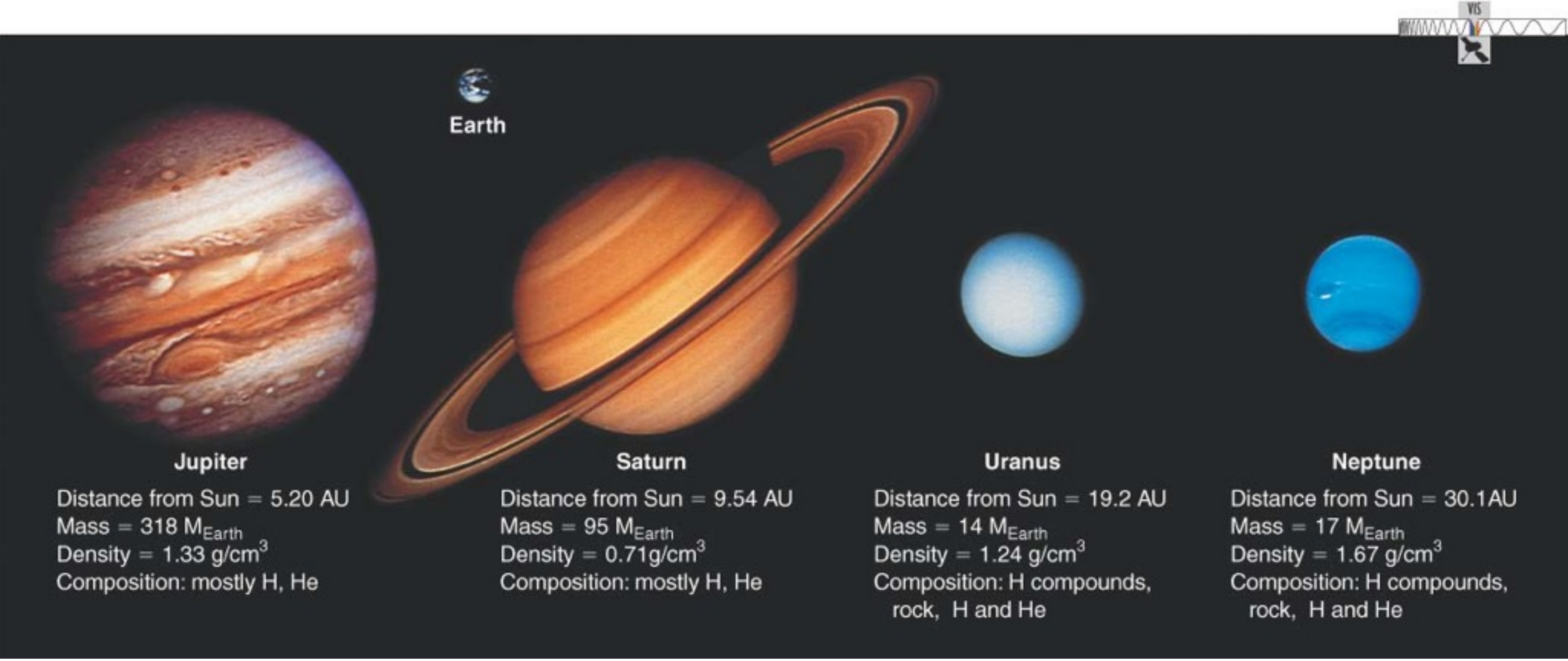
Jovian Planets

Ch. 6.1, 8



Jupiter is composed of 97% H and He

Saturn is composed of 90% H and He

Uranus and Neptune are primarily CH_4, H_2O and NH_3

Neptune and Uranus more dense than Jupiter and Saturn

Jupiter is *more* dense than Saturn

Jupiter

$a = 5.20$ AU

$R = 11.2\ R_{Earth}$

$M = 318\ M_{Earth}$

$\rho = 1.33\ g/cm^3$

$T = 125$ K

Moons: 63

Saturn

$a = 9.54$ AU

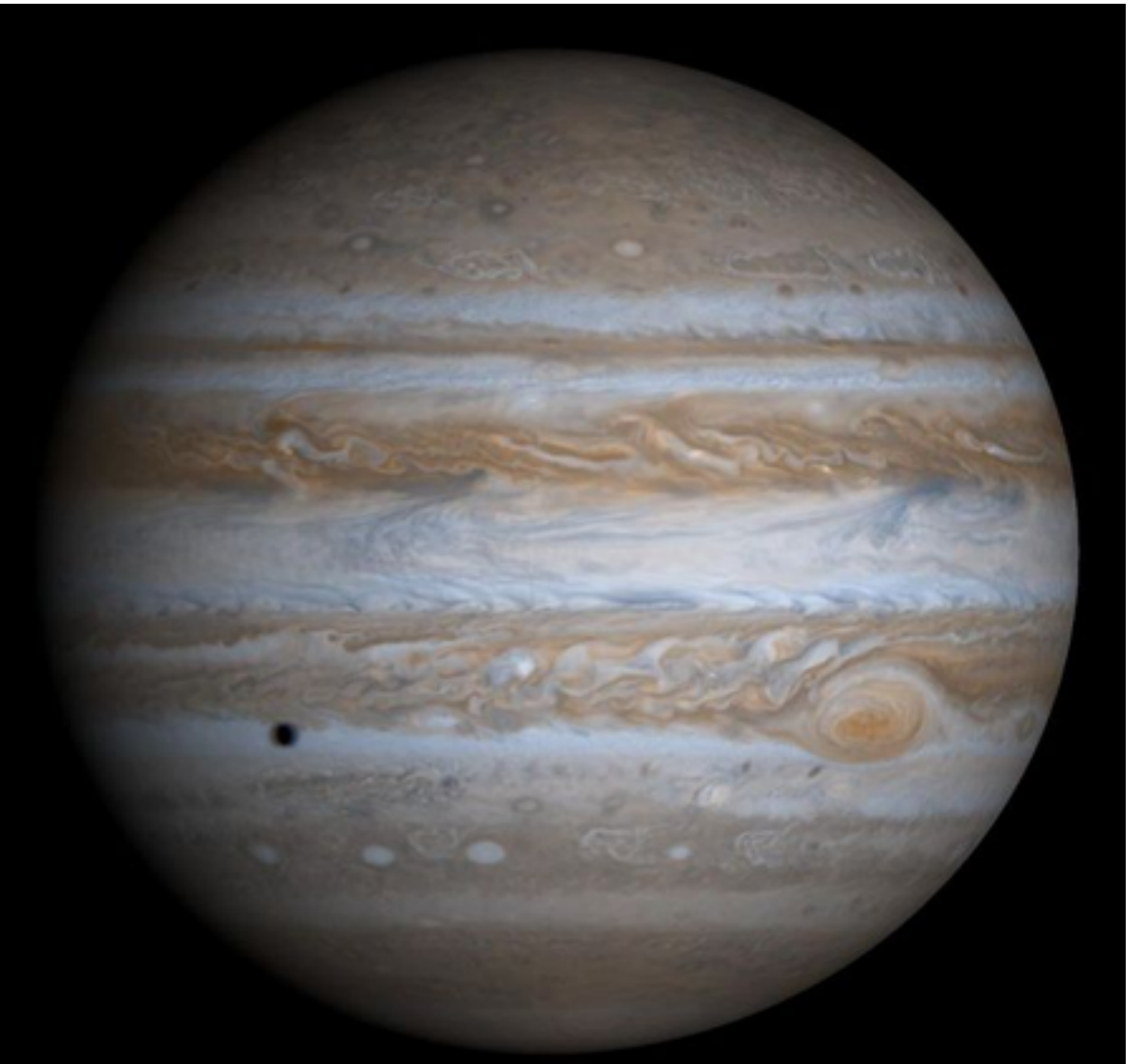
$R = 9.4\ R_{Earth}$

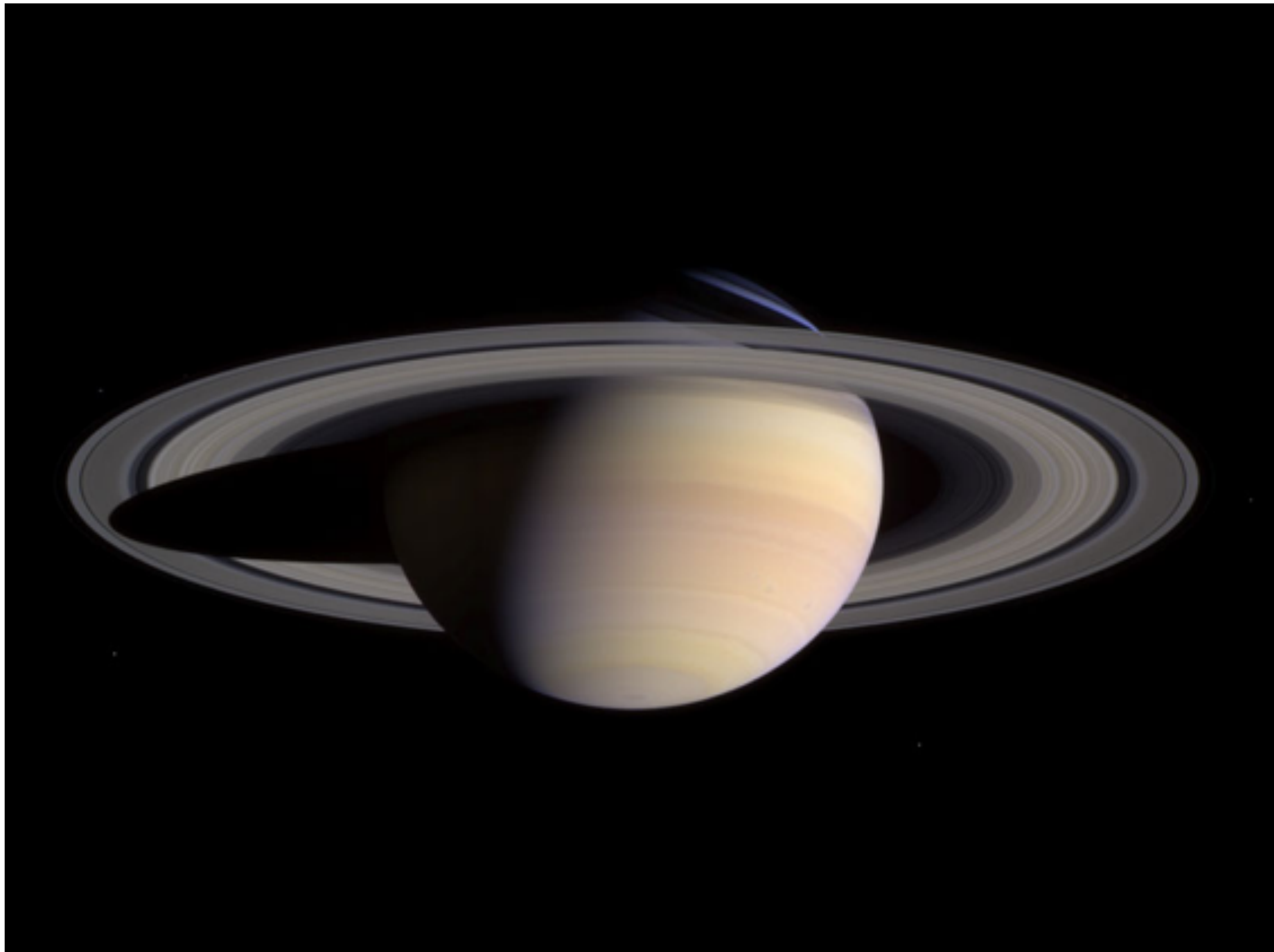
$M = 95.2\ M_{Earth}$

$\rho = 0.70\ g/cm^3$

$T = 95$ K

Moons: >60





Uranus

$a = 19.2$ AU

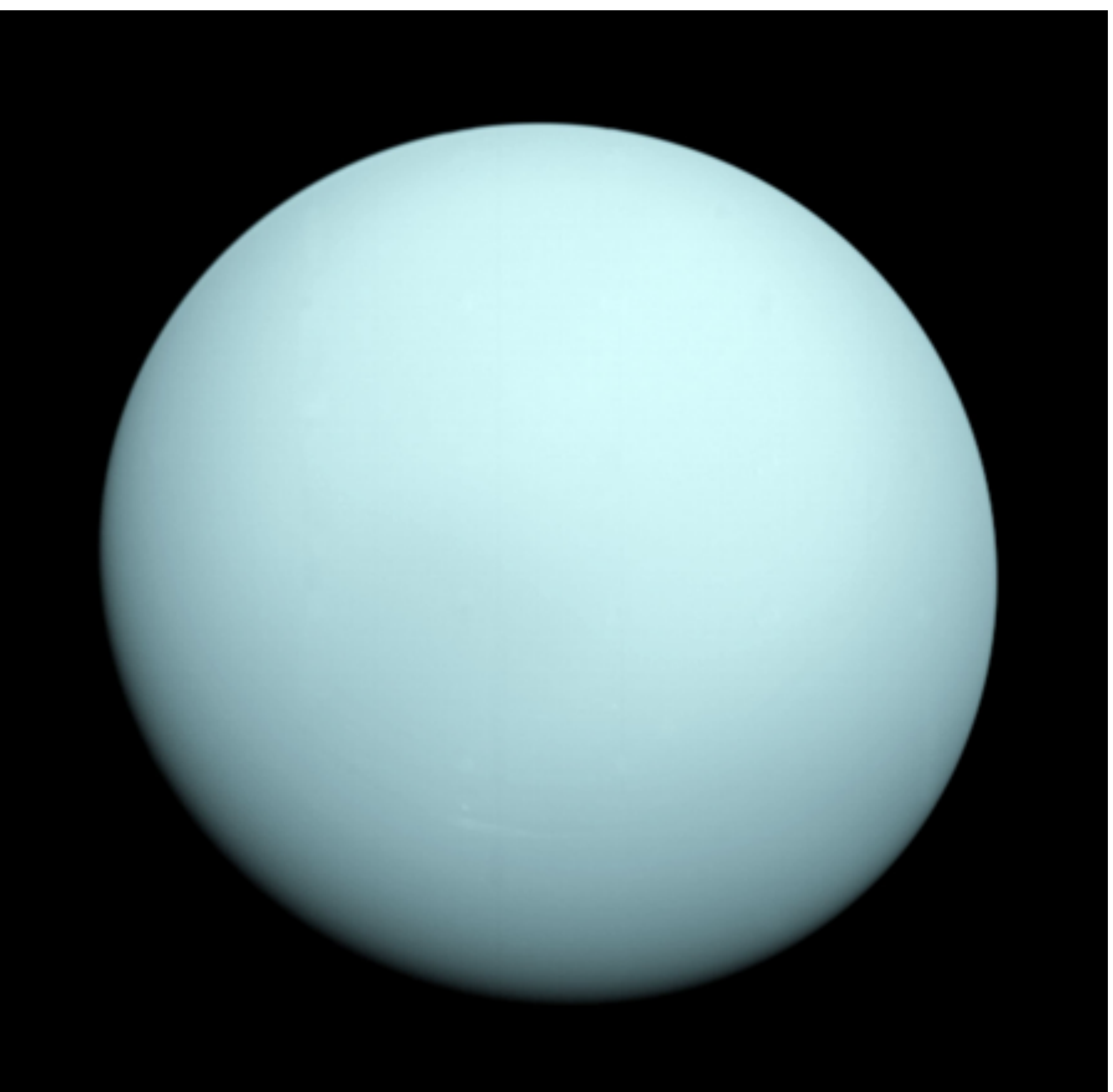
$R = 4.0\ R_{Earth}$

$M = 14.5\ M_{Earth}$

$\rho = 1.33\ g/cm^3$

$T = 60$ K

Moons: >27



Neptune

$a = 30.1$ AU

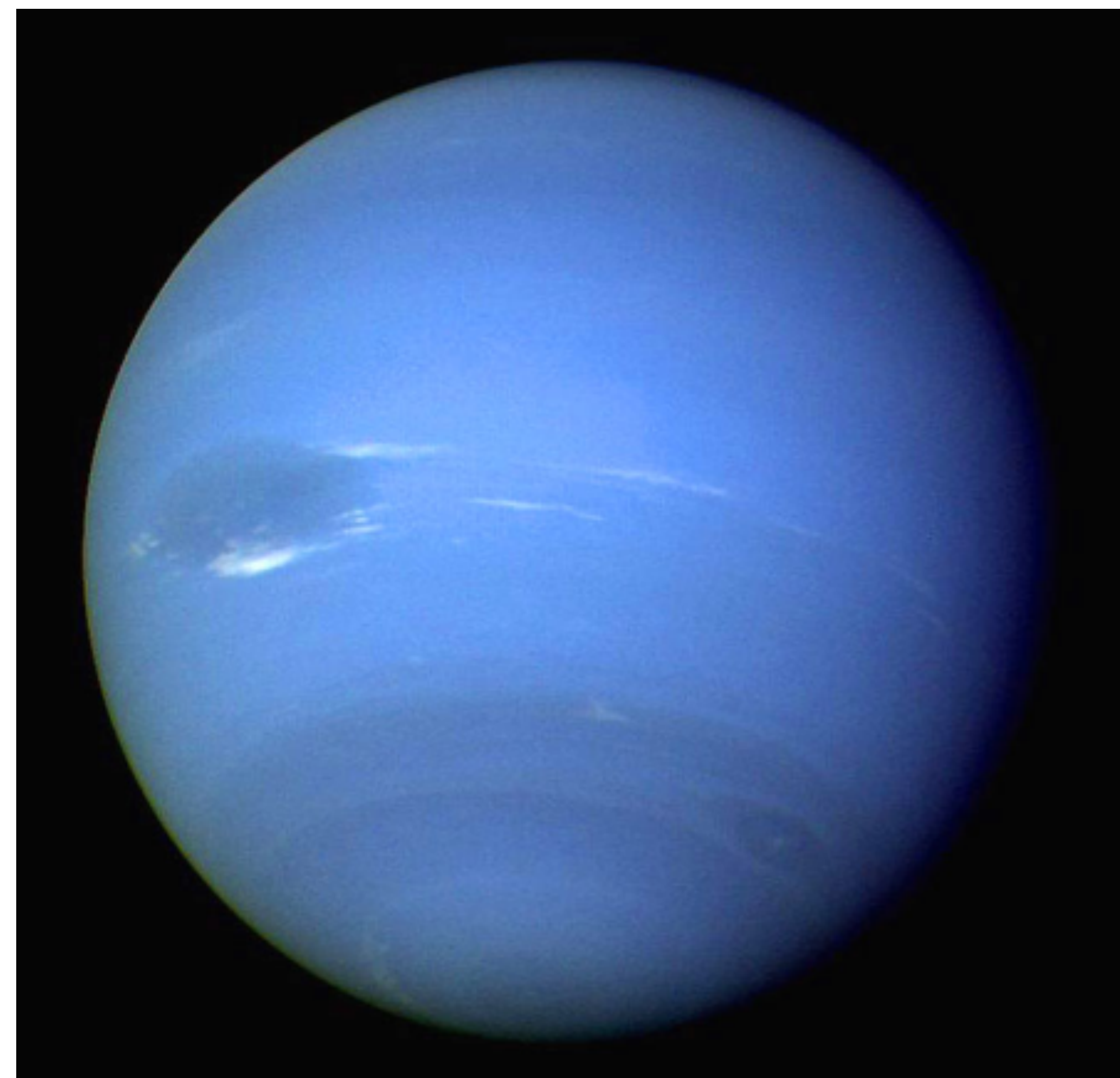
$R = 3.9\ R_{Earth}$

$M = 17.1\ M_{Earth}$

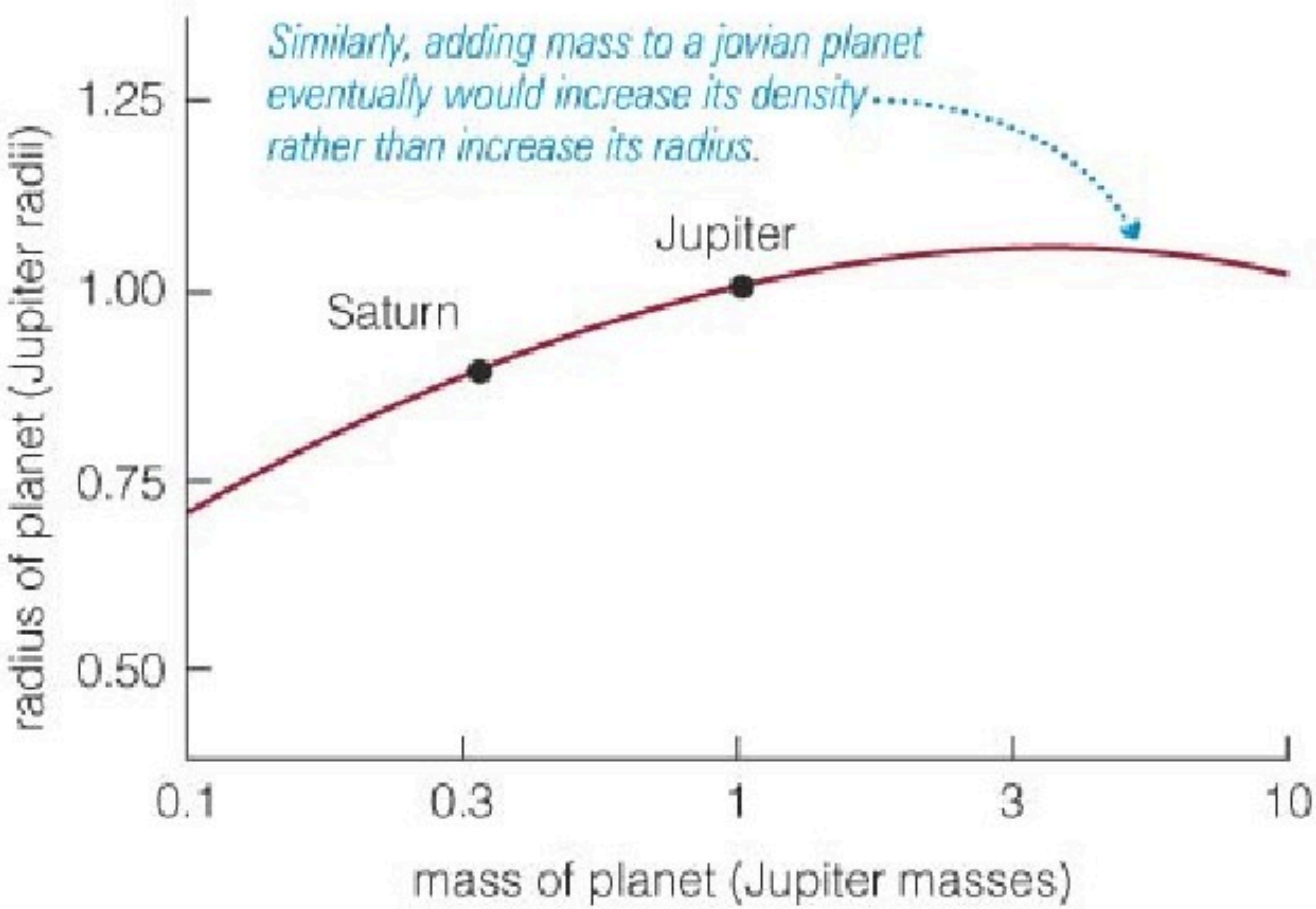
$\rho = 1.64\ g/cm^3$

