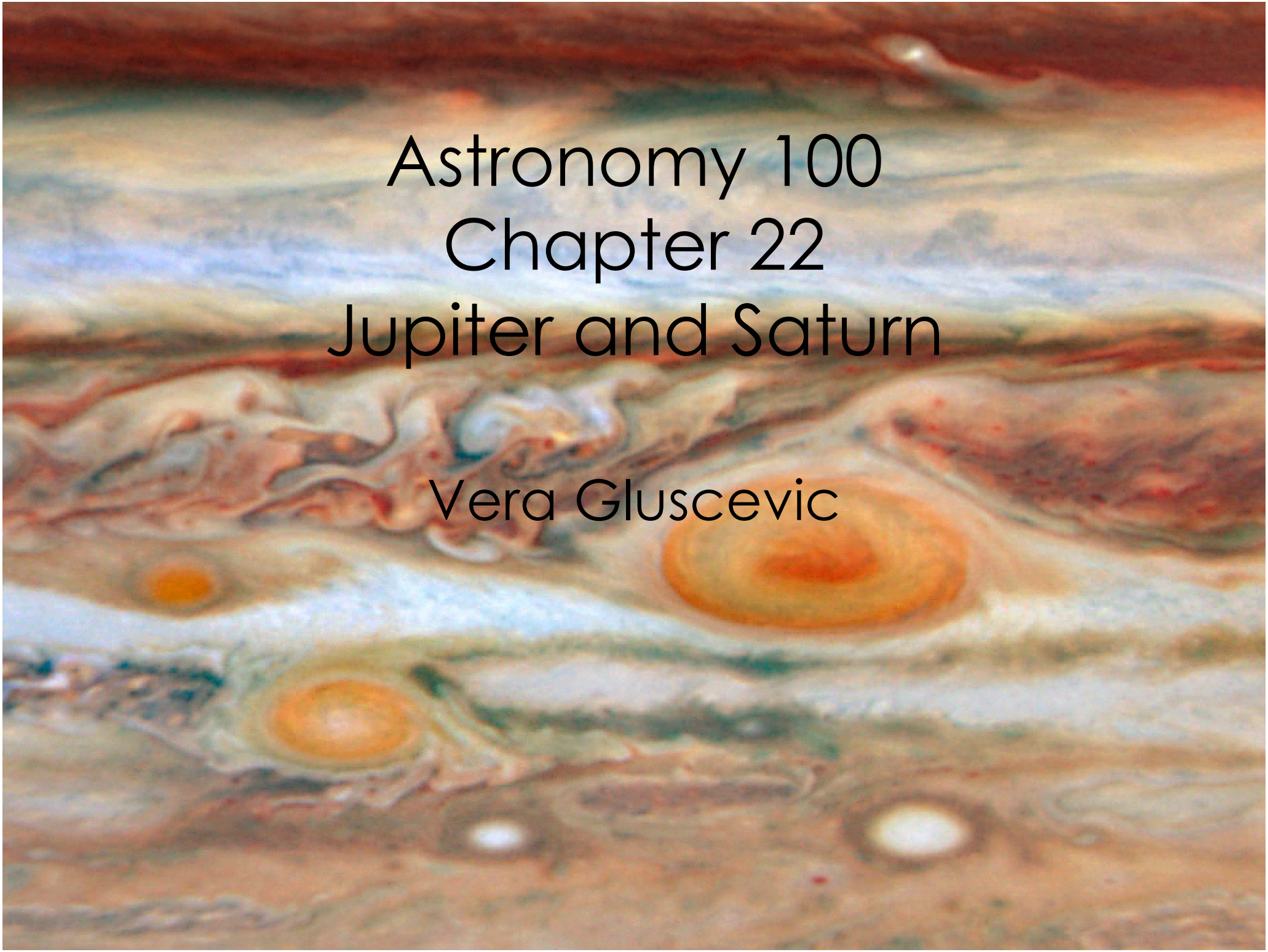


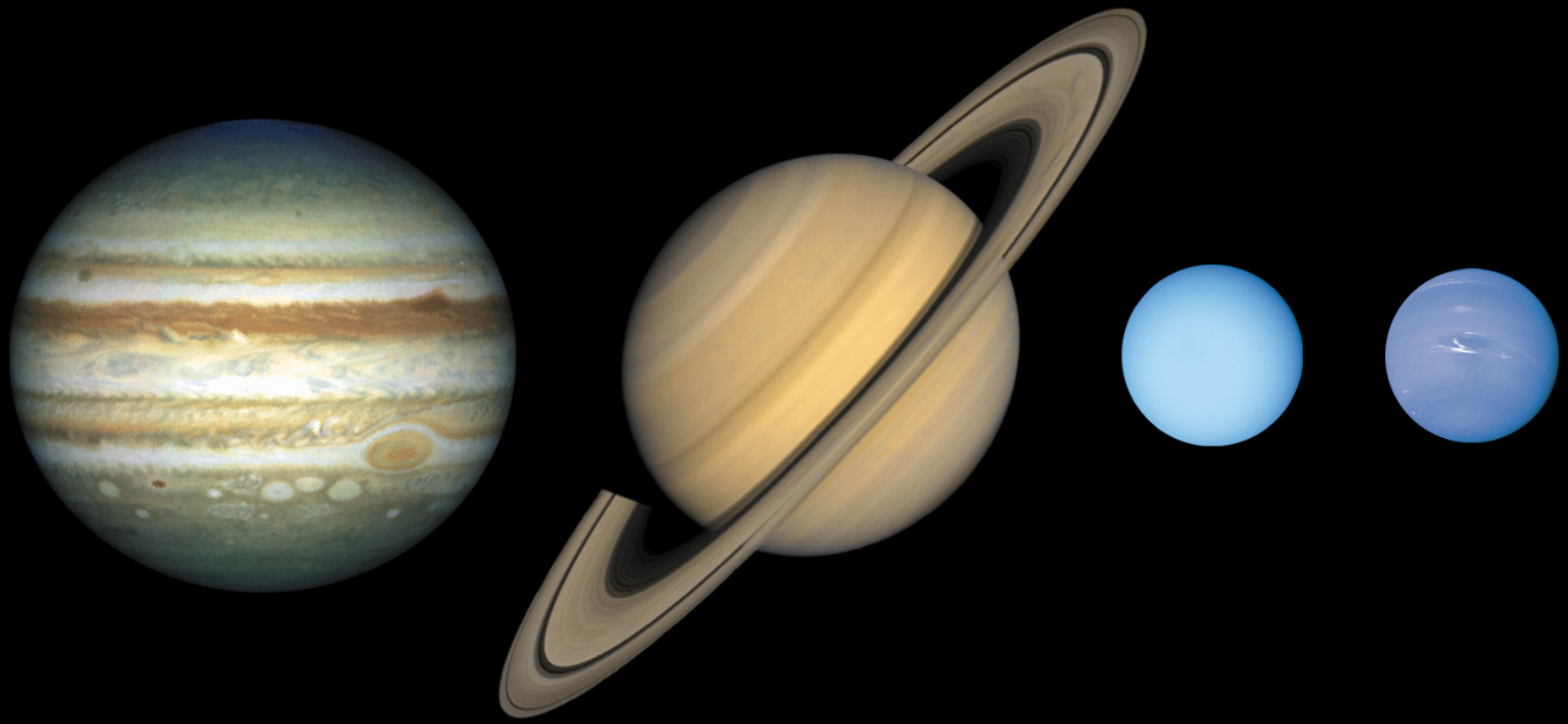
Astronomy 100
Chapter 22
Jupiter and Saturn

