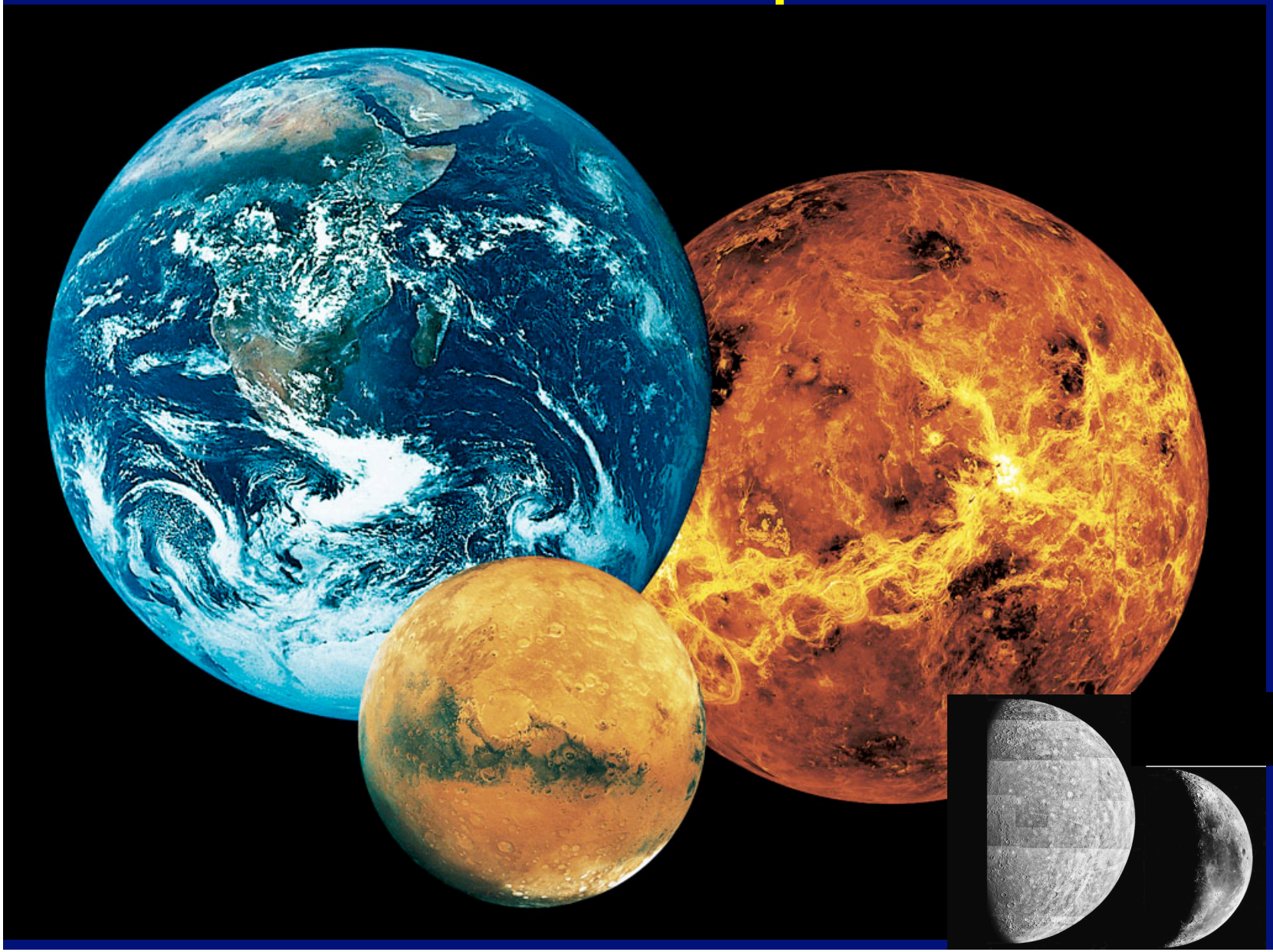
The Other Terrestrials

- Mercury
- Venus
- Mars

Terrestrial planets and moon to



Mercury: basic facts.

- Average distance from Sun = 0.39 AU
- Perihelion = 0.31 AU
- Aphelion = 0.47 AU ← orbit quite elliptical
- Orbital period = 0.24 years (88 days)
- Tilt of axis = 0 degrees
- Rotation period = 58.6 days
- Temperature range 100-700 K
- Size = 0.4 size of Earth
- Average density 5.4 g/cc

Venus: basic facts.

- Average distance from Sun = 0.72 AU
- Perihelion = 0.72 AU
- Aphelion = 0.73 AU – low e
- Orbital period = 0.62 years (225 days)
- Tilt of axis = 177 degrees (!)
- Rotation period = 243 days
- Temperature 745 K
- Size = 0.95 size of Earth
- Average density 4.2 g/cc (rocky)

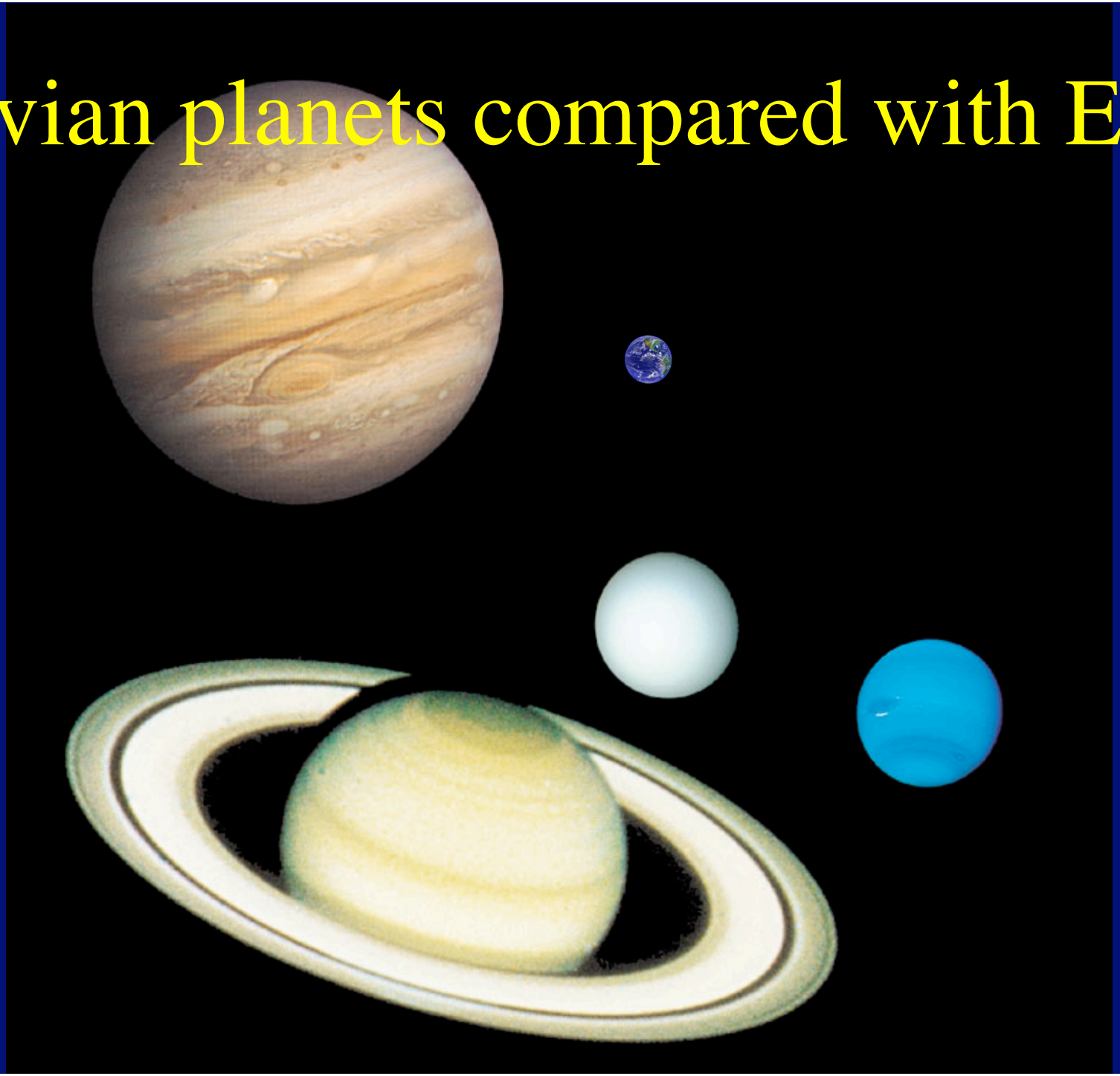
Mars: basic facts.

- Average distance from Sun = 1.52 AU
- Perihelion = 1.38 AU
- Aphelion = 1.66 AU ← orbit very elliptical,
- Orbital period = 1.88 years $(R_p/R_a)^2=0.69$
- Tilt of axis = 25 degrees
- Rotation period = 24 hrs, 37 min
- Temperature range 150-300 K (-220-68 F)
- Size = 0.5 size of Earth
- Average density 3.3 g/cc (light rocks)

The Gas Giants

- Jupiter
- Saturn
- Uranus
- Neptune

Jovian planets compared with Earth

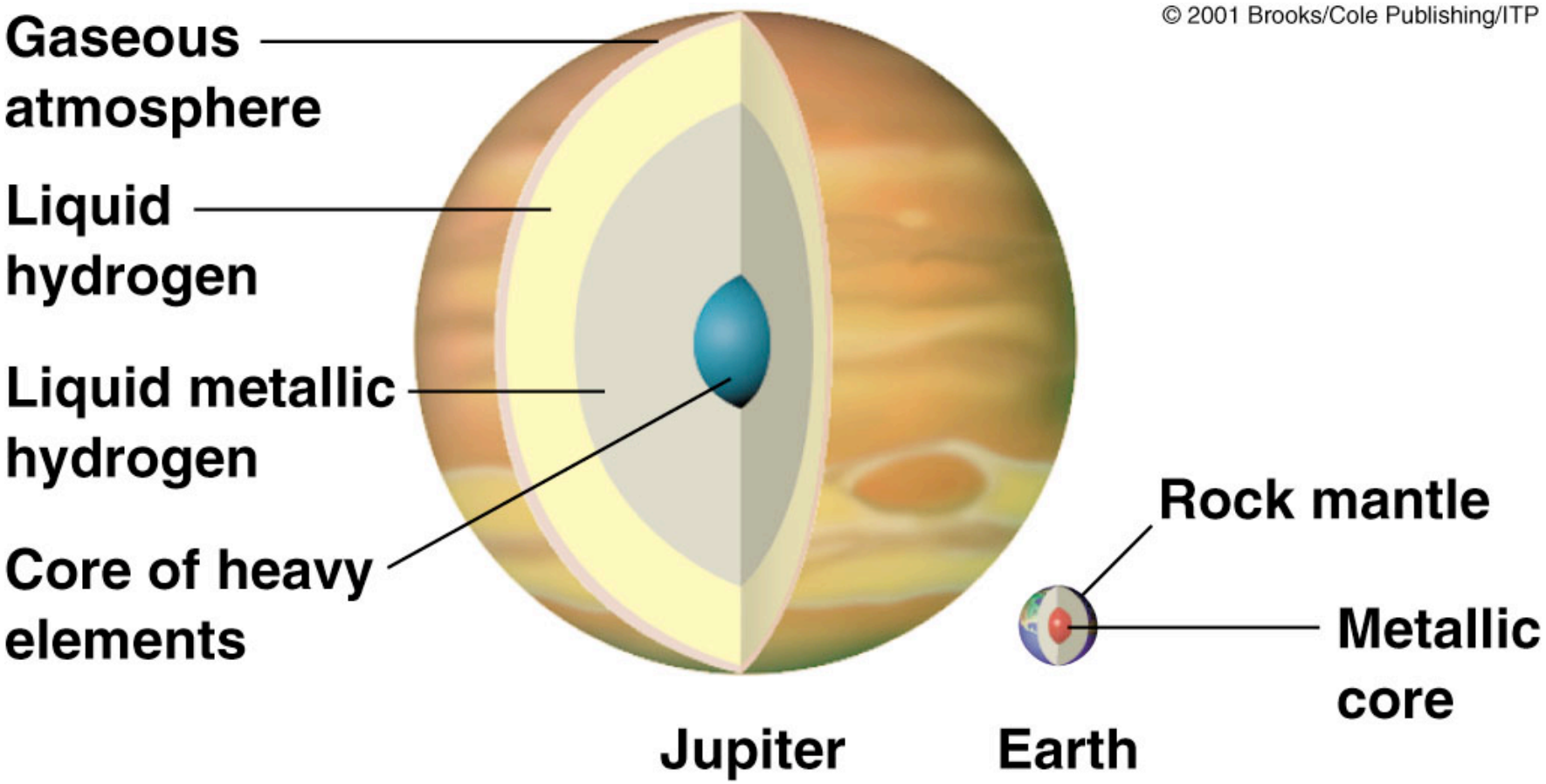


Jovian planets compared to Earth

	Distance from sun (AU)	Radius (Earth radii)	Mass (Earth masses)	Density (g/cc)
Earth	1	1	1	5.4
Jupiter	5	11	317	1.3
Saturn	10	9	95	0.7
Uranus	19	4	15	1.3
Neptune	30	4	17	1.7