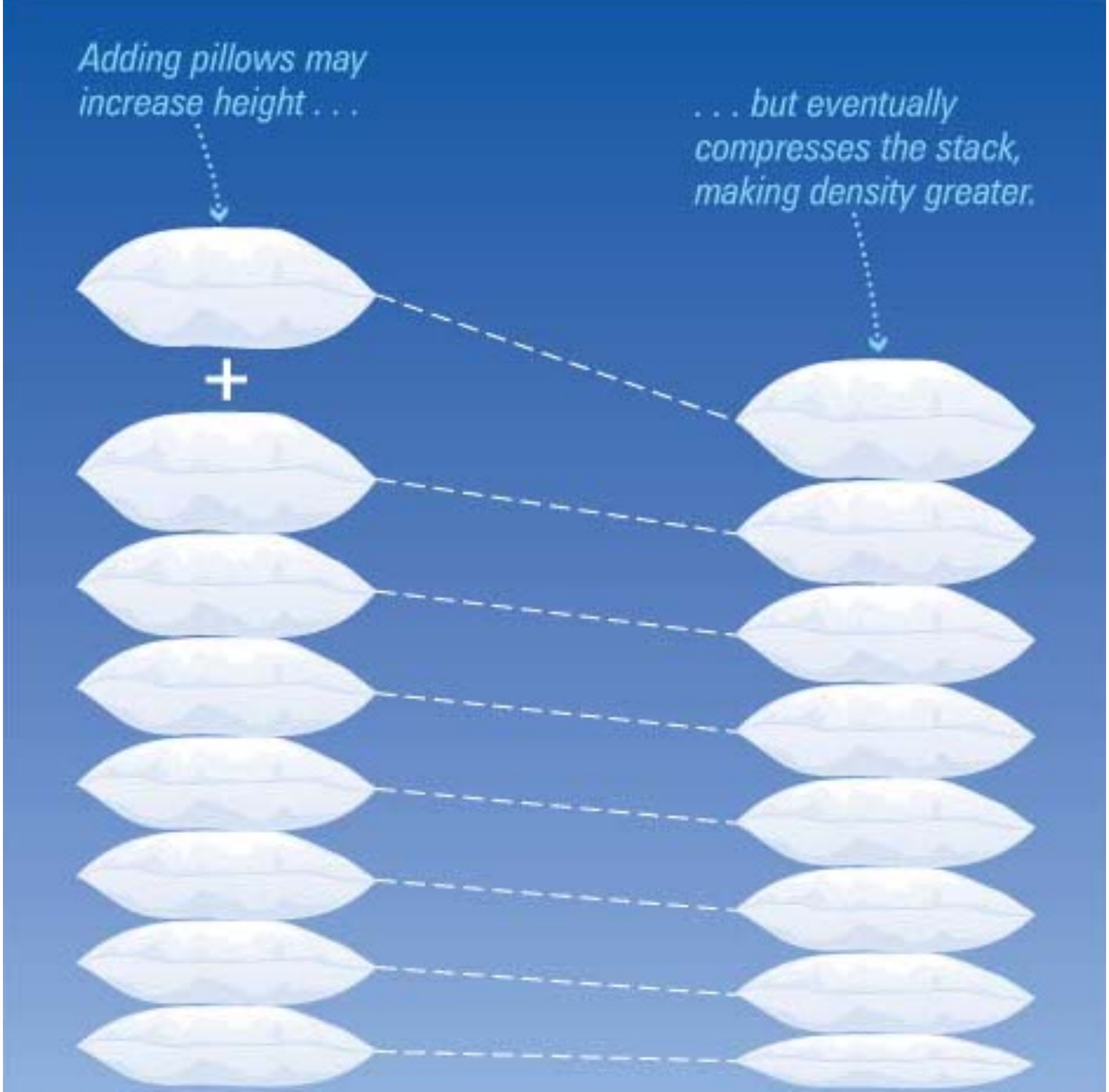
$T = 60$ K

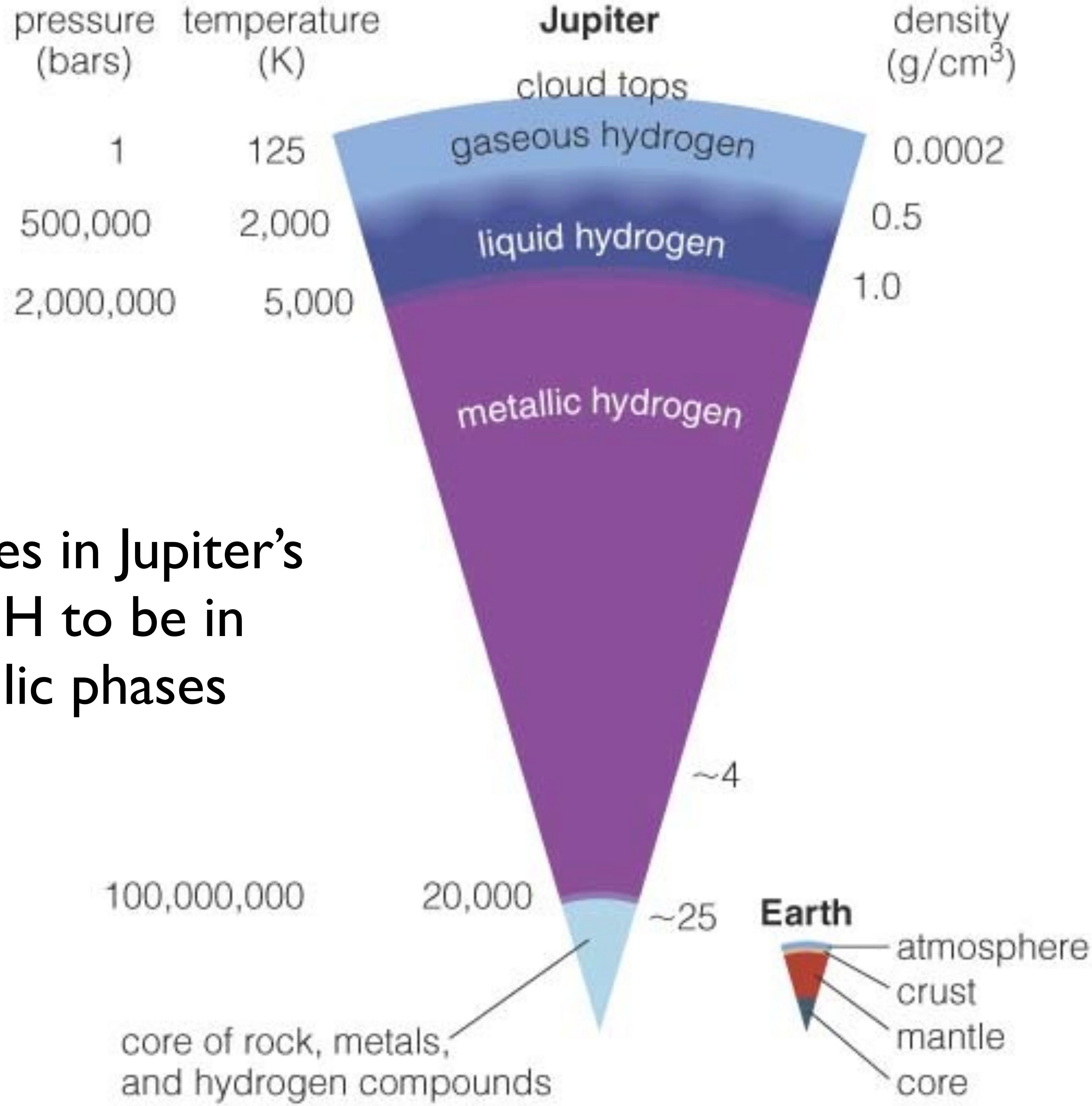
Moons: >13



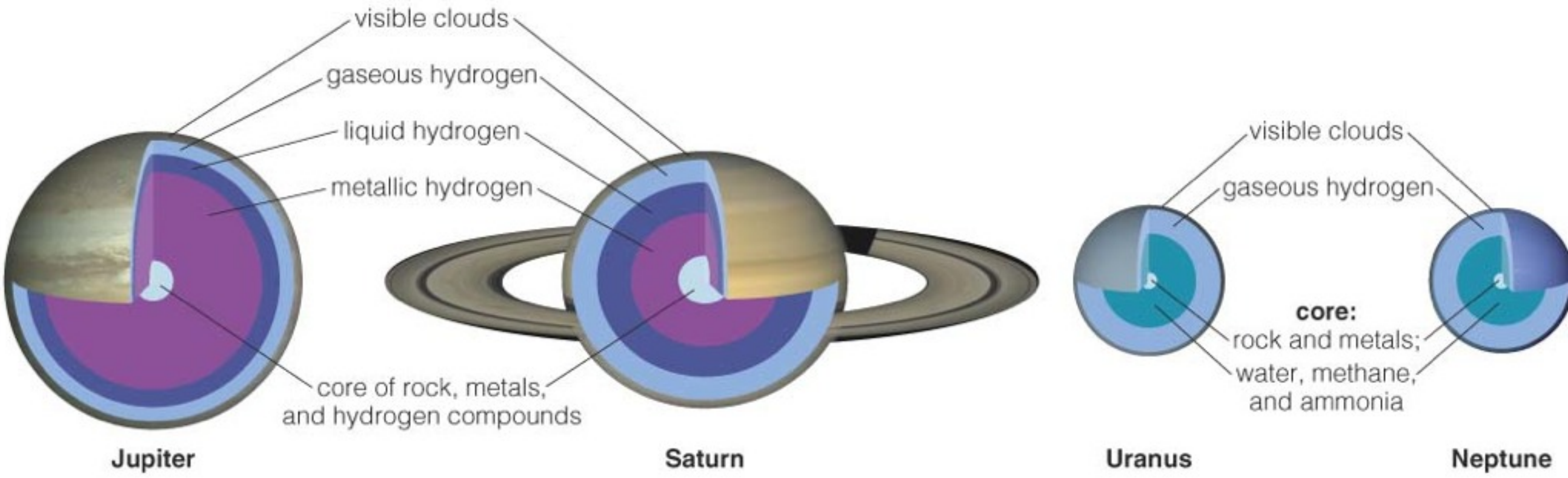
Mass, Density, & Radius




Adding pillows may increase height . . .
. . . but eventually compresses the stack, making density greater.



Extreme pressures in Jupiter's interior cause H to be in liquid & metallic phases

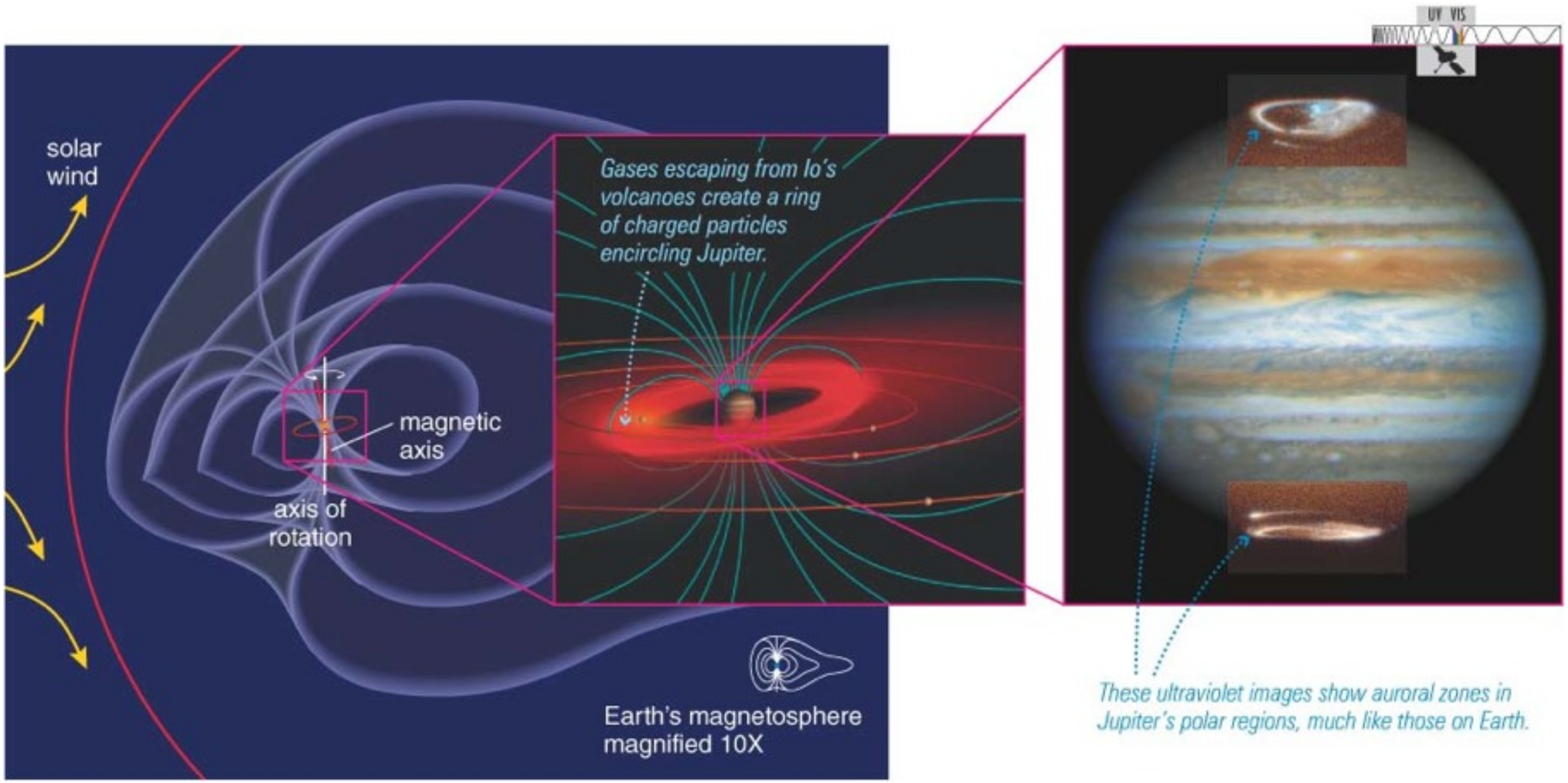


All the Jovian planets have cores of similar mass

Saturn is less massive than Jupiter so its layers of different H phases are more evenly spaced

Uranus and Neptune not massive enough to have liquid or metallic H

Jupiter’s Magnetic Field



20,000 times stronger than Earth’s magnetic field

Atmospheric Colors

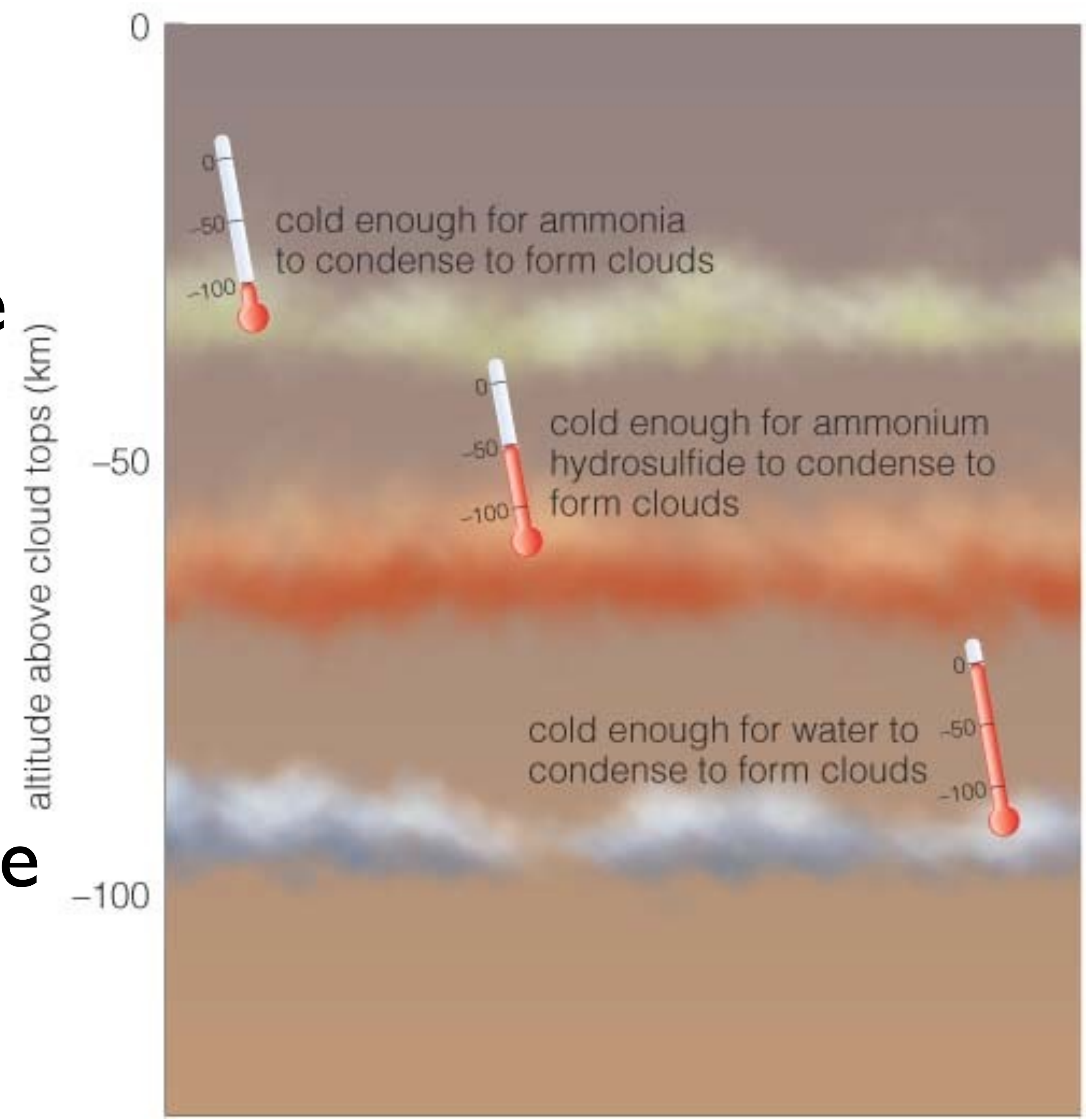
Gases condense at different temperatures to form clouds

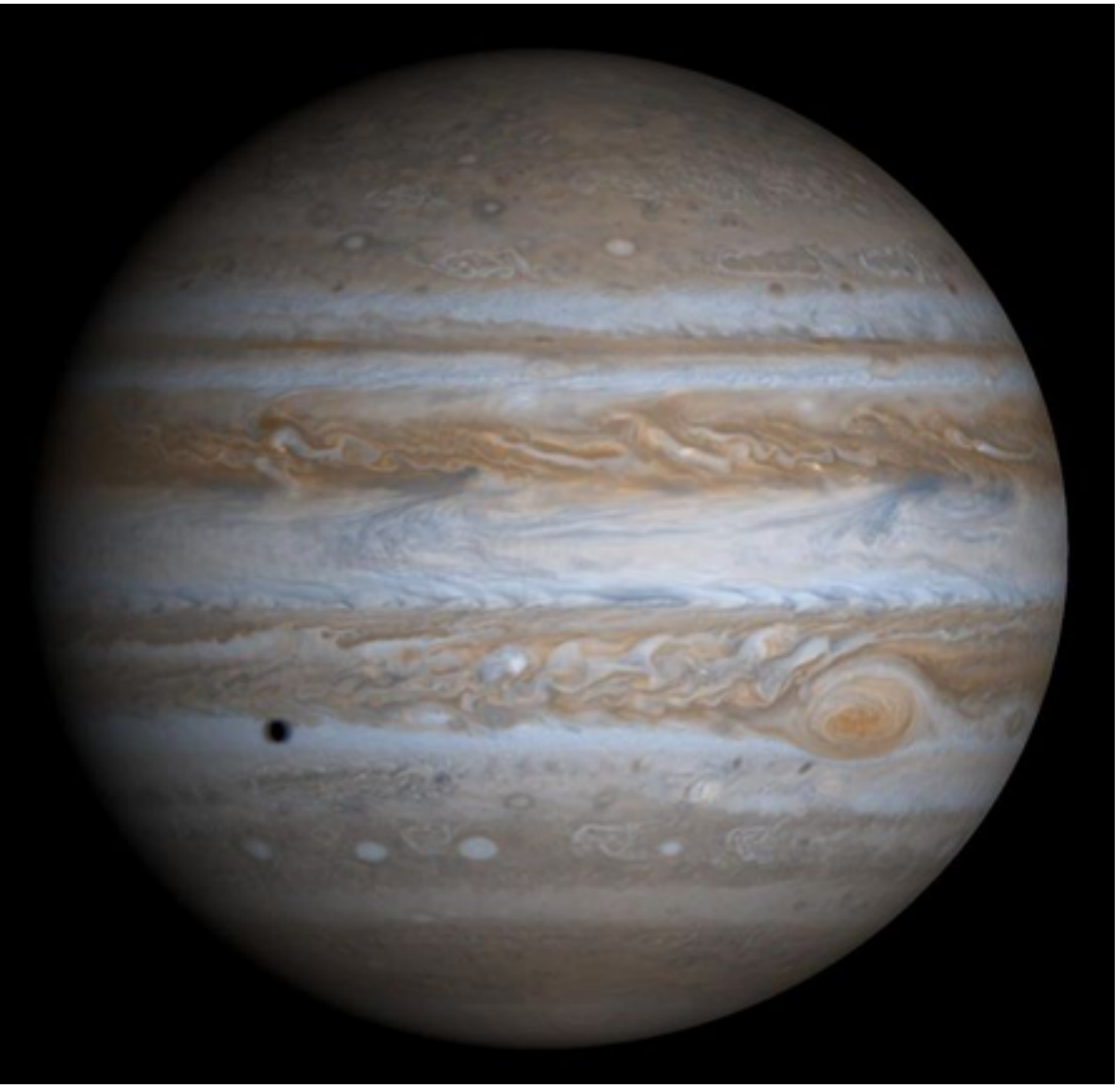
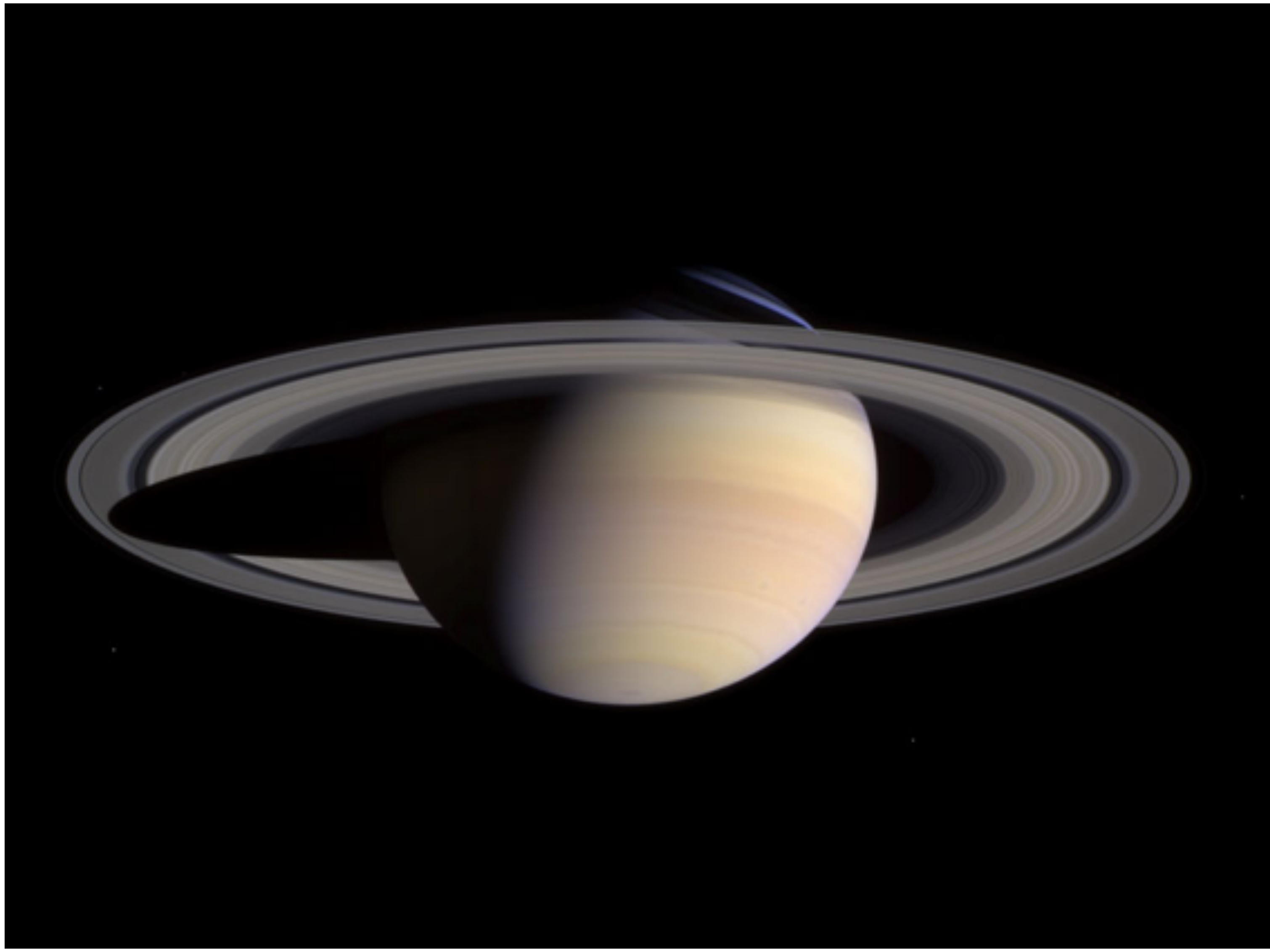
Jupiter has a thin atmosphere since the gravity is so strong