Vera Gluscevic

Jovian planets

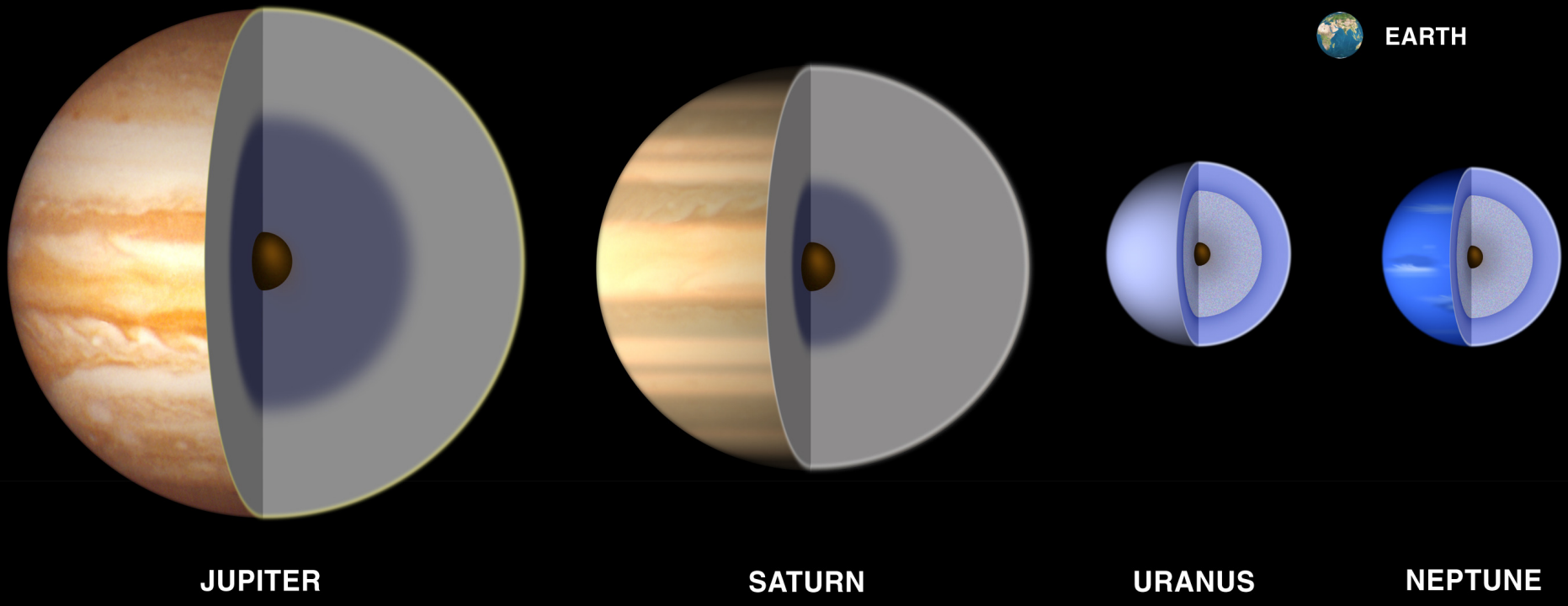
The Jovian planets

- Jupiter (5.2 AU), Saturn (9.5 AU), Uranus (19.2 AU), Neptune (30.1 AU).
- Bigger and more massive planets, but with much lower density than the terrestrial planets and a very different composition.