Jovian planets are further, bigger, more massive, less dense

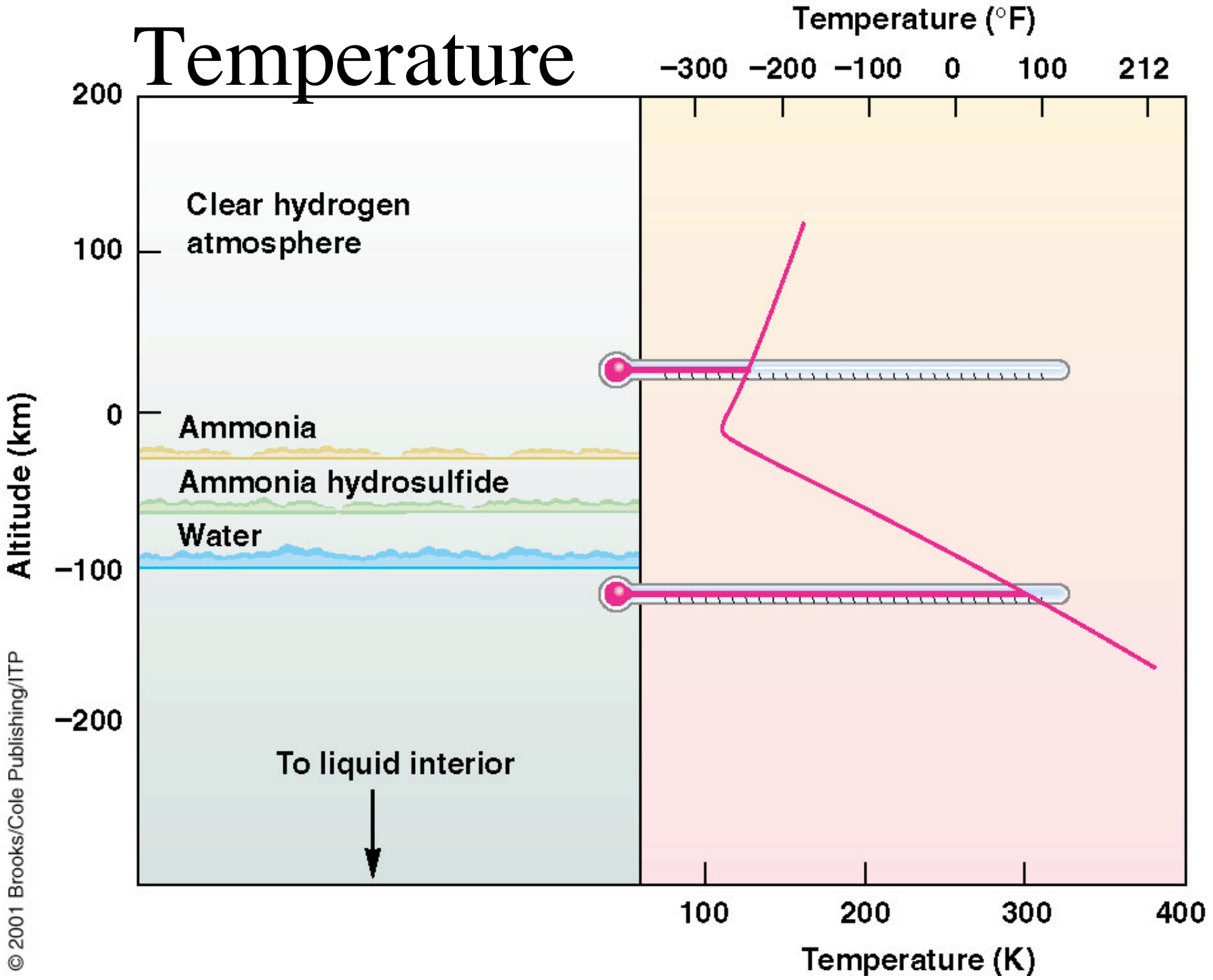
Structure and Composition of Jovian and Terrestrial Planets



Requires theoretical modeling - still controversial

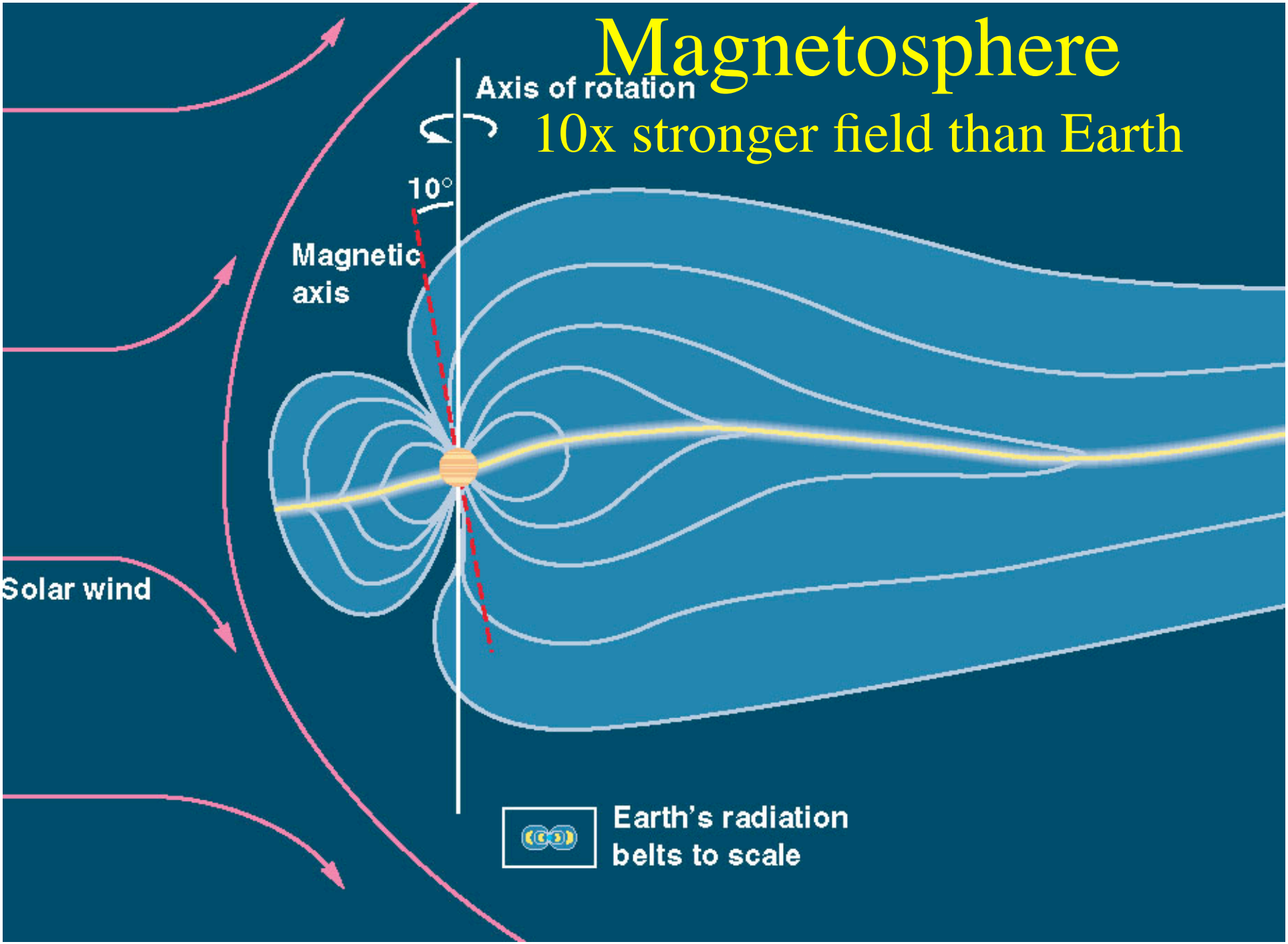
Equation of state $P(\rho,T)$ for H at extreme pressures uncertain

