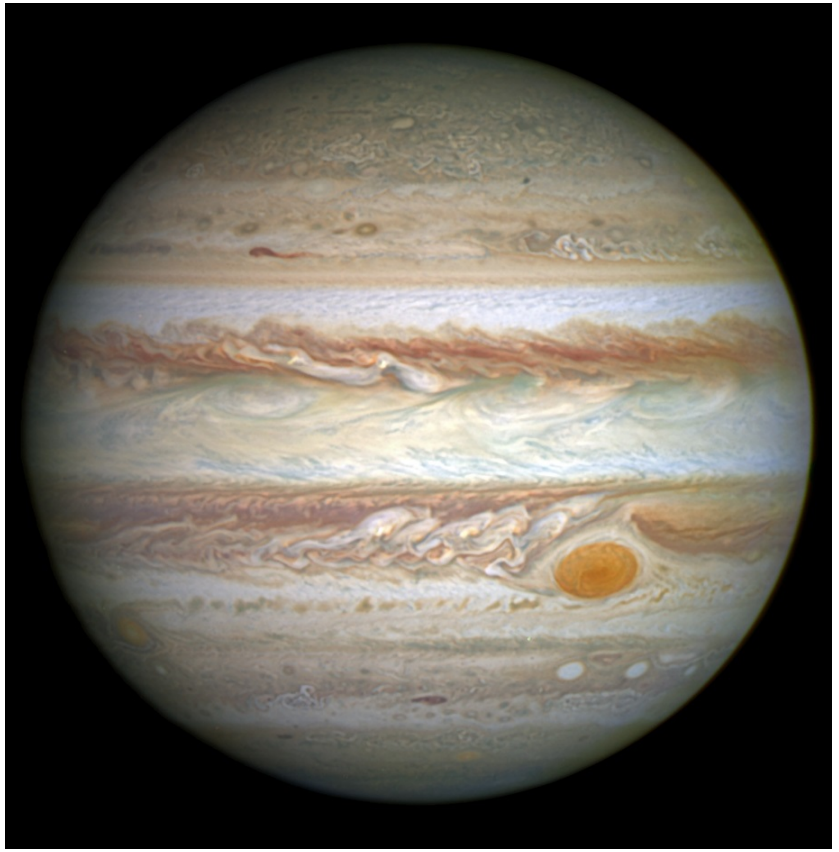
[18] Gas and Ice Giants (10/31/17)

Upcoming Items

1. Homework #8 due now.
2. Homework #9 due Nov 14 (after Midterm 2).
3. Read Ch. 11.2–11.3 by next class and do the self-study quizzes.

Jupiter Wikipedia page

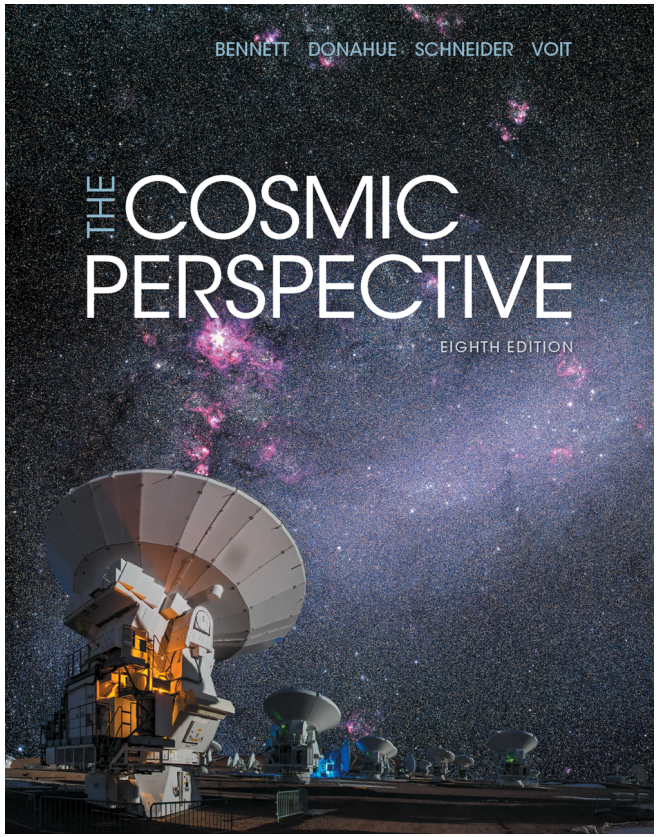


LEARNING GOALS

Chapter 11.1

For this class, you should be able to…

- *understand the differences between jovian and terrestrial planets;*
- *understand the shapes of rotating planets.*



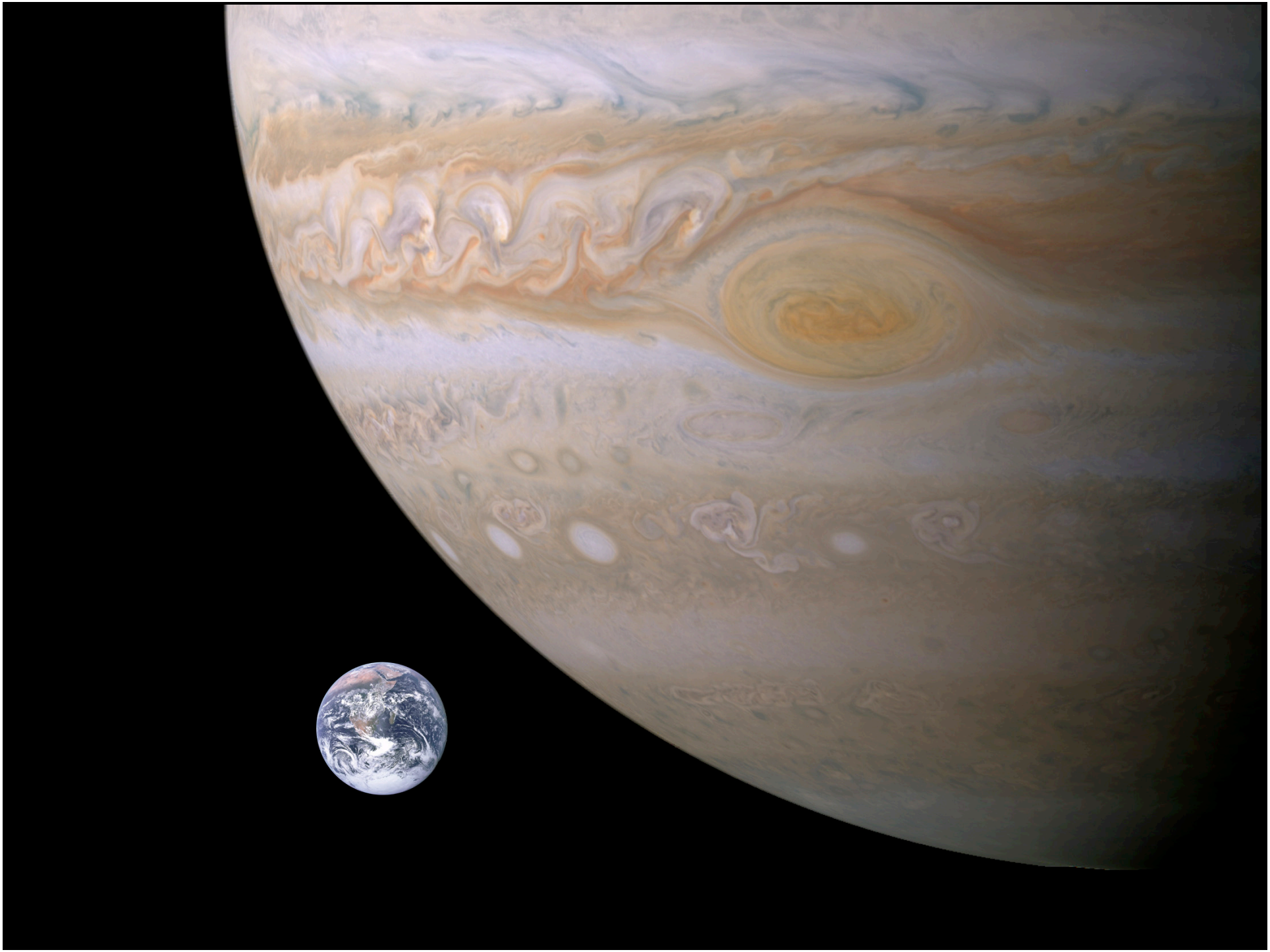
Any astro questions?

