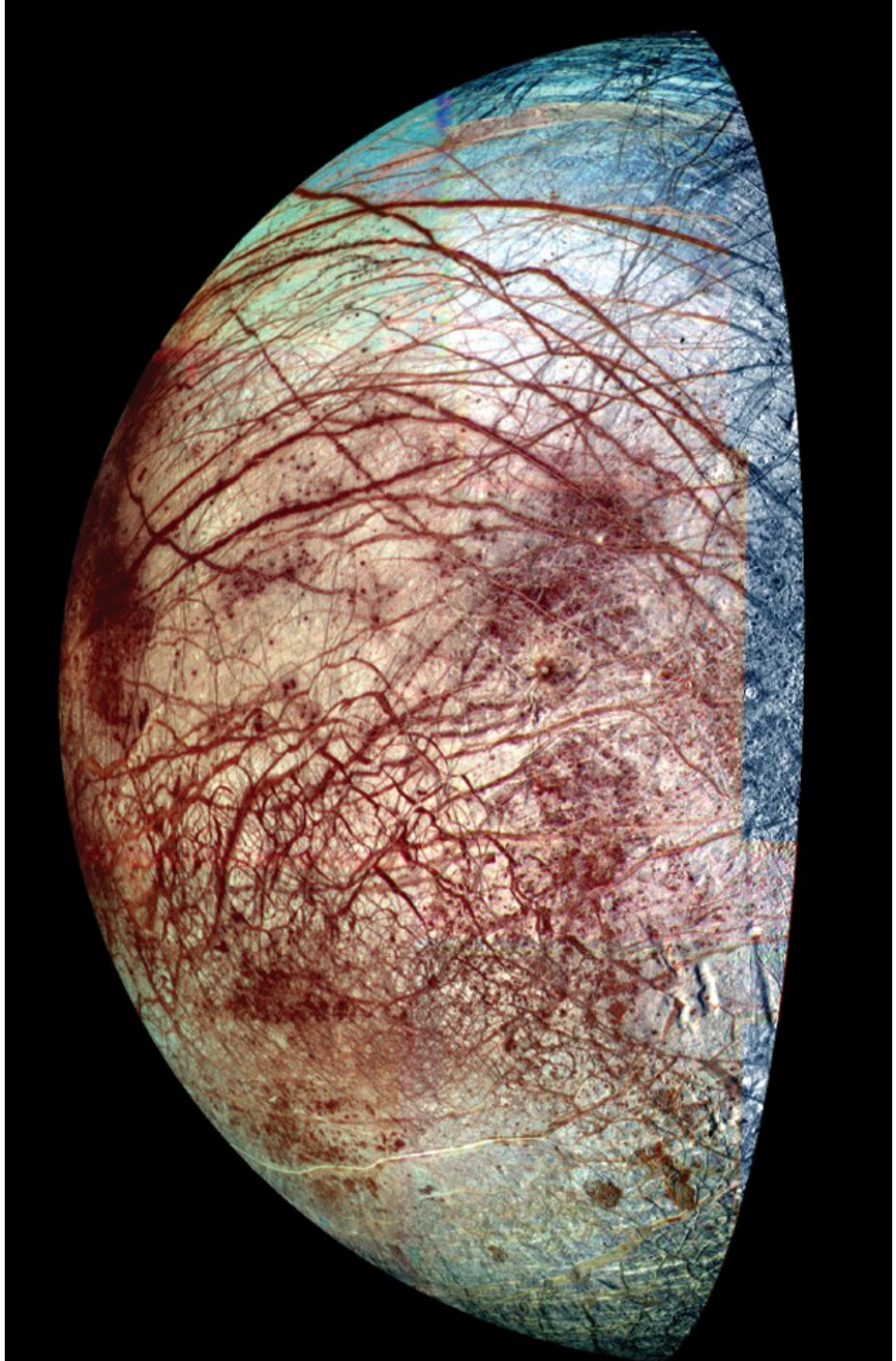


Jupiter and Saturn's Satellites of Fire and Ice

Chapter Fifteen

ASTR 111 – 003 **Fall 2006**
Lecture 12 Nov. 20, 2006

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II
Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury
Ch12: Cloud-covered Venus
Ch13: Red Planet Mars

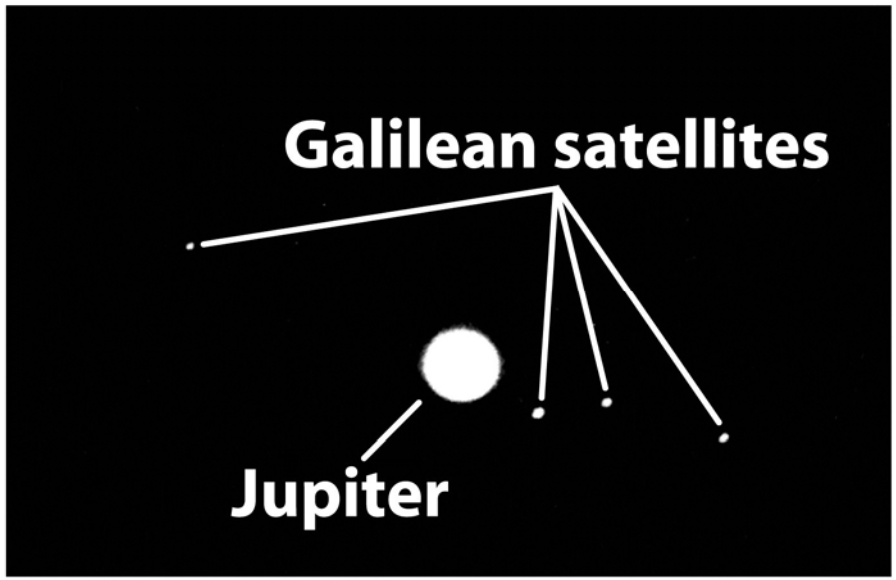
Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn

Ch16: Outer World
Ch17: Vagabonds of Solar System

Guiding Questions

1. What is special about the orbits of Jupiter's Galilean satellites?
2. Are all the Galilean satellites made of rocky material, like the Earth's moon?
3. What could account for differences between the inner and outer Galilean satellites?
4. Why does Io have active volcanoes? How does Io's volcanic activity differ from that on Earth?
5. How does Io act like an electric generator?
6. What is the evidence that Europa has an ocean beneath its surface?
7. What is unusual about the magnetic fields of Ganymede and Callisto?
8. How is it possible for Saturn's moon Titan to have an atmosphere?
9. Why do some of Jupiter's moons orbit in the "wrong" direction?
10. What kinds of geologic activity are seen on Saturn's medium-sized satellites?

Jupiter's Galilean satellites



Io

Europa

Ganymede

Callisto

- The four Galilean satellites orbit Jupiter in the plane of its equator:
- All are in synchronous rotation
  - Rotation period and orbital period are in a 1-to-1 ratio
- The orbital periods of the three innermost Galilean satellites, are in the ratio 1:2:4
  - This pattern indicates gravitational interaction among the satellites

