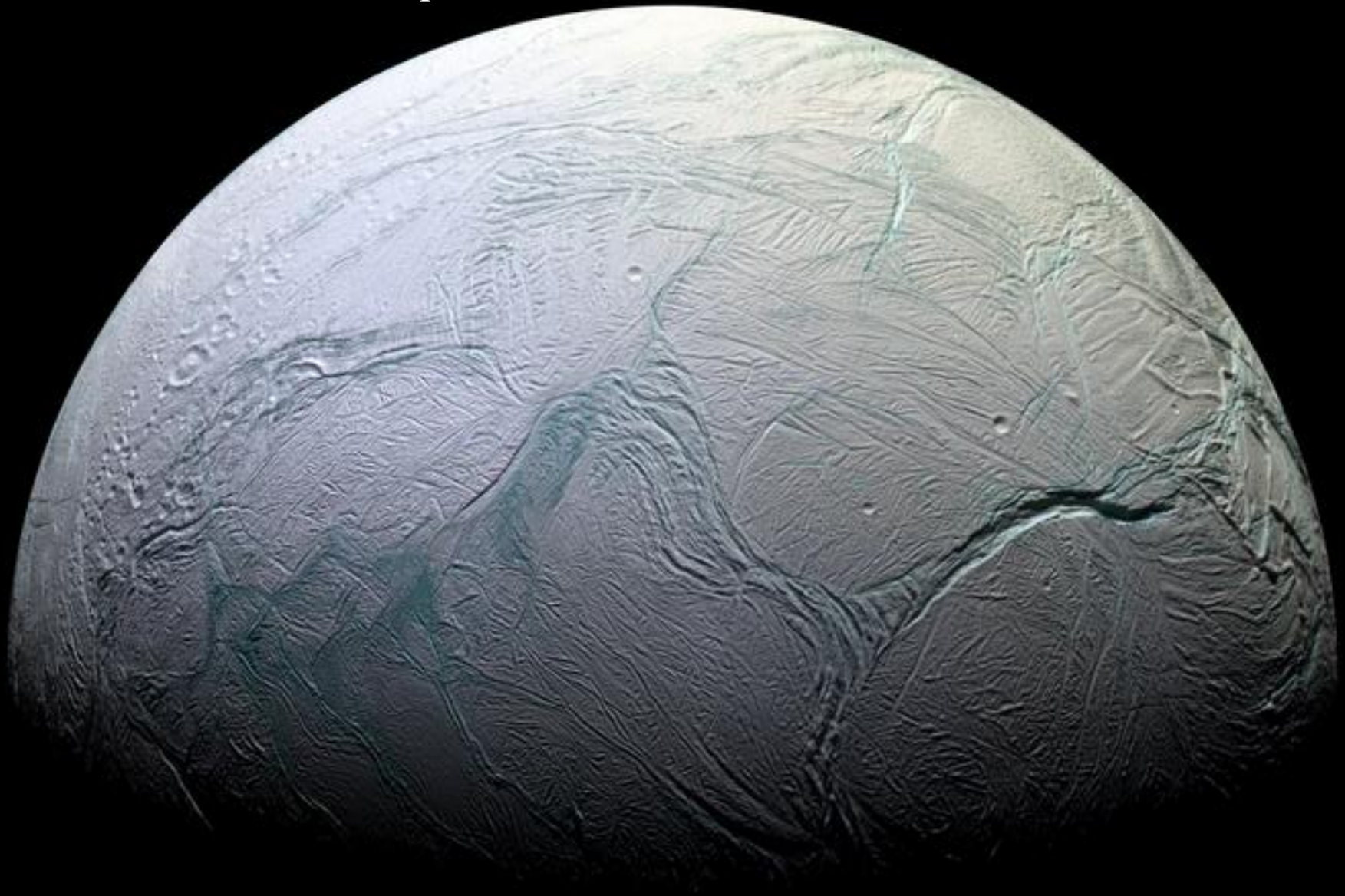


Ice particles from Enceladus
probably create the E ring

Saturn backlit as seen by Cassini



False color Enceladus up close from Cassini



Enceladus "Cold geyser" Model

H₂O vapor plus ice particles

H₂O Ice T = ~77 K

Vent to surface

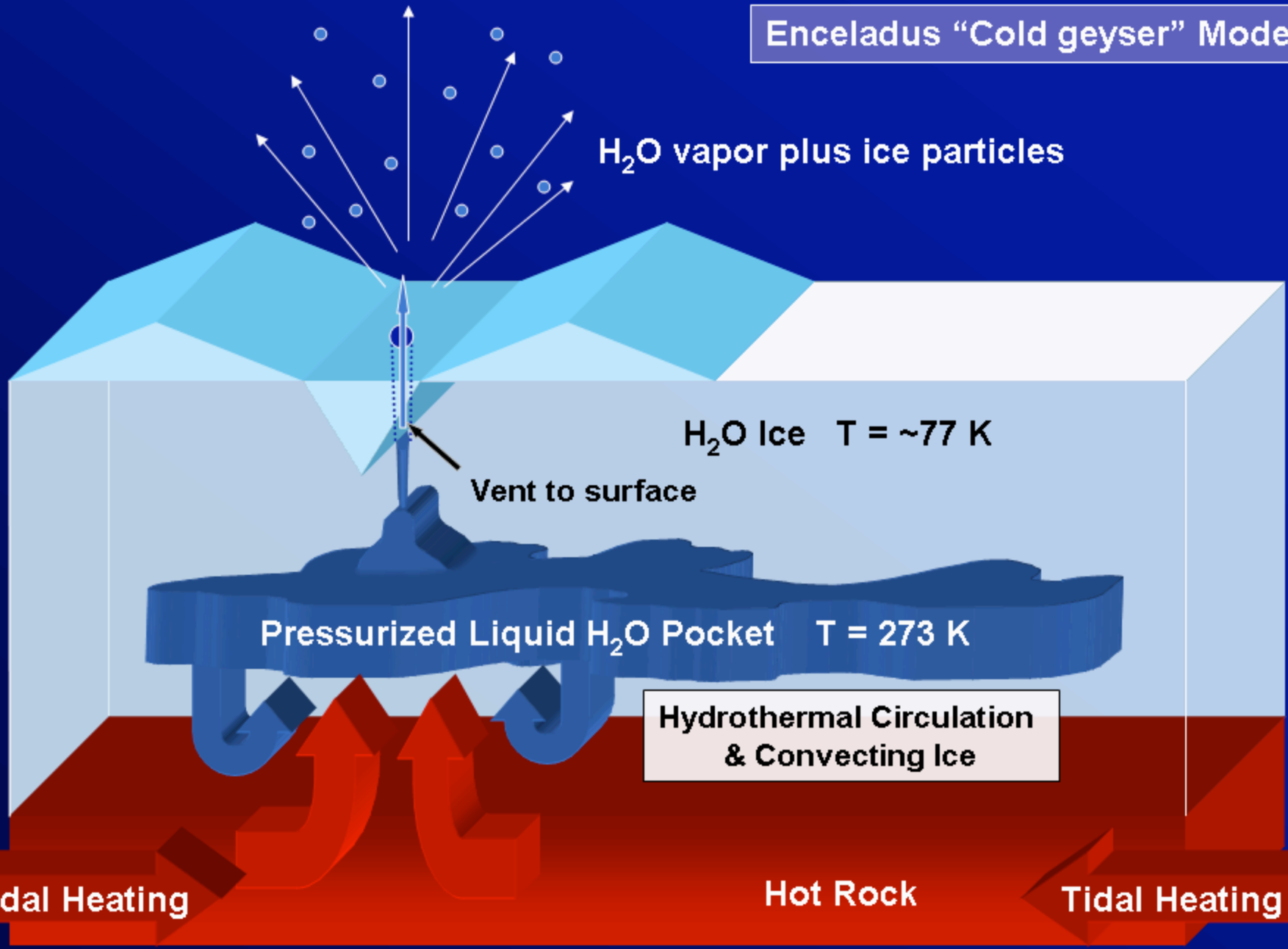
Pressurized Liquid H₂O Pocket T = 273 K

Hydrothermal Circulation
& Convecting Ice

Tidal Heating

Hot Rock

Tidal Heating





Summary

- **Nature of the four Galilean Satellites:**
 - orbit Jupiter in the plane of its equator in synchronous rotation.
 - The orbital periods of the three innermost Galilean satellites, Io, Europa, and Ganymede, are in the ratio 1:2:4.
 - The two innermost Galilean satellites, Io and Europa, have roughly the same size and density as our Moon -> composed principally of rocky material.
 - The two outermost Galilean satellites, Ganymede and Callisto, are roughly the size of Mercury. Lower in density than either the Moon or Mercury, they are made of roughly equal parts ice and rock.
 - The Galilean satellites probably formed in a similar fashion to our solar system but on a smaller scale.

Summary

- **Io:** volcanic activity powered by tidal forces.
- **Europa:** covered with a smooth layer of water ice, and perhaps oceans underneath. Tidal heating powers “water tectonics”
- **Ganymede:** highly differentiated, and probably has a metallic core. It has a surprisingly strong magnetic field and a magnetosphere of its own (liquid water). Tidal heating important in the past. Liquid ocean?
- **Callisto:** heavily cratered crust of water ice. The surface shows little sign of geologic activity, because there was never any significant tidal heating of Callisto. However, some unknown processes have erased the smallest craters and blanketed the surface with a dark, dusty substance.

Summary

- **Titan:** a terrestrial world with a dense nitrogen atmosphere. A variety of hydrocarbons are produced there by the interaction of sunlight with methane. These compounds form an aerosol layer in Titan's atmosphere and fall as a gentle rain on the surface, forming streams and rivers.
- Intermediate moons (Mimas, Enceladus, Tethys, Dione, Rhea, and Iapetus). They are probably composed largely of ice, but their surface features and histories vary significantly.
- Smaller moons include shepherd satellites that control the shapes of Saturn's rings and captured asteroids in large retrograde orbits.

The End

See you on Monday!