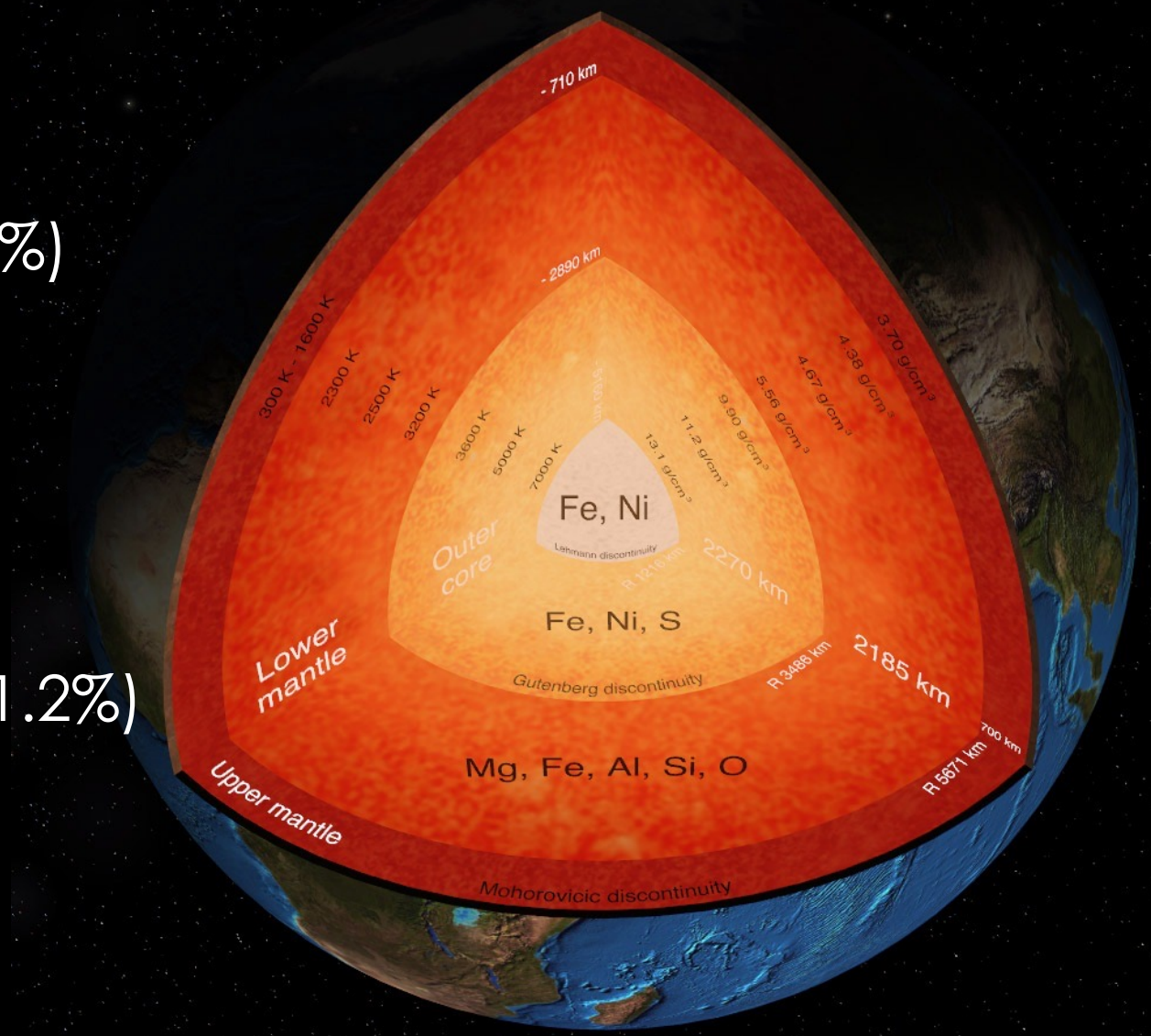
Composition of Jovian planets

- Mostly H + He



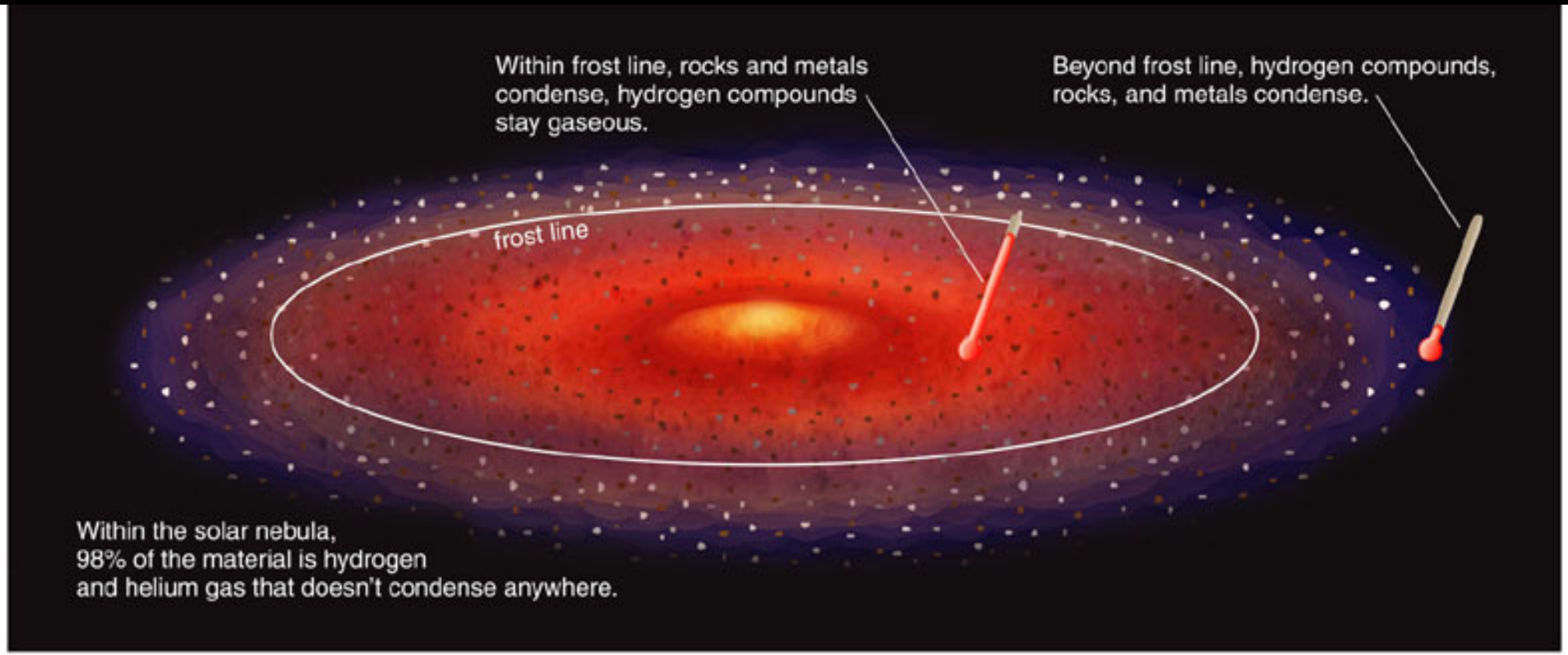
Compare to Earth!

- Iron (32.1%)
- Oxygen (30.1%)
- Silicon (15.1%)
- Magnesium (13.9%)
- Sulfur (2.9%)
- Nickel (1.8%)
- Calcium (1.5%)
- Aluminum (1.4%)
- Trace elements (1.2%)