Temperature



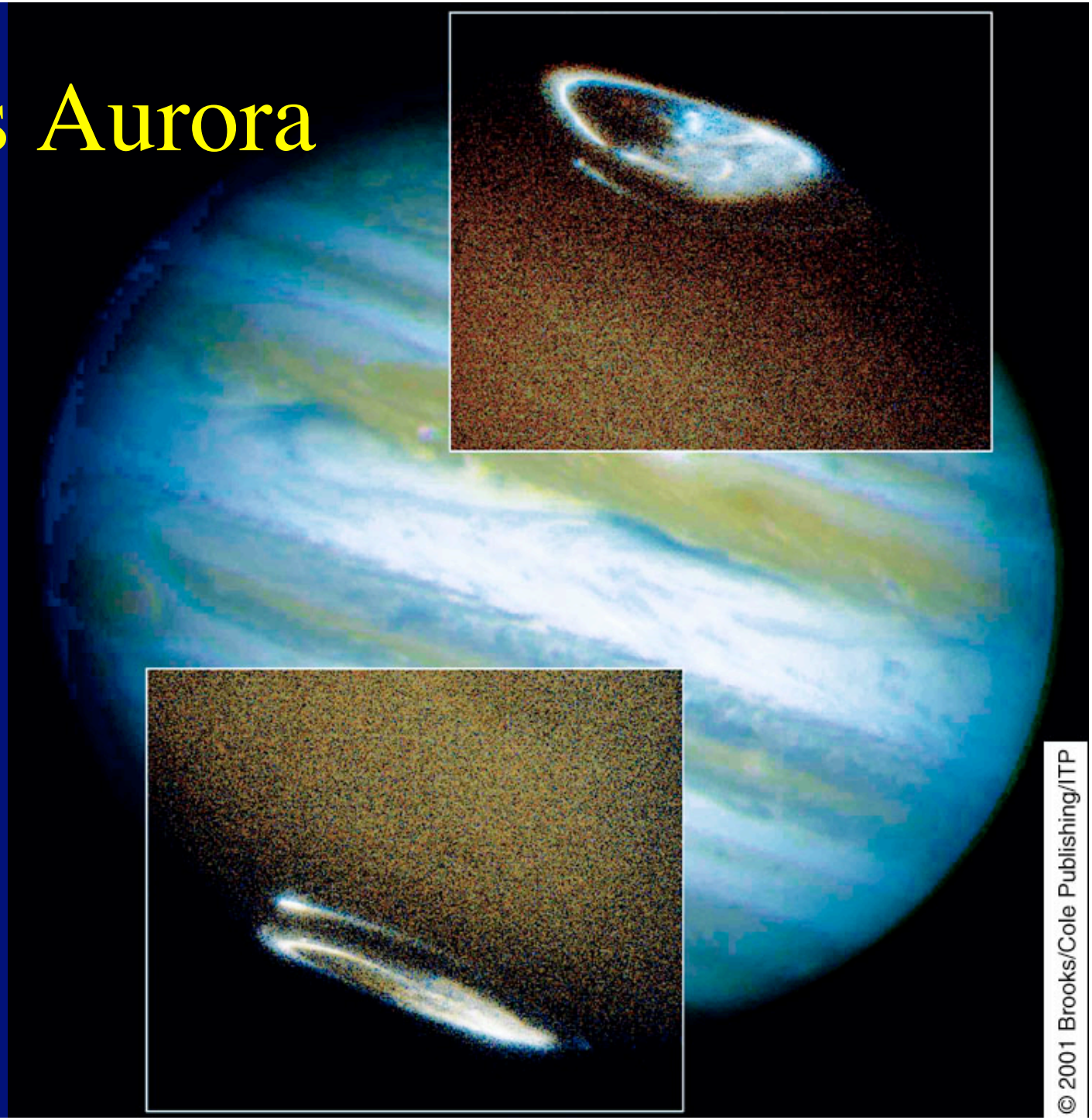
Magnetosphere

10x stronger field than Earth



Jupiter's Aurora

Seen in ultraviolet at magnetic poles



Jupiter's atmosphere

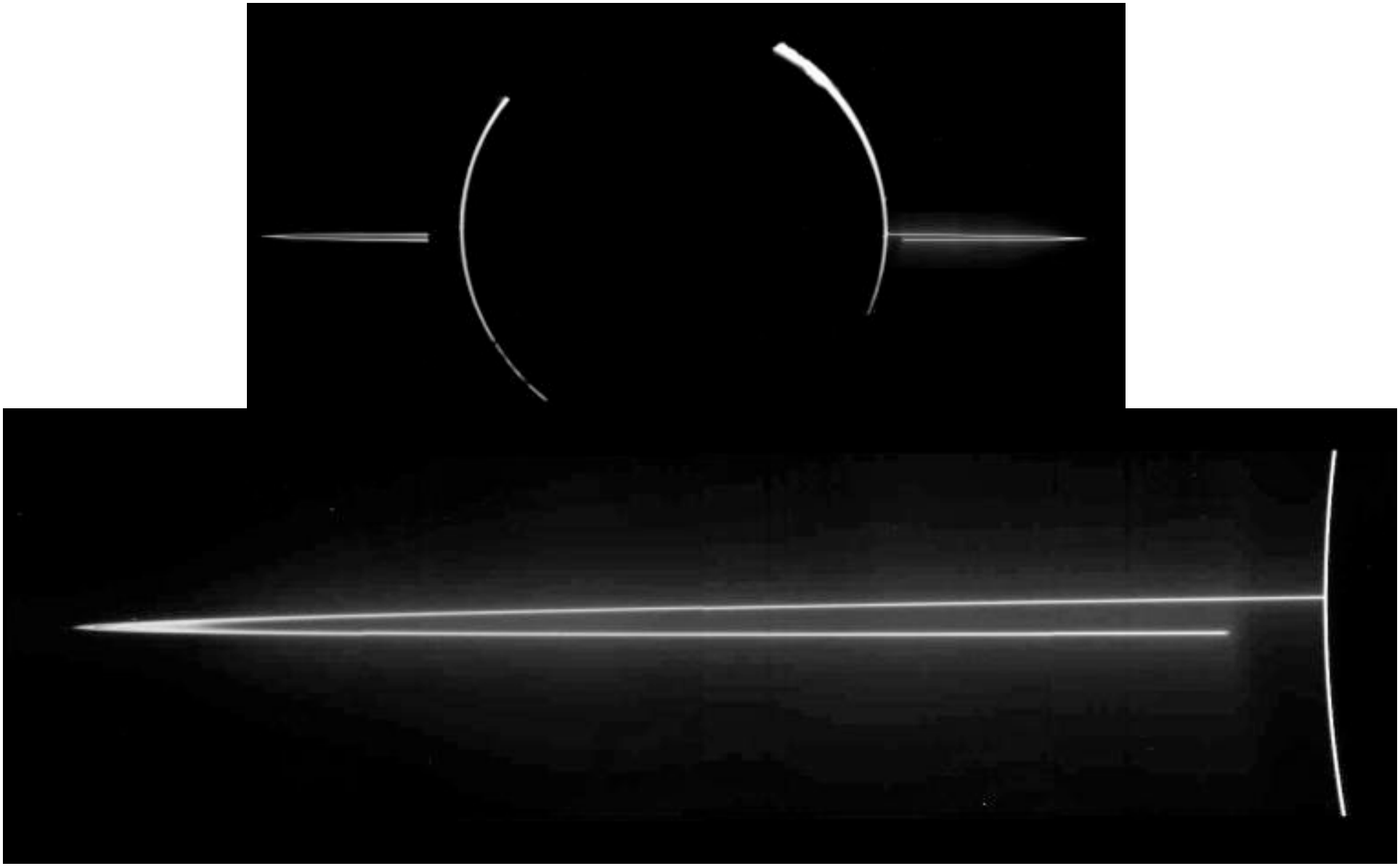
- Turbulent and stormy
- Radiates twice as much heat as absorbs from Sun, still shrinking and cooling

Why is Jupiter so big?

- Jupiter formed far enough from Sun that most common elements (H, C, O, N) are frozen into ice
- These ices together with rocks and metals made a much larger protoplanetary core
- Once the icy/rocky/metallic protoplanet grew to about 15 M_{Earth}, it could gravitationally capture gas (mostly H and He)
  - So Jupiter grew to 317 times mass of Earth

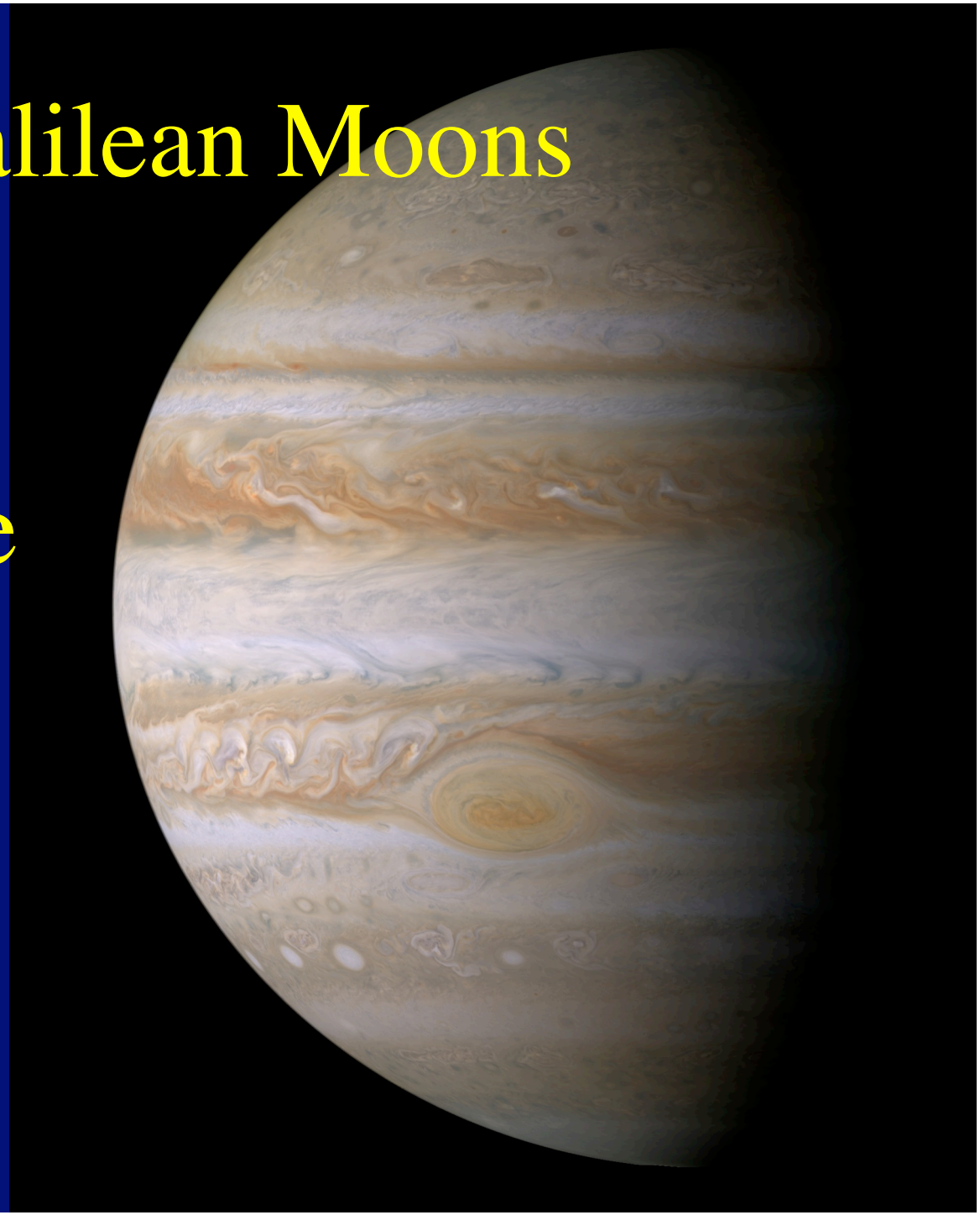
Jupiter's Ring

composed of dust from moons



Jupiter's Galilean Moons

- Io
- Ganymede
- Callisto
- Europa

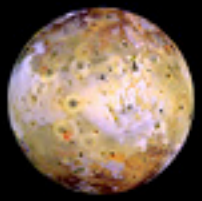


Jupiter's Galilean Moons compared with Earth's Moon

Volcanically active Io

- Density of 3.5 g/cc and magnetic field
  - Metallic core
  - Rocky, sulfur-rich core
  - No evidence for water (ice)
  - No impact craters
- Many erupting volcanoes have been seen
- Surface changes dramatically in a few years