- Light penetrates to all the depths where the clouds form

Saturn has a thick atmosphere

- Light cannot penetrate as deeply and so fewer colors are seen



Explaining Jupiter's Colors

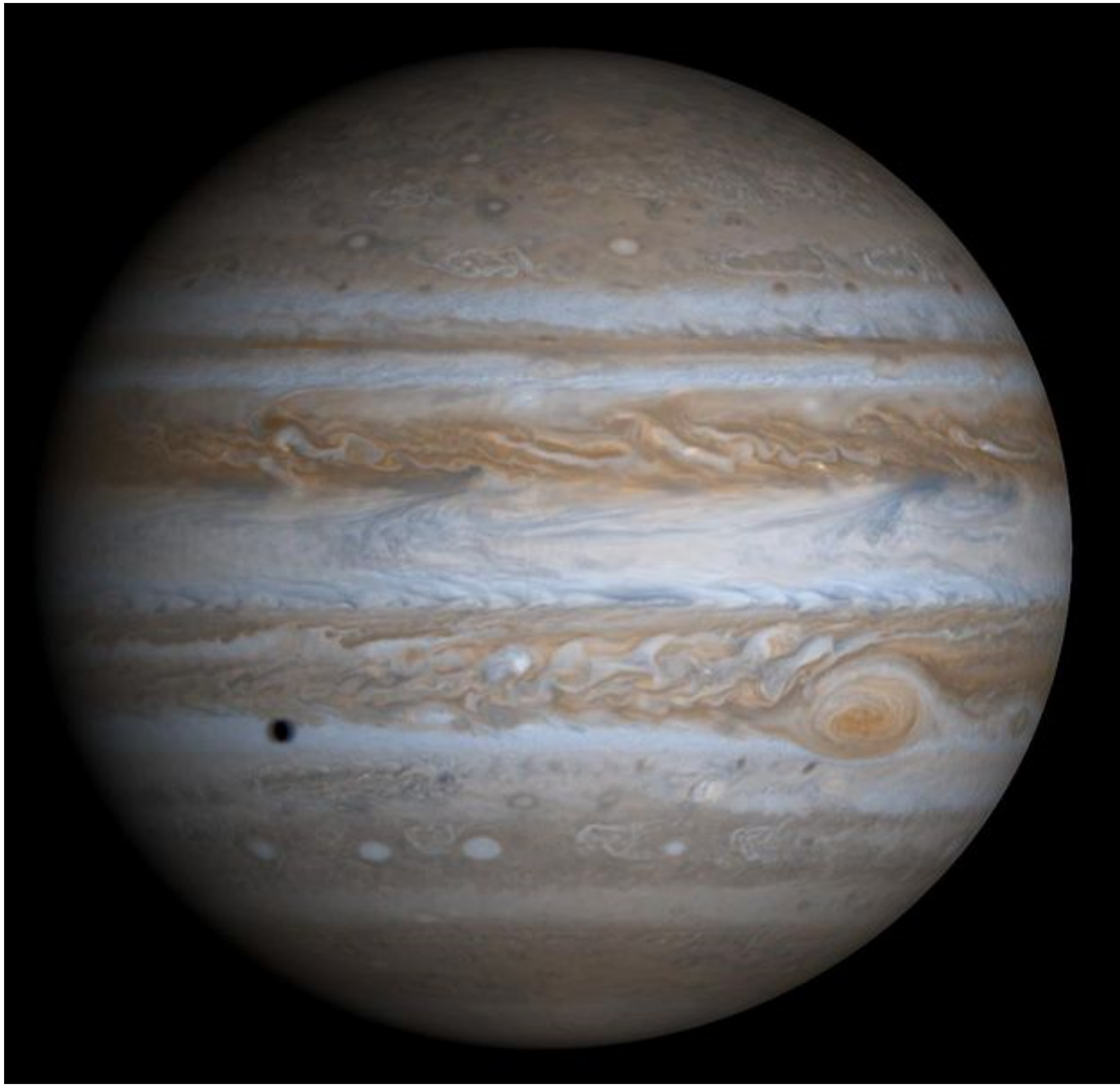
Jupiter is covered in red-brown ammonium sulfide clouds

High pressure material rises and ammonia condenses to form white clouds

Ammonia clouds snow thereby depleting the ammonia

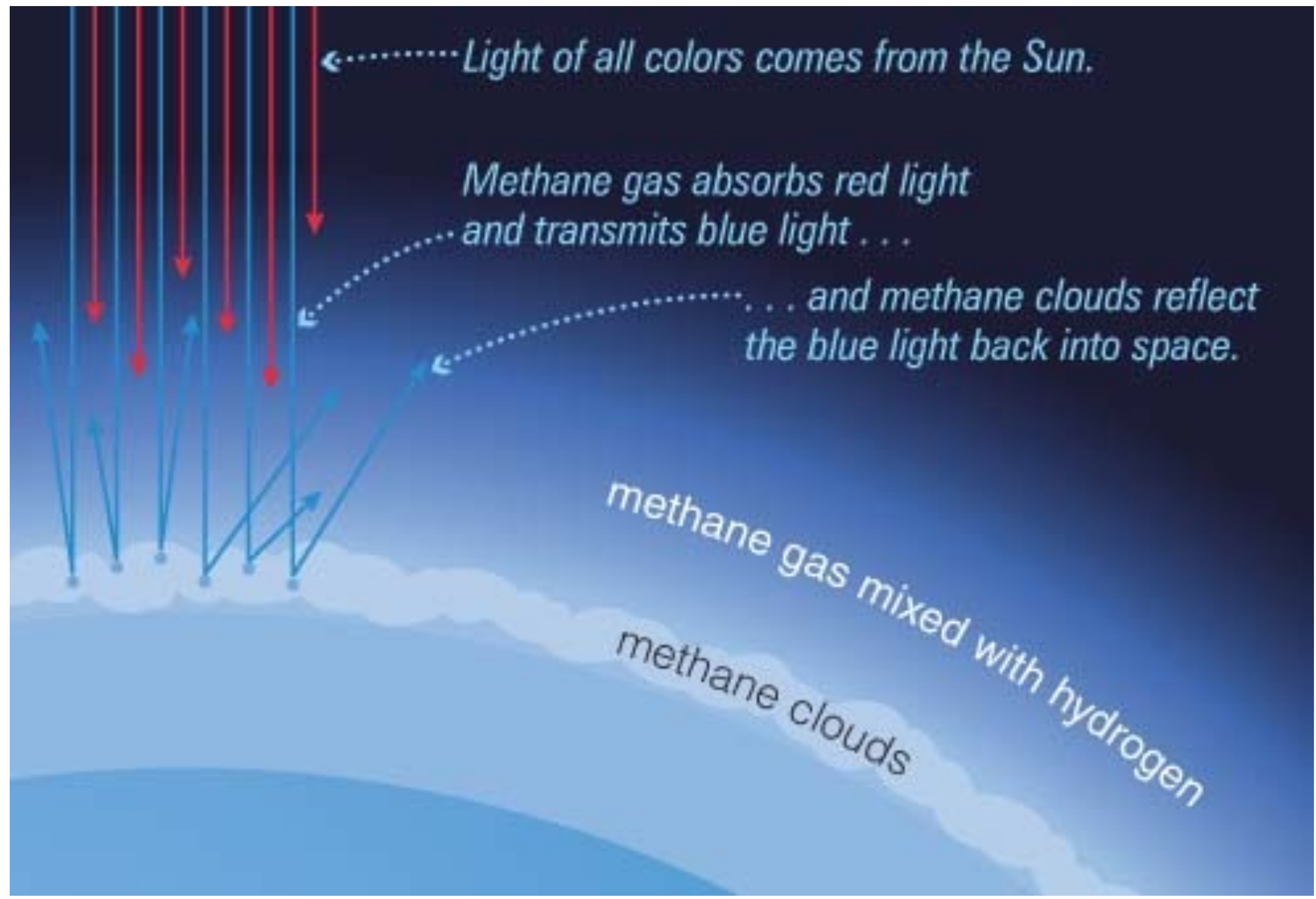
Material spills over North and South

Ammonia is depleted and ammonium sulfide clouds become visible



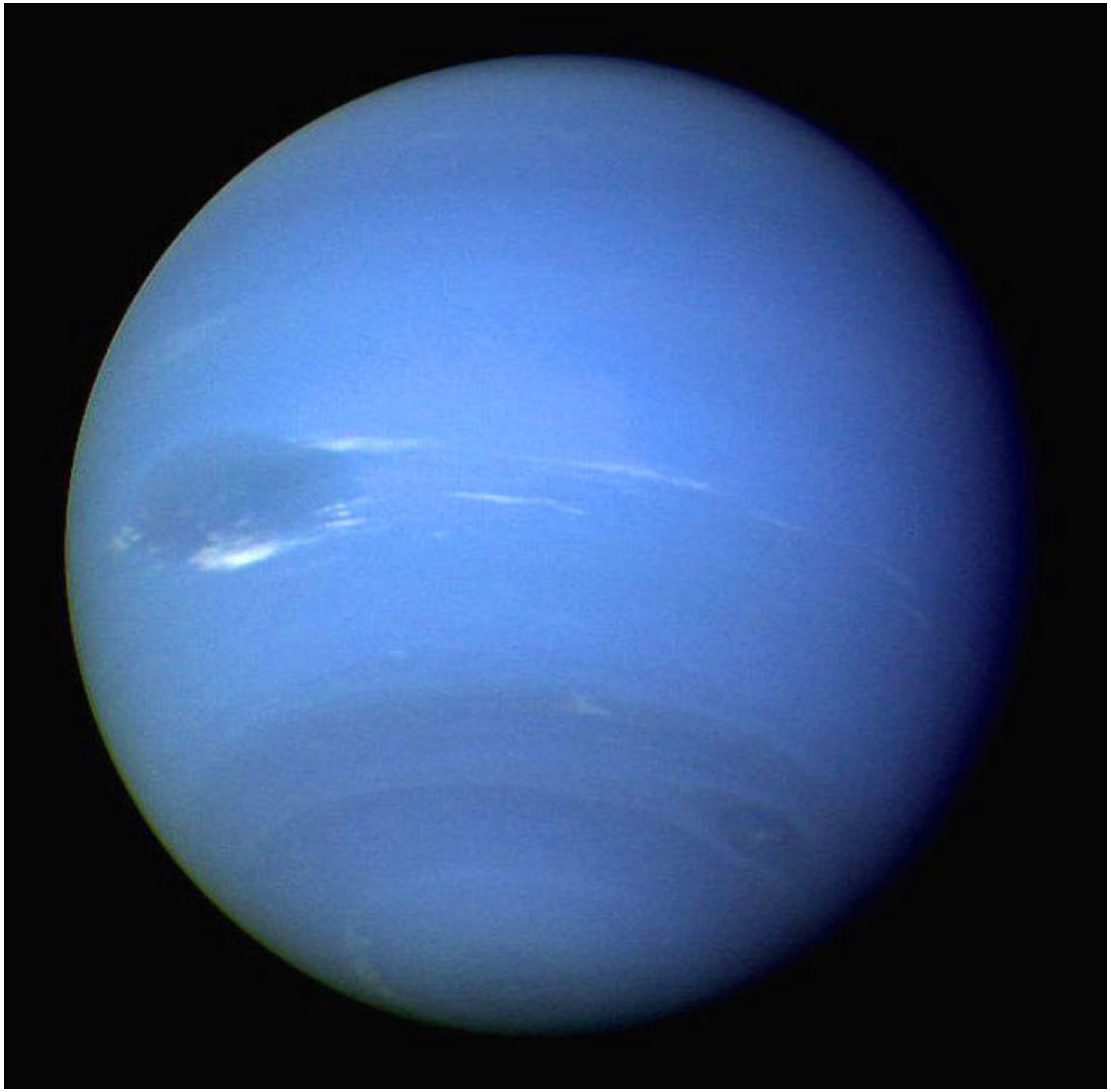
Atmospheric Colors

Neptune and Uranus are composed mostly of hydrogen compounds



Methane gas absorbs red light

Liquid methane clouds reflect blue light



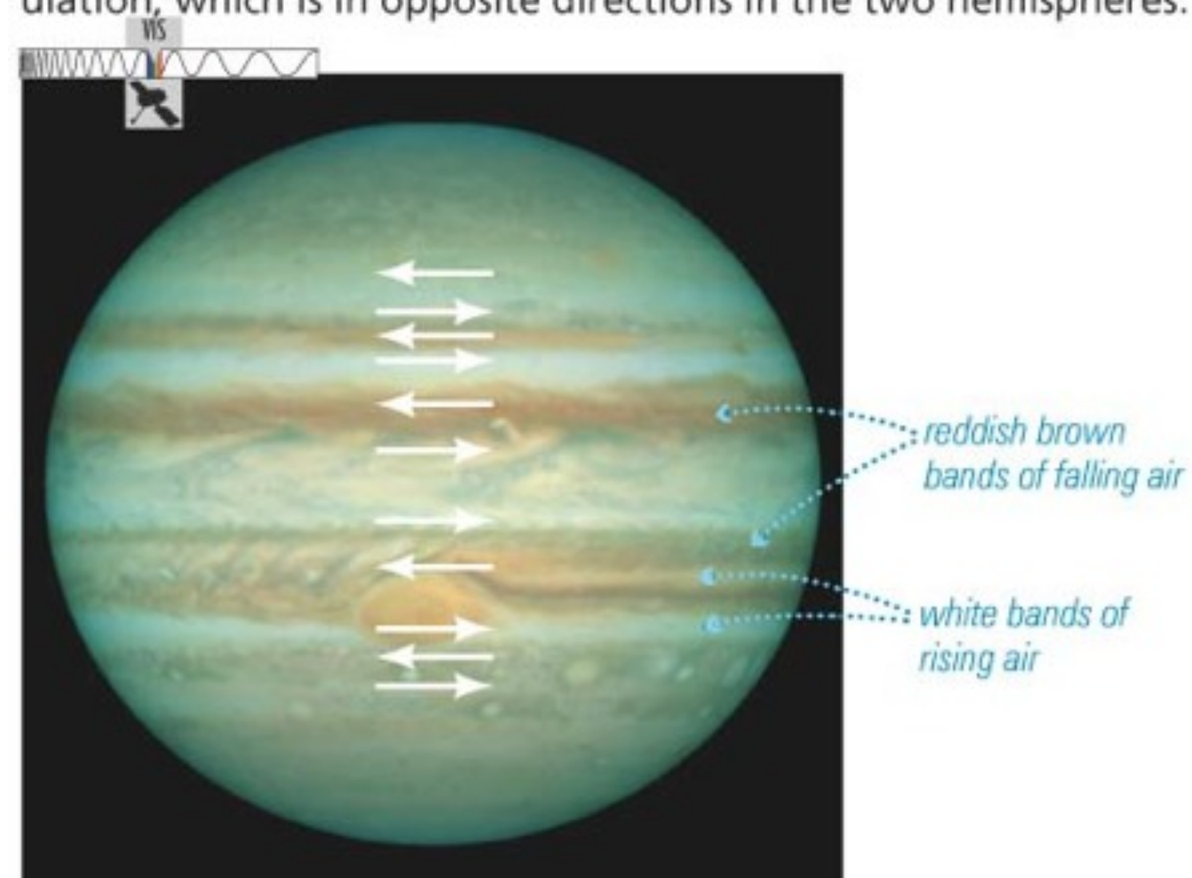
Coriolis Effect

<u>Coriolis effect</u> - the deflection of material due to rotation

Coriolis effect on Earth causes storms to circulate around regions of low pressure

Extreme Coriolis effect on Jupiter cause storms to circulate around the entire planet

a This photograph shows how storms circulate around low pressure regions (L) on Earth. Earth's rotation causes this circulation, which is in opposite directions in the two hemispheres.

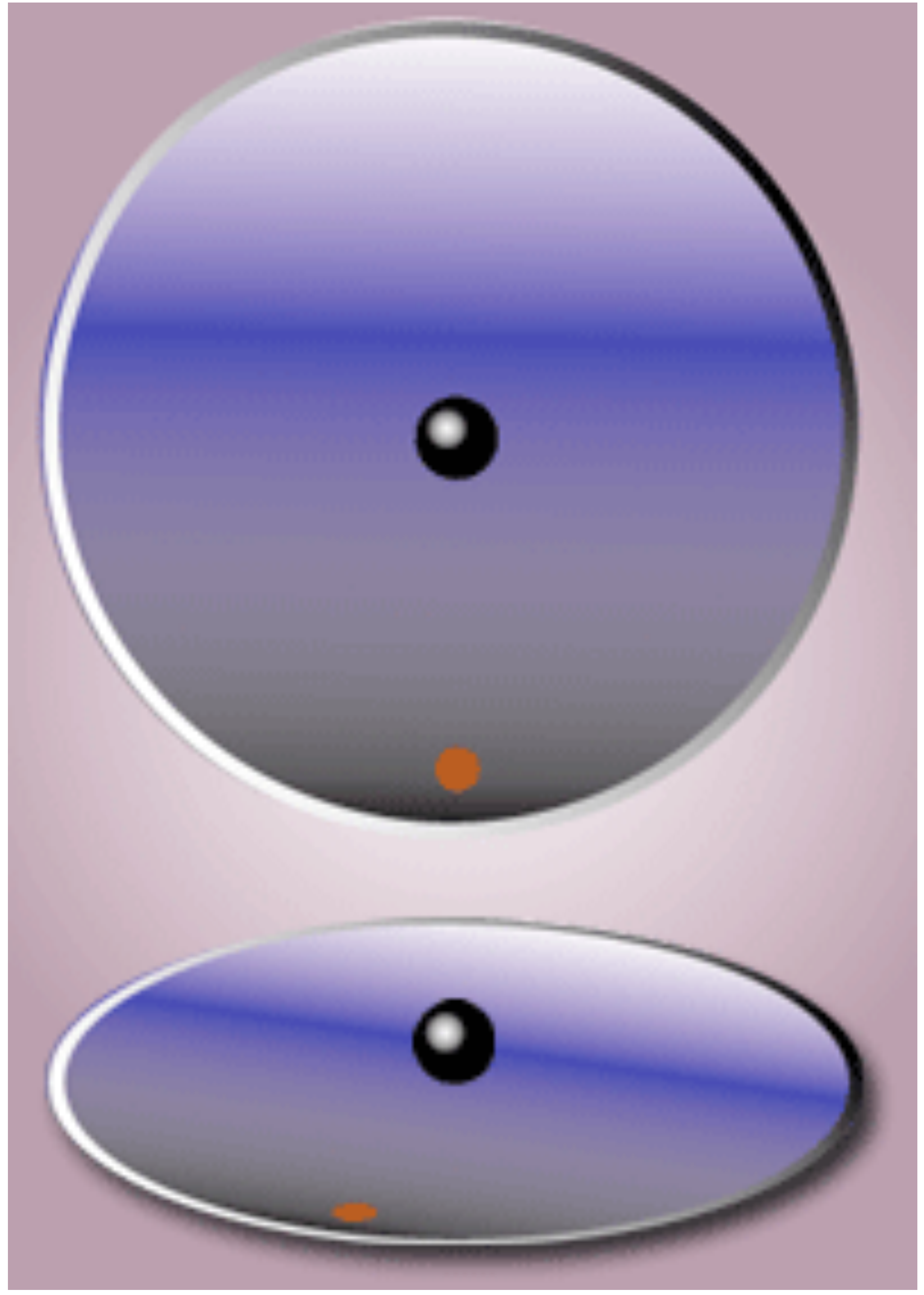


b Jupiter's faster rotation and larger size essentially stretch out the circulation patterns that occur on Earth into planet-wide bands of fast moving air.