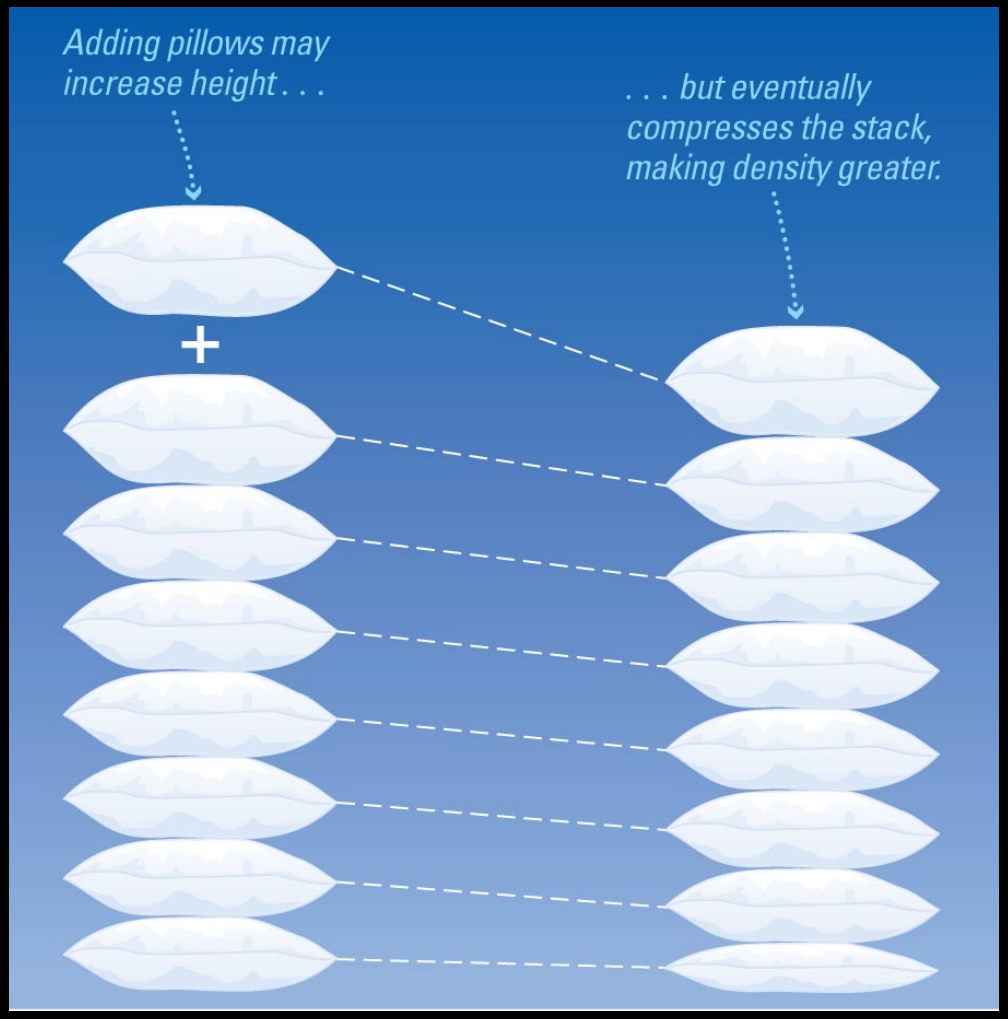
Why this difference? The Frost Line!

- Solar nebula was 98% hydrogen and helium, and 2% other elements.



Size versus density

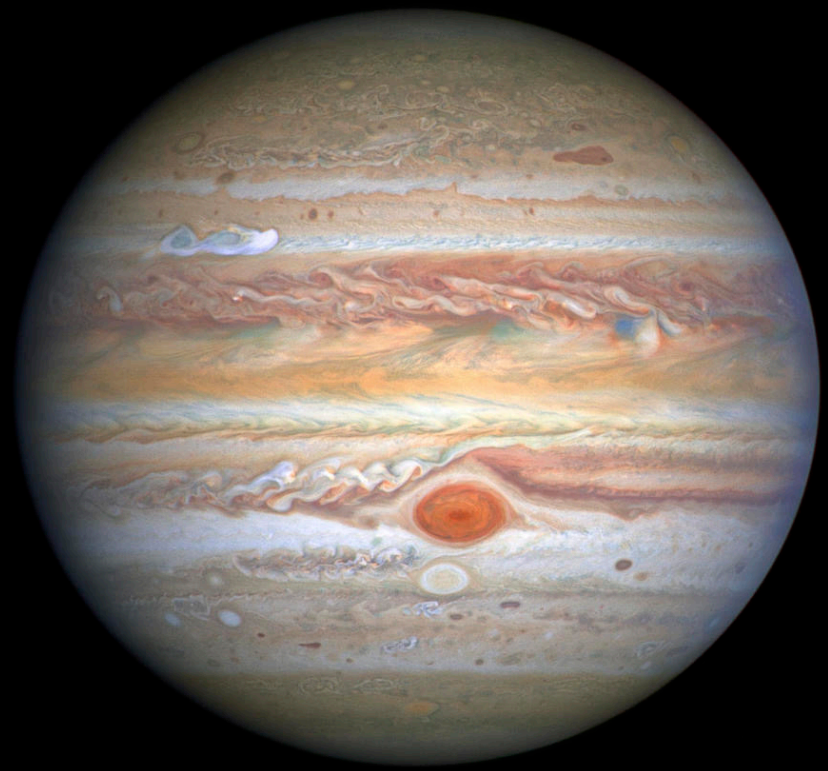
Increasing mass doesn't necessarily mean an increase in radius, especially for gas giants (Jupiter's density is almost 2x that of Saturn; Saturn is less dense than water).