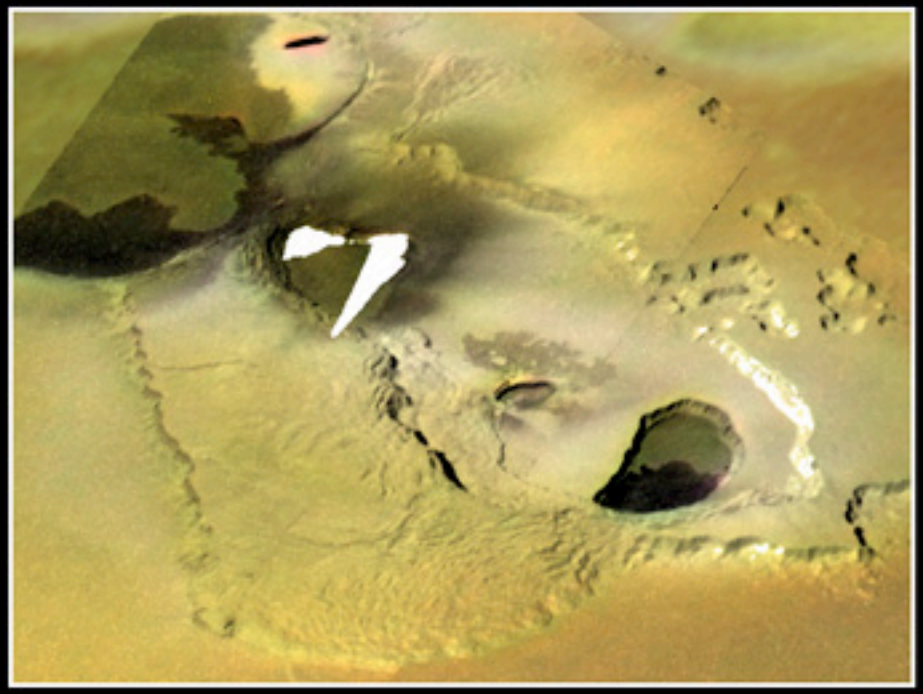
Volcano on Io as seen by Galileo

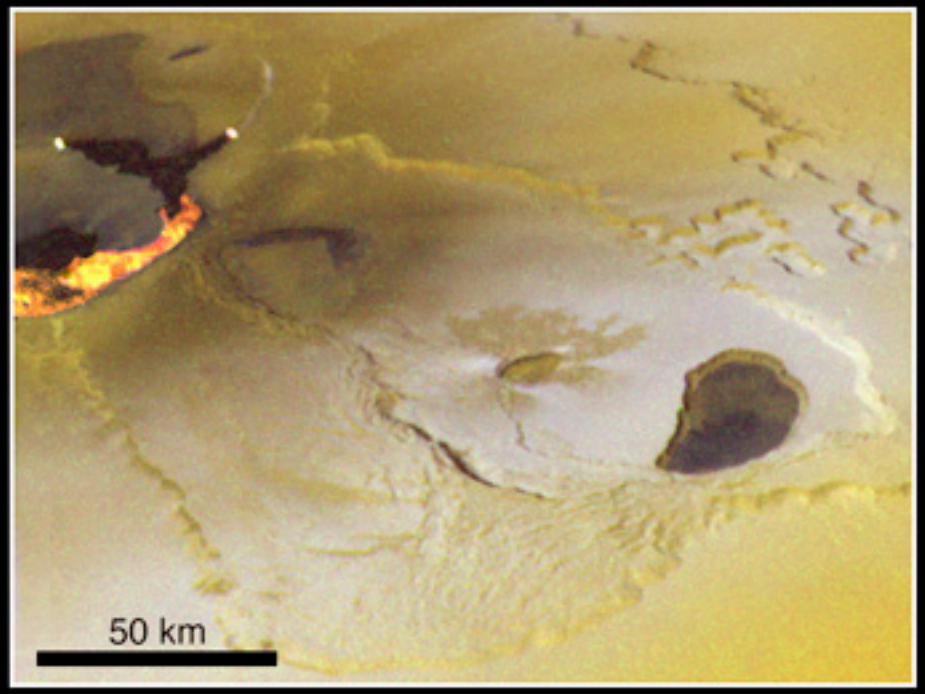


Io — Tvashtar Catena

I25 (26 Nov 1999)
+ C21 low-resolution color

I27 (22 Feb 2000)
visible wavelength data
+ IR data of active lava flow



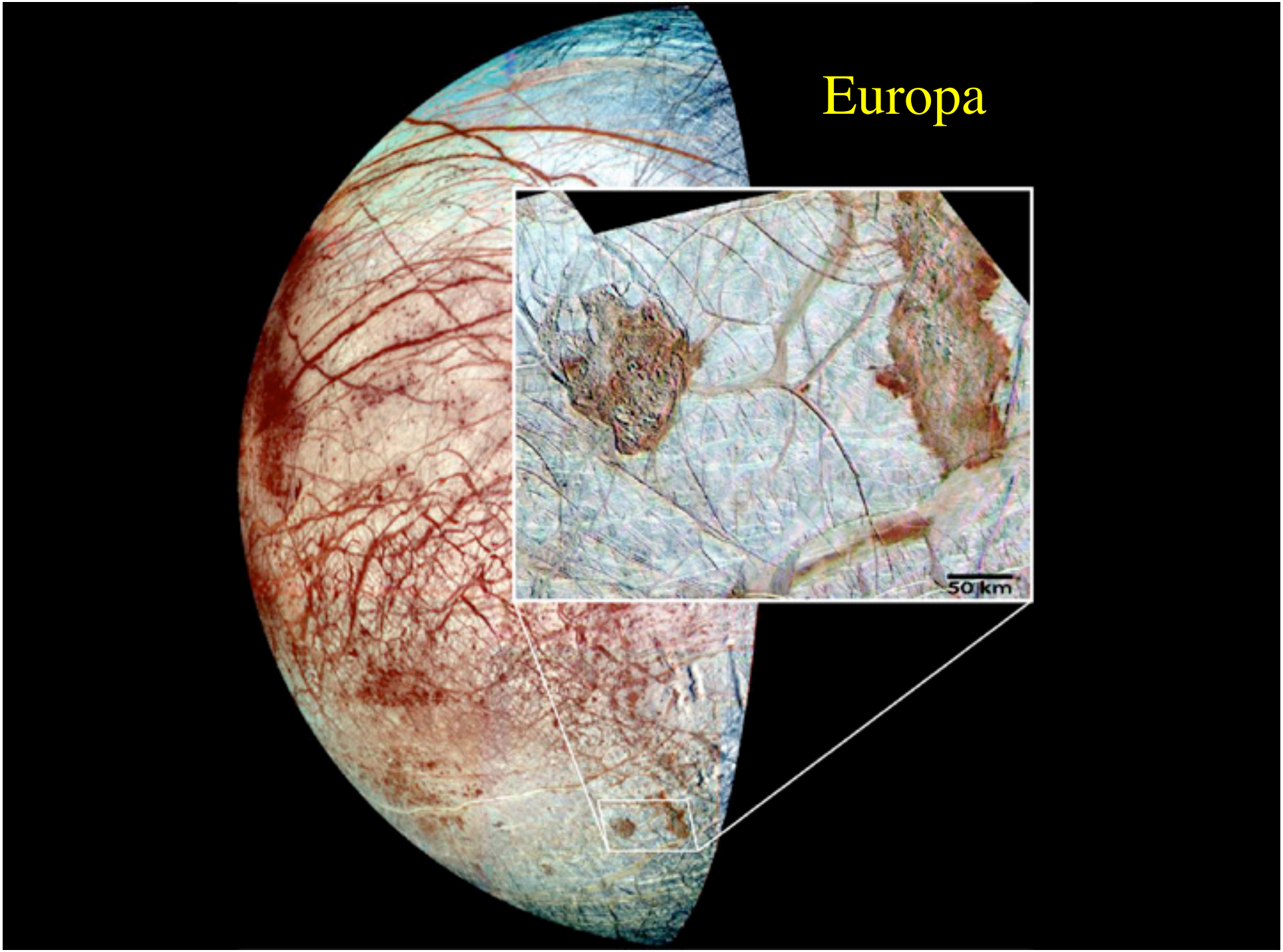


Why is Io most active object in solar system?

- Too small to have retained much heat from its formation epoch
- Reason: *Tidal heating*:
  - Elliptical orbit, relatively near to Jupiter
  - Tidal forces of Jupiter flex and stretch Io, causing tremendous heating
- Perturbations from other moons keep Io from circularizing orbit

Europa: geologically active

- Density 3 g/cc
  - Mostly rock with thin icy crust
- Surface:
  - Clean ice, very few craters
    - Less than 10 million years old
- Jumbled ice blocks
  - Pack ice, perhaps floating on ocean below