Debate!

- Which is more likely to host current life: Mars or Europa?

Astro major?

- Our undergrad advisor, Dr. Melissa Hayes-Gehrke, wants to know:
- By show of hands, how many of you intend to pursue an astronomy major, and therefore take ASTR 121 next semester?
- Thanks!

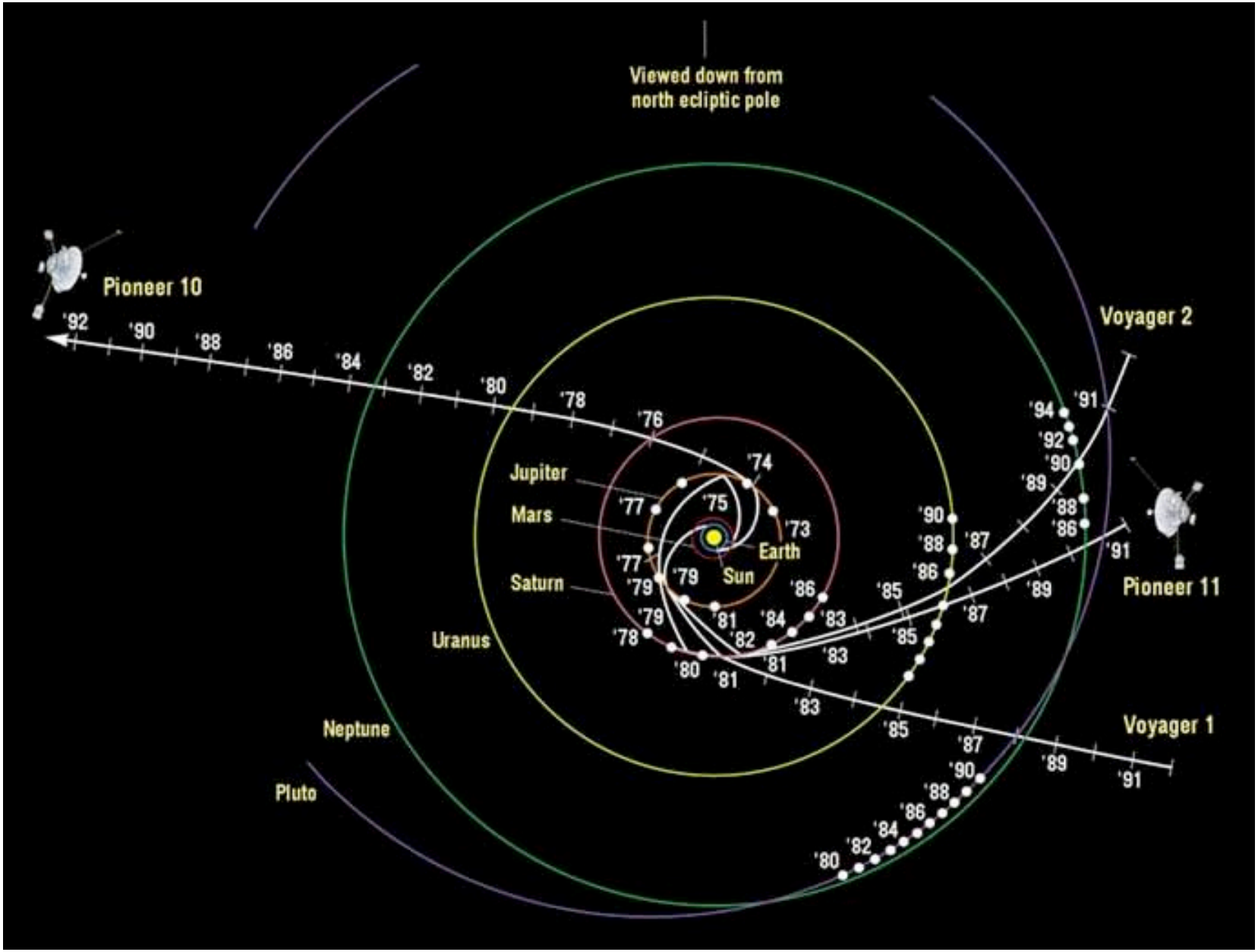


A Different Kind of Planet

- Bigger and more massive.
- Lower density, different composition.
- Rings.
- Numerous moons.

Robotic Exploration of the Outer Solar System

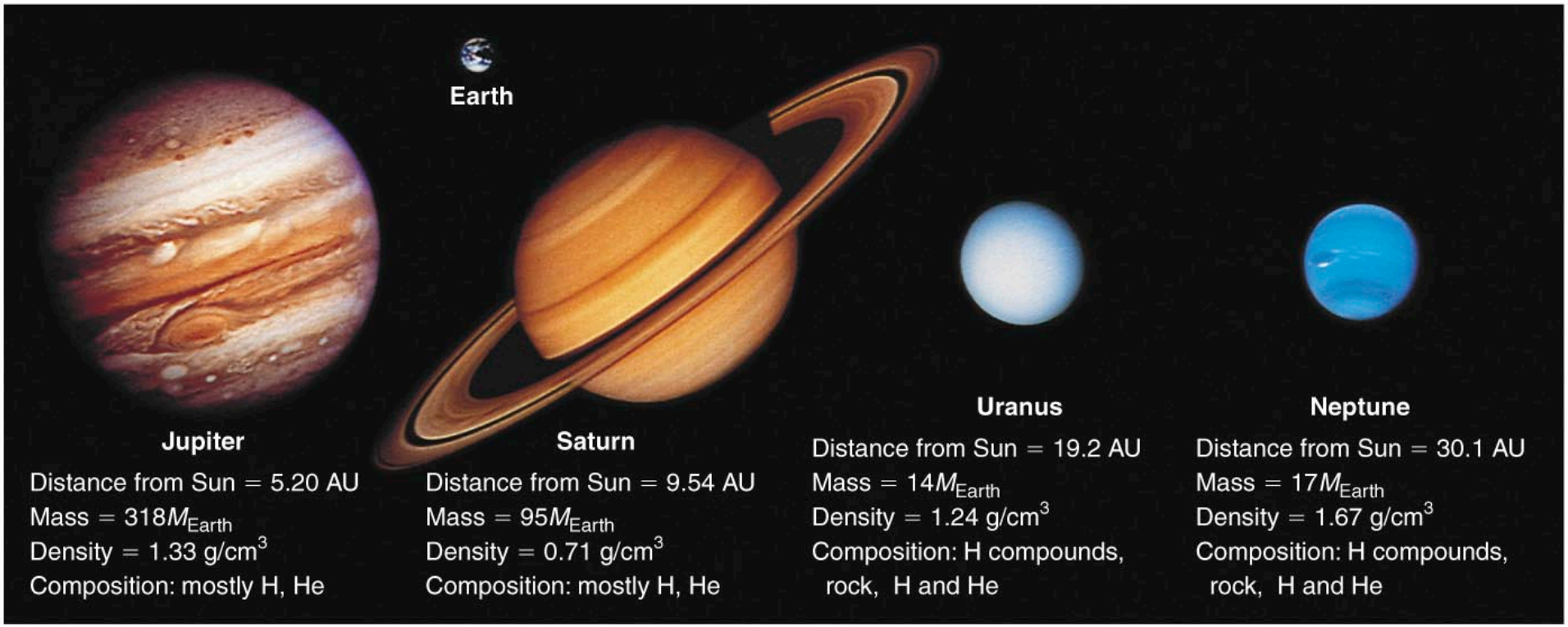
- Most of our knowledge of the outer solar system comes from six probes…
  - Pioneer 10 and 11 (last contacts 2003, 1995).
  - Voyager 1 and 2.
  - Galileo. RIP
  - Cassini. RIP
- Use “orbital assists” to boost their orbital energies.
- Require alternative to solar power… use plutonium-238 radio-isotope thermal generators (RTGs). Controversy!
- Juno arrived at Jupiter in 2016.