Coriolis Effect

In the reference frame of the ball, it goes in a straight line

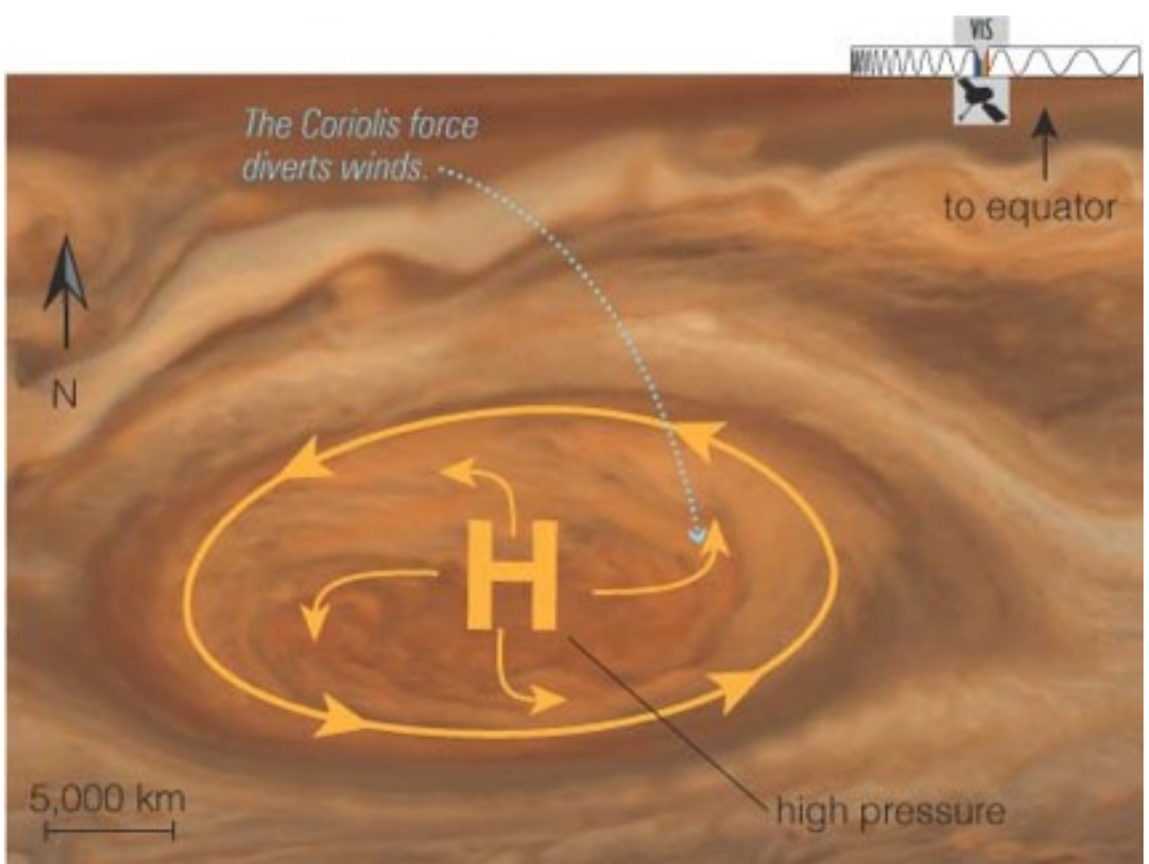
In the reference frame of the spinning disk, the ball takes a curved path

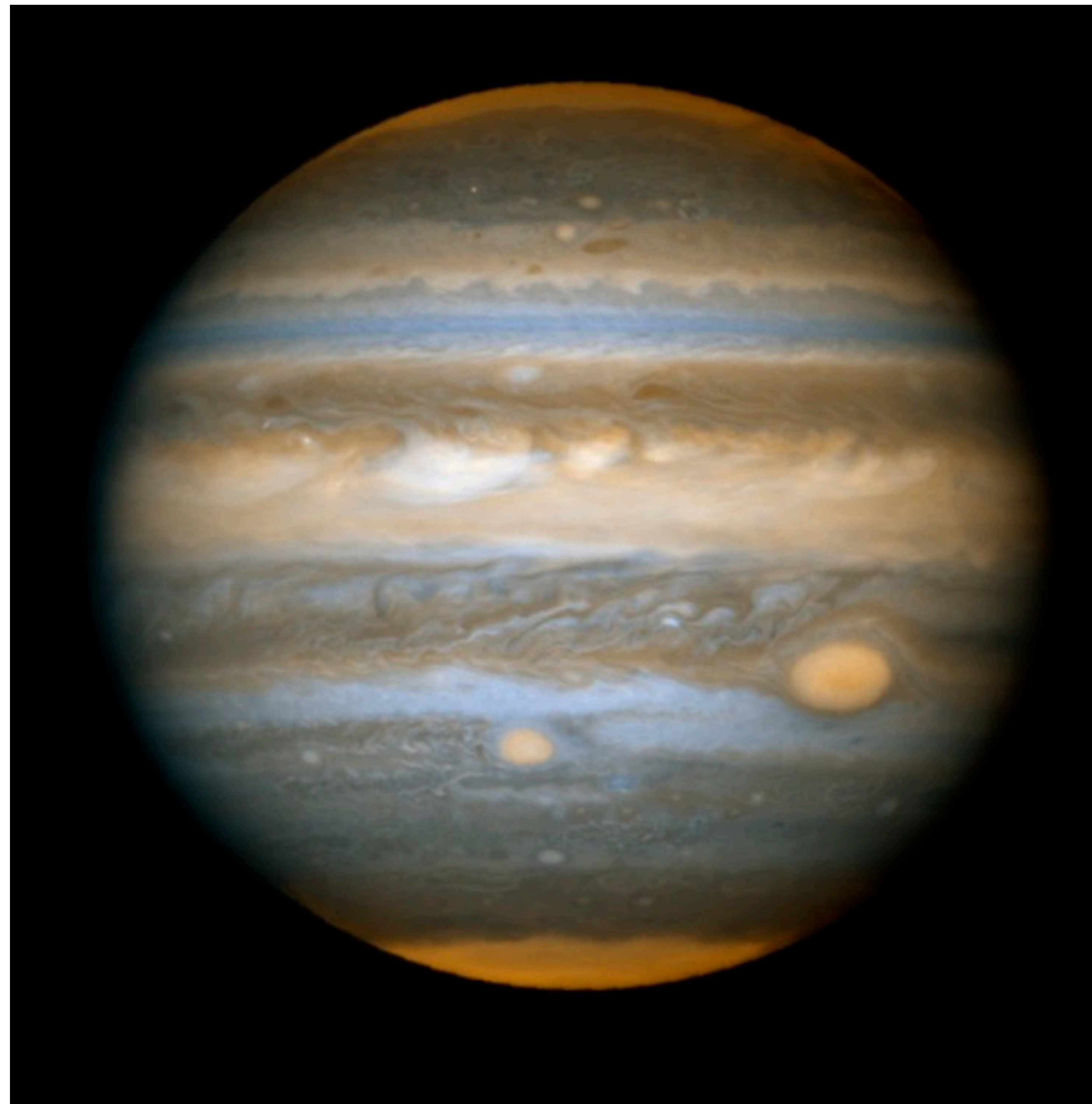


The Great Red Spot

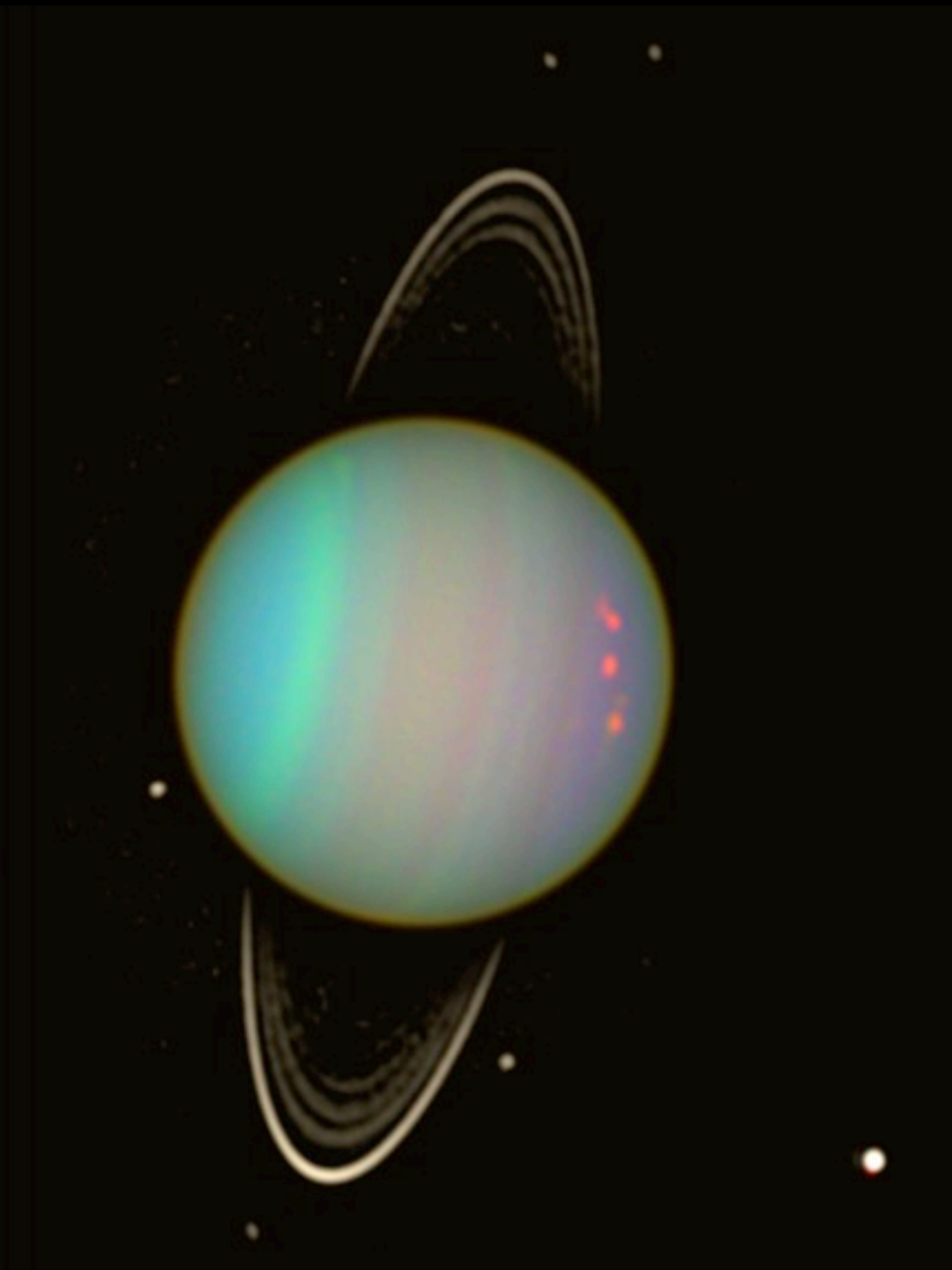
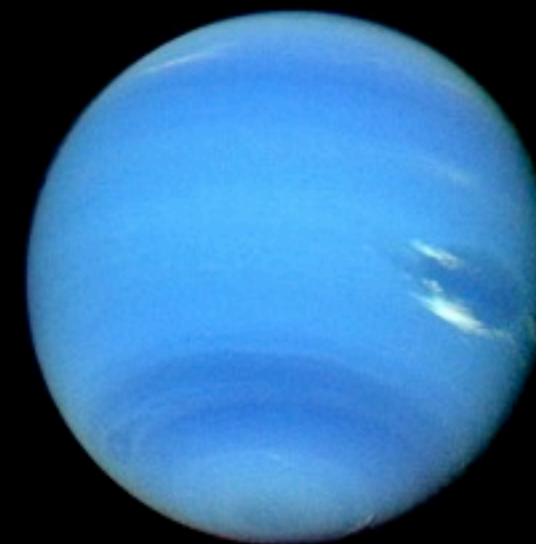
Lasted for as long as astronomers have been able to look at Jupiter!

At least twice as large as Earth





The other Jovian planets show similar characteristics to Jupiter, like *banding* and *mega-storms*


Jovian Moons

150+ known moons orbiting the jovian planets

Largest moons were likely formed at the same time as the parent body

- The small moons resemble potatoes - were likely captured

The largest moons resemble the terrestrial planets

- spherical
- solid surface
- geology
- atmospheres
- hot interiors
- magnetic fields

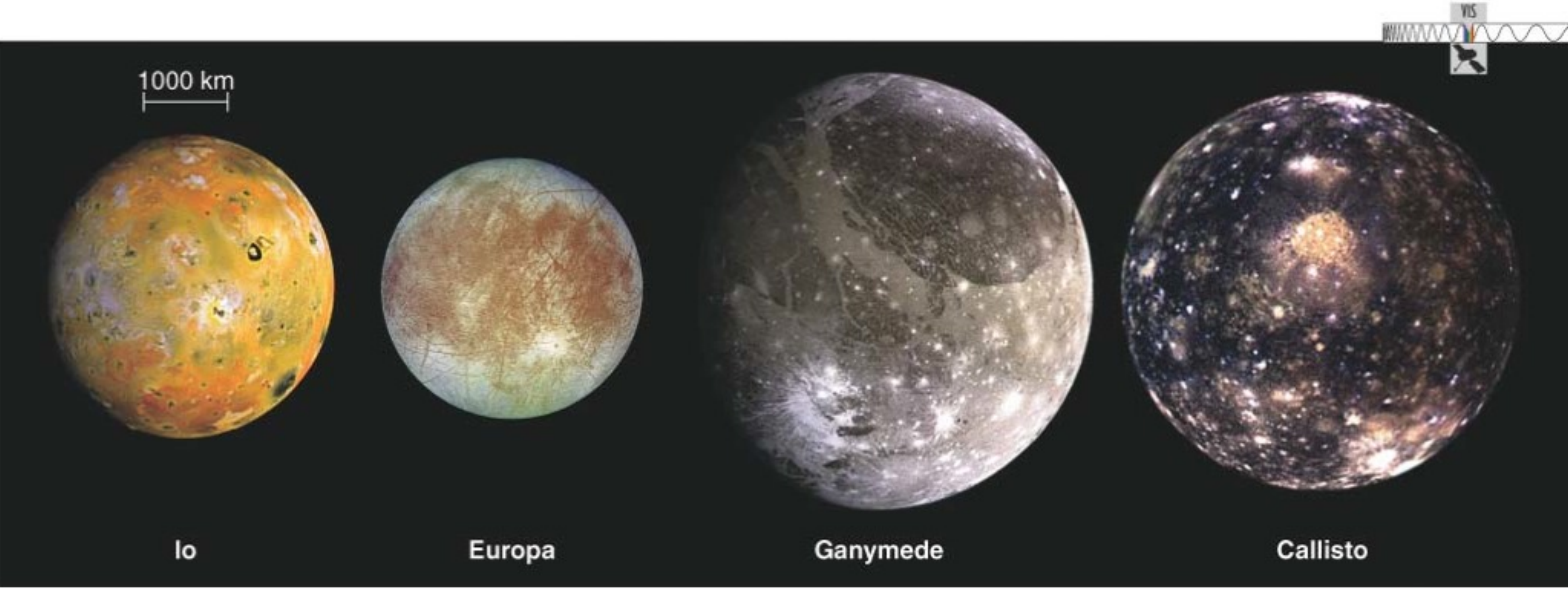
Terrestrial Planet Geology

- Internal heat, primarily from radioactive decay, can cause volcanic and tectonic activity.
- Only large planets retain enough internal heat to stay geologically active today.
- Example: Mars (photo above) probably retains some internal heat. If it had been smaller, like Mercury, it would be geologically “dead” today. If it had been larger, like Earth, it would probably have much more active and ongoing tectonics and volcanism.

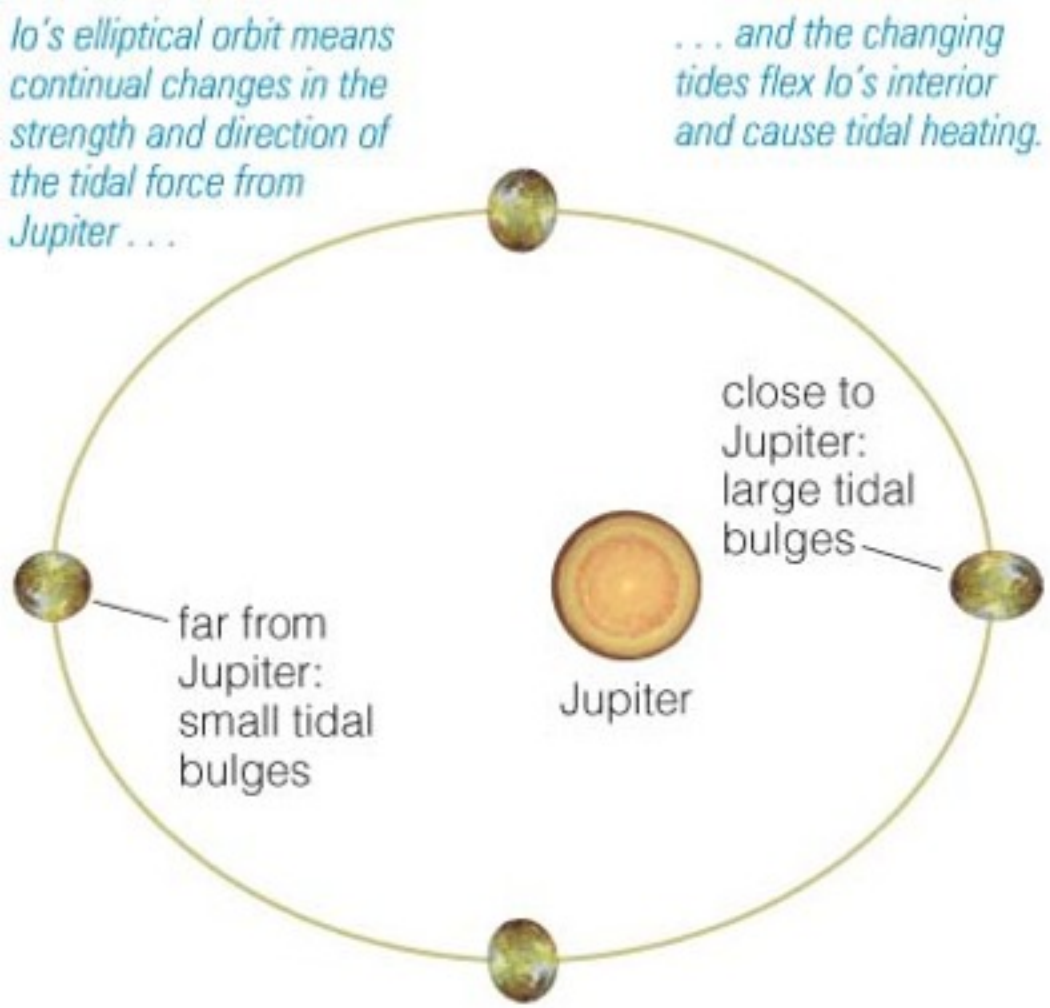
Jovian Moon Geology

- Tidal heating can cause tremendous geological activity on moons with elliptical orbits around massive planets.
- Even without tidal heating, icy materials can melt and deform at lower temperatures than rock, increasing the likelihood of geological activity.
- Together, these effects explain why icy moons are much more likely to have ongoing geological activity than rocky terrestrial worlds of the same size.
- Example: Ganymede (photo above) shows evidence of recent geological activity, even though it is similar in size to the geologically dead terrestrial planet Mercury.