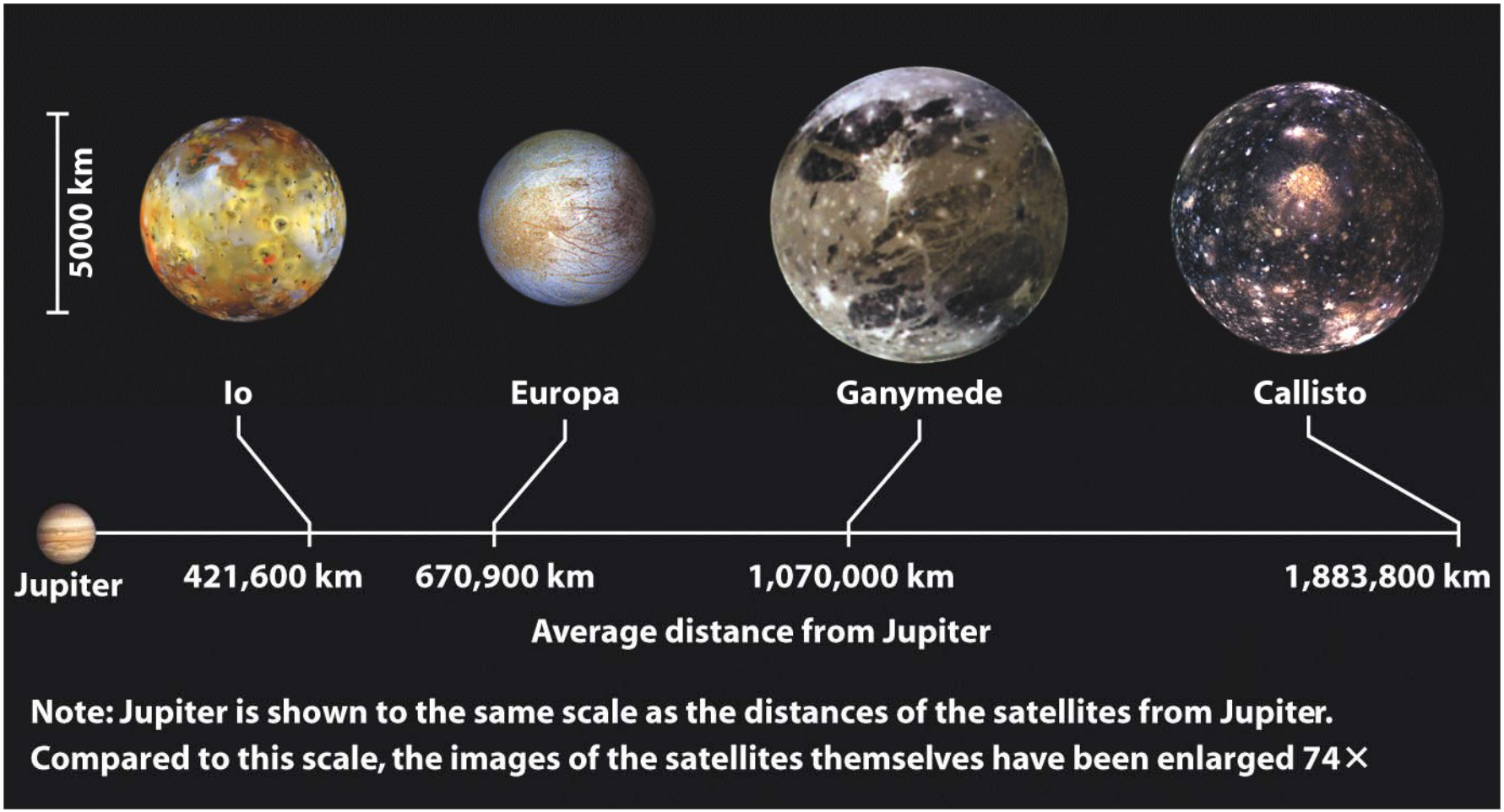
Jupiter's Galilean satellites

table 15-1 The Galilean Satellites Compared with the Moon, Mercury, and Mars

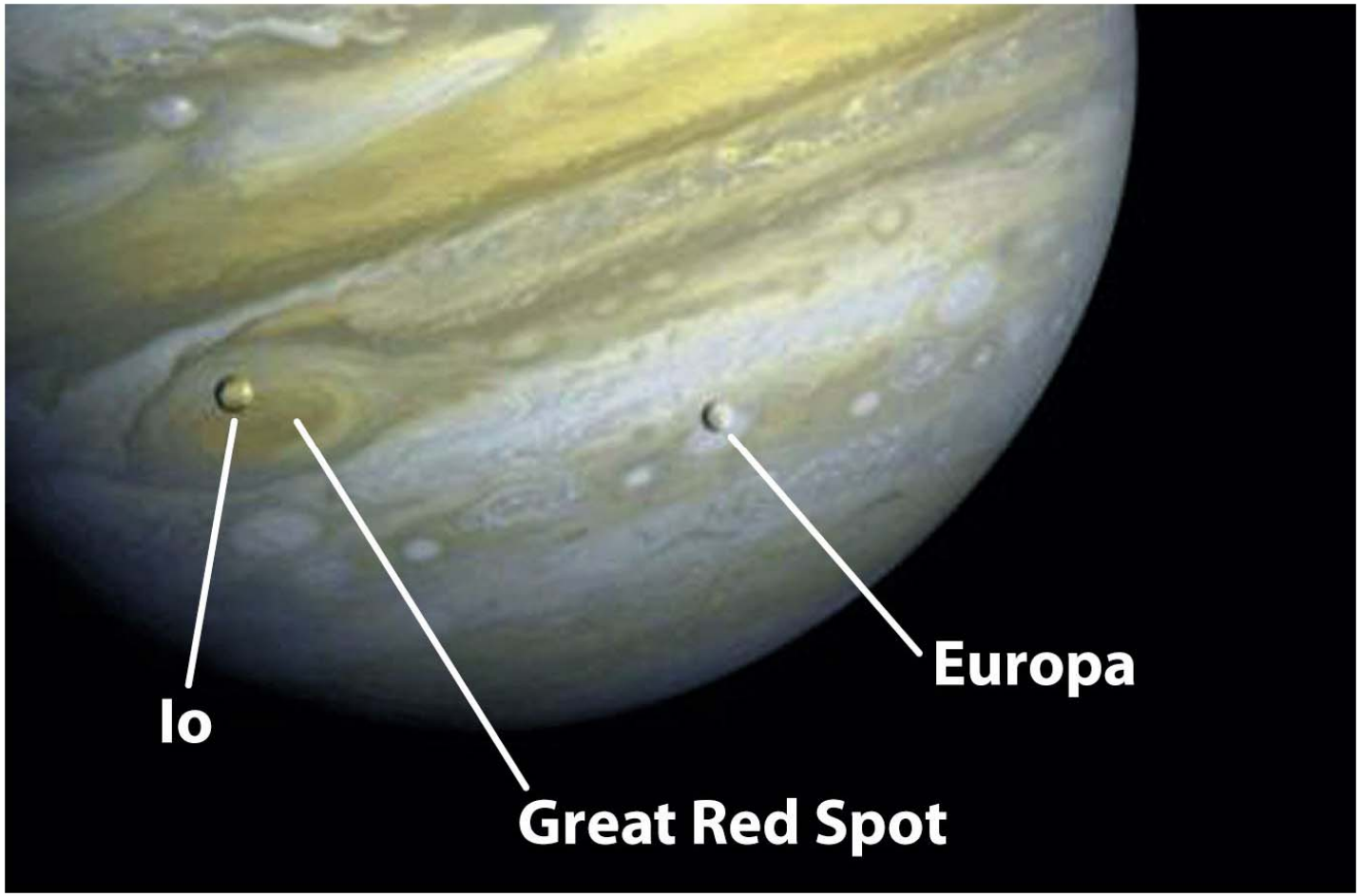
	Average distance from Jupiter (km)	Orbital period (days)	Diameter (km)	Mass (kg)	Mass (Moon = 1)	Average density (kg/m^3)	Albedo
Io	421,600	1.769	3642	8.932×10^{22}	1.22	3529	0.63
Europa	670,900	3.551	3120	4.791×10^{22}	0.65	3018	0.64
Ganymede	1,070,000	7.155	5268	1.482×10^{23}	2.02	1936	0.43
Callisto	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

- The two innermost Galilean satellites, Io and Europa, have roughly the same size and density as our Moon
- They are 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 of ice and rock

Jupiter’s Galilean satellites



Jupiter’s Galilean satellites



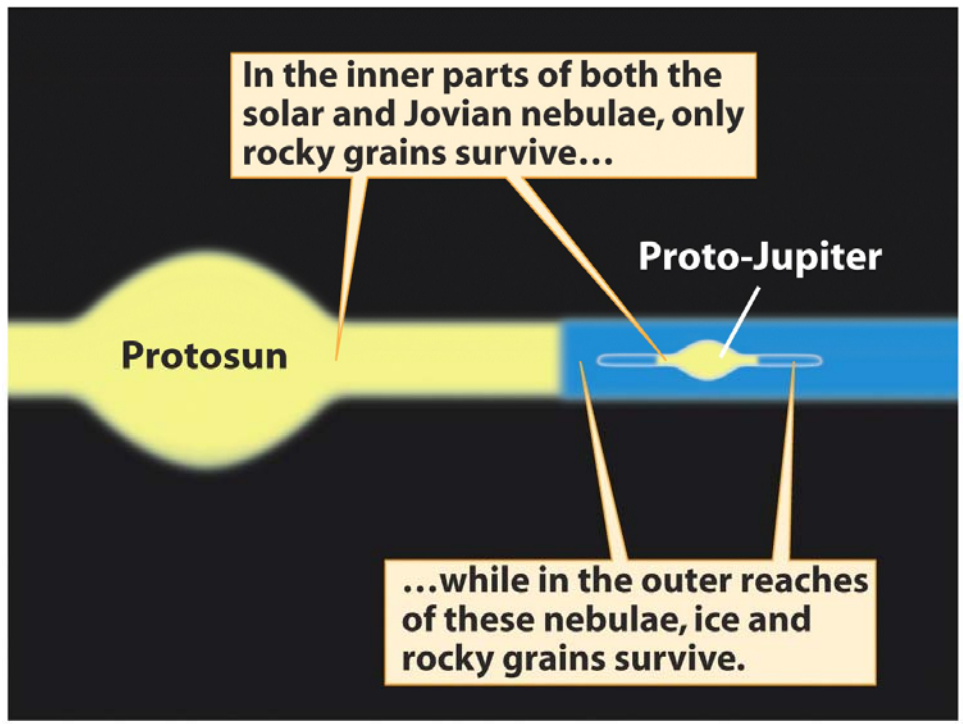
Transits of Jupiter’s Satellites

Origin of Galilean satellites

- The Galilean satellites formed like a solar system in miniature
  - Similarity in density pattern: decease as moving outward
- Jupiter is a “failed star”
- Its internal temperature and pressure is not high enough to ignite nuclear reaction