Europa
50 km

Ice blocks on Europa

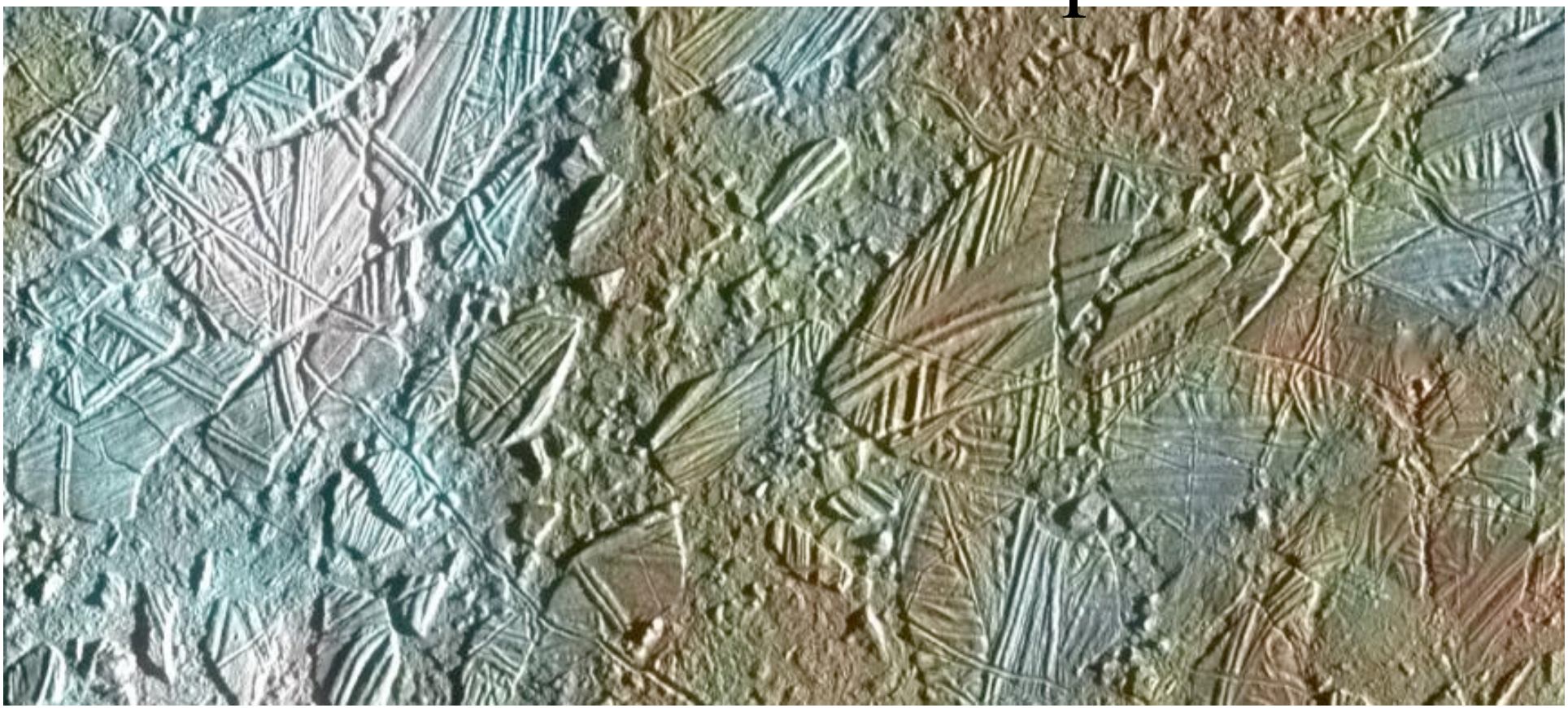


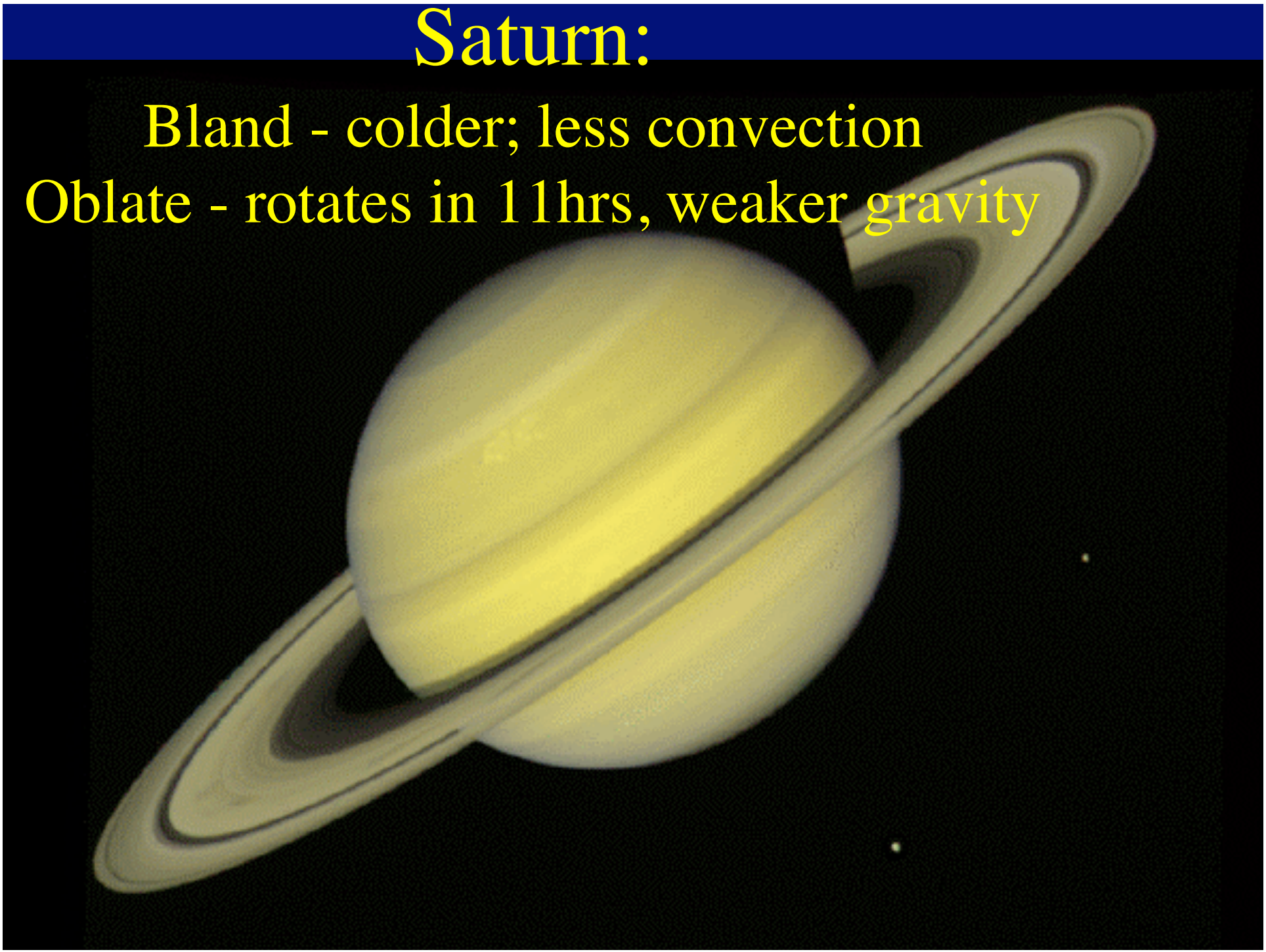
Image shows area 20x40 miles

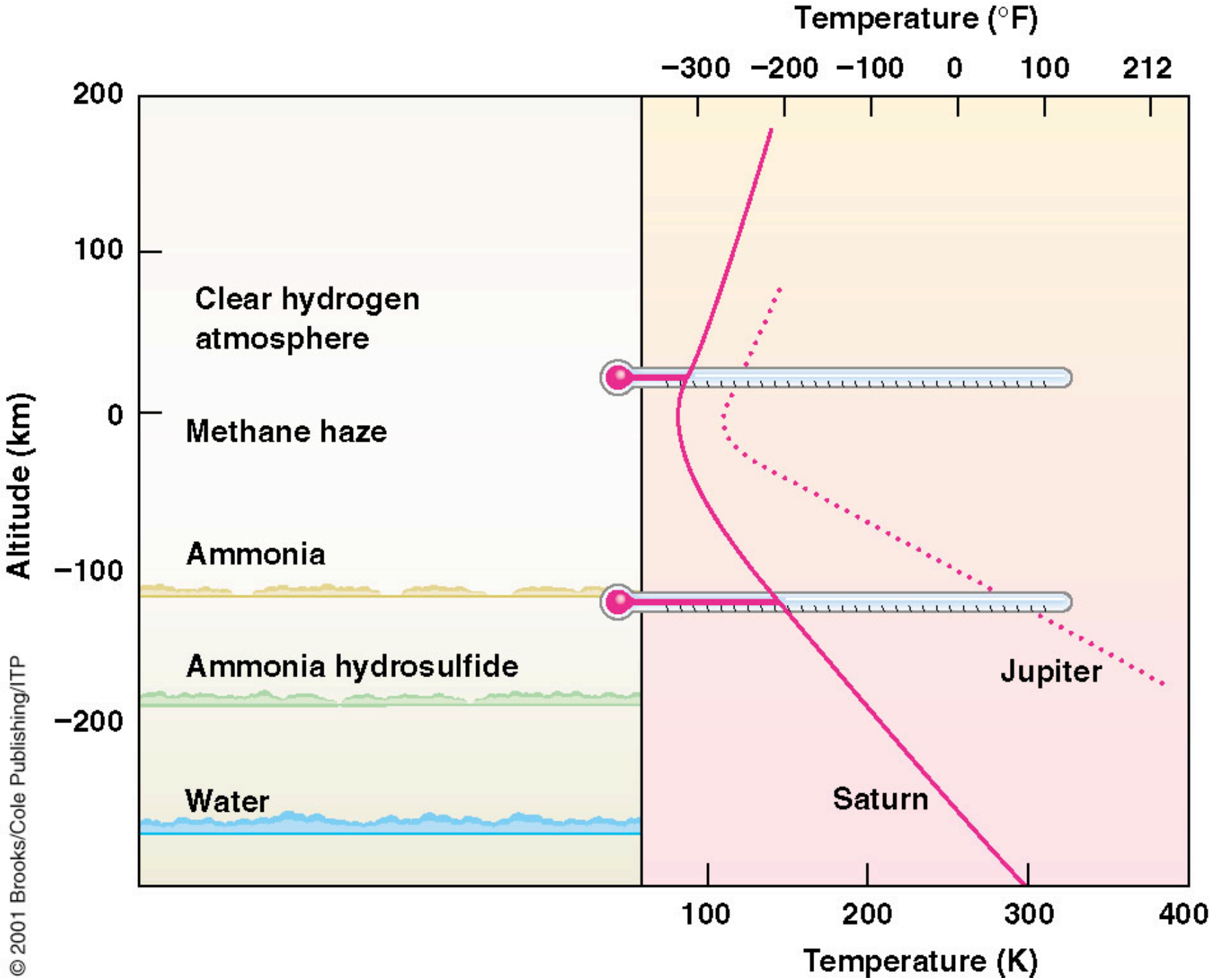
Is there life in seas below pack ice? What is brown stuff?

Saturn:

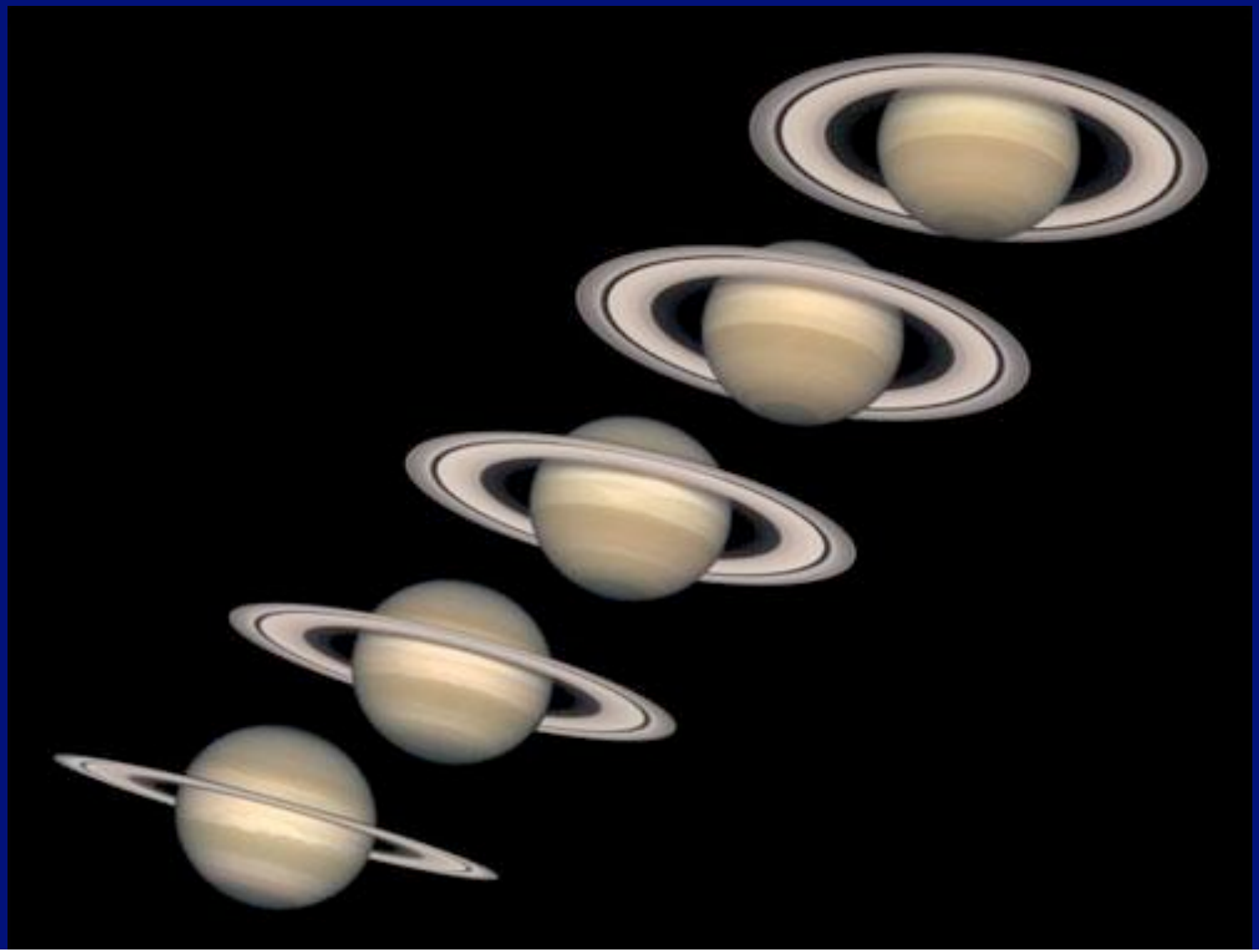
Bland - colder; less convection

Oblate - rotates in 11hrs, weaker gravity



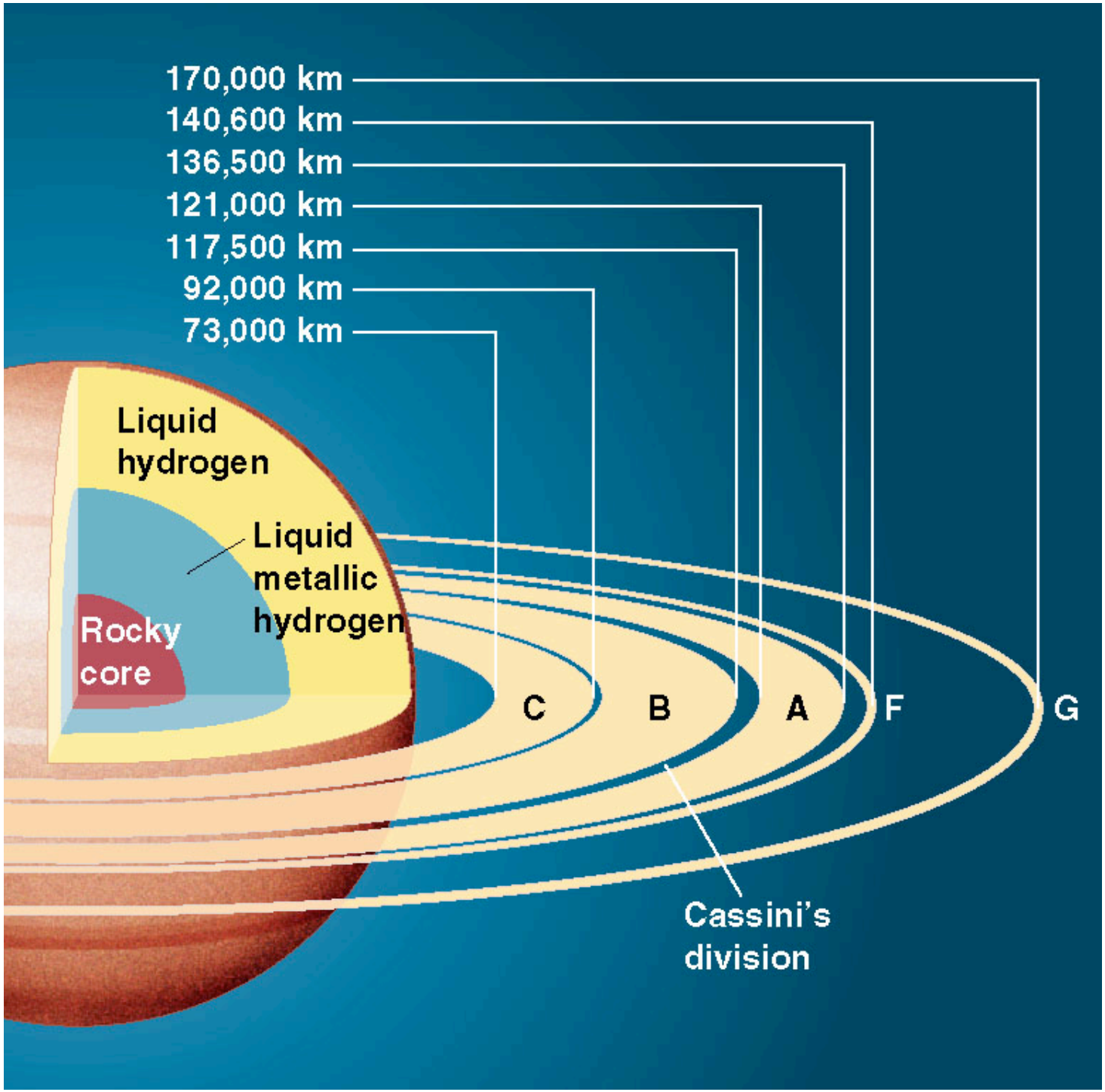


Plane of rings as seen from Earth tilts as Saturn orbits Sun - Allows study of geometry of rings