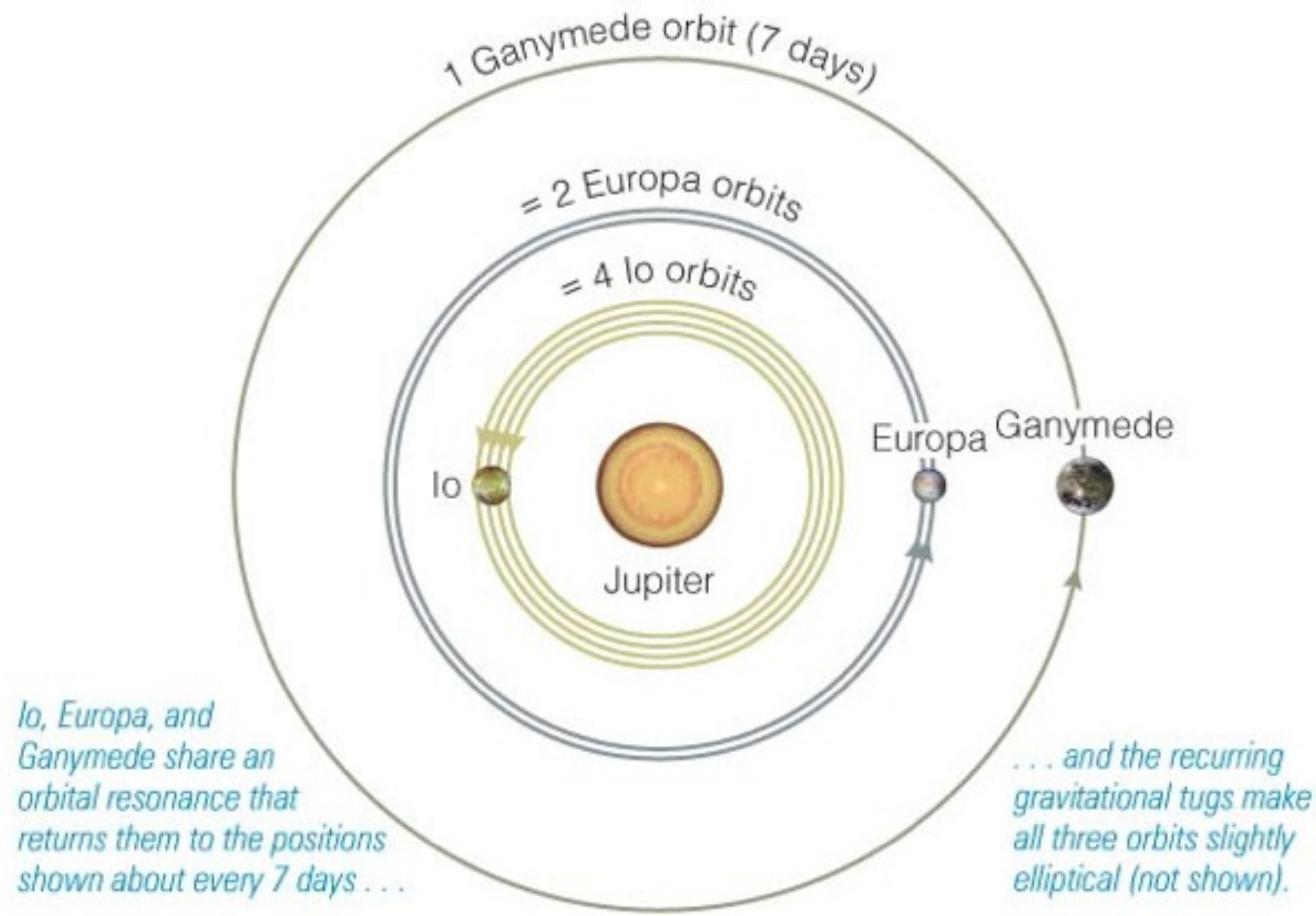
Jupiter's Galilean Moons



Io



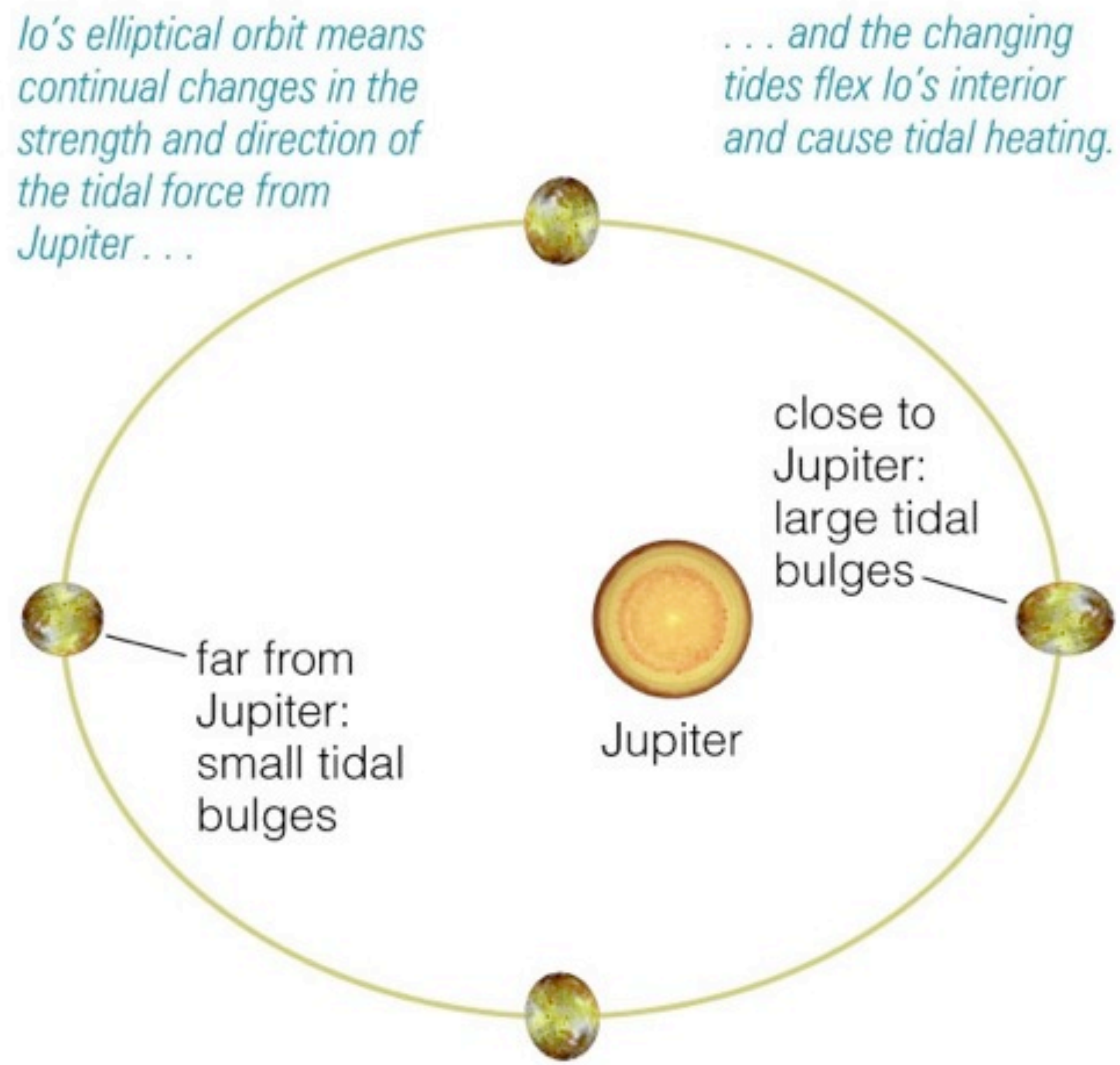
a Tidal heating arises because Io's elliptical orbit (exaggerated in this diagram) causes varying tides.



b Io's orbit is elliptical because of the orbital resonance it shares with Europa and Ganymede.

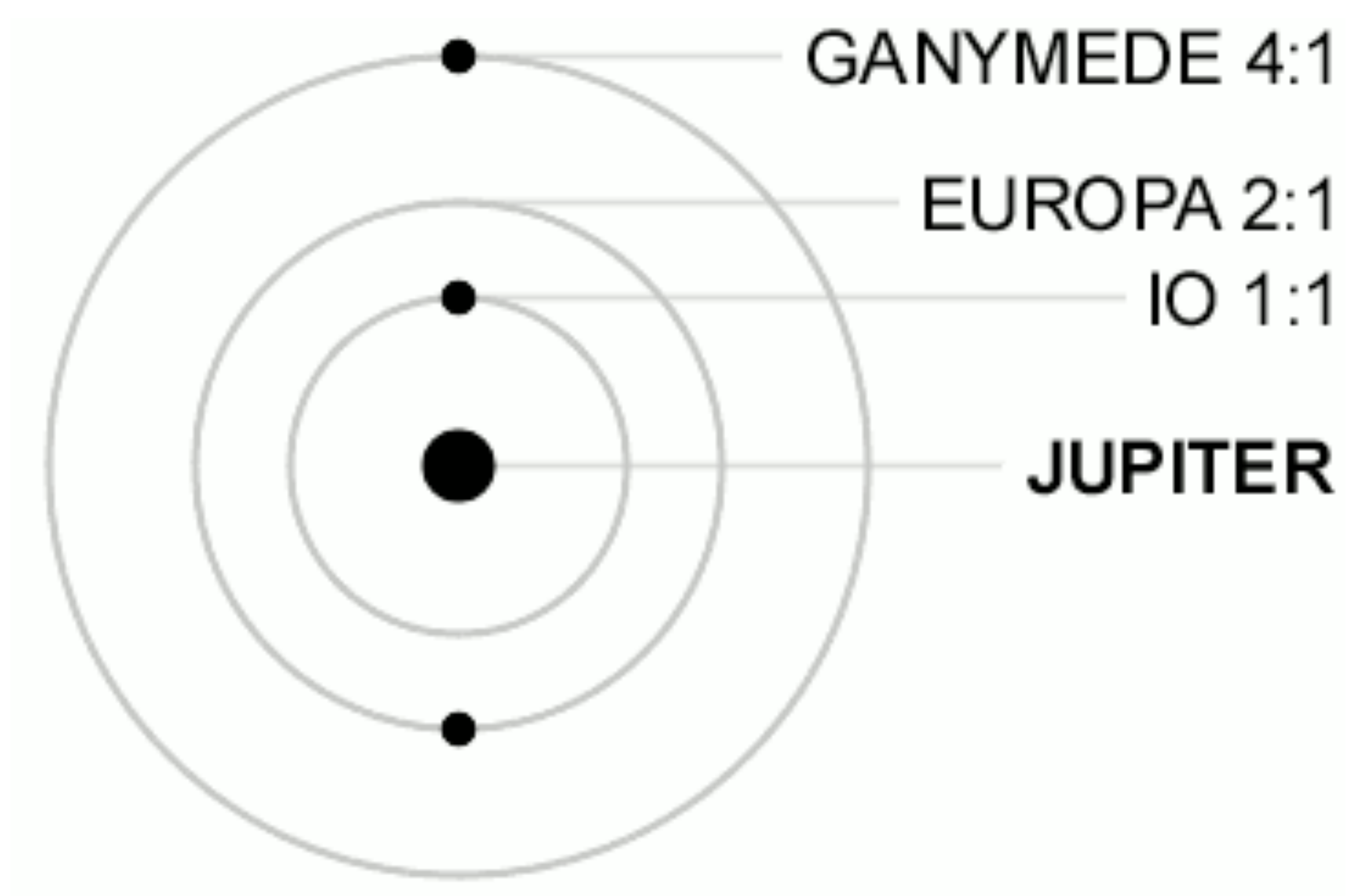
Tidal Heating

Tidal heating - heating of a body due to friction induced by tidal forces



Orbital Resonance

Orbital resonance - when objects line up in their orbits so gravity continuously affects them in the same direction.



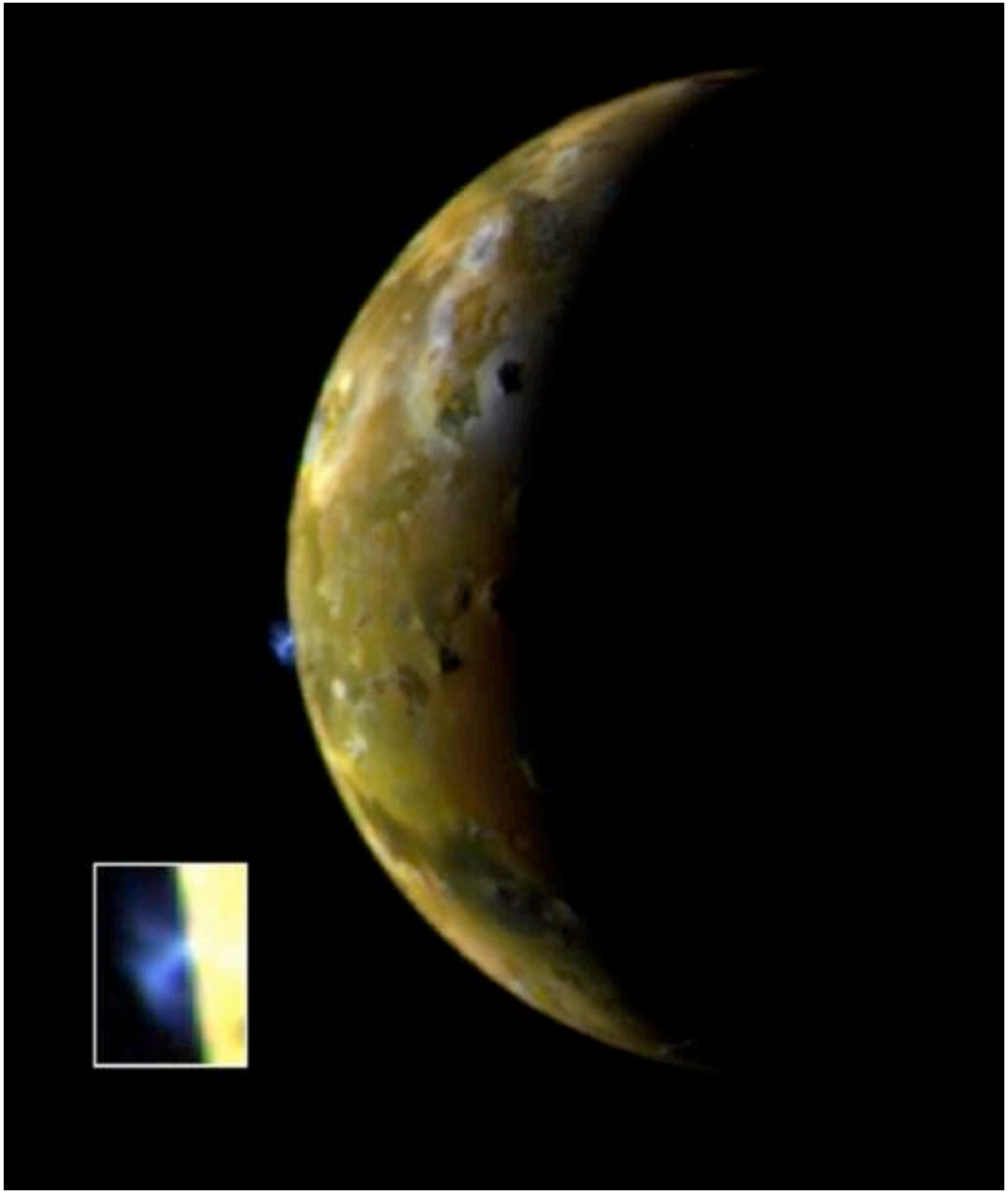
- Due to the periods of the orbits being simple fractions of each other
- Causes the orbit to be slightly elliptical

Io

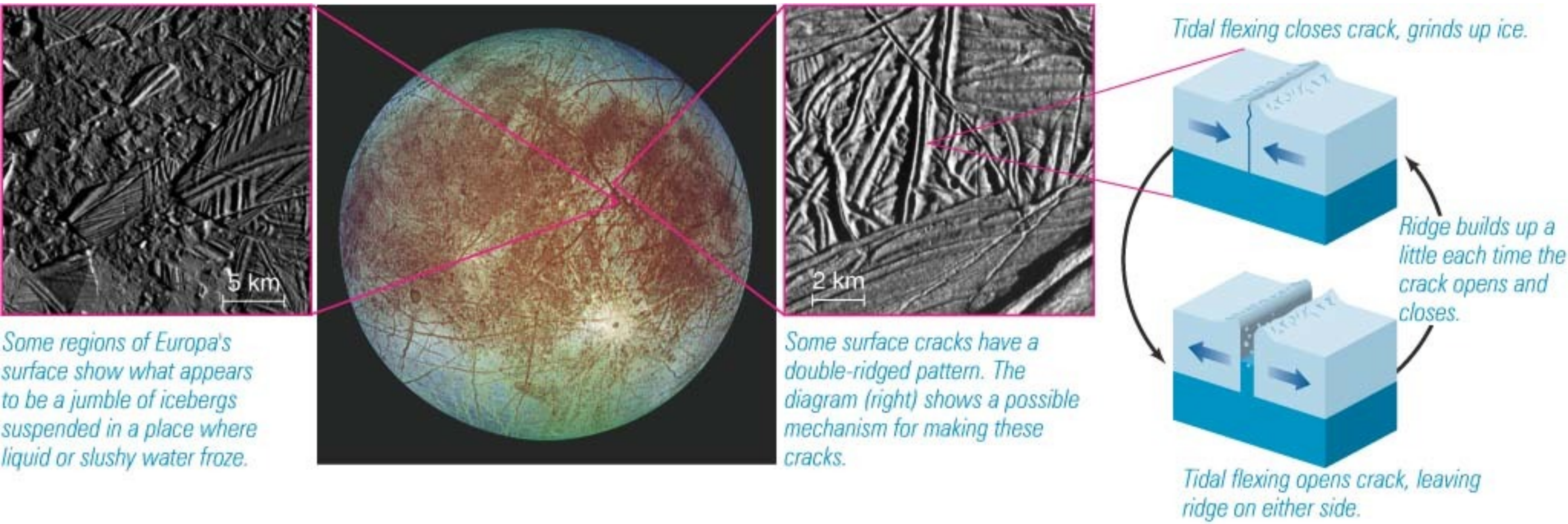
Io is the most volcanically active body in the solar system and is covered with active volcanoes

Giant eruption seen by *Galileo*'s camera in 1996

- Plume extends 60miles above the surface
- Blue is frozen sulfur dioxide



Europa

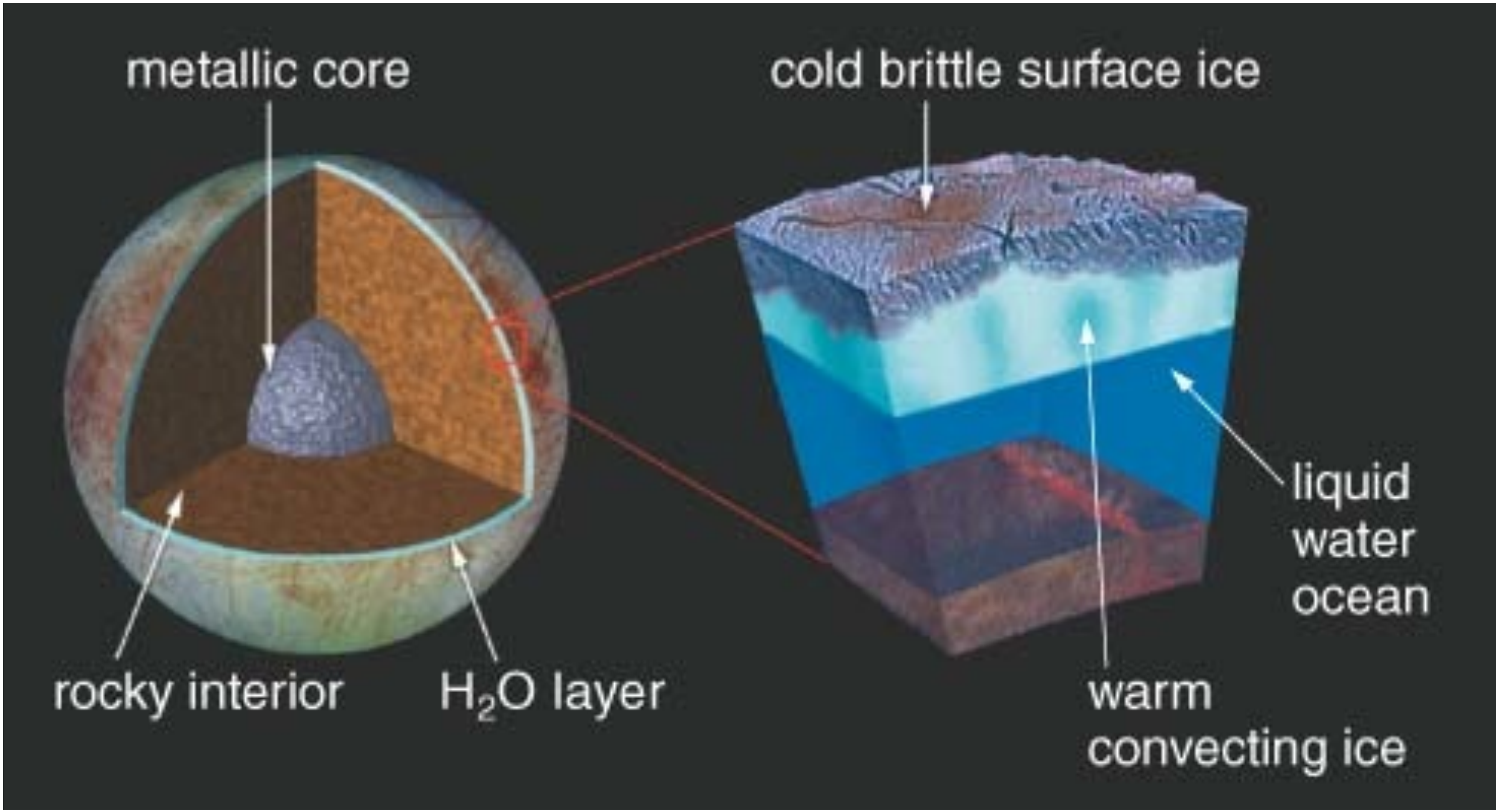


Surface is covered in *water ice*

Tidal stress induces heating which keeps a layer of *liquid water* beneath the surface

Very few craters suggests ongoing geological activity

Europa



Contains most liquid water in the Solar System:
More than TWICE as much liquid water as on Earth!!!

Ganymede and Callisto

Other Jovian Moons

Titan

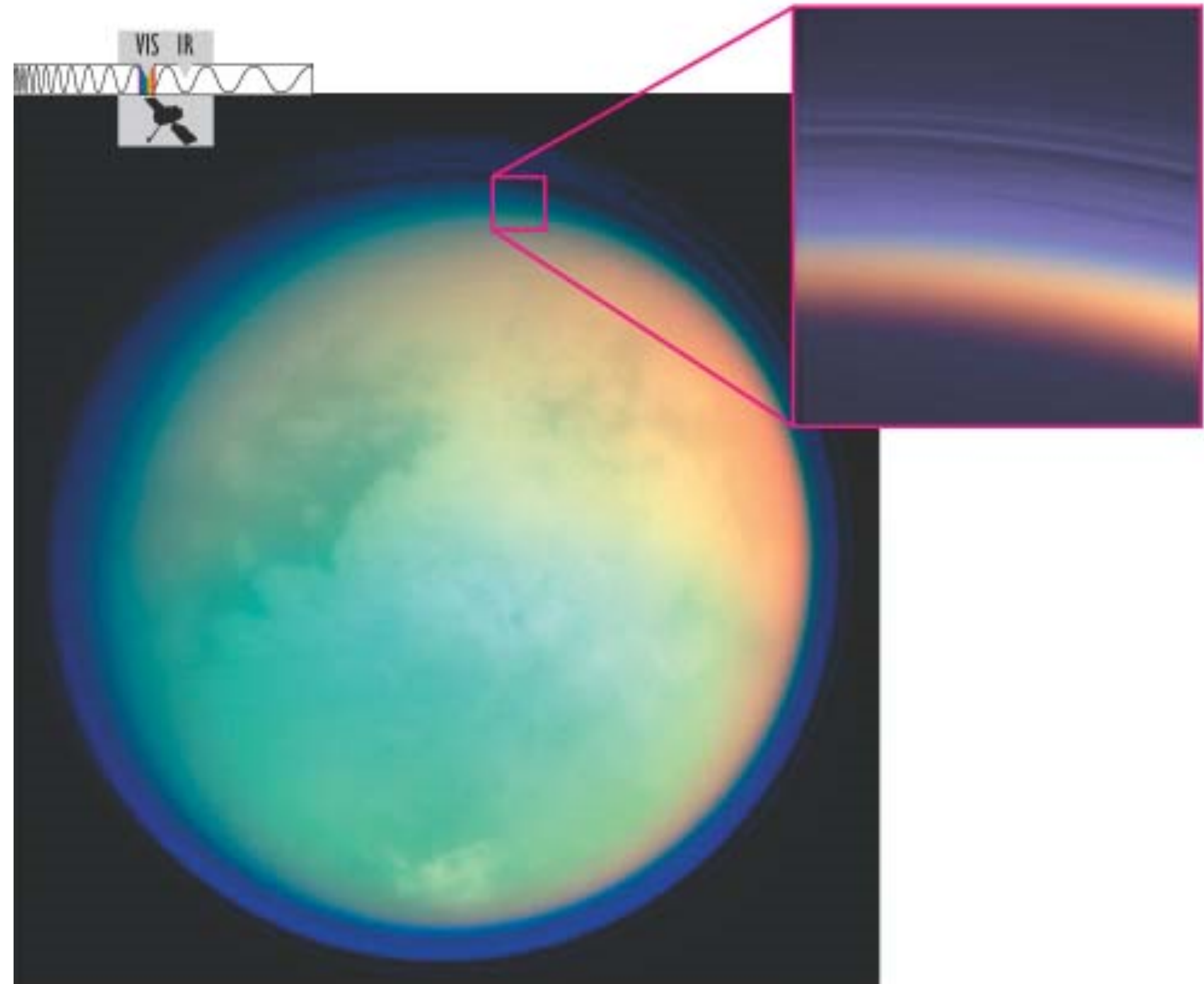
Thick atmosphere
>90% N_2
rest is argon, methane, ethane