Jupiter

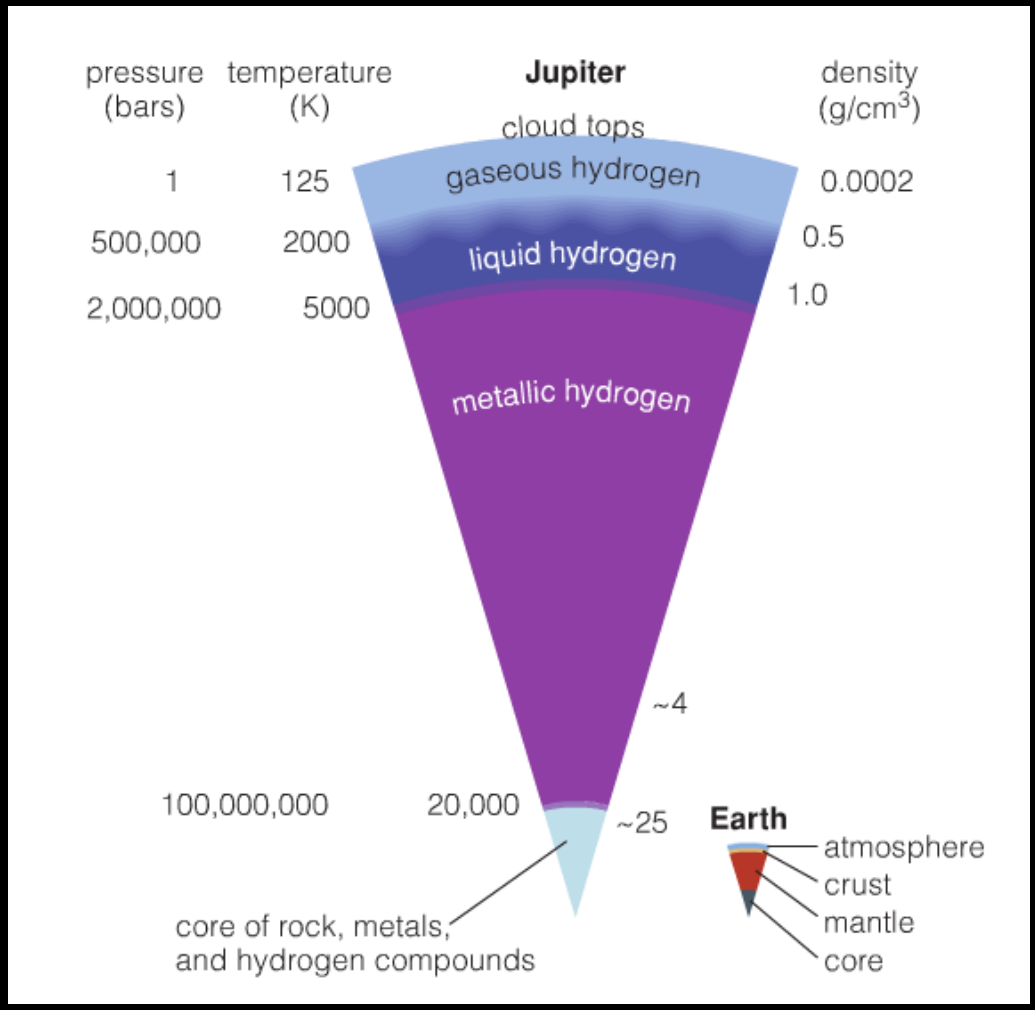
Jupiter

- Mass 318x Earth's mass
- Spins so rapidly that it's oblate.
- Has 79 satellites.
- Gives off ~2 times the energy it receives from the Sun.