Viewed down from
north ecliptic pole
Pioneer 10
Voyager 2
Pioneer 11
Voyager 1
Jupiter
Mars
Saturn
Uranus
Neptune
Pluto
Earth
Sun
'92
'90
'88
'86
'84
'82
'80
'78
'76
'74
'77
'75
'73
'79
'81
'83
'85
'87
'89
'91
'94

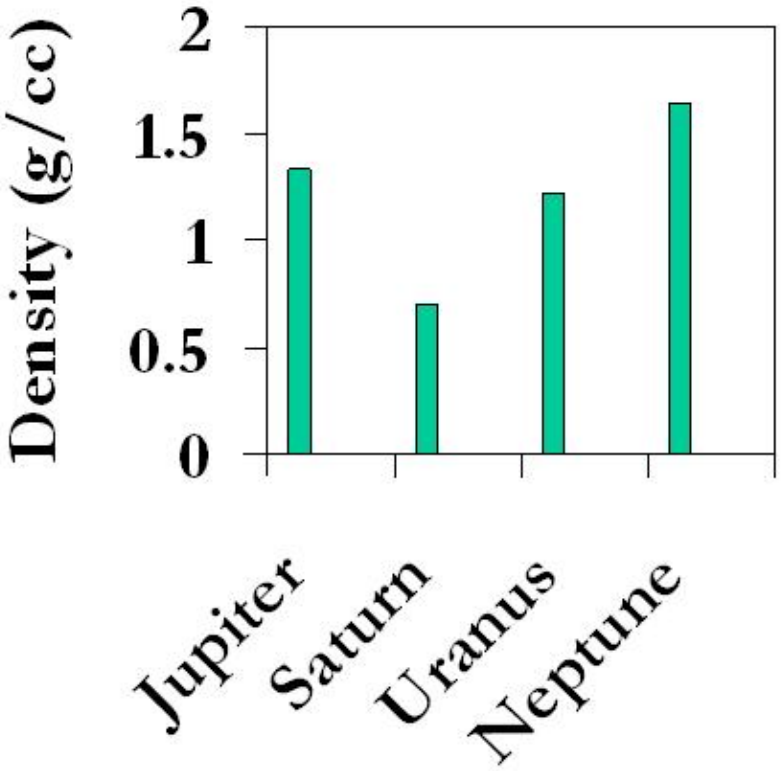

CASSINI-HUYGENS
MISSION TO SATURN,
ITS RINGS, AND MOONS.

Jovian Planet Composition

- Jupiter and Saturn
  - Mostly H and He gas.
  - Some hydrogen compounds, metal, rock.
- Uranus and Neptune
  - Mostly hydrogen compounds: water (H_2O), methane (CH_4), ammonia (NH_3).
  - Some H, He, metal, and rock.
- Jupiter and Saturn managed to accrete more light gases from the solar nebula than Uranus and Neptune.
  - Why?

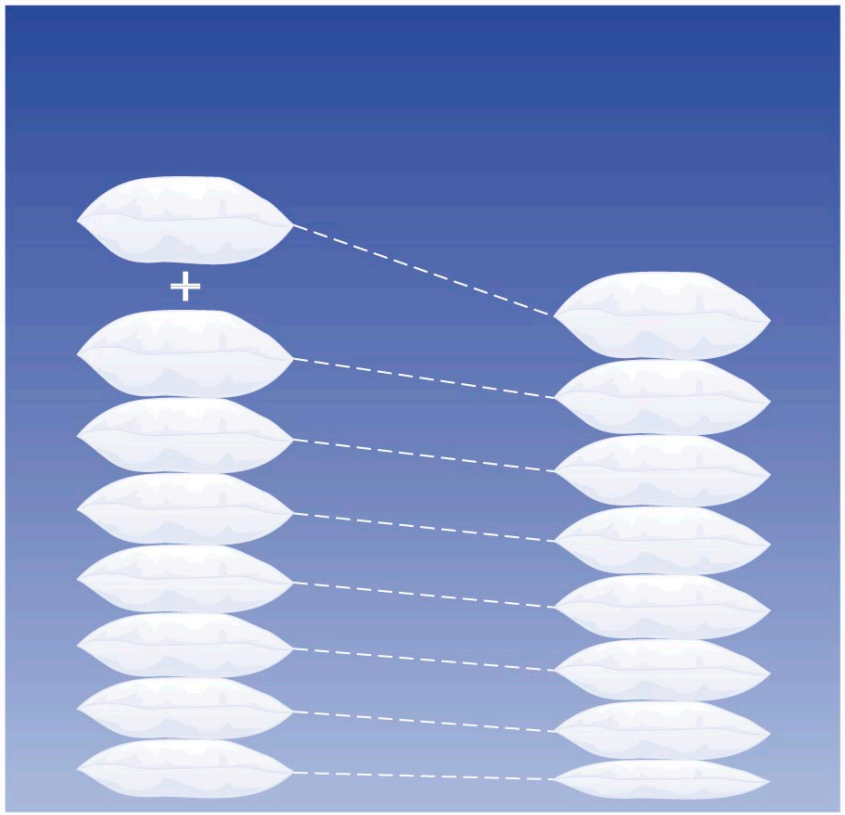

Earth
Jupiter
Distance from Sun = 5.20 AU
Mass = 318M_{Earth}
Density = 1.33 g/cm^3
Composition: mostly H, He
Saturn
Distance from Sun = 9.54 AU
Mass = 95M_{Earth}
Density = 0.71 g/cm^3
Composition: mostly H, He
Uranus
Distance from Sun = 19.2 AU
Mass = 14M_{Earth}
Density = 1.24 g/cm^3
Composition: H compounds, rock, H and He
Neptune
Distance from Sun = 30.1 AU
Mass = 17M_{Earth}
Density = 1.67 g/cm^3
Composition: H compounds, rock, H and He

Density Differences



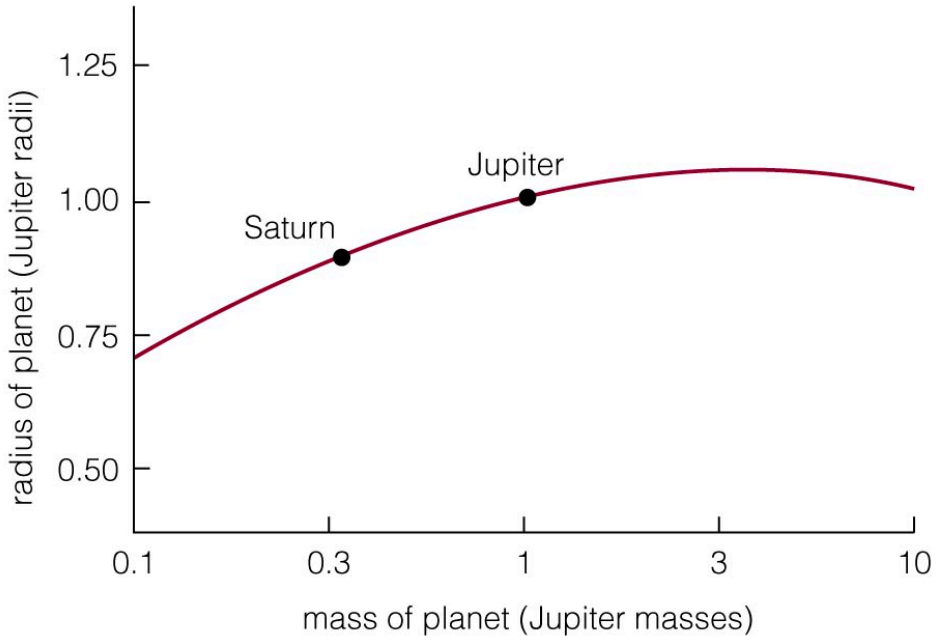
- Uranus and Neptune are denser than Saturn because they have less H and He, proportionately.
- But why is Jupiter so dense?