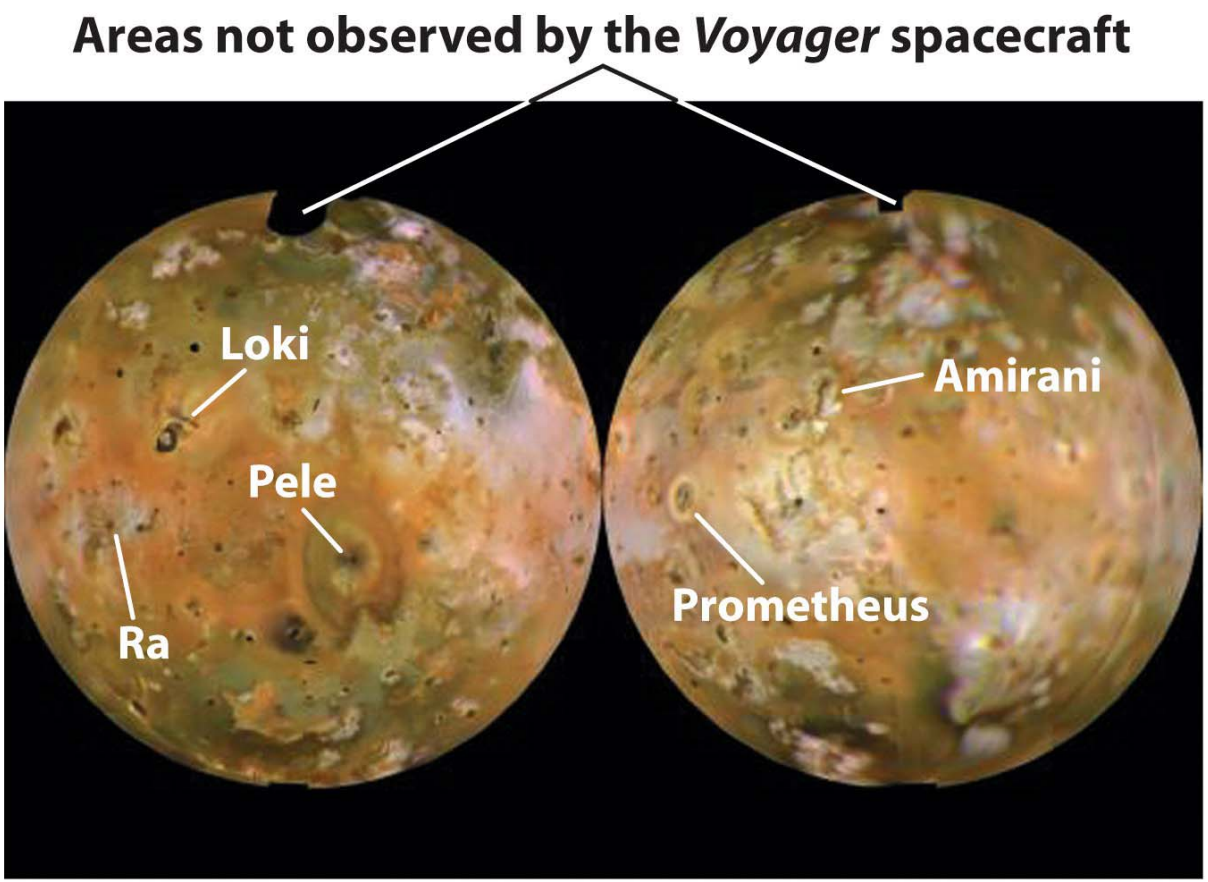
Origin of Galilean satellites

- Jovian nebula
  - In the inner part where is warmer, only dense and rocky grains were able to survice
  - In the outer part where is cooler, dust grains were able to retain icy coating of low density material such as water and ammonia



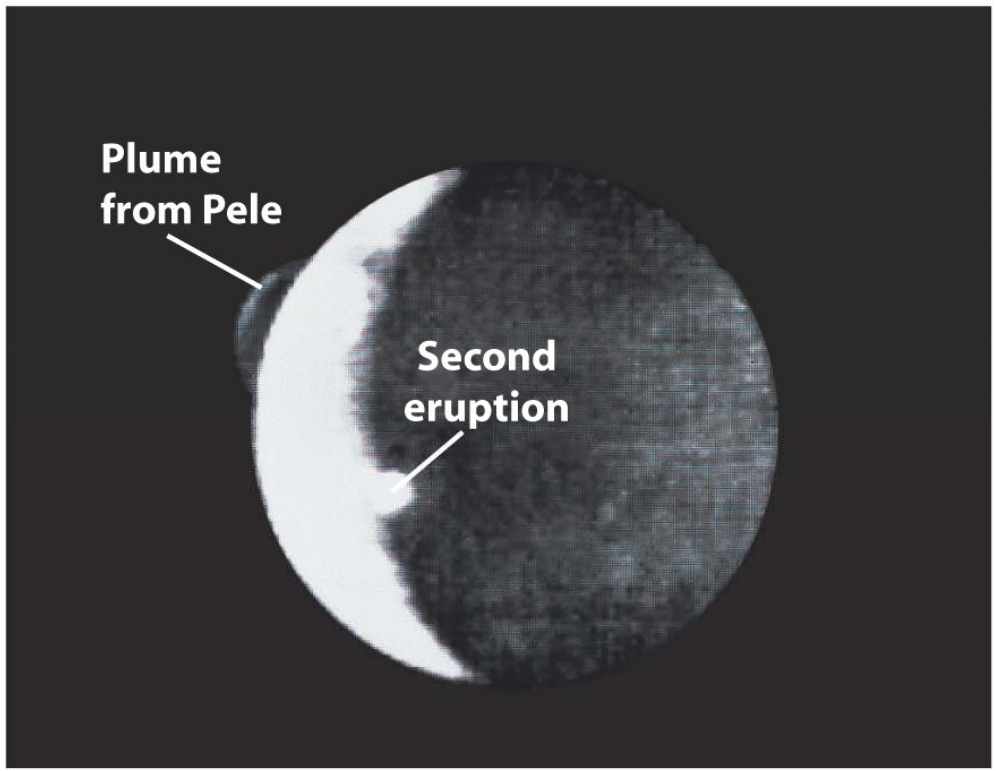
Io

- Unlike the Moon, Io is geologically active
- It has no impact craters
- Io has numerous volcanoes; some are active

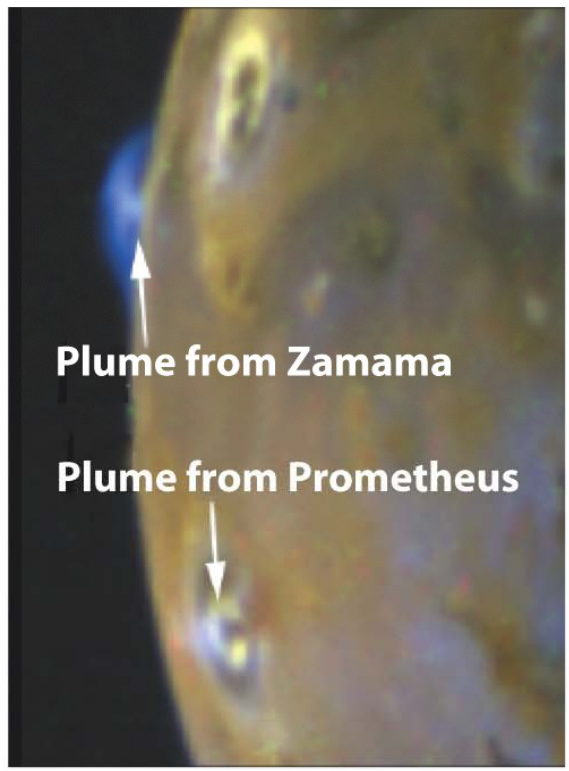


Io

- Plumes are more like geysers: heated steam erupts explosively.
- The plumes are probably sulfur dioxide (SO_2)
- Io's dramatic coloration is due to sulfur and its compounds