Greenhouse Effect
T ~ 93 K

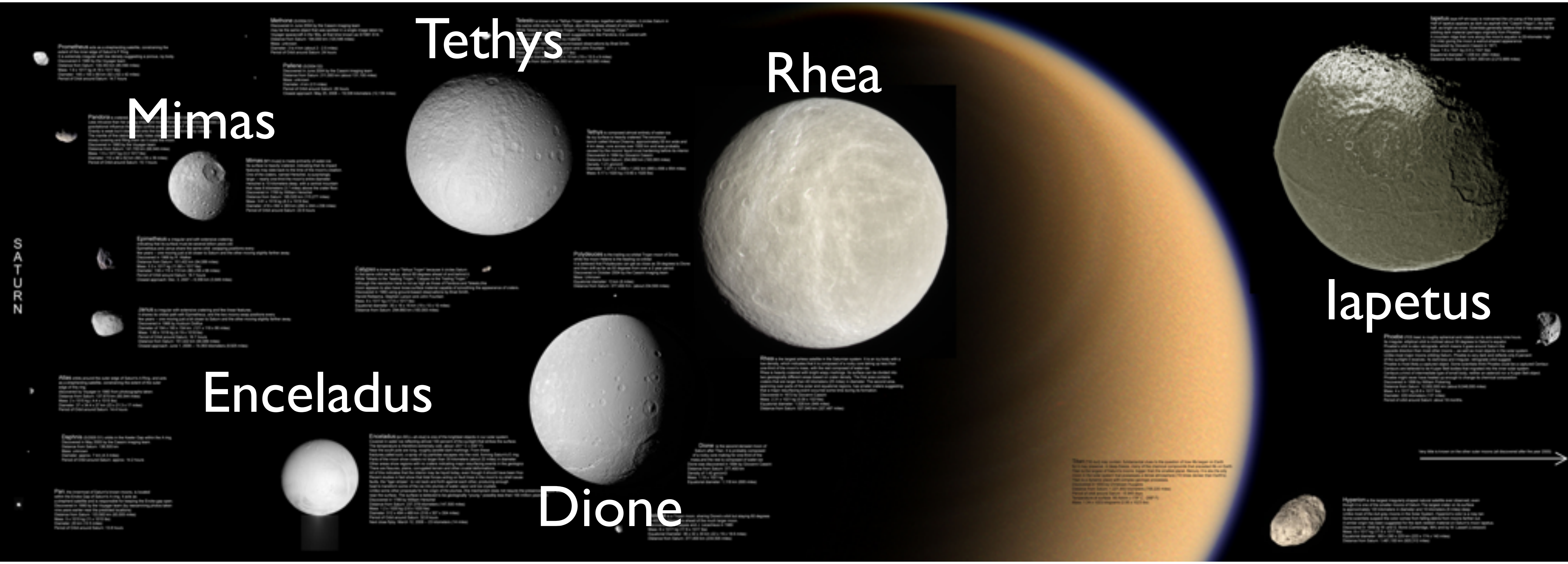
1.5X Earth's surface pressure

Methane, Ethane rivers
and lakes near poles

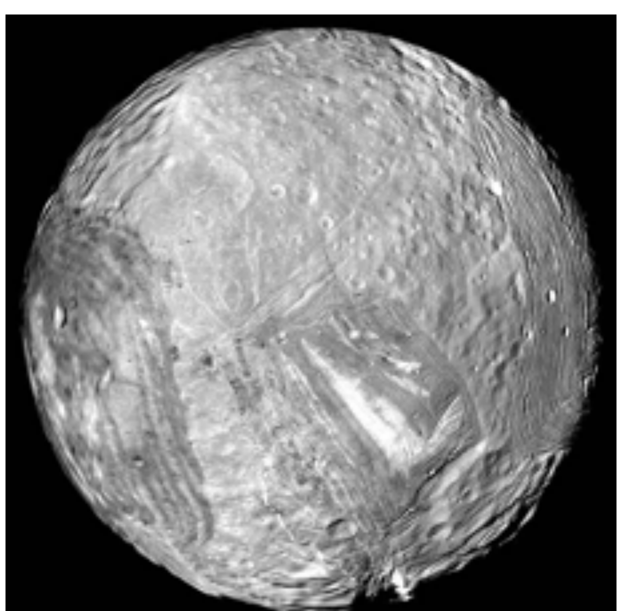
Organic compounds,
but still, too cold for life



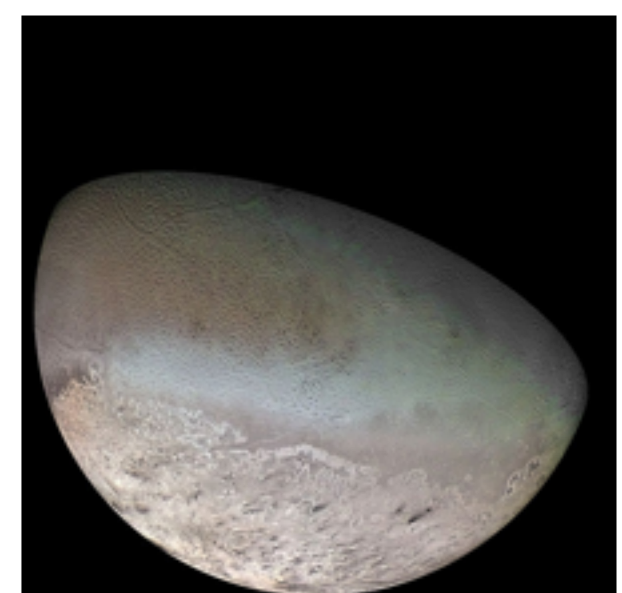
Saturn’s Medium Moons



Uranus’
Miranda

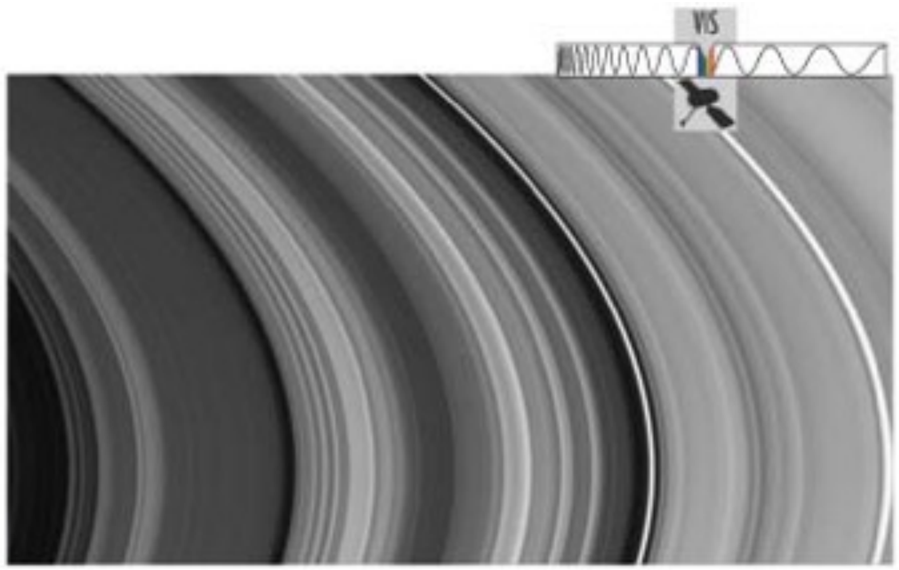


Neptune’s
Triton



Jovian Planet Rings

a This Earth-based telescopic view of Saturn makes the rings look like large, concentric sheets. The dark gap within the rings is called the Cassini division.



b This image of Saturn's rings from the *Cassini* spacecraft reveals many individual rings separated by narrow gaps.

c Artist's conception of particles in a ring system. All the particles are moving slowly relative to one another and occasionally collide.

Rings are extremely thin due to frequent collisions

Made mostly of water ice

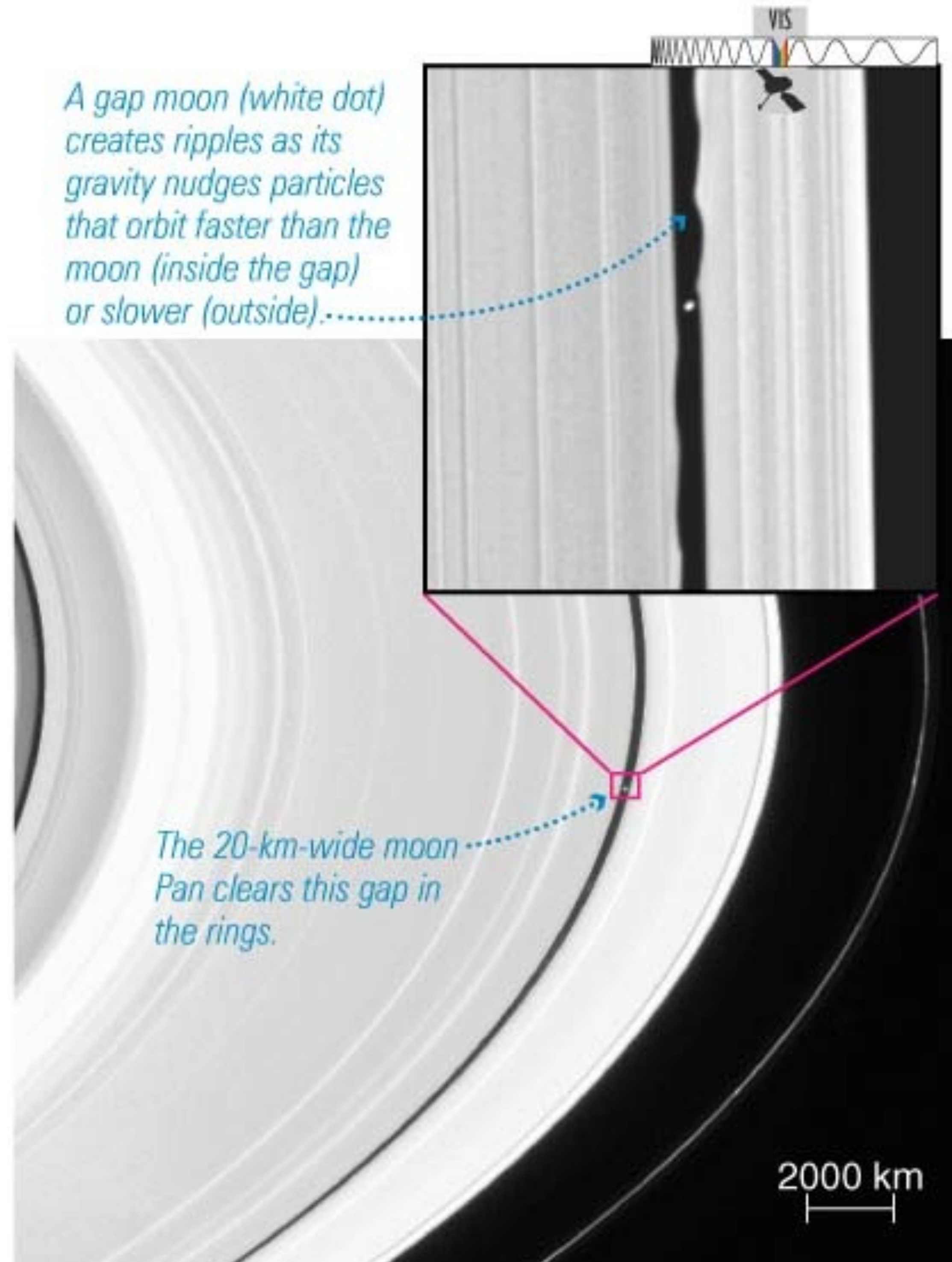
Rings are thousands of meters wide but only a few meters thick

Rings and Gaps

Rings are caused by particles being "bunched up" into some orbital distances

Gaps are caused by:

- Small moons
- Orbital resonances of large moons



Cause of Rings

Was once thought that rings were unique to Saturn

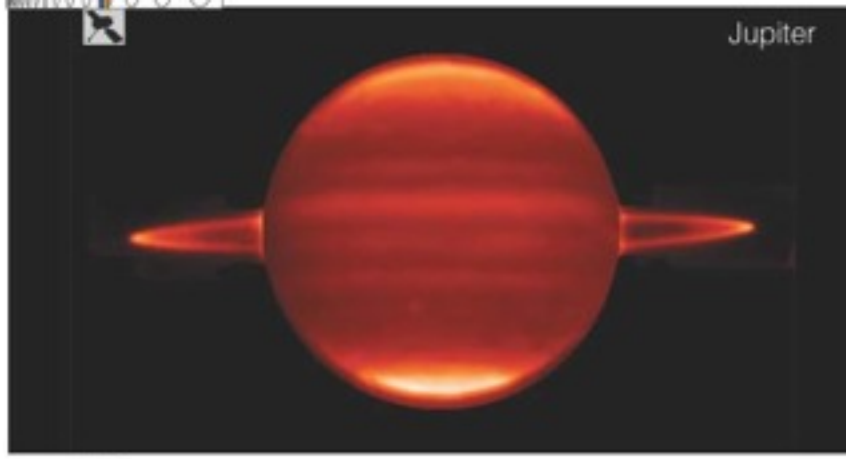
- Not true since we find rings on all the Jovian planets

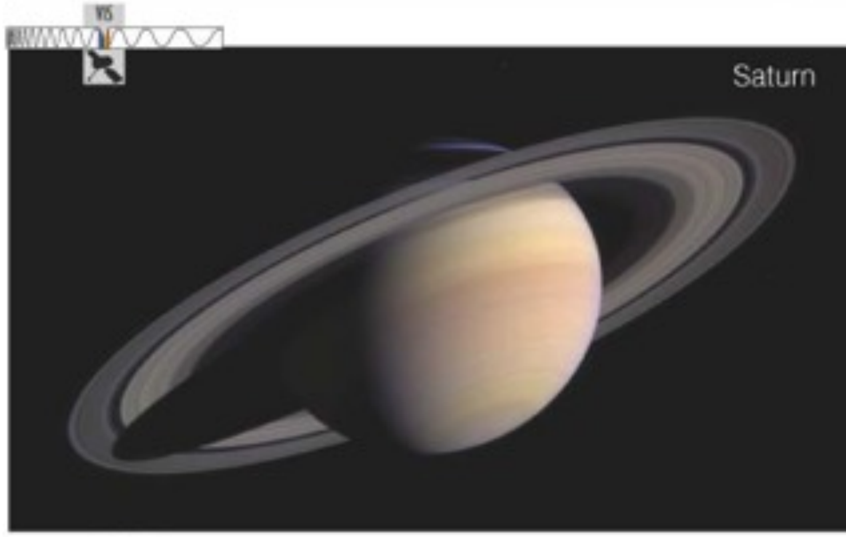
Not remnants of some ancient formation material

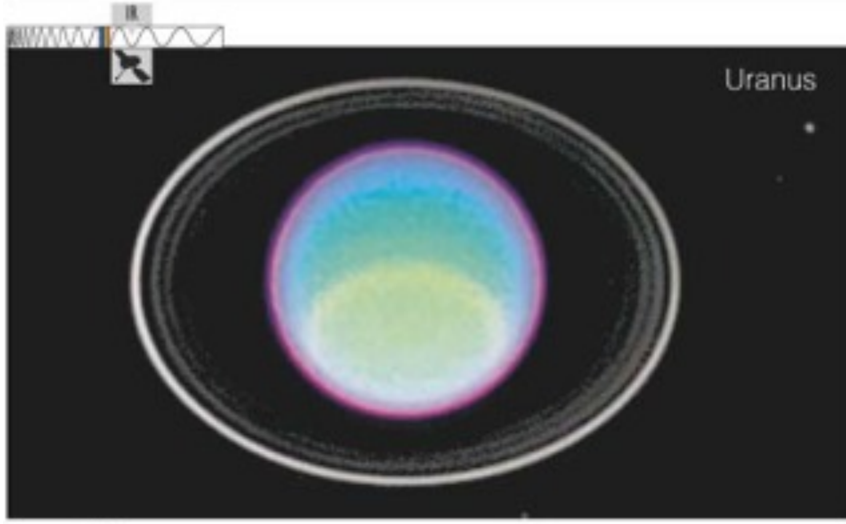
- Too small to survive billions of years

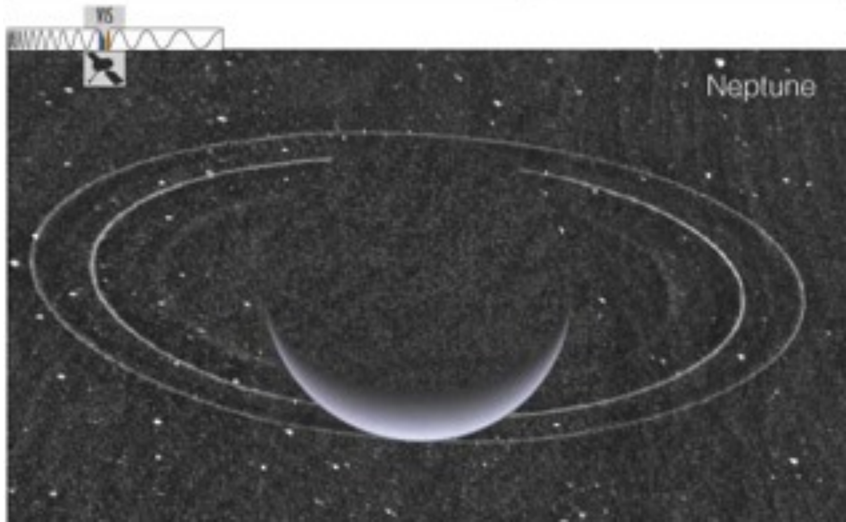
Must be constantly resupplied

- Constant collisions with small moons or geological activity on moons





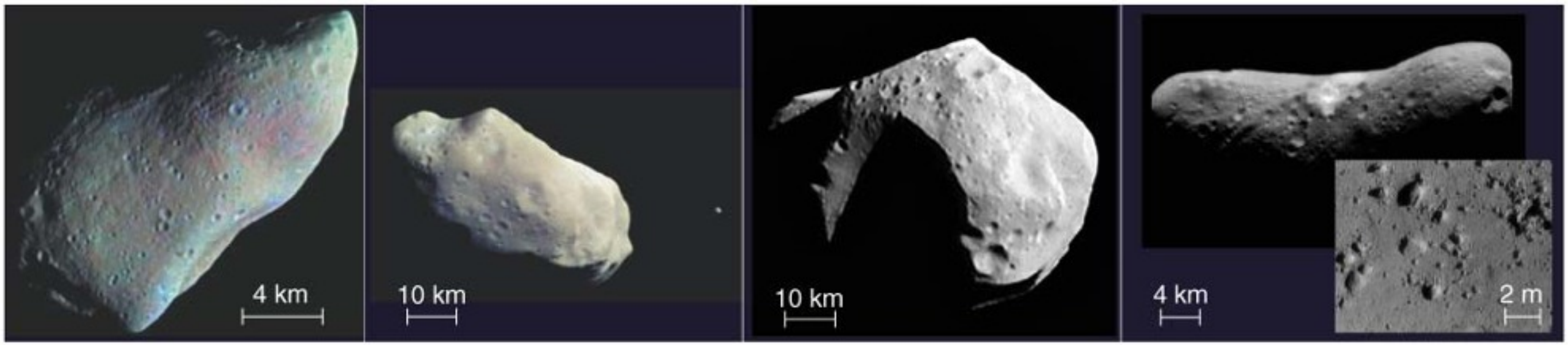




Comets & Asteroids

Ch. 9

Asteroids



a Gaspra, photographed by the *Galileo* spacecraft.

b Ida, photographed by the *Galileo* spacecraft. The small dot to the right is Dactyl, a tiny moon orbiting Ida.

c Mathilde, photographed by the Near-Earth Asteroid Rendezvous (NEAR) spacecraft on its way to Eros.

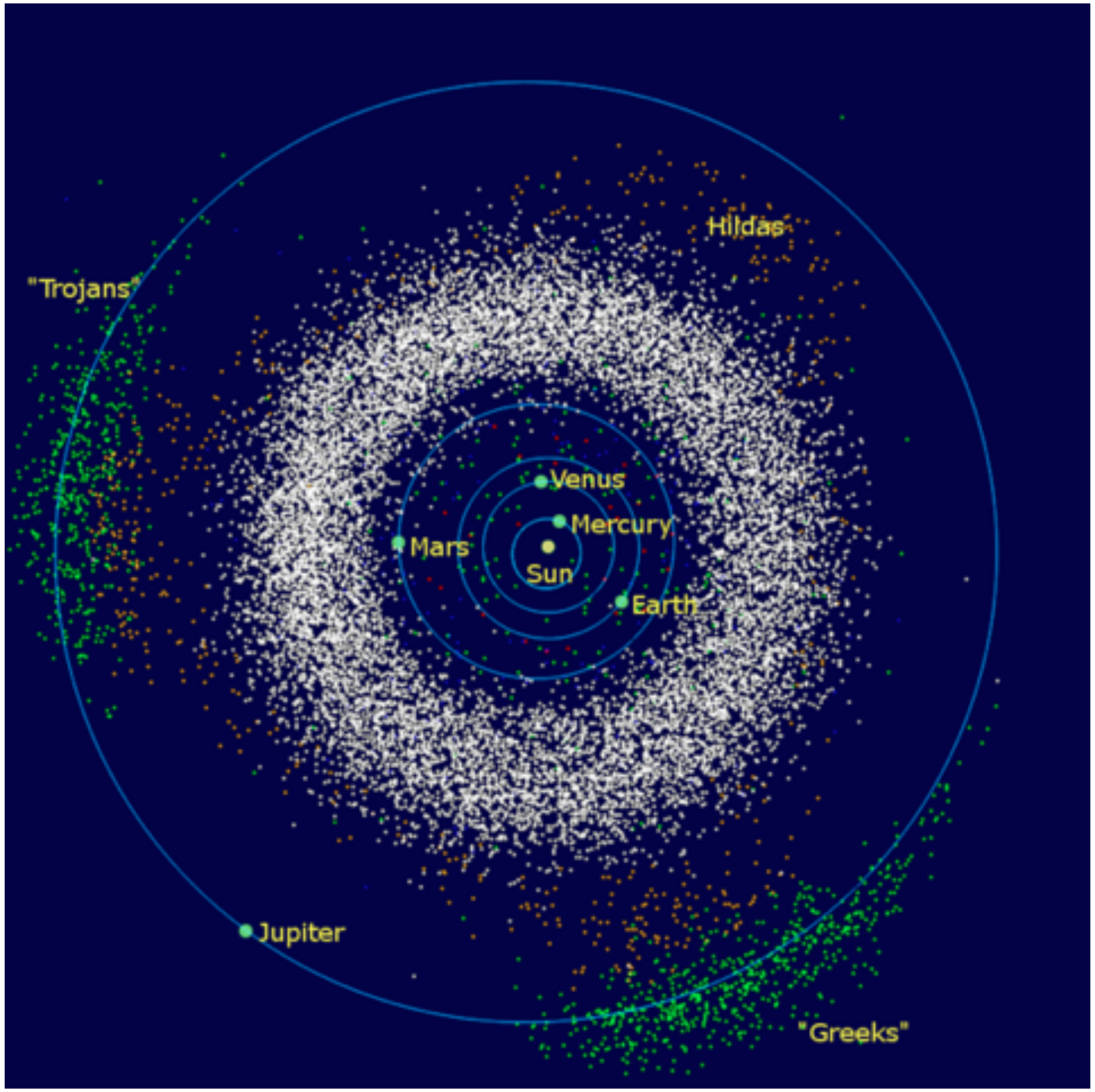
d Eros, photographed by the NEAR spacecraft, which orbited Eros for a year before ending its mission with a soft landing on the asteroid's surface. The inset photo was taken by NEAR just before it landed.