Sizes of Jovian Planets



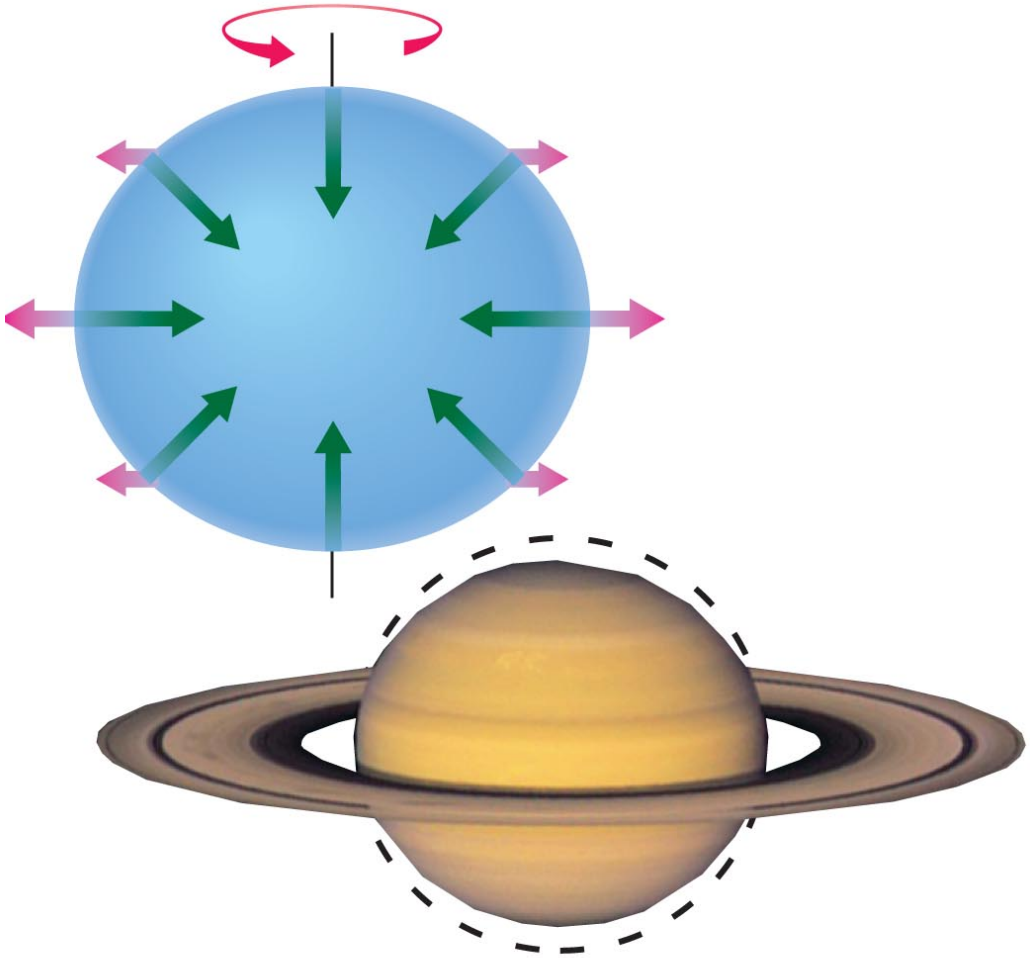
- Adding mass to a jovian planet compresses the underlying gas layers.

Sizes of Jovian Planets



- Greater compression is why Jupiter is not much larger than Saturn even though it is three times more massive.
- Jovian planets with even more mass can be *smaller* than Jupiter.
  This is also why Earth is the densest terrestrial, even though Mercury is made of intrinsically denser stuff

Rotation and Shape

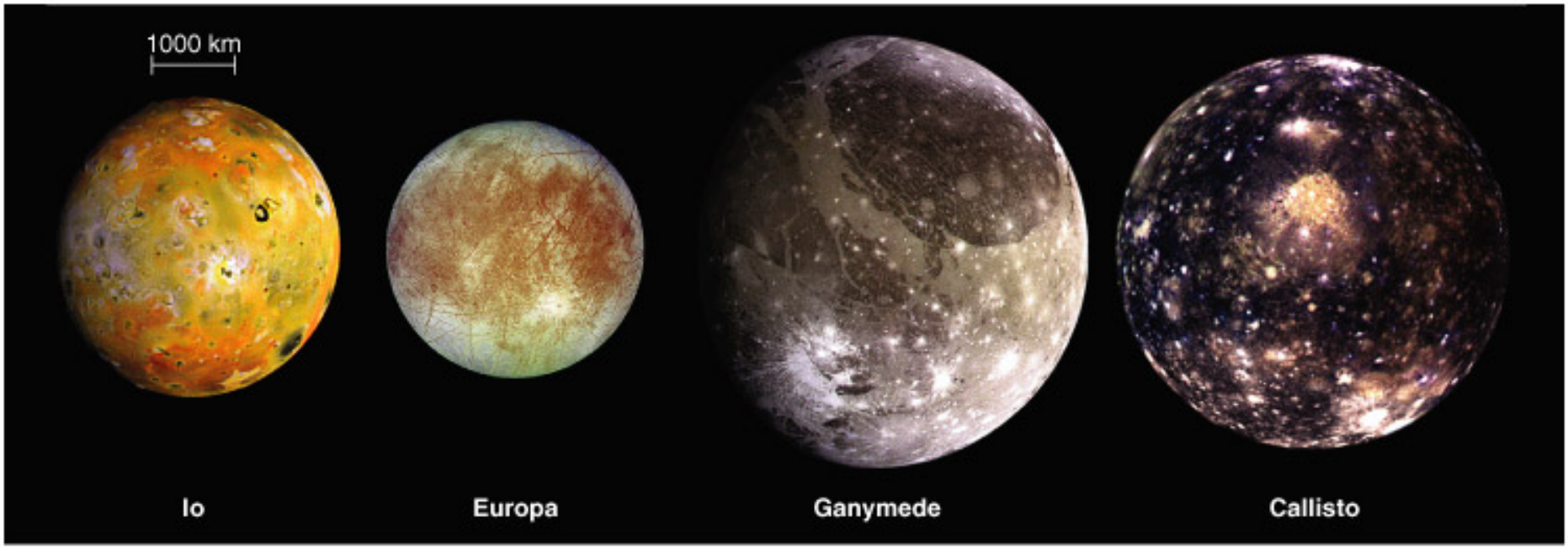


- Jovian planets are not quite spherical because of their rapid rotation.
- Faster rotation for a given density means more oblate shape
- Saturn eq/pole ratio is about 1.1!