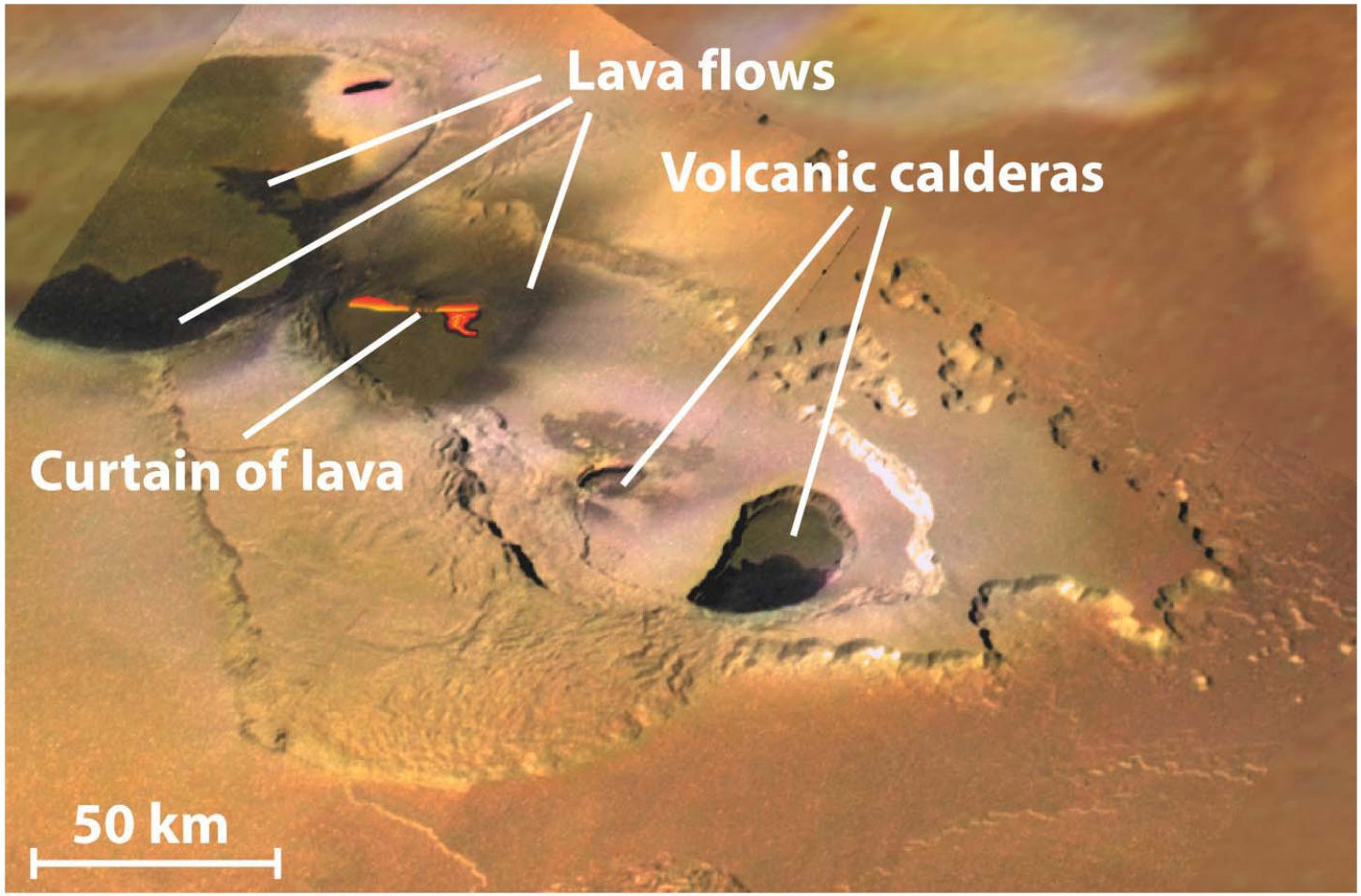


(a) *Voyager 1*, March 1979



(b) *Galileo*, November 1997

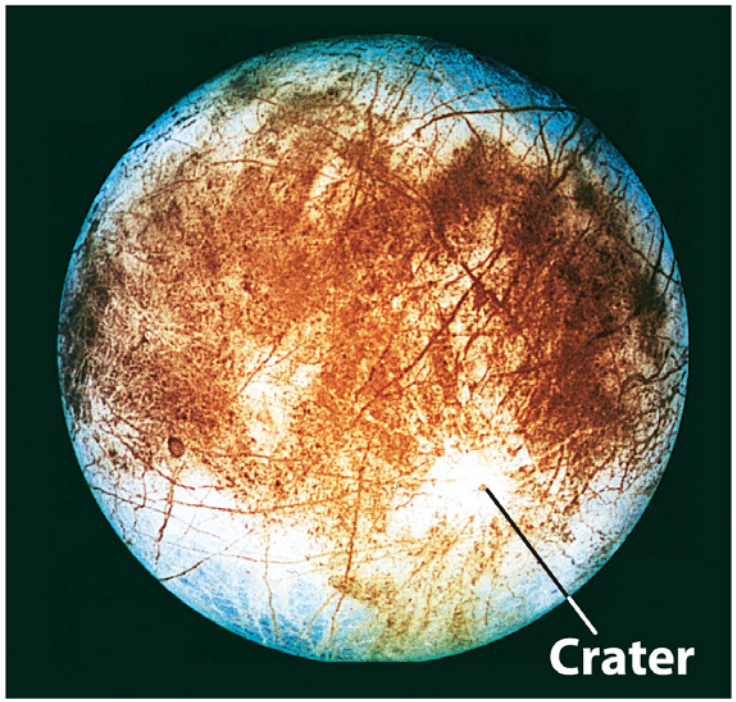
Io



Io: Tidal Heating

- The energy to heat Io's interior and produce the satellite's volcanic activity comes from tidal forces that flex the satellite
- Europe and Gallisto exert gravitational force on Io, and distort Io's orbit into ellipse
- Io's long axis "nods" back and forth half degree
- The tidal stress that Jupiter exerts on Io varies periodically
- The varying tidal stresses alternatively squeeze and flex Io
- This tidal flexing is aided by the 1:2:4 ratio of orbital periods among the inner three Galilean satellites
- Tidal heating provides 2.5 Watts of power per square meter of Io's surface
- As comparison, the average heat flow through Earth is 0.06 Watts per square meter.