Saturn's Rings

Core about 13 M_{Earth}

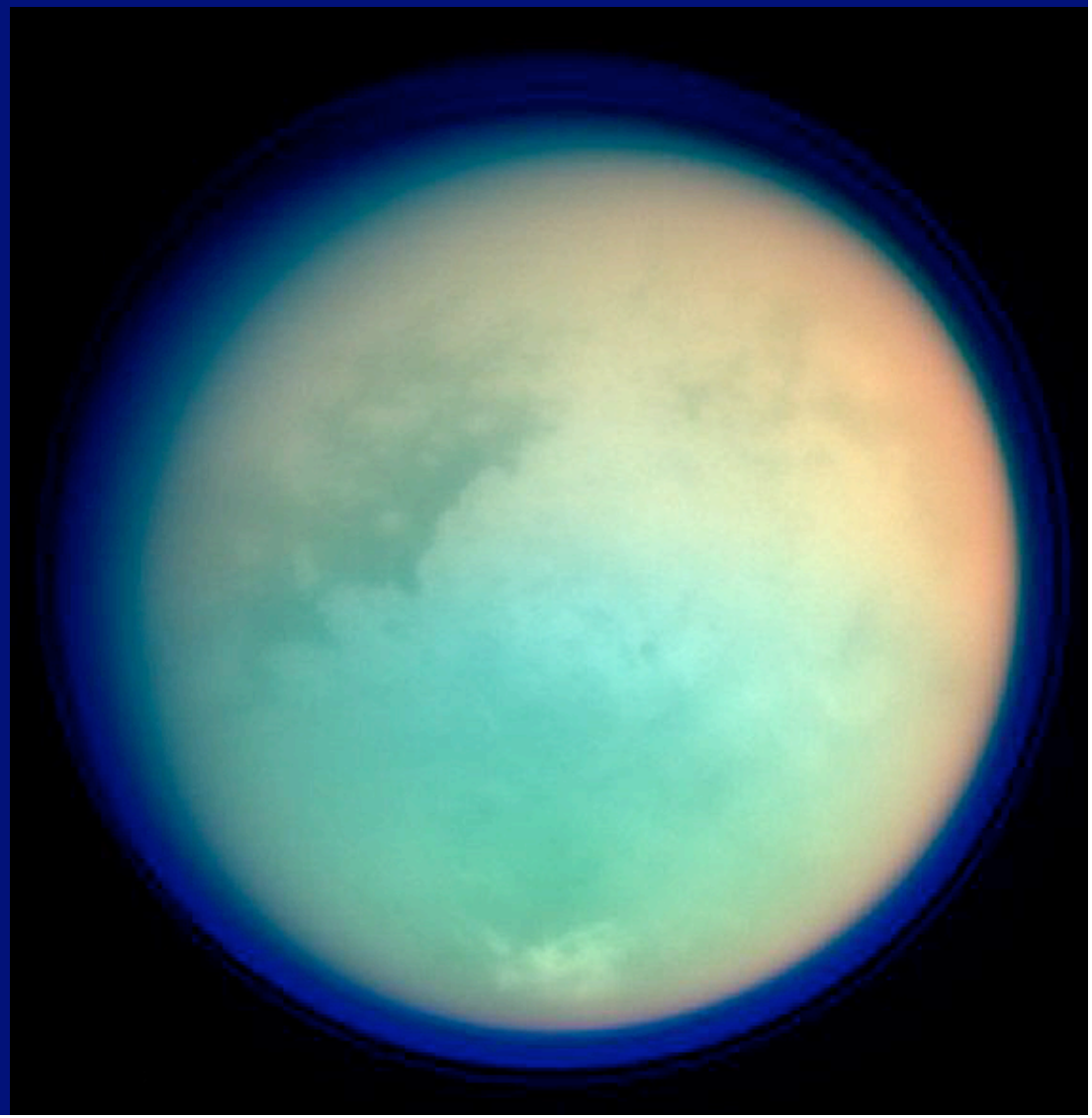


More about the rings

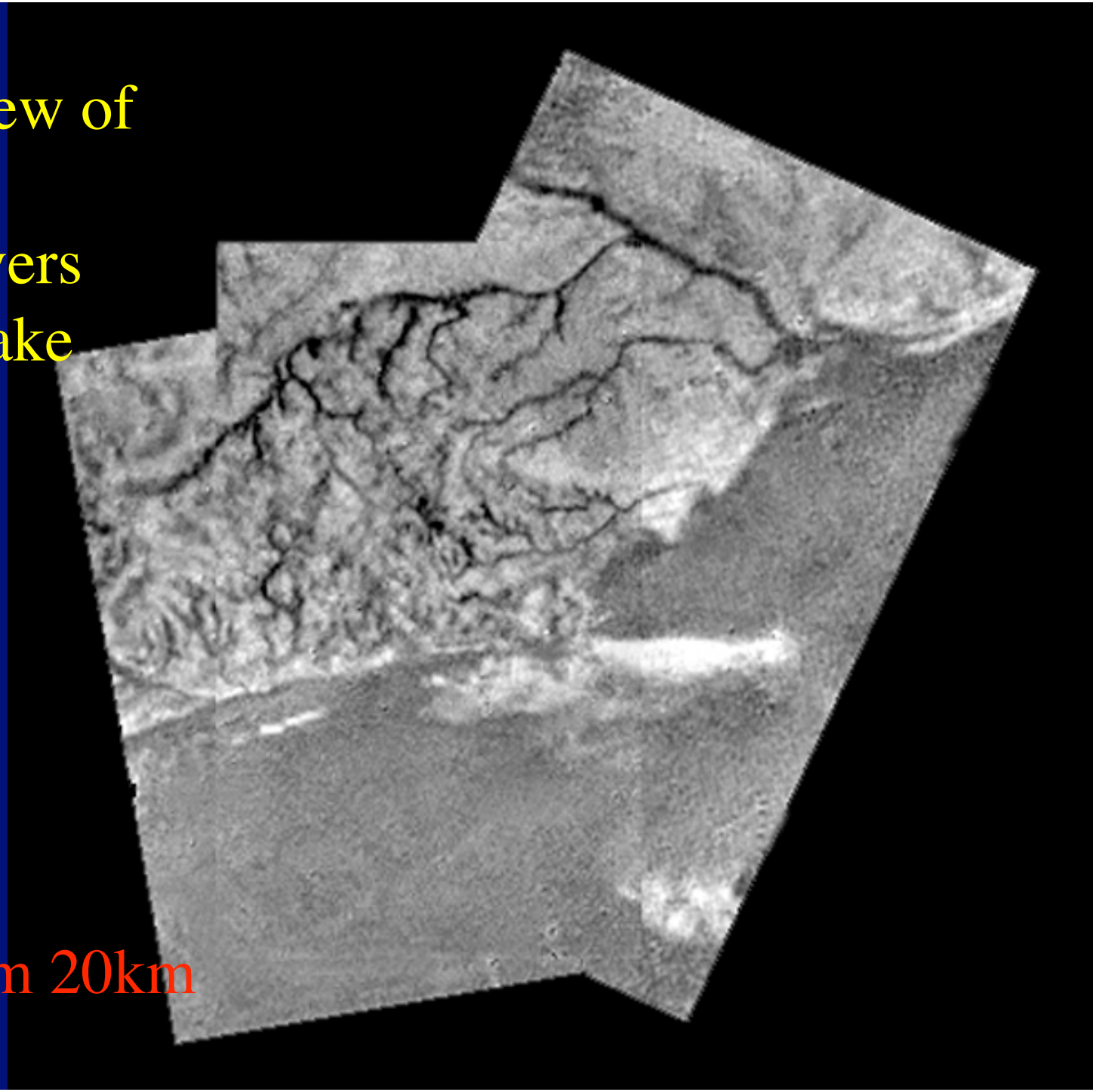
- 70,000 km wide, only 20m thick (!)
- Composed of solid particles from mm to 10s of m
- Total mass = moon of diameter 300m
- Gaps, braids, filaments, sharp edges caused by gravitational effects of shepherd moons
- Collisions causing ring particles to drift inward, so rings must have formed relatively recently
- Rings produced by tidal forces?

Titan: organic haze

- Mercury-sized, but cold
  - Hangs on to atmosphere
  - Organic haze
  - Methane oceans



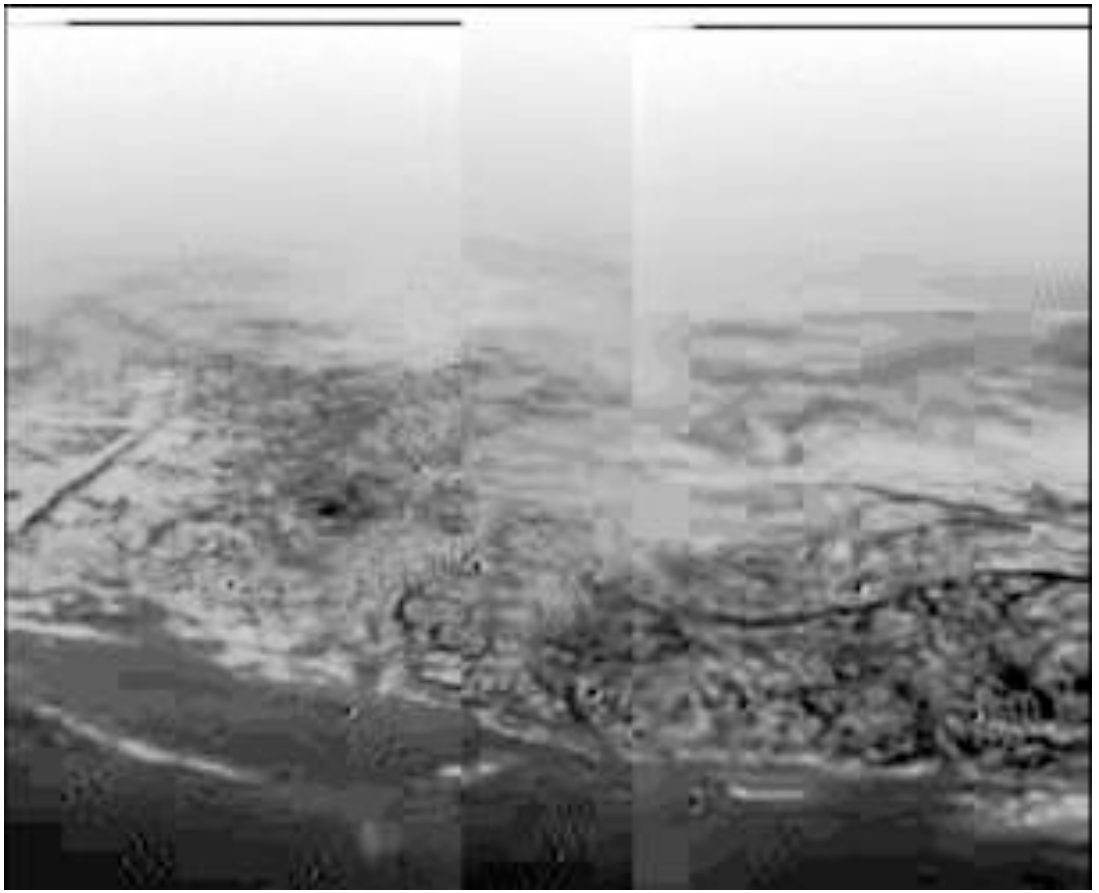
Huygens view of Titan:
Methane rivers leading to lake