More About Rotation and Shape

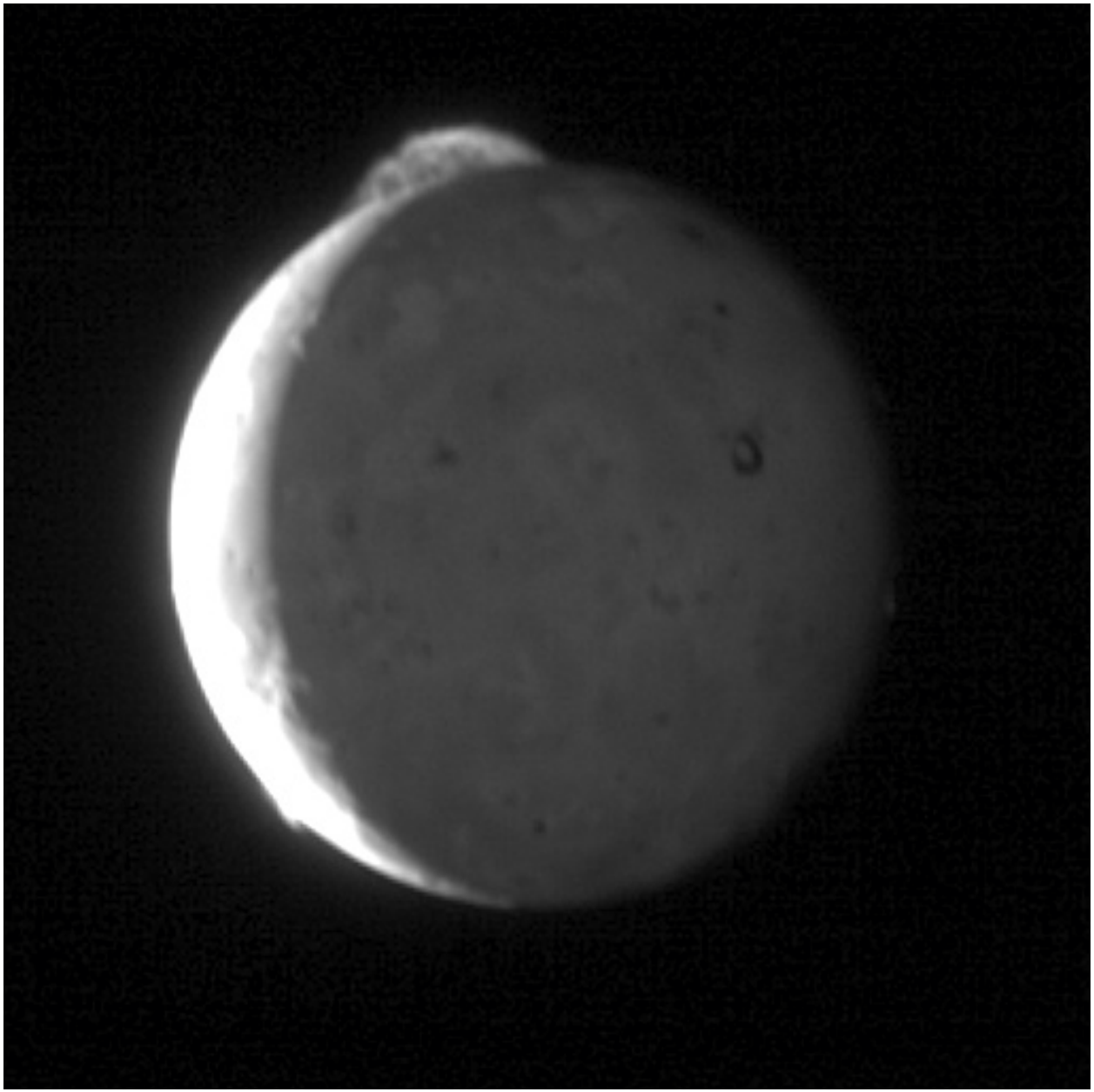
- What is the shape of a rotating, self-gravitating fluid?
  Subject of dispute between Newton and Cassini
  Newton: oblate (polar flattening); Cassini: prolate (football!)
- Newton was right, unsurprisingly
- Argument: centrifugal acceleration opposes gravity
  Centrifugal acceleration: $r\Omega^2$ (r=radius, Ω=ang. vel)
- Say that gravitational acceleration is g
- If we drill a hole to the center from the pole, and from the equator, pressures at center have to balance (why?)
- If pressure proportional to hole height times net accel, then:
  height(equator)~1/(g - $r\Omega^2$); height(pole)~1/g; oblate!
- Details matter, but symmetry supports Ω^2 (why???)
- Group question: how can you check this dependence?

The Galilean Moons of Jupiter

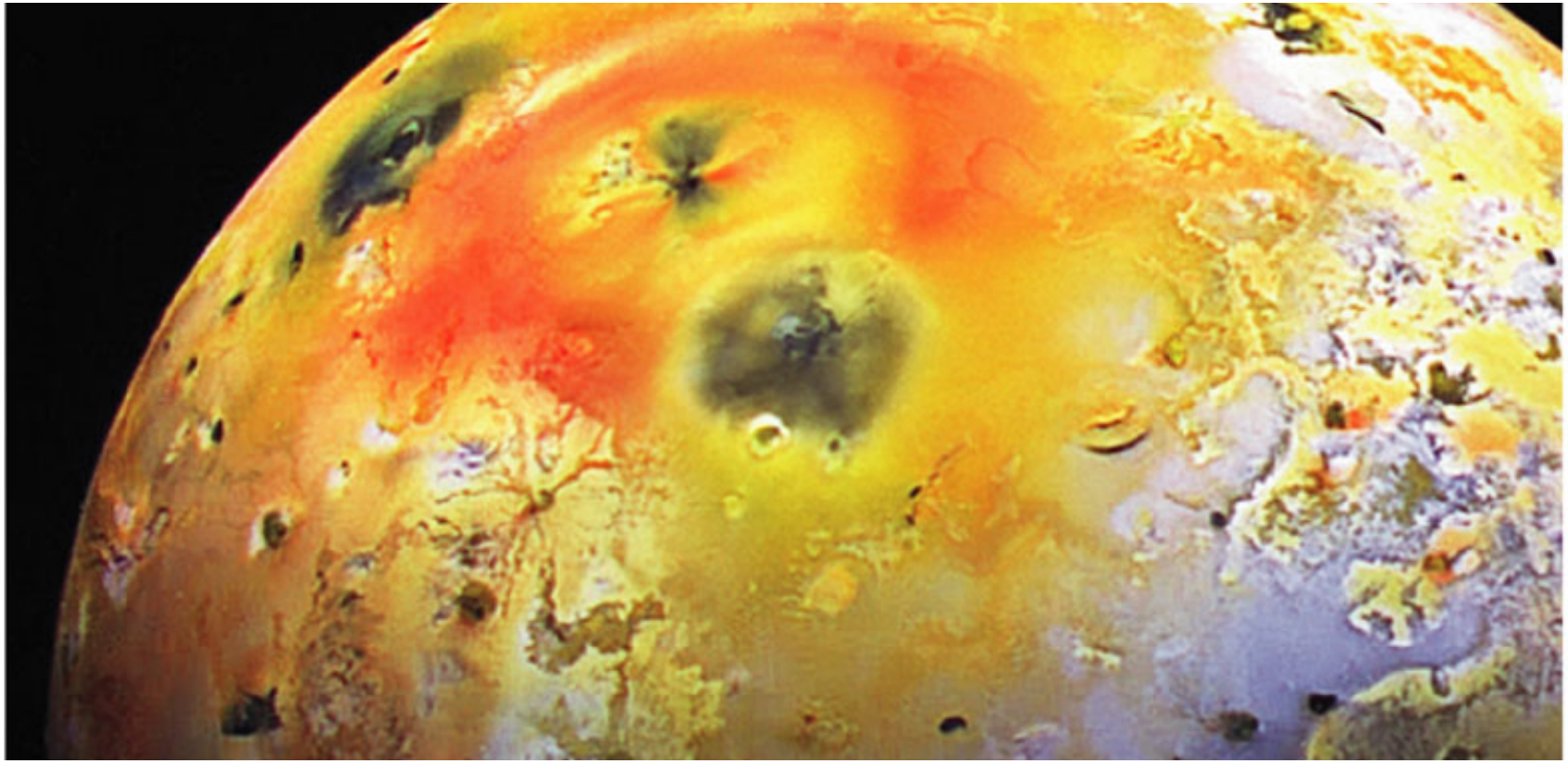


The Galilean Moons: Quick Overview

- Io
  - Most volcanically active body in the solar system.
- Europa
  - Possible subsurface ocean.
- Ganymede
  - Biggest moon in the solar system.
- Callisto
  - A big ice ball.