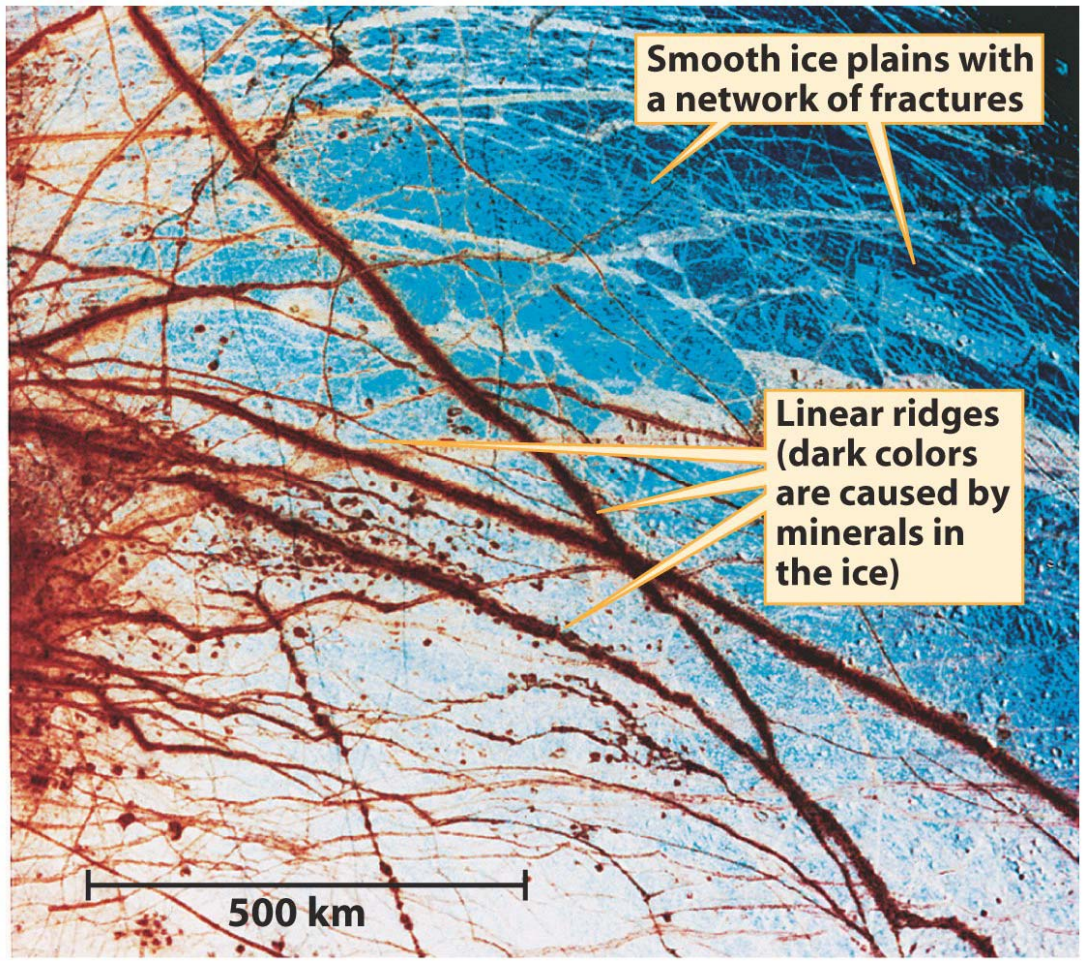
Europa



- While composed primarily of rock, Europa is covered with a smooth layer of water ice
- The surface has hardly any craters, indicating a very young surface and geologically active history
- Water is brought from interior to the surface, making a fresh, smooth layer of ice.
- Europa is too small to have retained the internal heat it had when it first formed.
- As for Io, tidal heating is responsible for Europa's internal heat

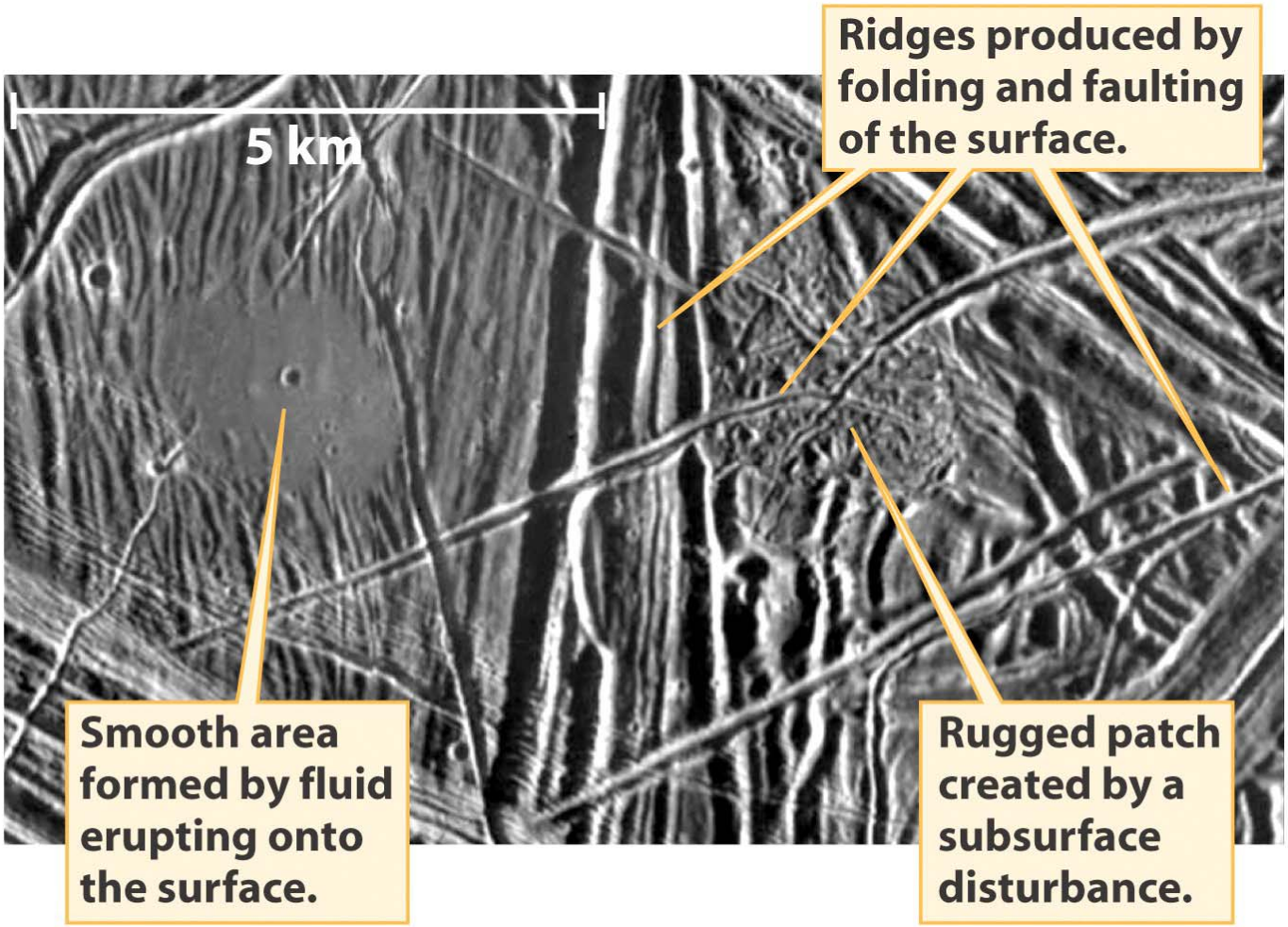
Europa

•A worldwide network of long cracks and ice rafts that indicate a subsurface layer of liquid water or soft ice