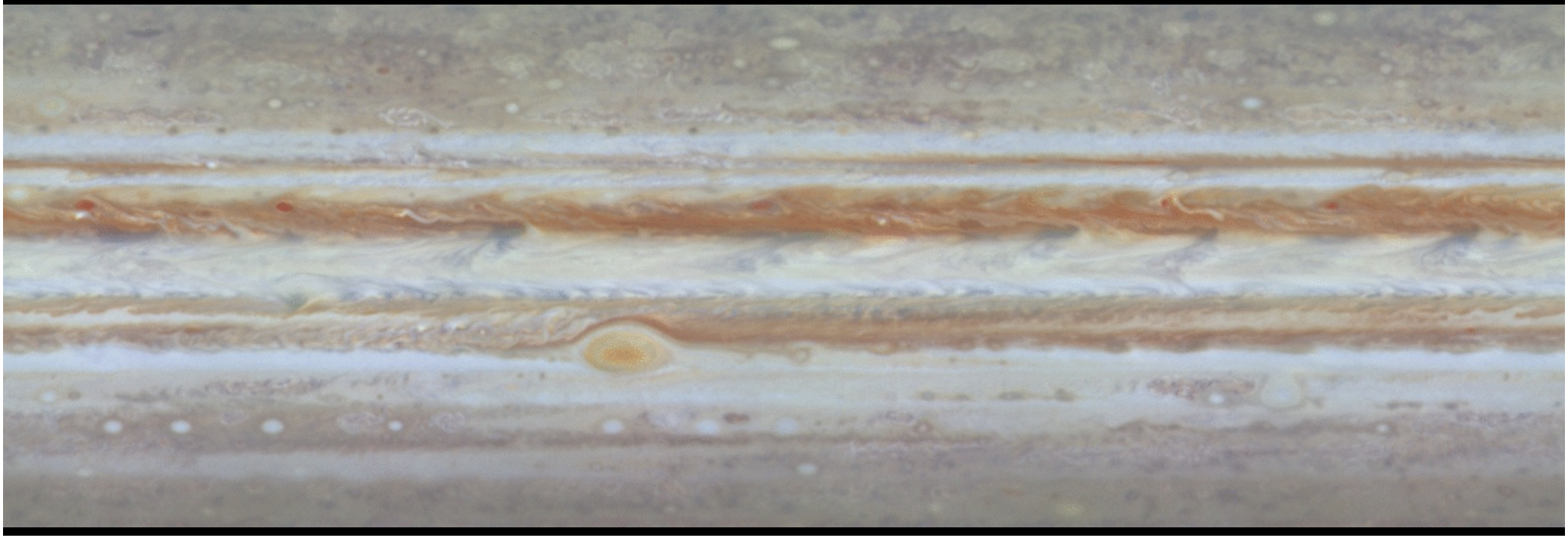
Jupiter's Interior

- No solid surface
- Density 1.33 g/cm^3 (Earth's is 5.51 g/cm^3)
- Bizarre and unusual liquid and metallic phases of hydrogen and helium (so compressed that the atoms share electrons, just like in metals).



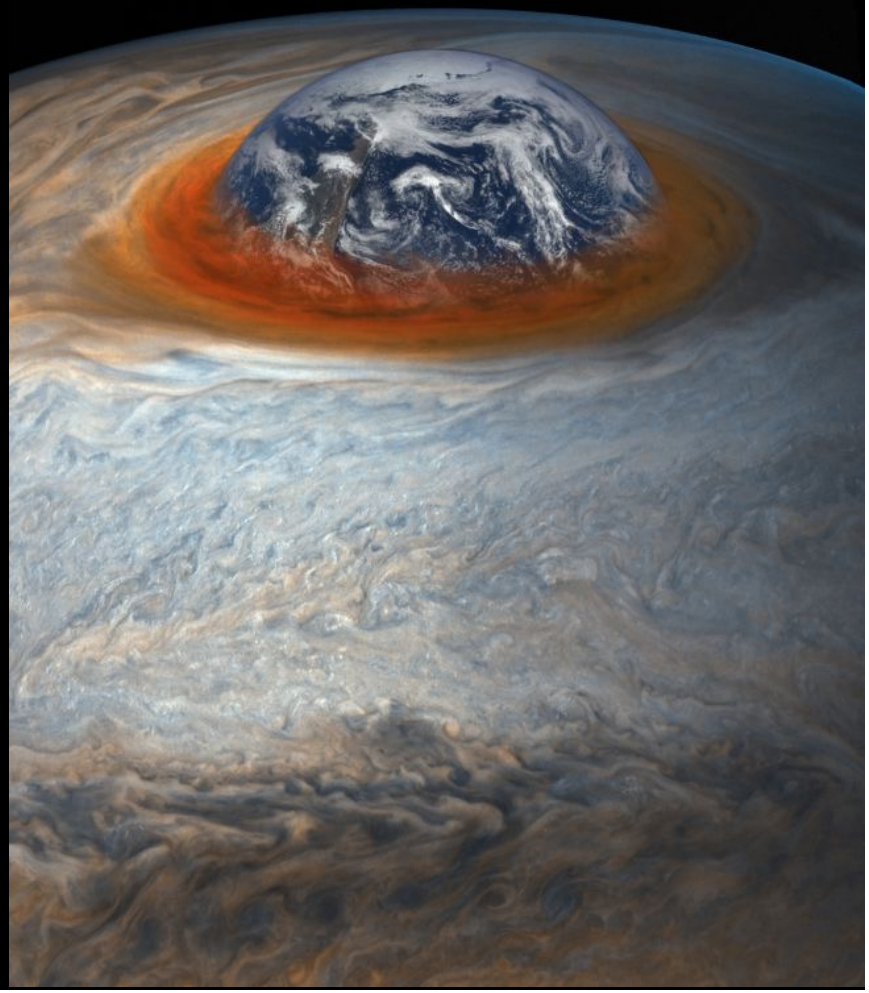
Jupiter's atmosphere

- Jupiter rotates in 10 hours!
- Fast rotation stretches **storms** into colorful bands surrounding the entire planet.
- **Winds as high** as 250 mph in the outer layers, because of **rotation**.