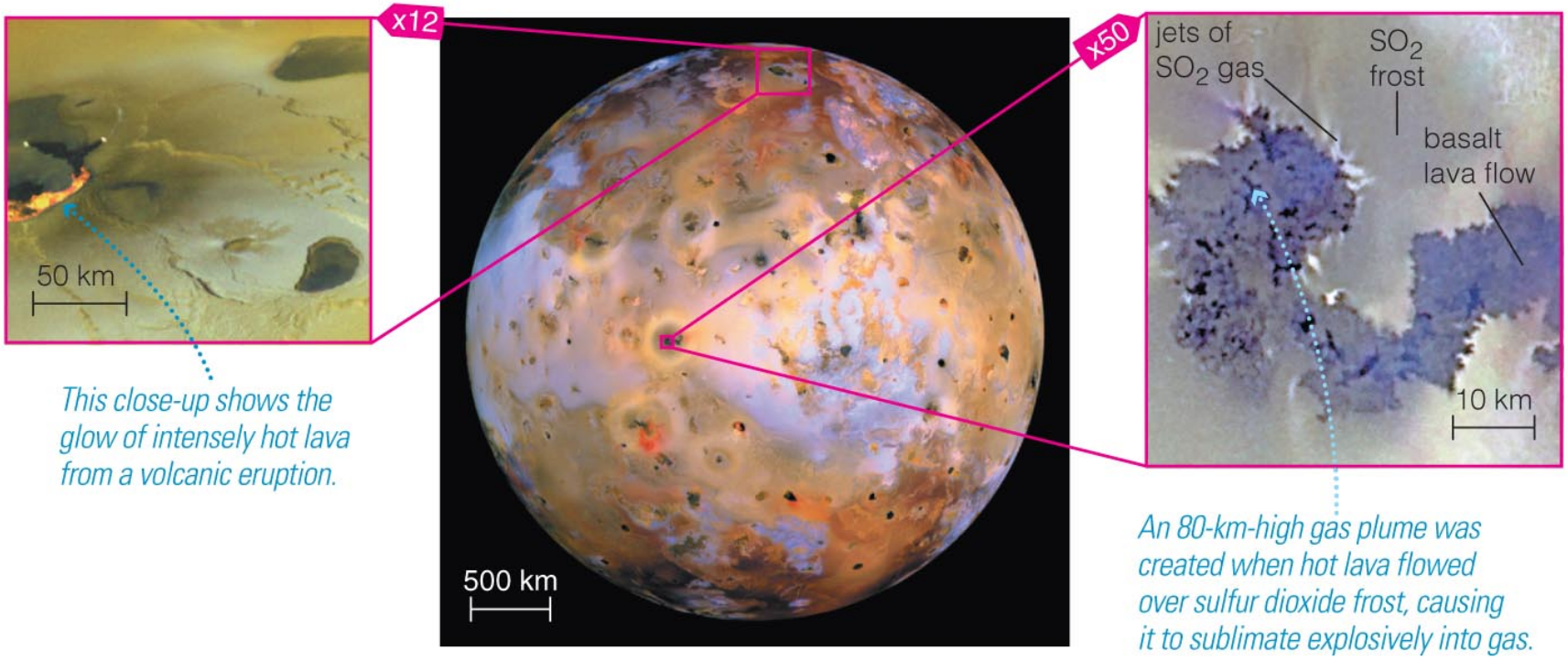


Io's Volcanic Activity



- Volcanic eruptions continue to change Io's surface.

Io's Volcanic Activity

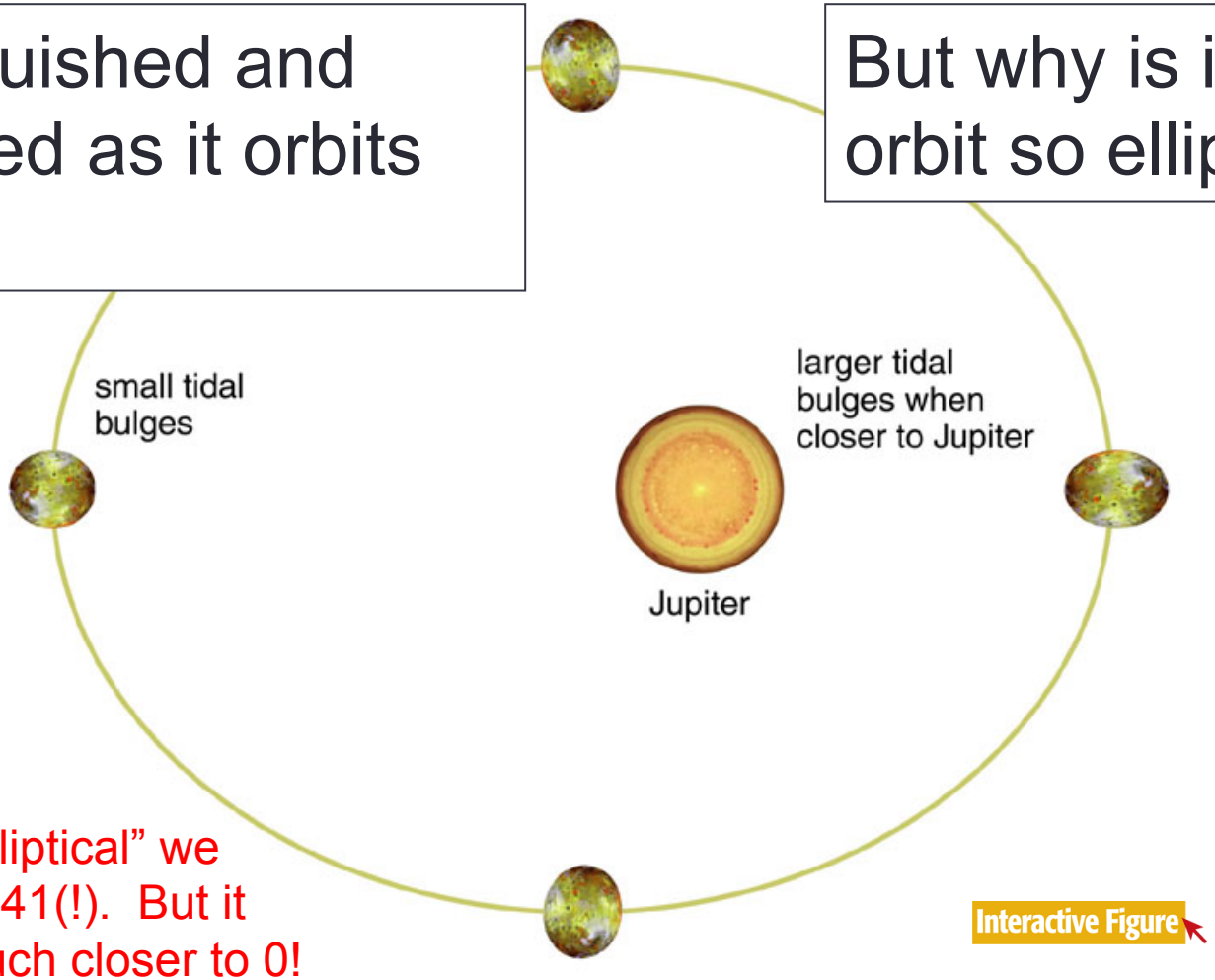


- Eruptions emit mostly SO_2 and S, supply thin atmosphere and Io torus, condense to form colors.

Tidal Heating

Io is squished and stretched as it orbits Jupiter.

But why is its orbit so elliptical?