- Aspherical
- Cratered
- Not very massive

Asteroid Belt

Density of asteroids is very small

- Average separation is thousands to millions of km



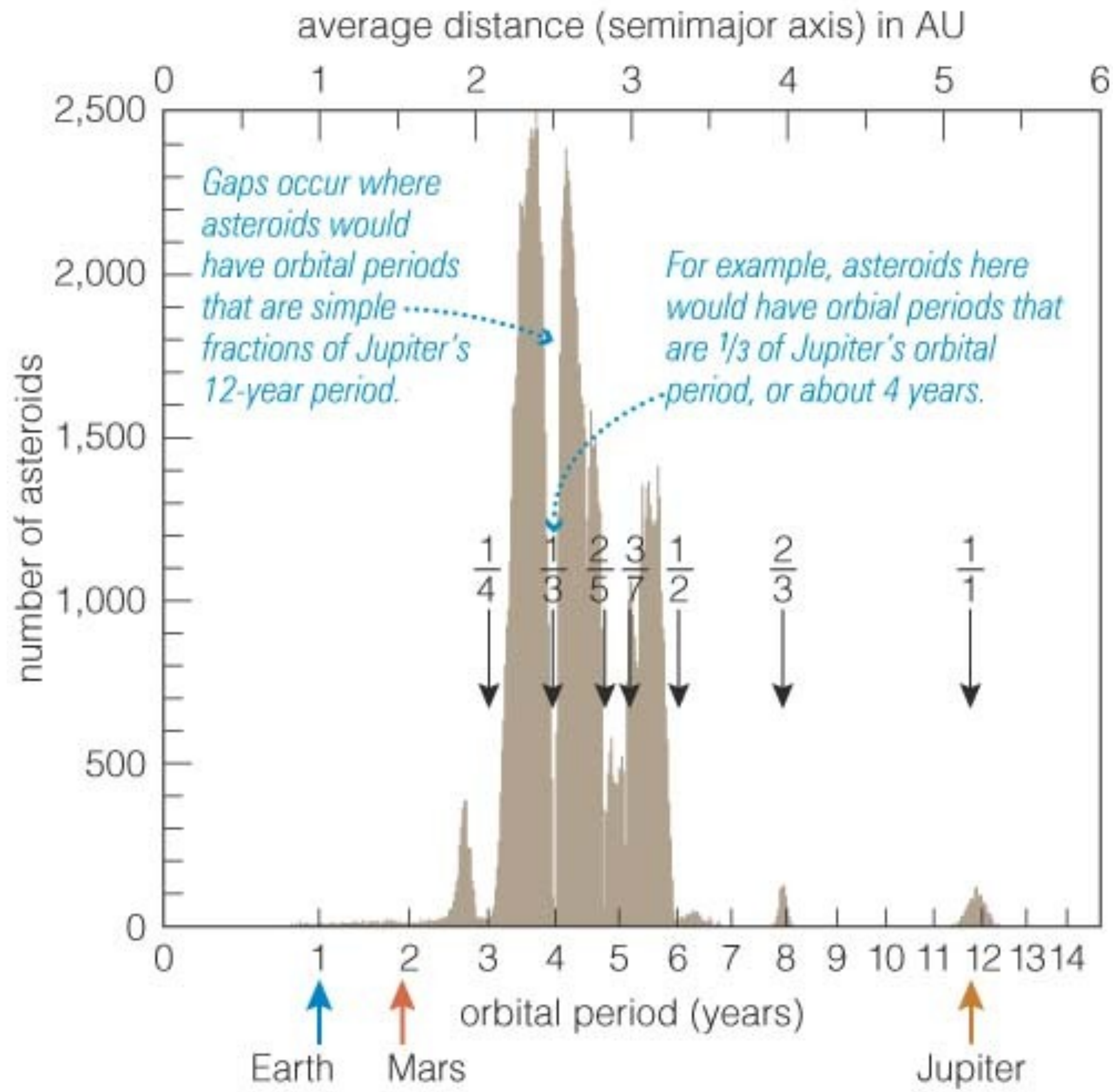
The only place where the planetesimals could survive for billions of years

Jupiter Resonances

<u>Kirkwood gaps</u> - gaps in the asteroid belt due to orbital resonances with Jupiter

A planet could not form from the asteroids due to resonances with Jupiter

- Each gravitational nudge pushes objects out of its normal orbit



Meteoroids, Meteors, Meteorites

Meteoroids

Small rocky or metallic object traveling in space

Meteors

Flash of light as meteoroids burn in Earth's atmosphere

Meteorites

Remnant of a meteoroid after it impacts Earth's surface

<u>primitive</u> vs <u>processed</u> meteorites

Comets

a Comet Hyakutake.

b Comet Hale-Bopp, photographed at Mono Lake, CA.

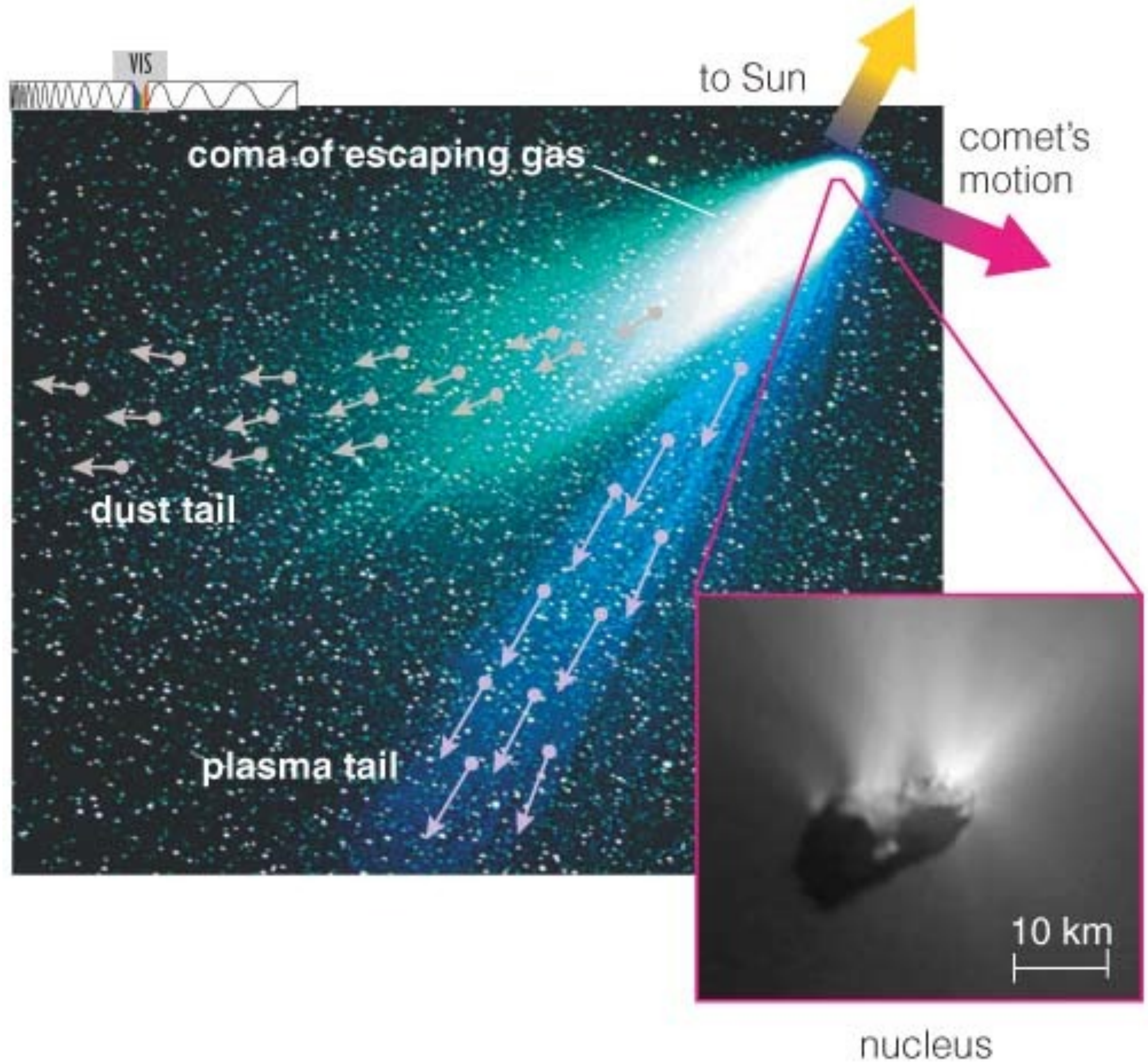
Temple 1 - Deep Impact

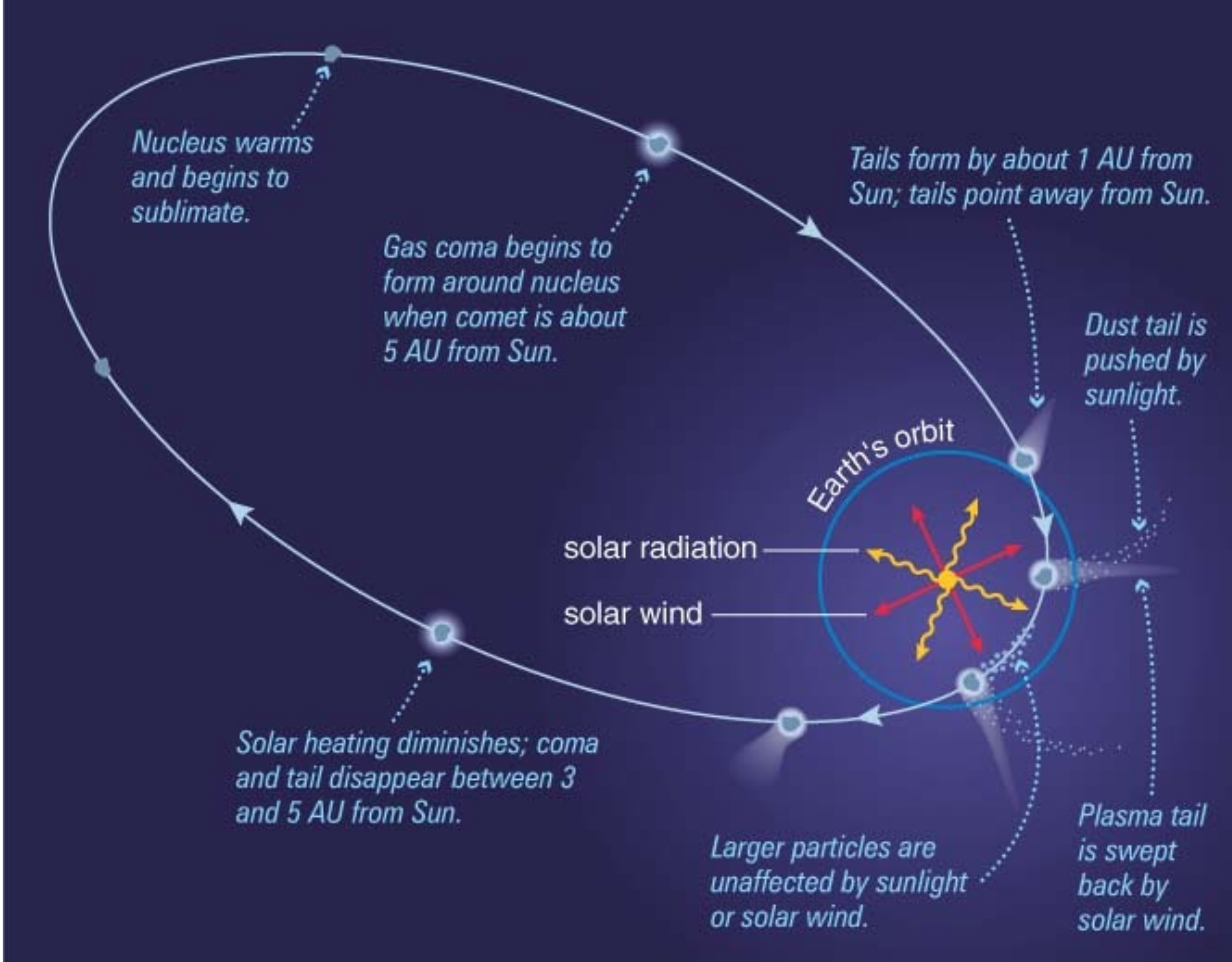
Nucleus - the central chunk of ice and dirt

Coma - huge dusty atmosphere which is much larger than the nucleus

Dust tail - small pieces of dust coming off the comet's coma

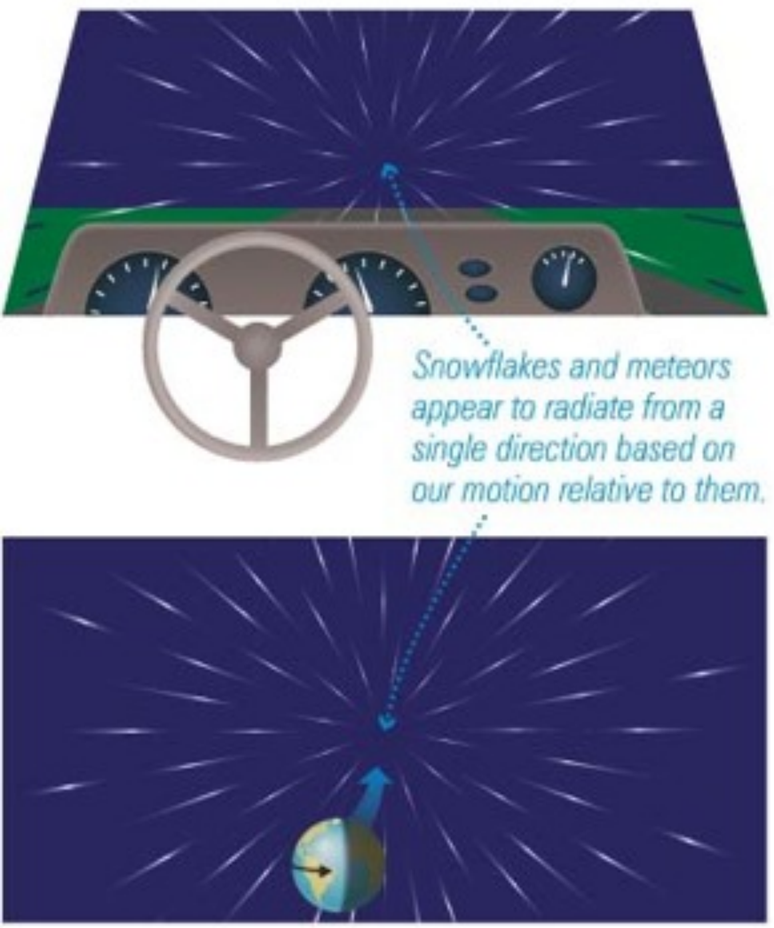
Plasma tail - gas escaping the coma due to the solar wind





Nucleus warms and begins to sublimate.
Gas coma begins to form around nucleus when comet is about 5 AU from Sun.
Tails form by about 1 AU from Sun; tails point away from Sun.
Dust tail is pushed by sunlight.
Earth's orbit
solar radiation
solar wind
Solar heating diminishes; coma and tail disappear between 3 and 5 AU from Sun.
Larger particles are unaffected by sunlight or solar wind.
Plasma tail is swept back by solar wind.

Meteor Showers



a Meteors appear to radiate from a particular point in the sky for the same reason that we see snow or heavy rain come from a single point in front of a moving car.

b This digital composite photo, taken in Australia during the 2001 Leonid meteor shower, shows meteors as streaks of light. The large rock is Uluru, also known as Ayers Rock.