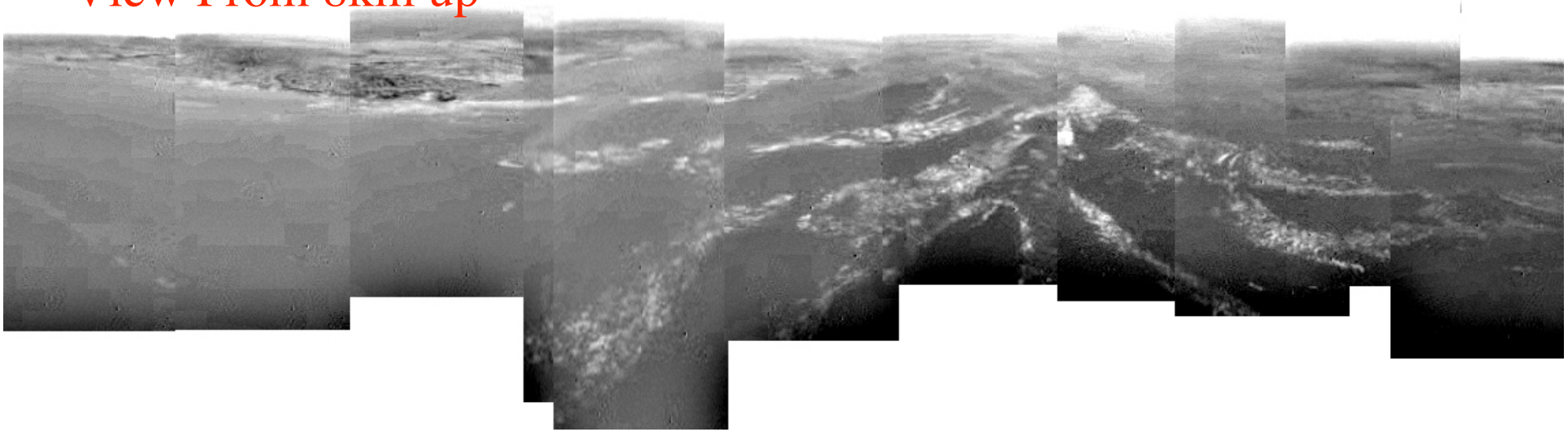
View from 20km

Images from descent of Huygens probe

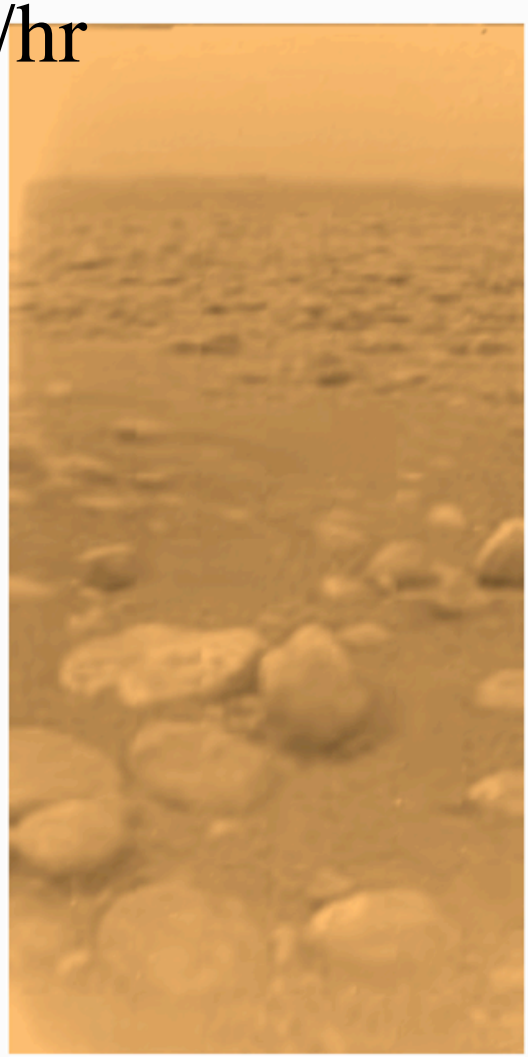
Methane seas

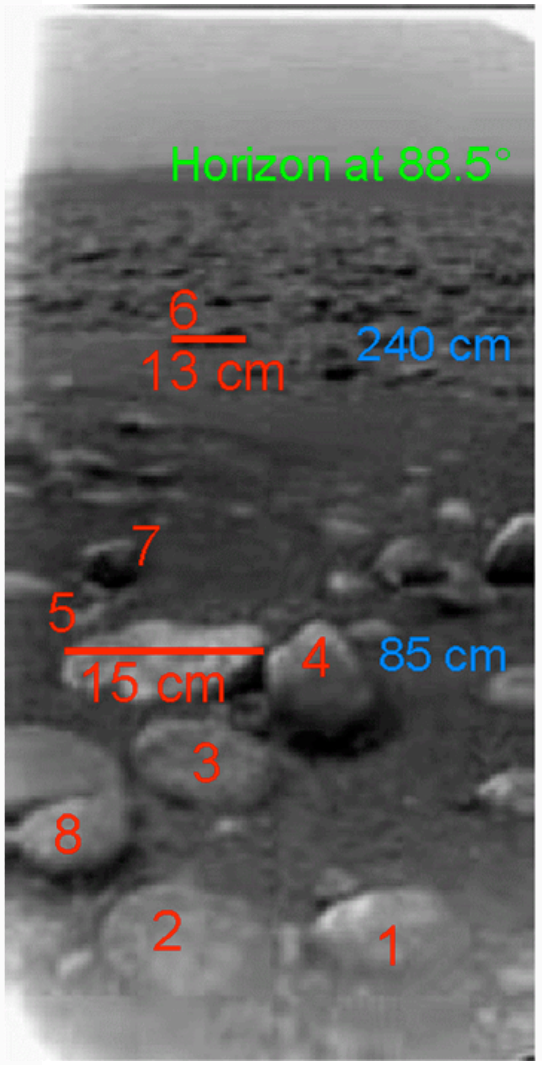


View From 8km up



Huygens view from the surface
From force of impact, landed on slushy not solid ice
Not rocks, but ice chunks
Wind speed: 8km/hr

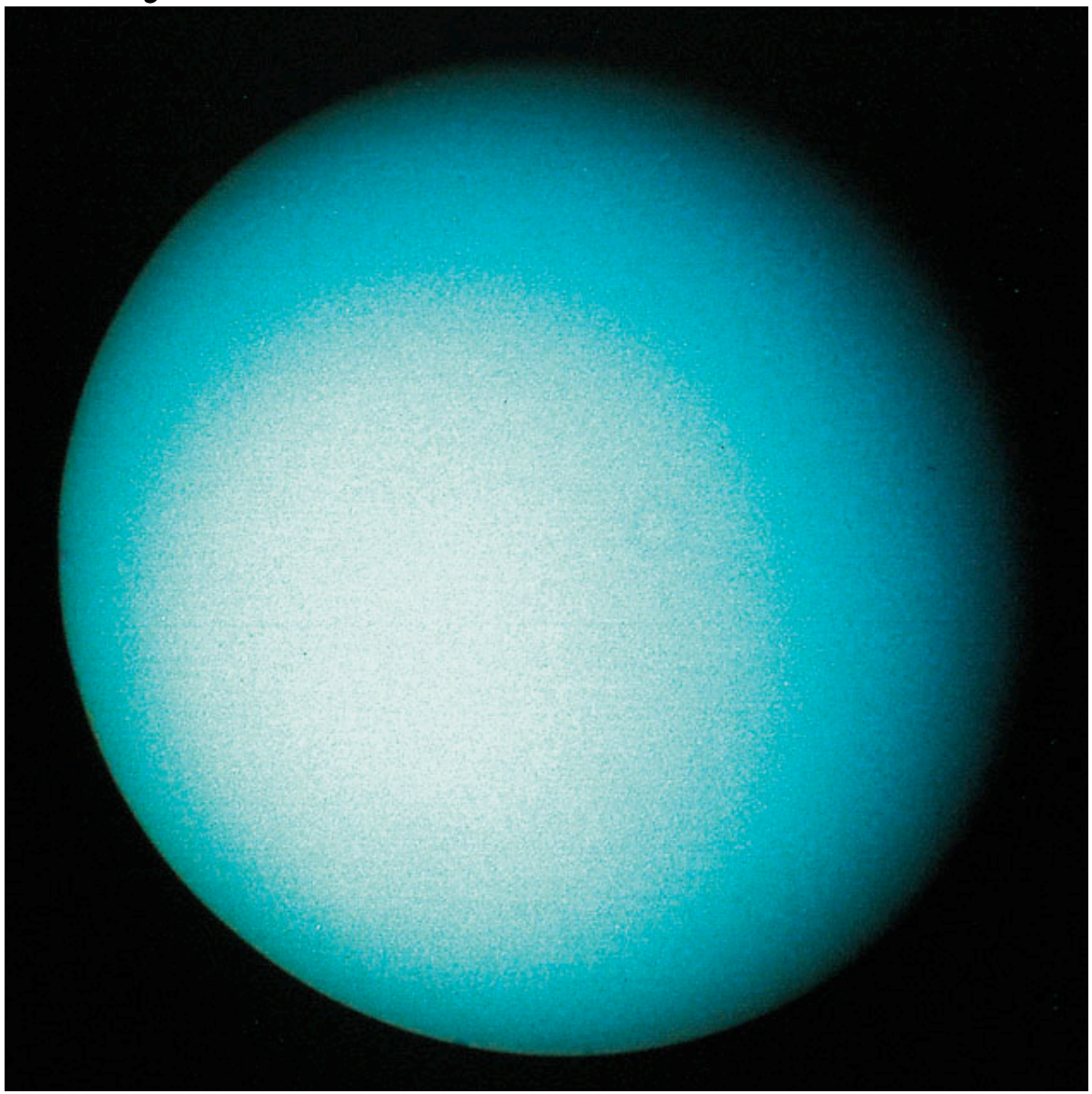




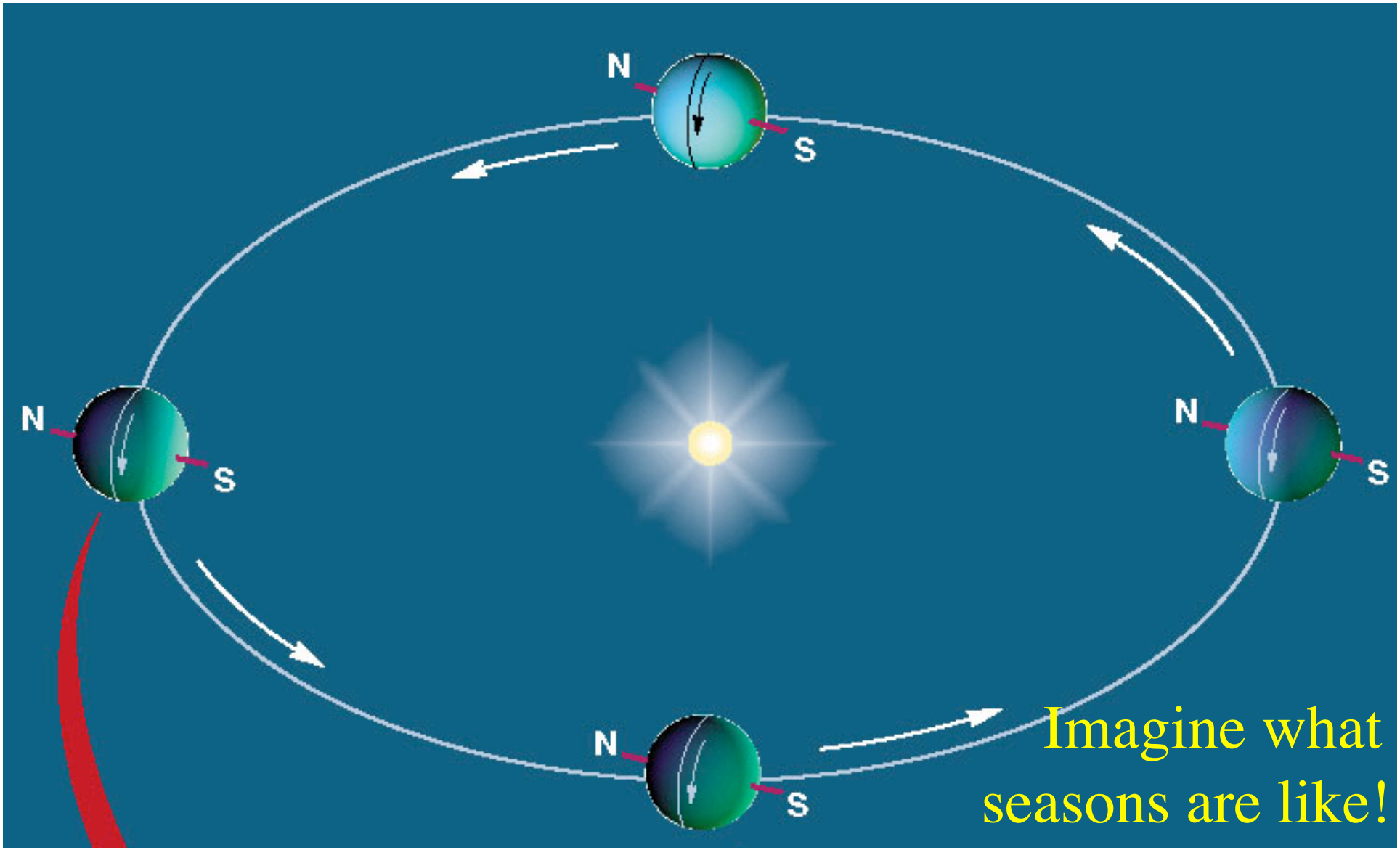
Uranus

discovered by Herschel in 1781

- View from Voyager 2
- Featureless atmosphere, blue from methane
- 13 M_{earth} core is very large fraction of total mass