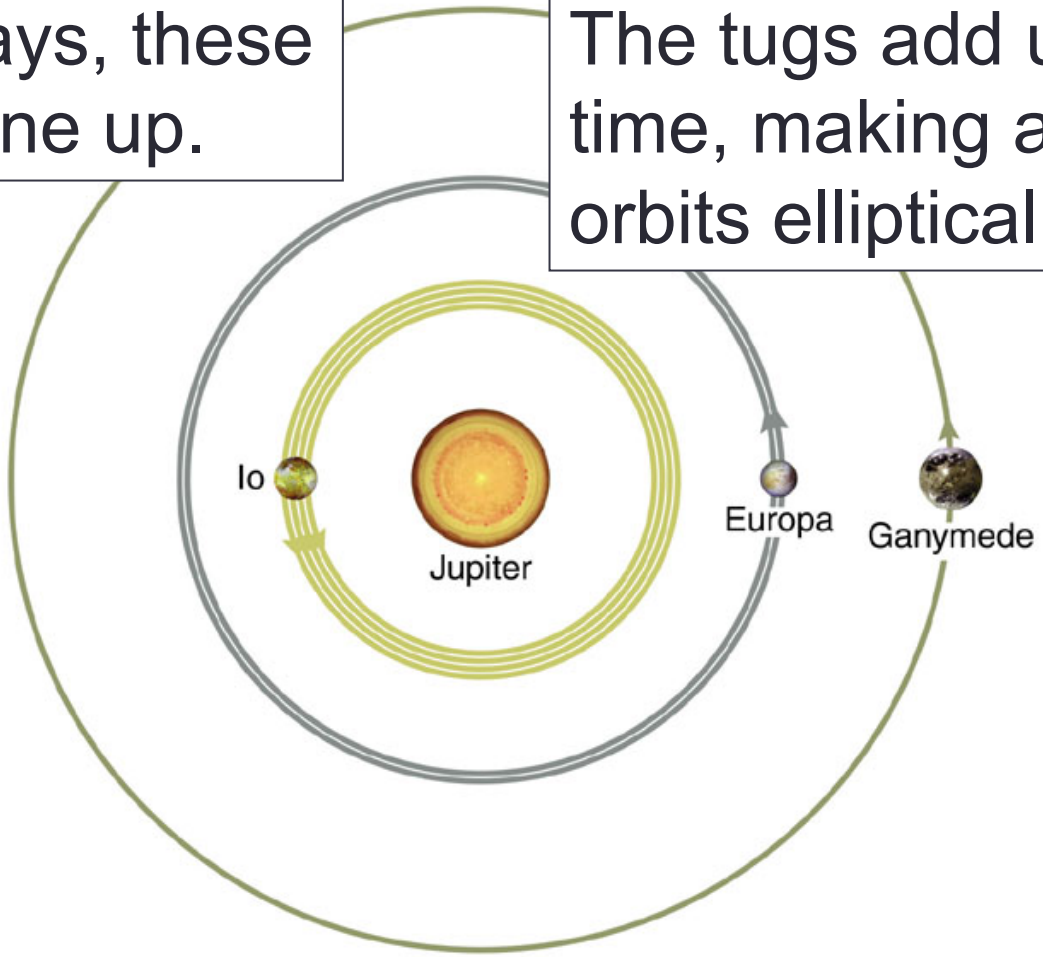


P.S. by “so elliptical” we mean e=0.0041(!). But it should be much closer to 0!

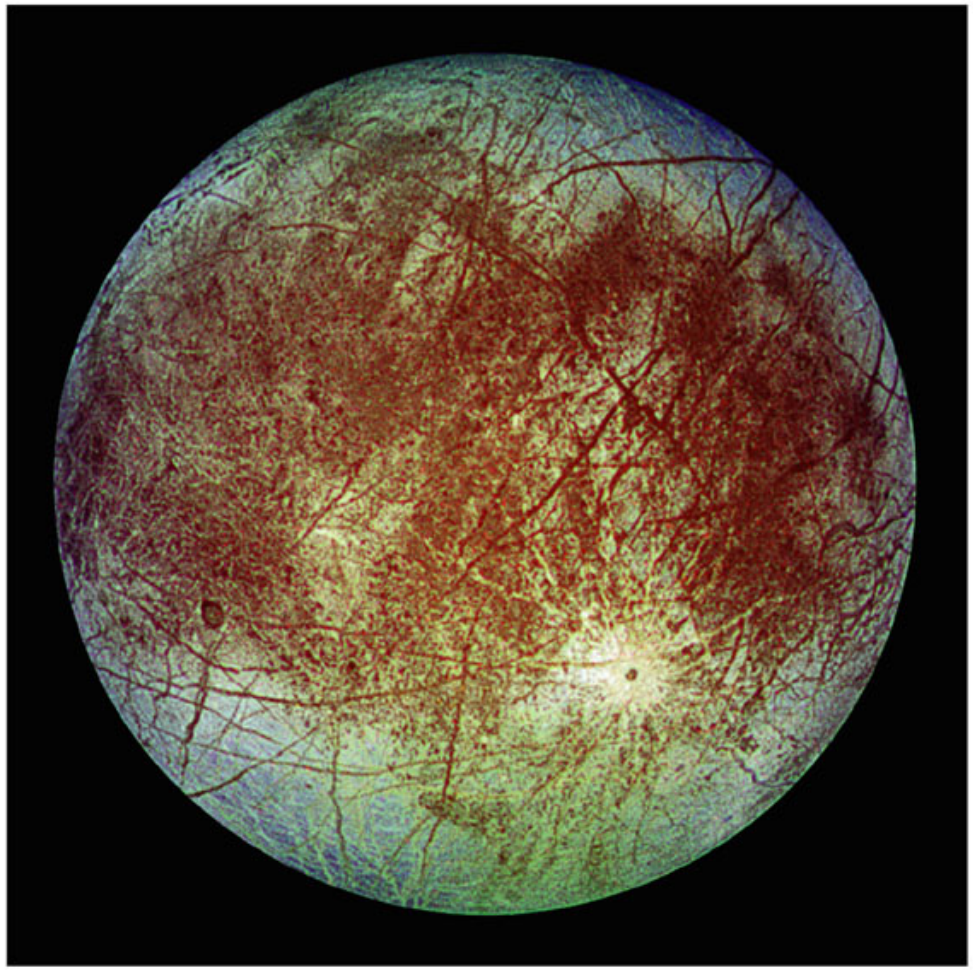
Orbital Resonances

Every 7 days, these 3 moons line up.

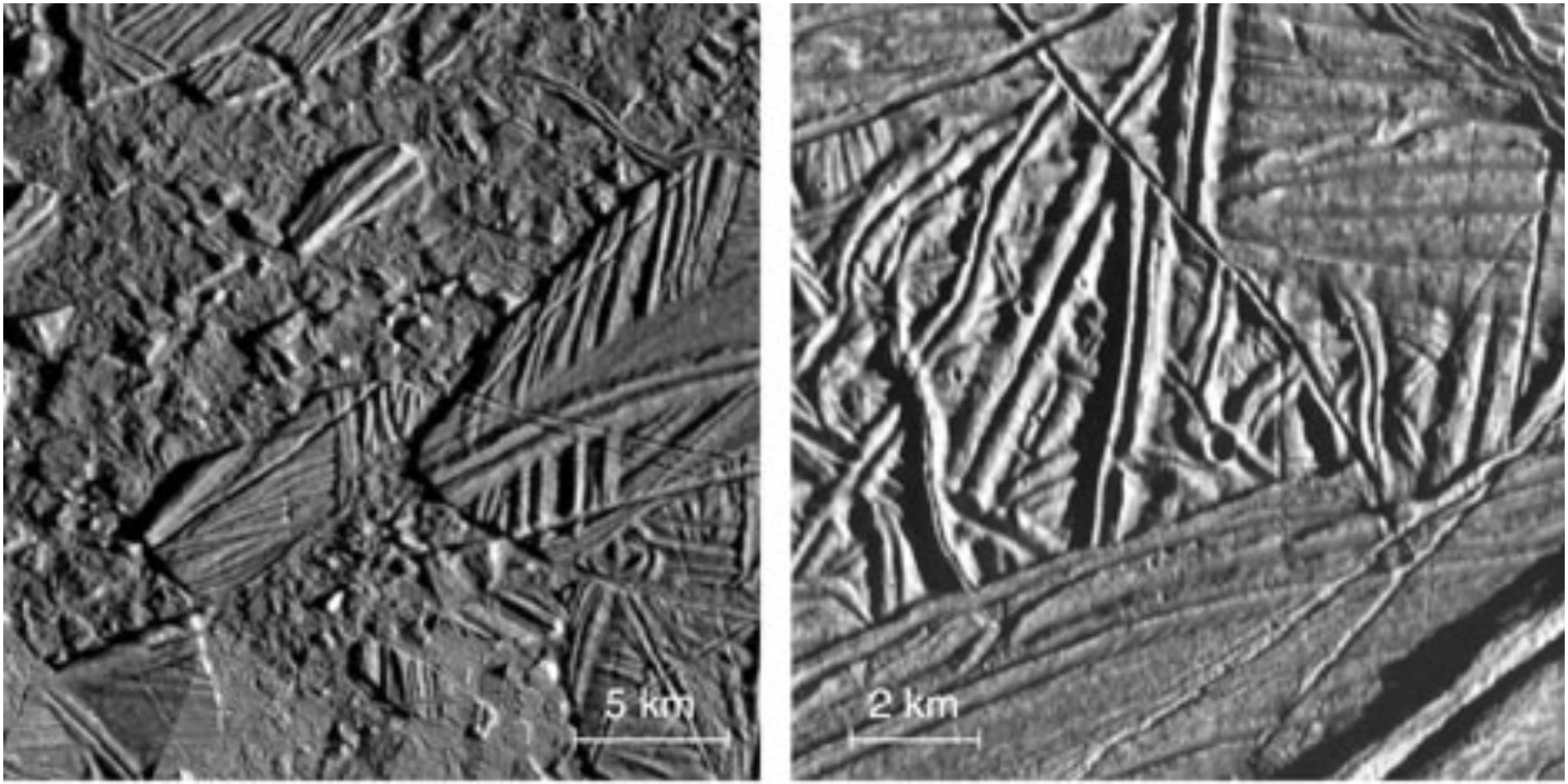
The tugs add up over time, making all 3 orbits elliptical.