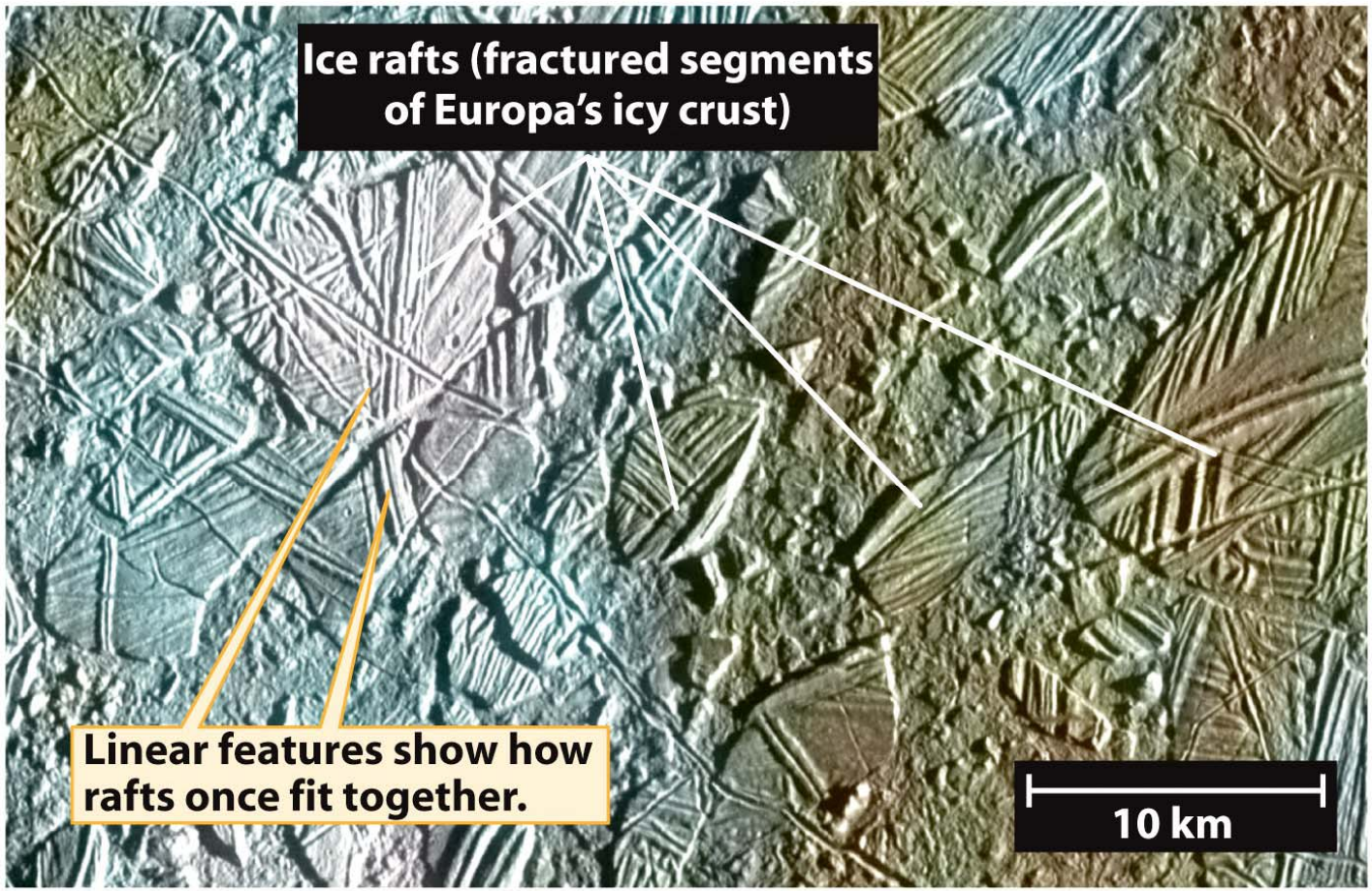
Europa

Complex geologic activity: need enough energy to power



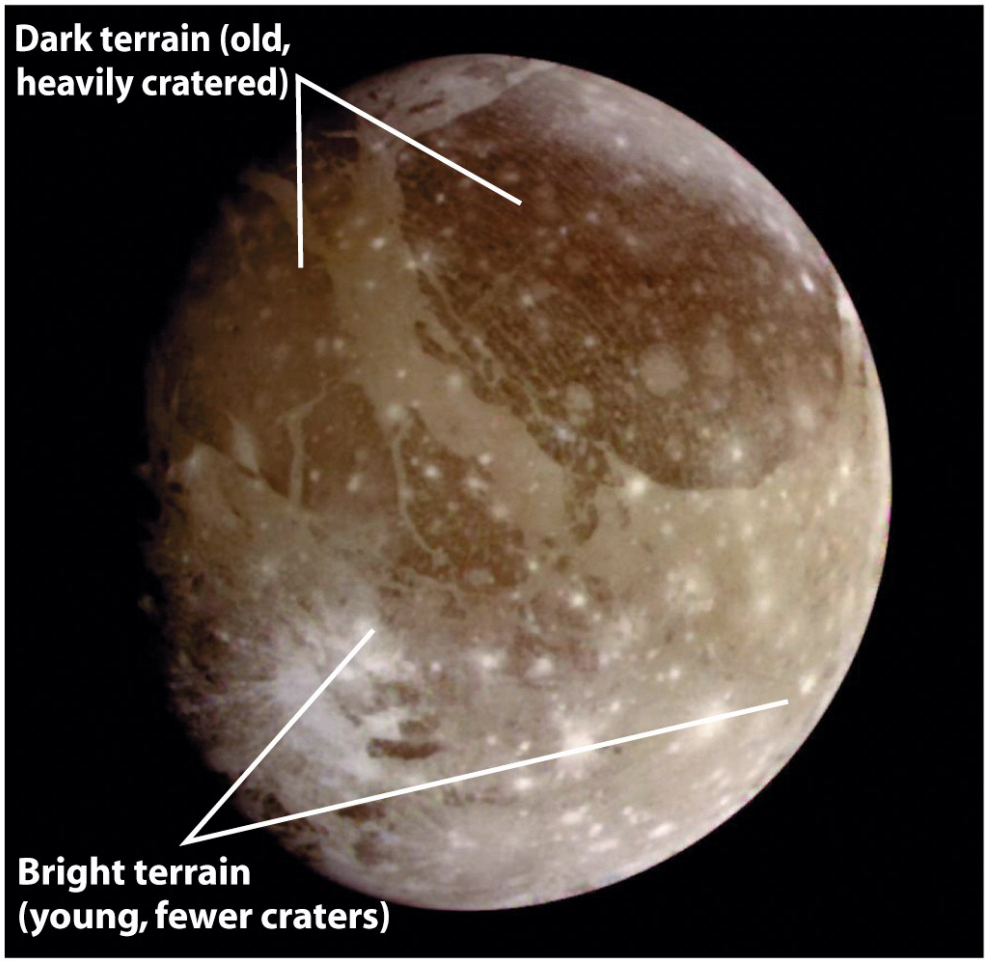
Europa

Complex geologic activity: need enough energy to power



Ice rafts on Europa

Ganymede

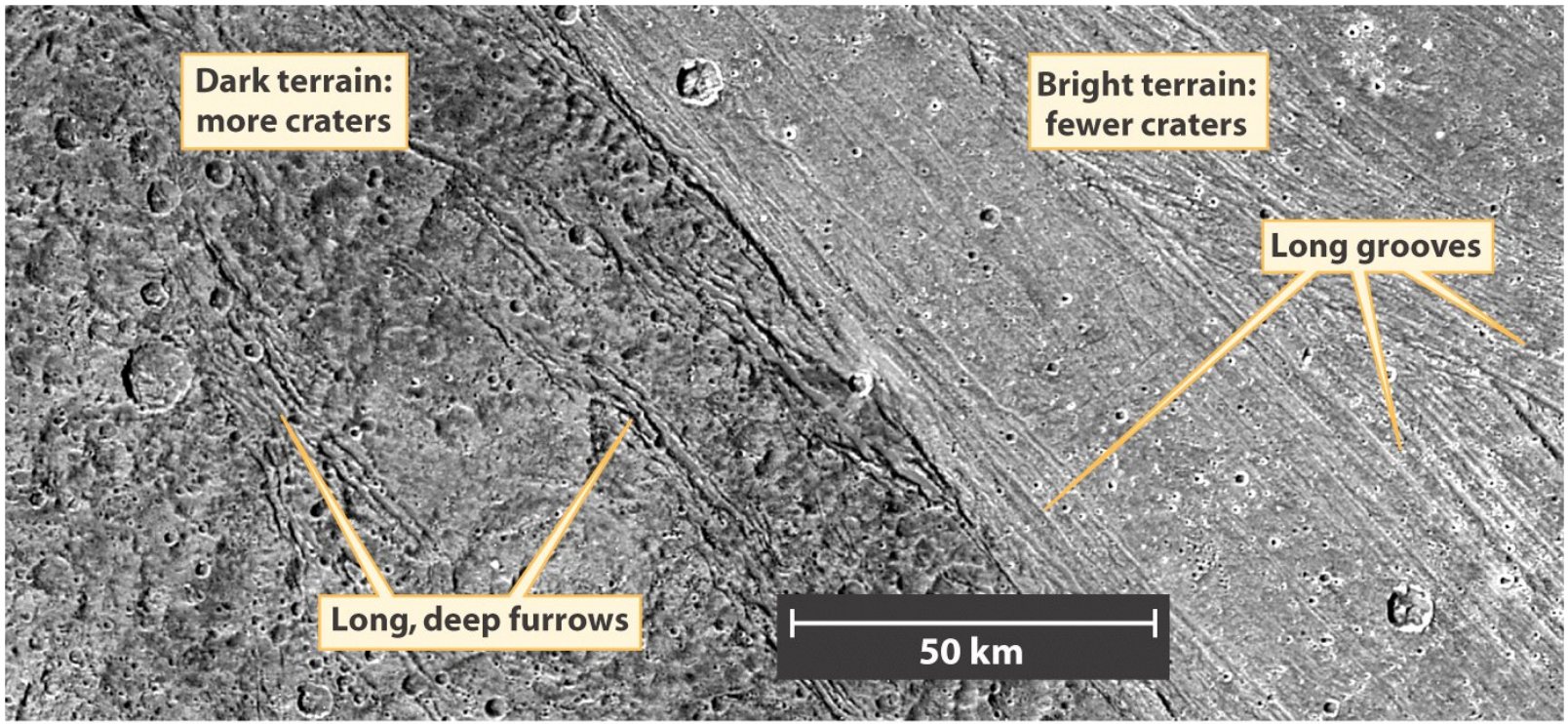


- Ganymede has two kinds of terrain
- Dark terrain
  - Heavily cratered
  - Older
- Bright terrain
  - Less cratered
  - Younger

- As comparison, moon has young but dark mare, and old but bright highland.