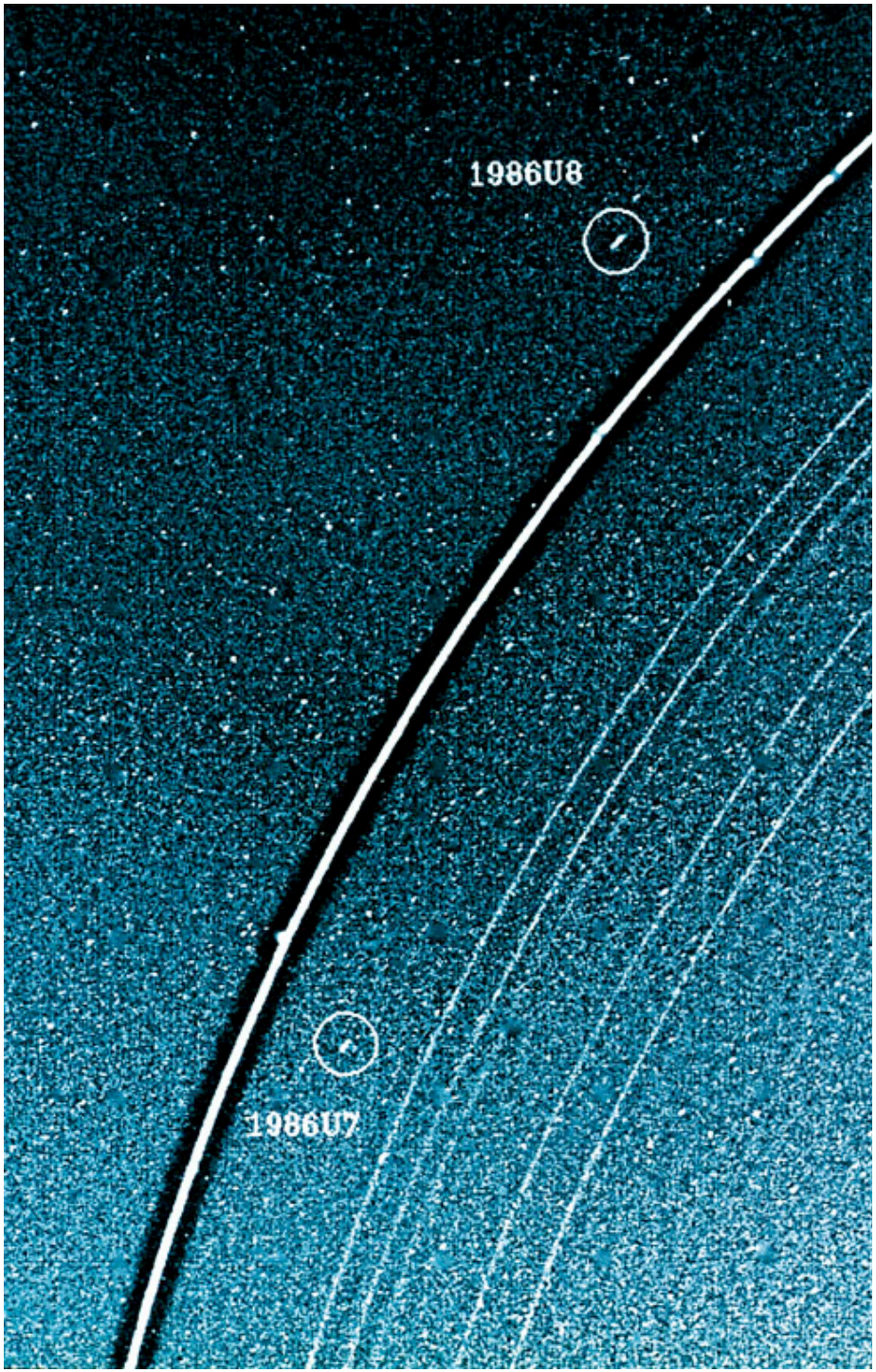


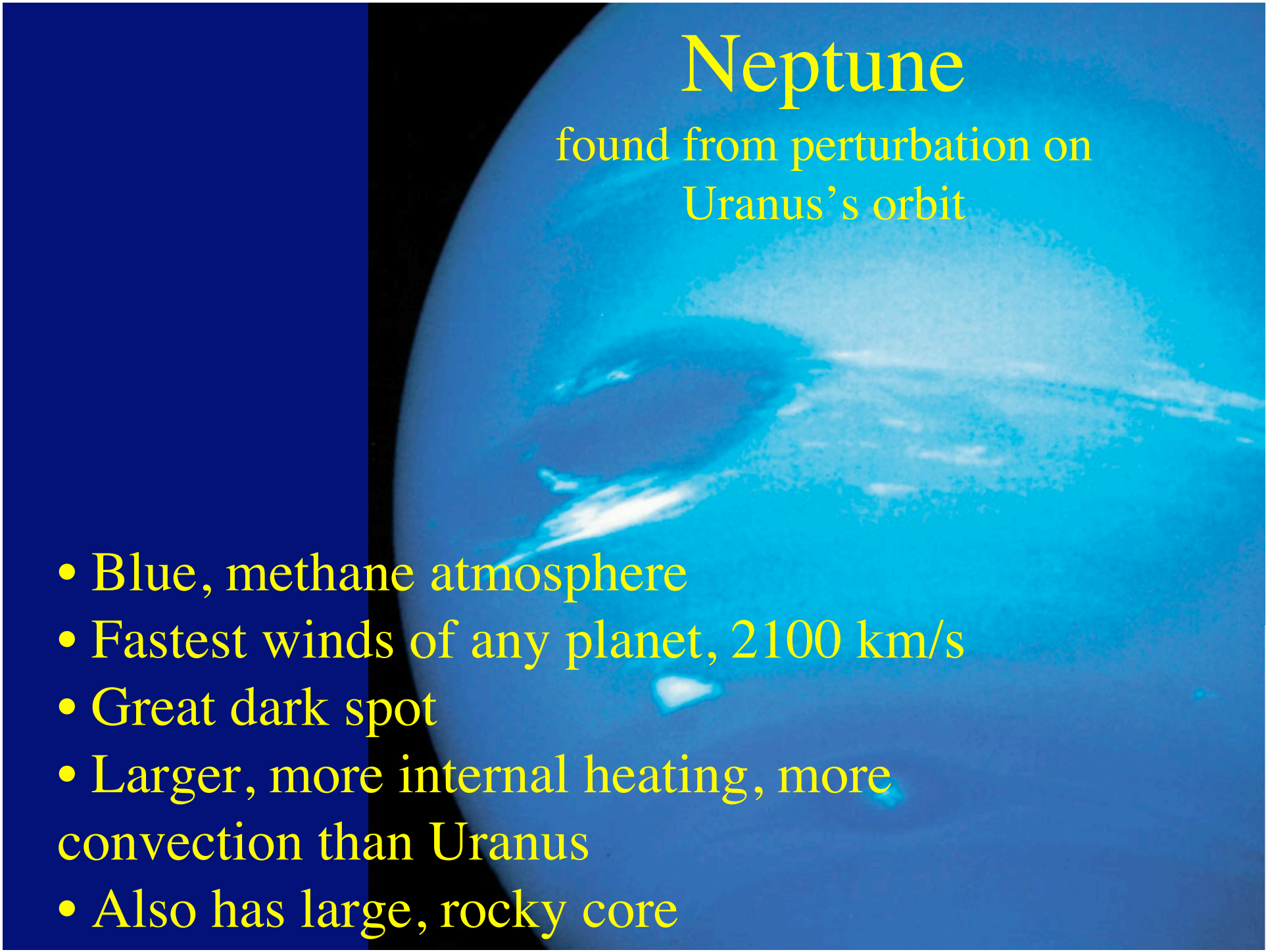
Rotation axis tipped 98 degrees relative to orbit plane – probably caused by giant impact



Uranus rings

- Why so narrow?
  - Shepherd moons
- Rings made in last few million years from debris of comets hitting moons
- Ring plane tilted same as rotation axis

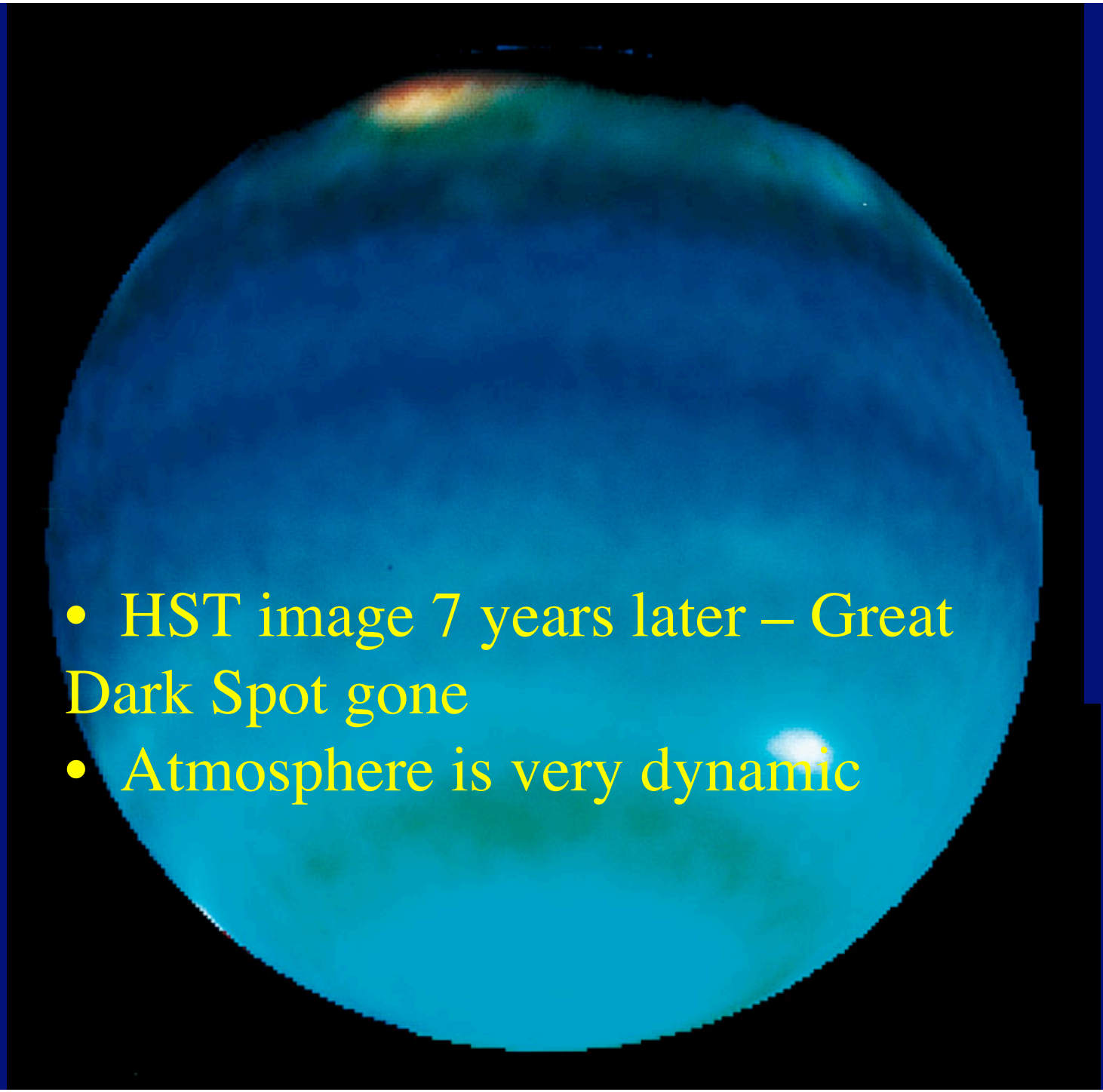




Neptune

found from perturbation on Uranus's orbit

- Blue, methane atmosphere
- Fastest winds of any planet, 2100 km/s
- Great dark spot
- Larger, more internal heating, more convection than Uranus
- Also has large, rocky core



- HST image 7 years later – Great Dark Spot gone
- Atmosphere is very dynamic

Neptune's Rings

discovered by stellar occultations, observed by Voyager 2