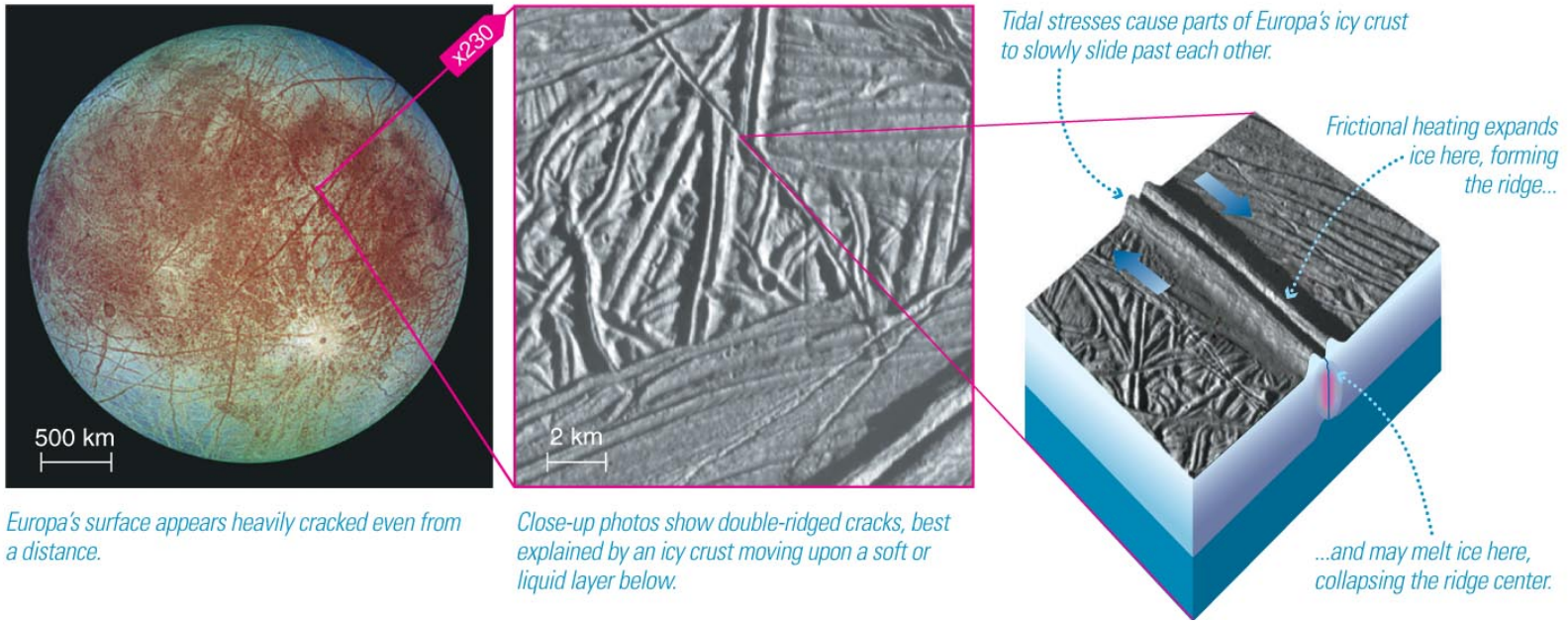
Europa's Ocean: Waterworld?



Tidal stresses crack Europa's surface ice



Tidal stresses crack Europa's surface ice

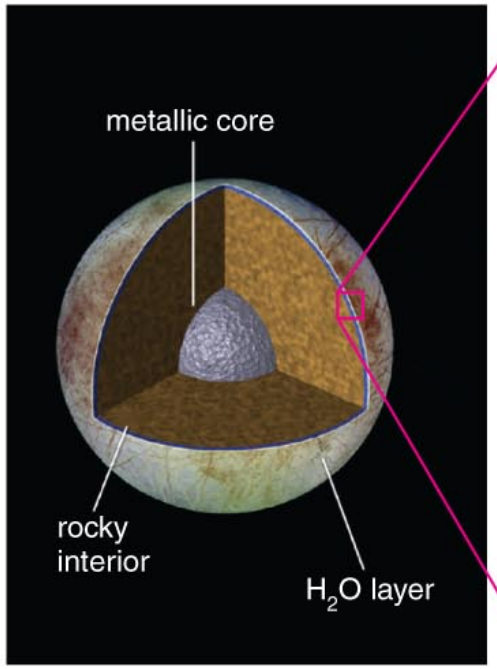


Europa's surface appears heavily cracked even from a distance.

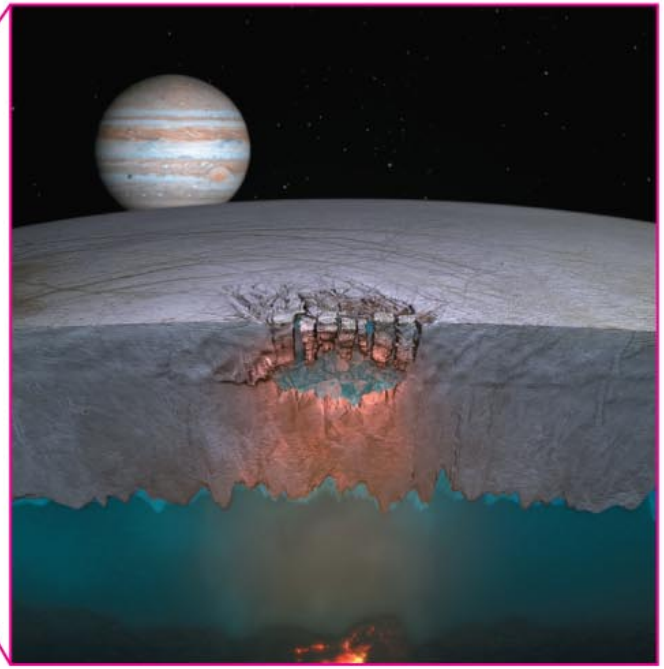
Close-up photos show double-ridged cracks, best explained by an icy crust moving upon a soft or liquid layer below.

- Smoothest solar system body: nothing higher than 100 m.
- Tidal flexing ~25% as strong as Io's.
- Induced magnetic field ➔ dissolved minerals in water ocean (field changes during orbit!).

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.