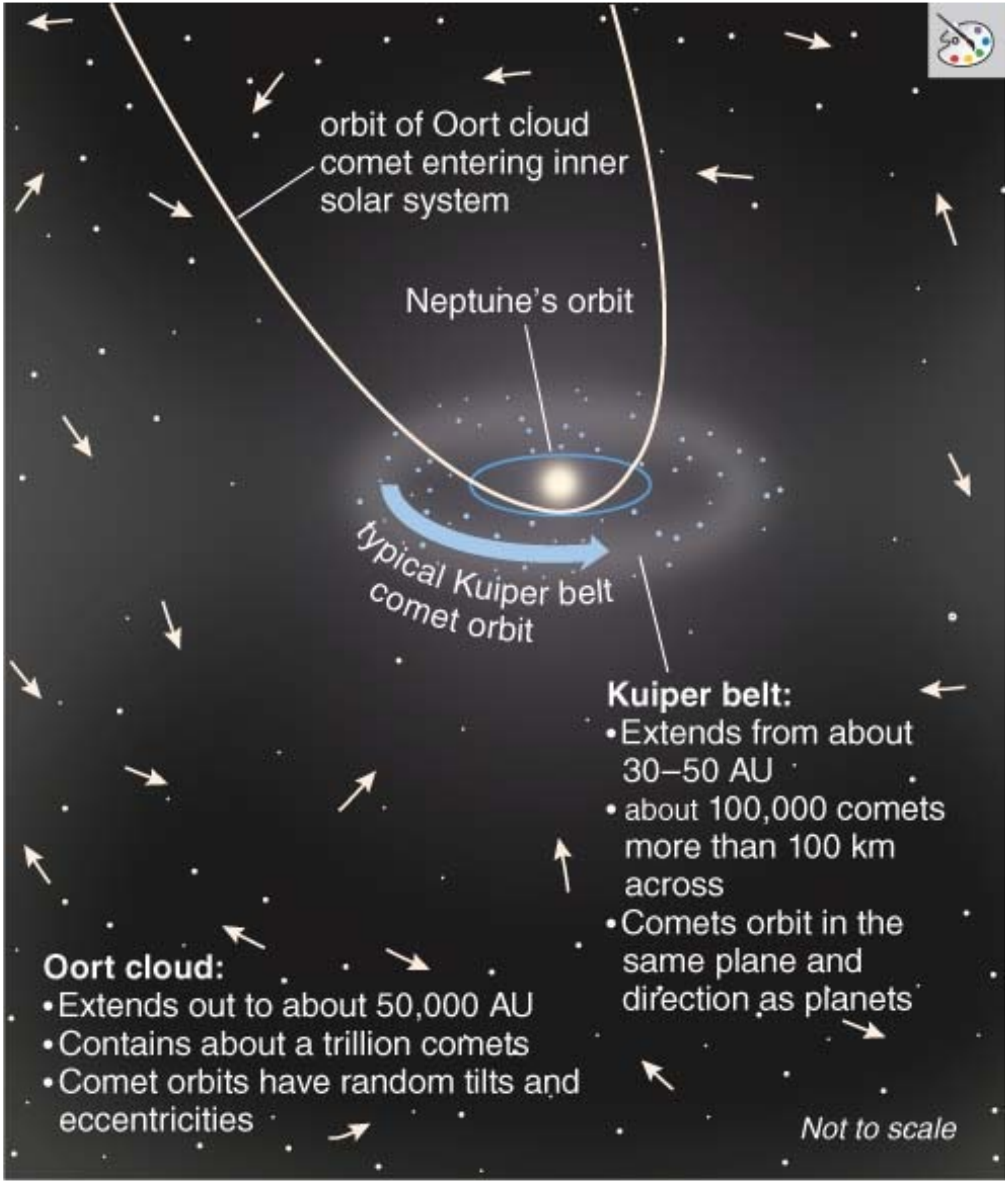
Origin

Comets lose a little bit of material with each passage near the sun

- Only last a few hundred orbits

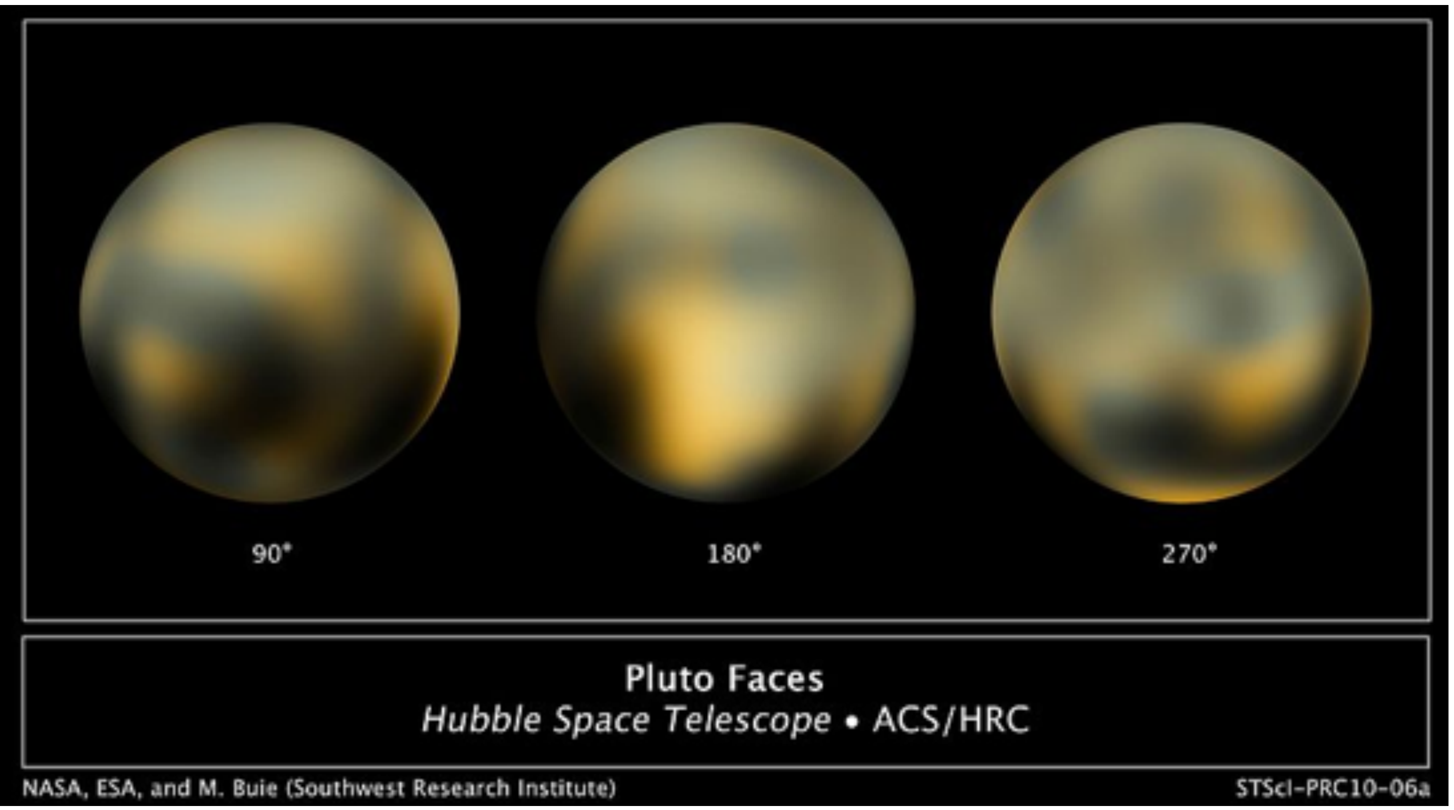
Comet reservoirs

- Kuiper belt
- Oort cloud



Pluto

Pluto



Pluto

a = 39.5 AU

$R = 0.18\ R_{Earth}$

$M = 0.0022\ M_{Earth}$

$\rho = 2.0\ g/cm^3$

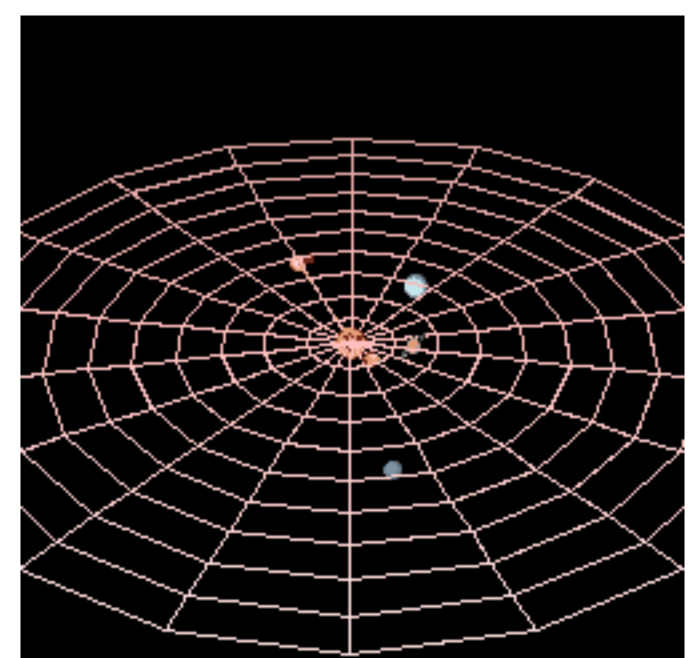
T = 40 K

Moons: 3

Composed of ice & rock

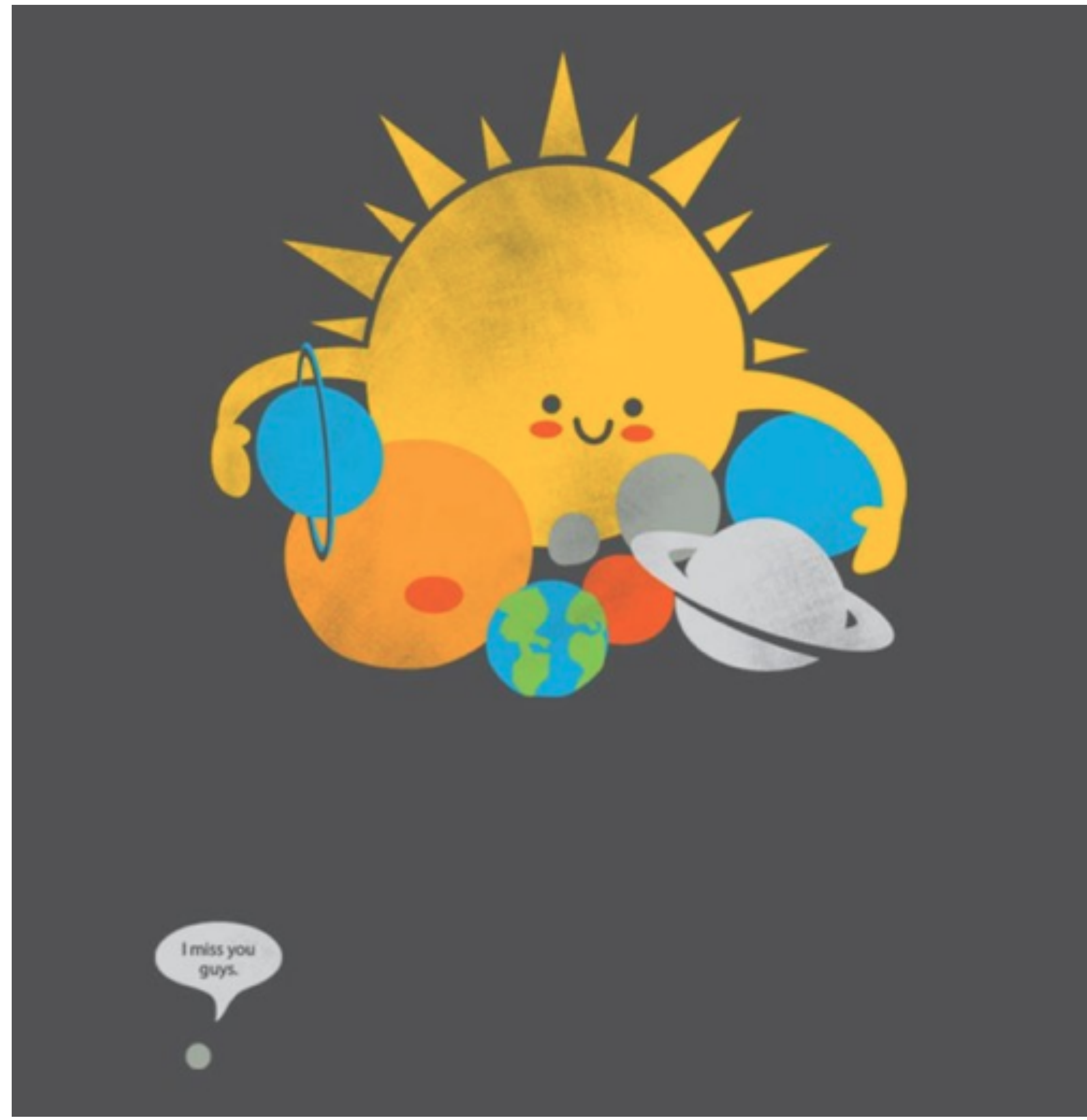
Thin N_2 atmosphere

Highly eccentric, 248-year orbit in a 2-3 resonance with Neptune

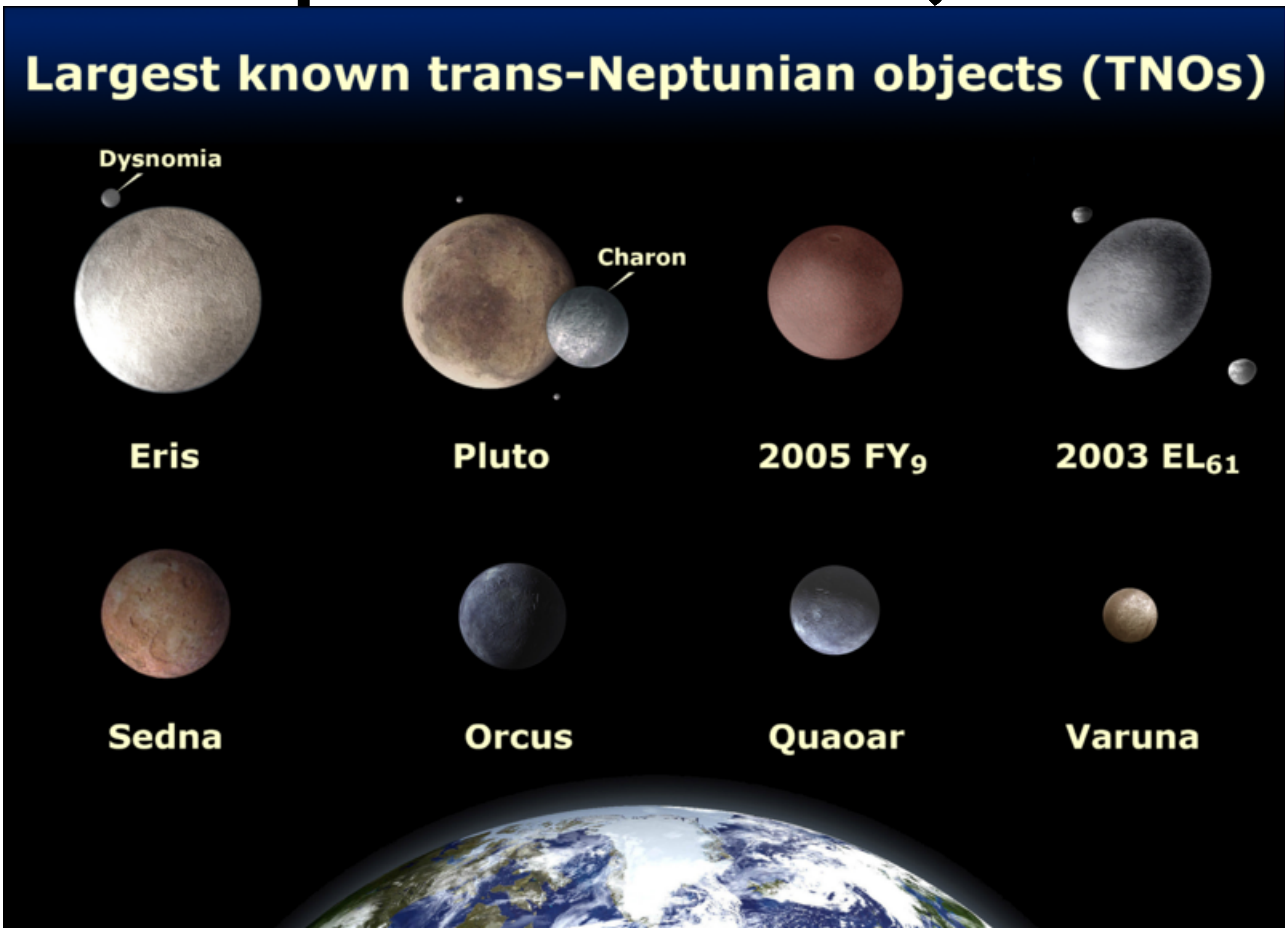


Planet Requirements?

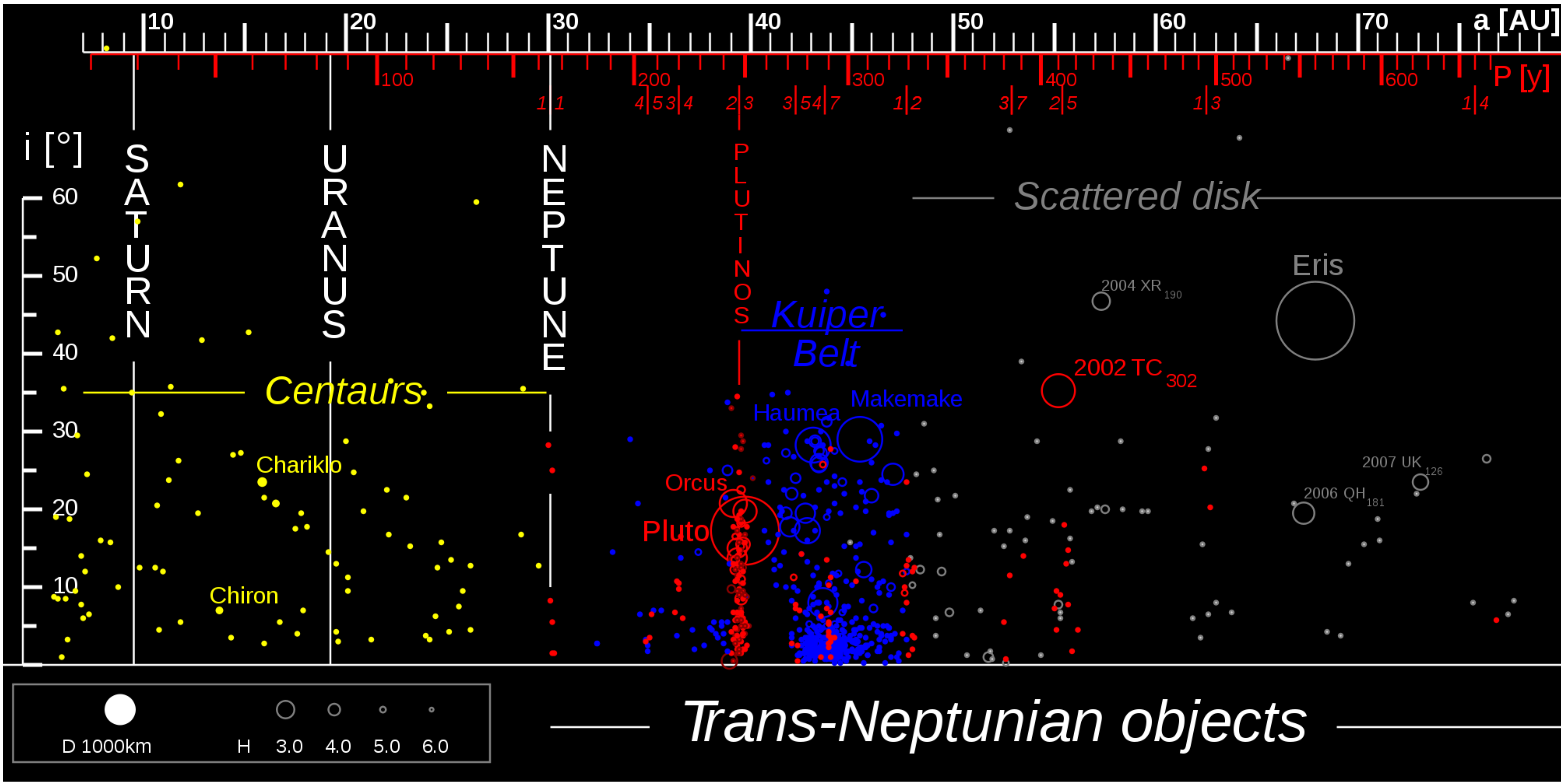
1. Orbit a star
2. Massive enough to have a round shape
3. Cleared out orbital neighborhood
    - Pluto is only 0.07X the mass of the other stuff in its orbit



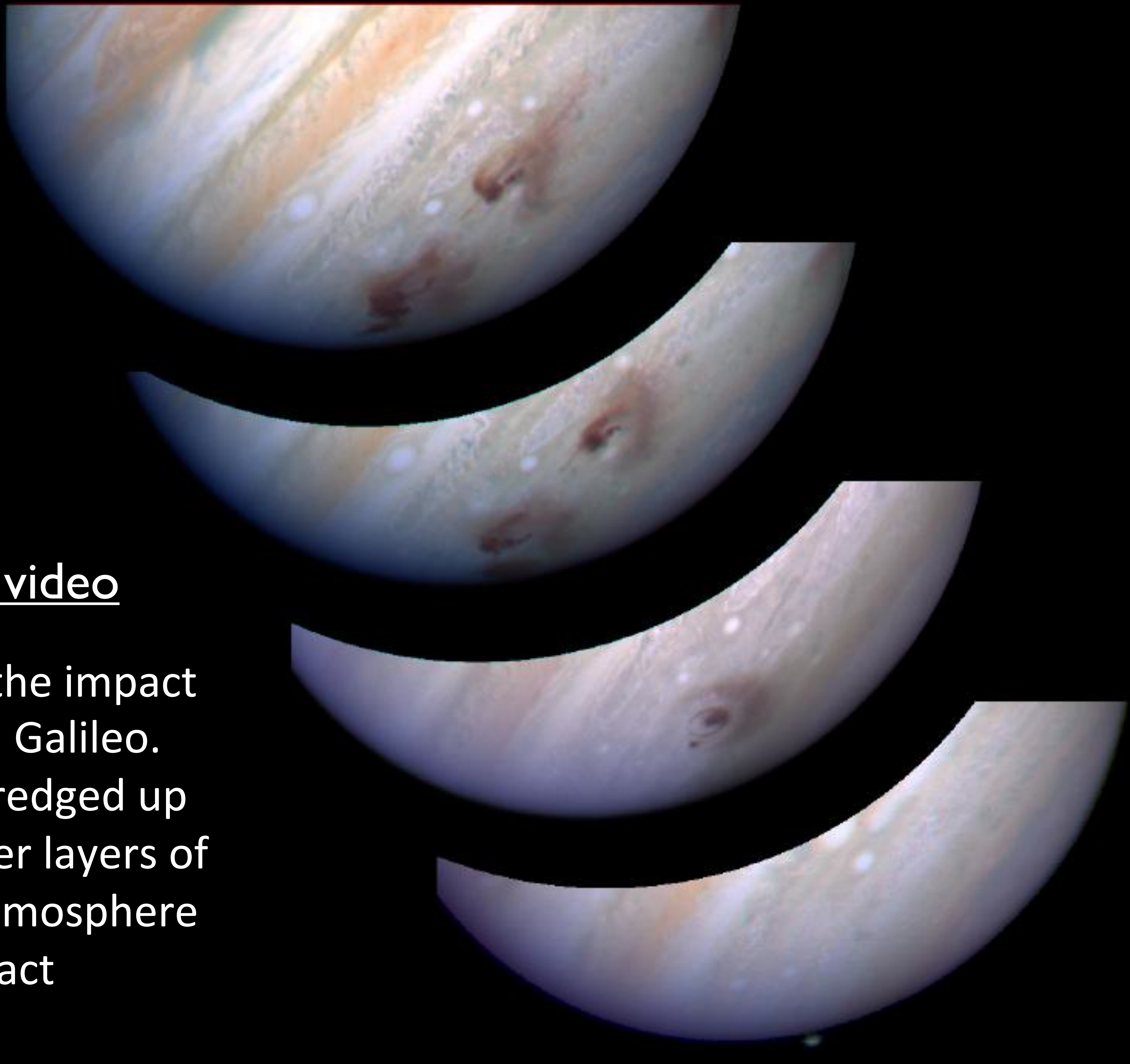
Trans-Neptunian or Kuiper Belt Objects



Trans-Neptunian or Kuiper Belt Objects



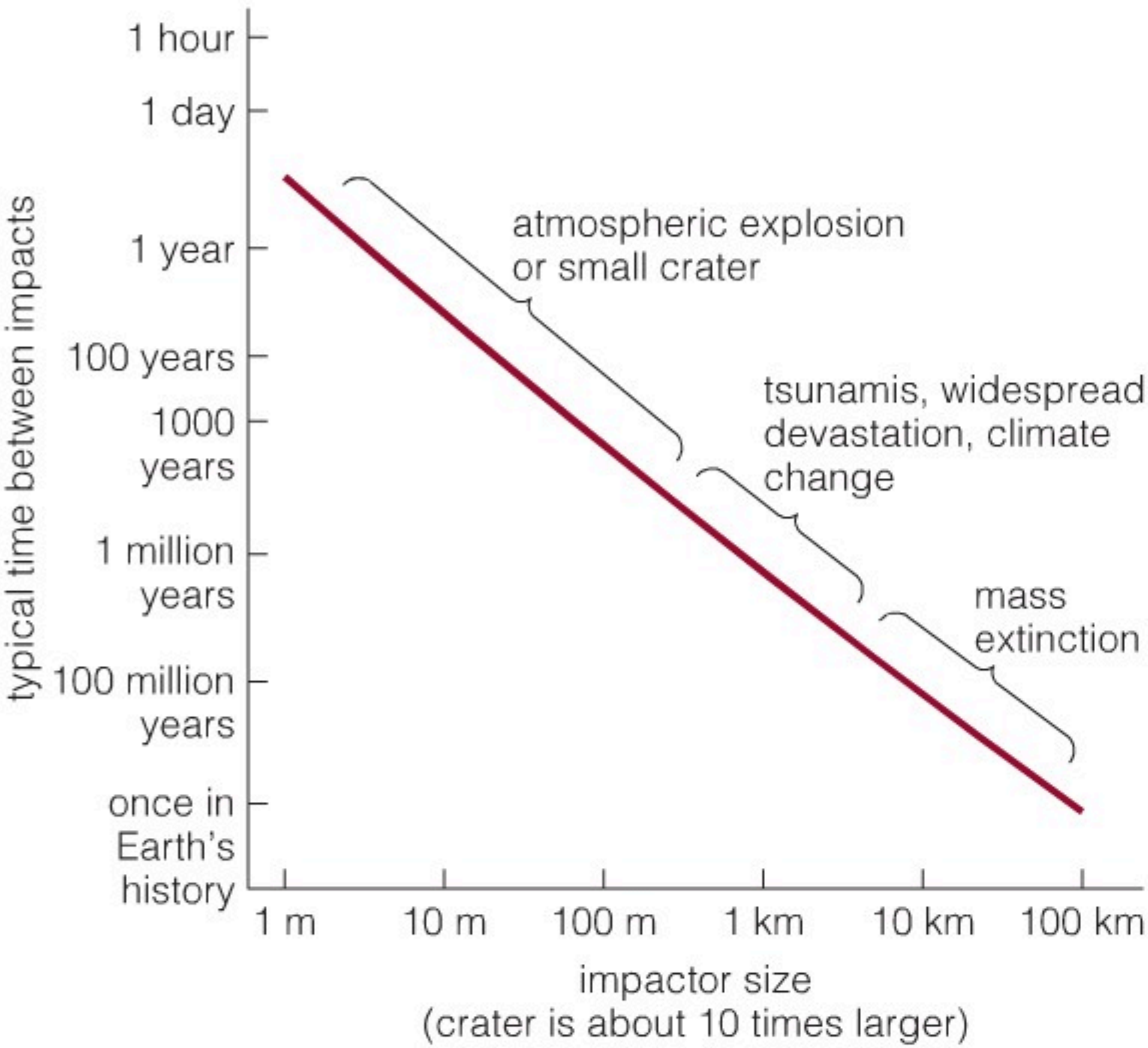
Major Impacts



Impact video

Images of the impact taken from Galileo. Material dredged up from deeper layers of Jupiter’s atmosphere by the impact

Major Impacts & Earth



65 million years ago

<u>Extinction of dinosaurs</u>