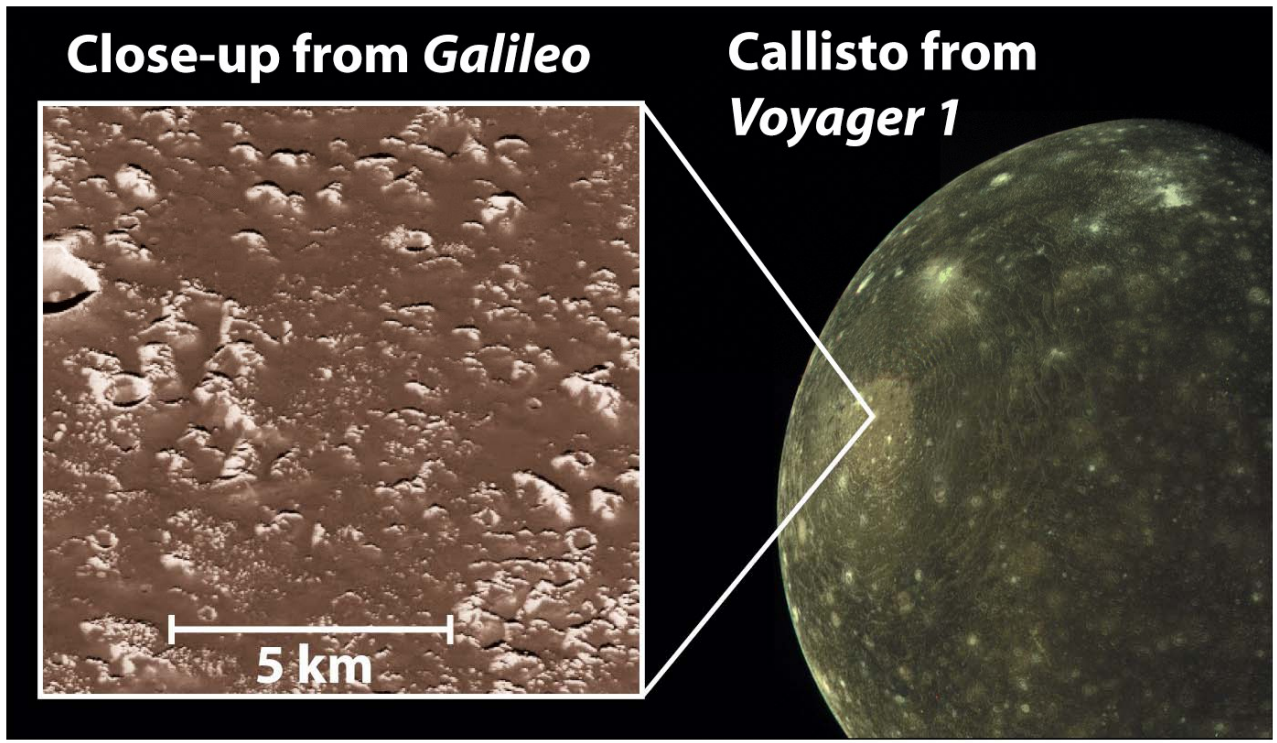
Ganymede

- Bright terrain is heavily grooved
- Bright terrain appeared to be flooded by a watery fluid that subsequently froze, along the long grooves.
- Ganymede has liquid water a billion years ago



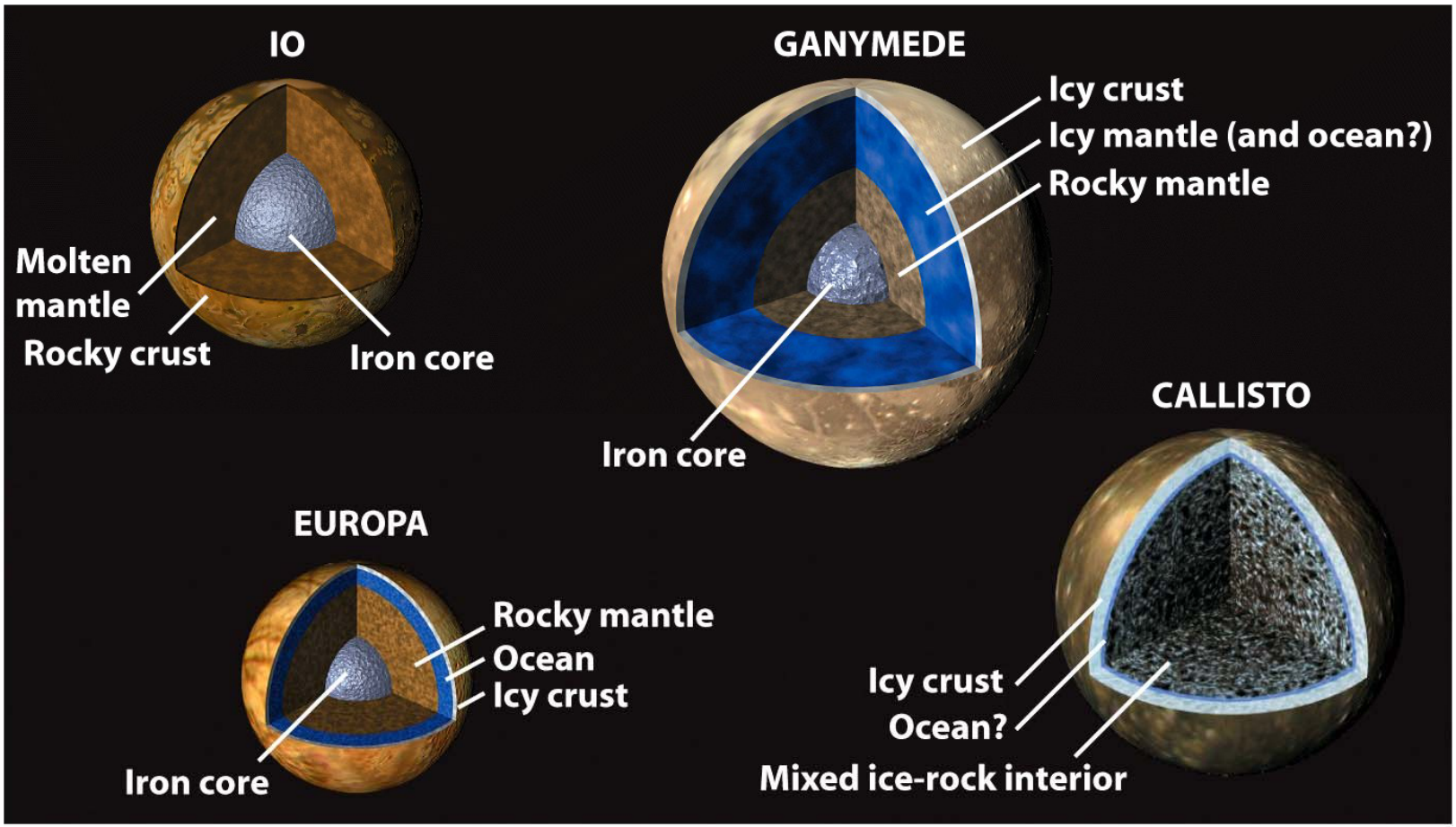
Callisto

- Callisto has a 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



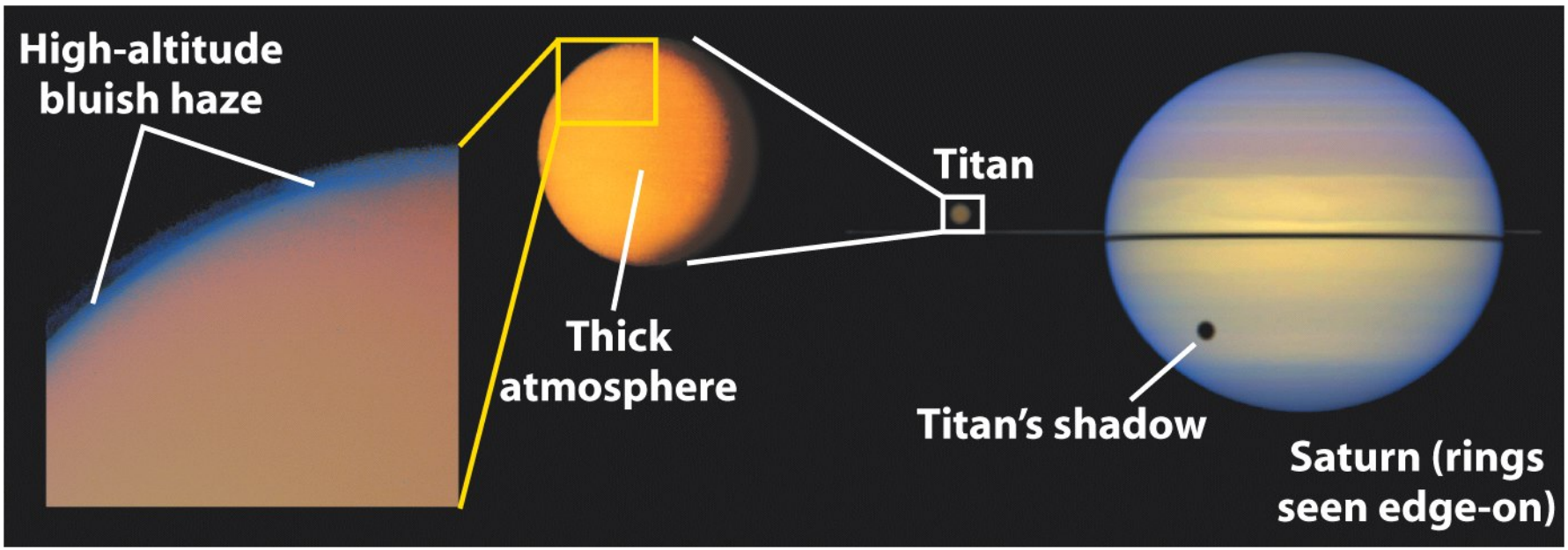
Interiors of Galilean Satellites

- Europe and Ganymede may have global liquid water ocean beneath the icy crust

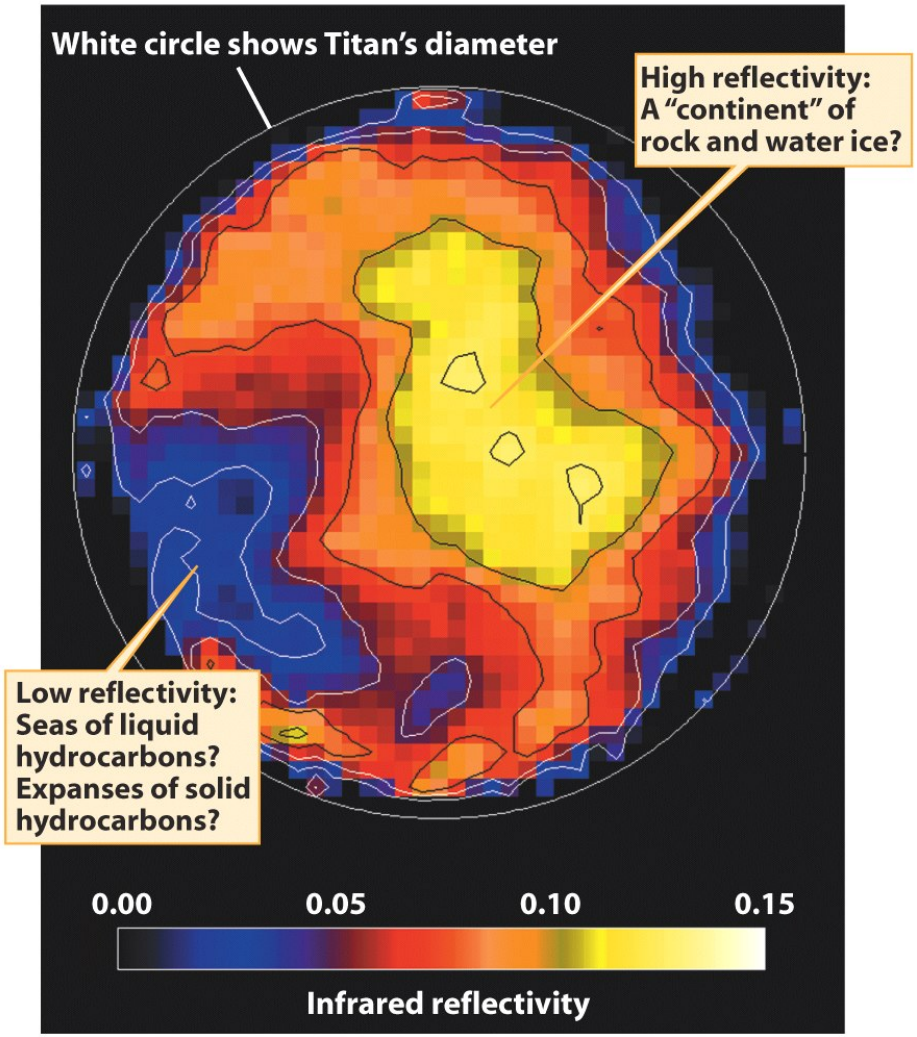


Titan

- Titan is the largest satellite of Saturn
- The featureless appearance indicates it has a thick atmosphere
- Titan is the only satellite in the solar system with an appreciable atmosphere
  - Because it is cool enough and massive enough



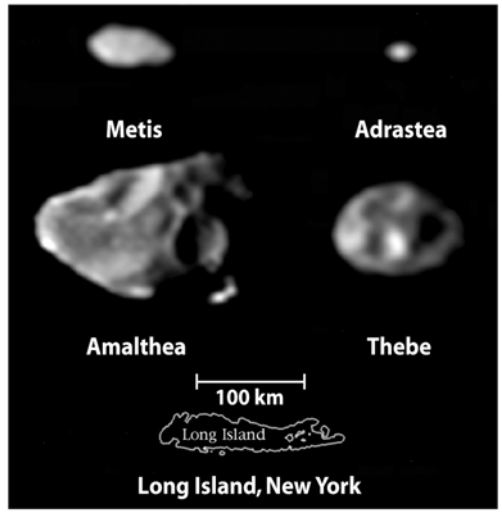
Titan



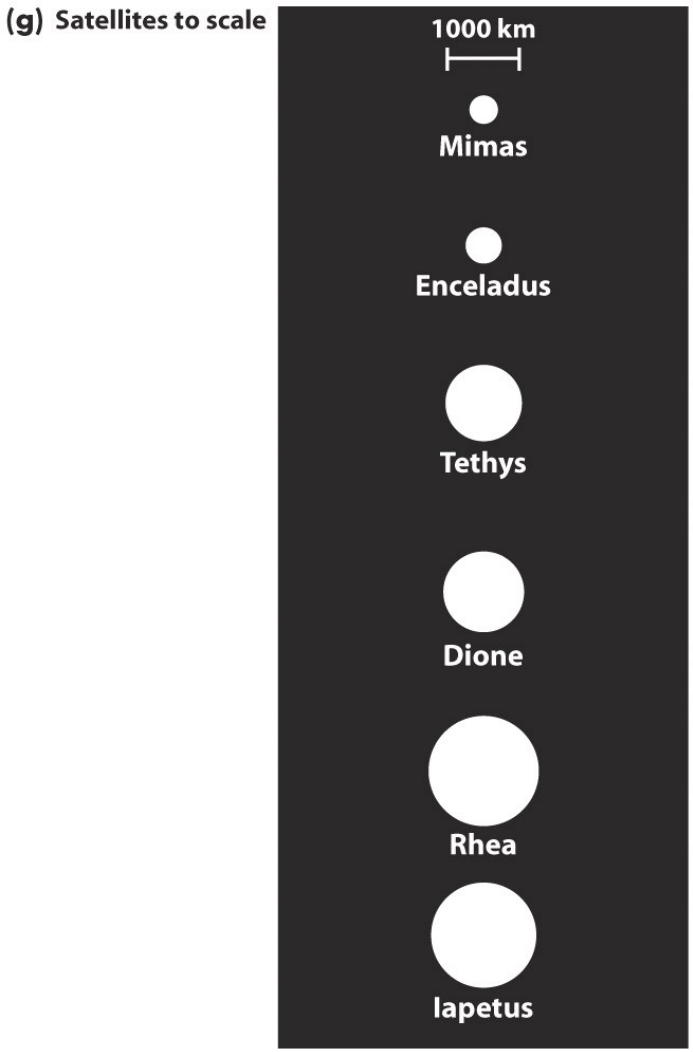
- Titan atmosphere is 90% nitrogen
- The second most abundant gas is methane (CH_4)
- Methane, interaction with ultraviolet light from the Sun, produces a variety of other carbon-hydrogen compounds.
- Titan surface may have liquid methane lake

Jupiter's small satellites

- As of early 2004, Jupiter has a total of 63 known satellites
- In addition to the Galilean satellites, Jupiter has four small inner satellites that lie inside Io's orbit
- Like the Galilean satellites, these orbit in the plane of Jupiter's equator
- The remaining satellites are small and move in much larger orbits that are noticeably inclined to the plane of Jupiter's equator
- Many of these orbit in the direction opposite to Jupiter's rotation
- These small outer satellites are probably asteroids captured by Jupiter's gravity



Saturn’s moons



- As of early 2004, Saturn has a total of 31 known satellites
- In addition to Titan, six moderate-sized moons circle Saturn in regular orbits: Mimas, Enceladus, Tethys, Dione, Rhea, and Iapetus
- They are probably composed largely of ice, but their surface features and histories vary significantly
- The other, smaller moons are captured asteroids in large retrograde orbits

Final Notes on Chap. 15

- There are 10 sections in total.
- The following sections are not covered
  - 15-5 (Io plasma torus)