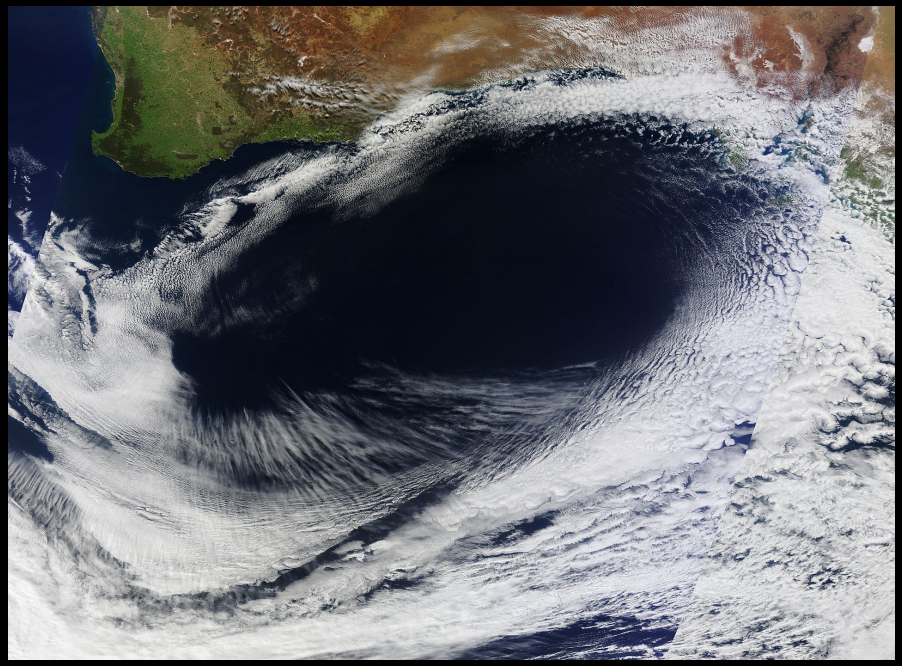


The Great Red Spot

- **Anticyclone** larger than the whole planet Earth.
- Persisted 180 – 345 years, but is shrinking now.

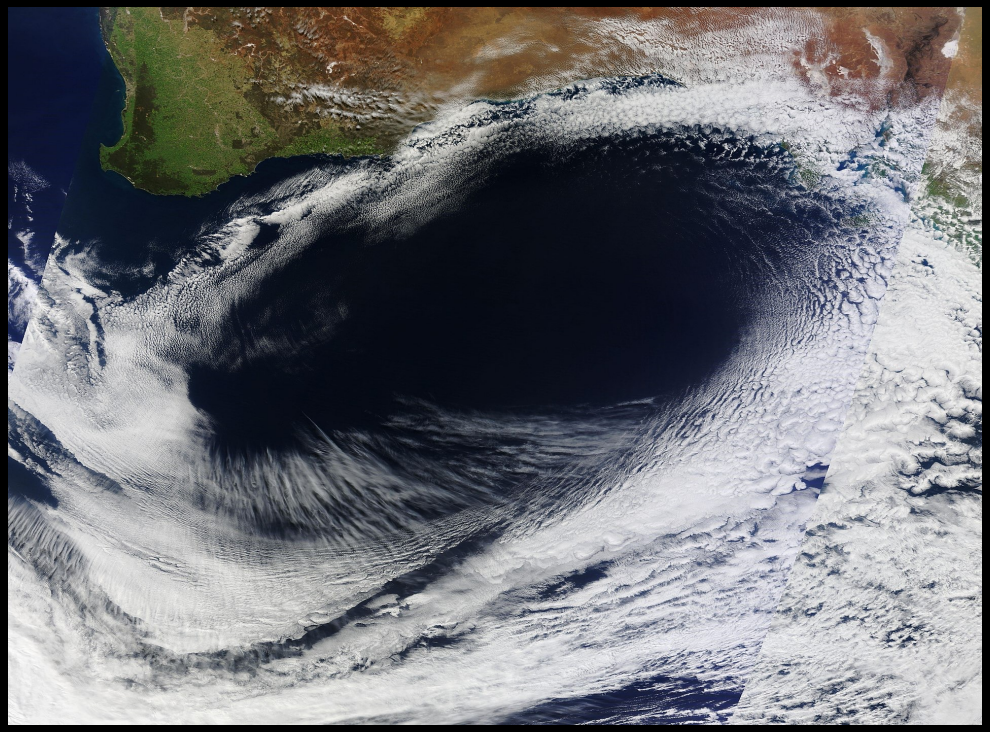


The Great Red Spot vs. Earth's anticyclone

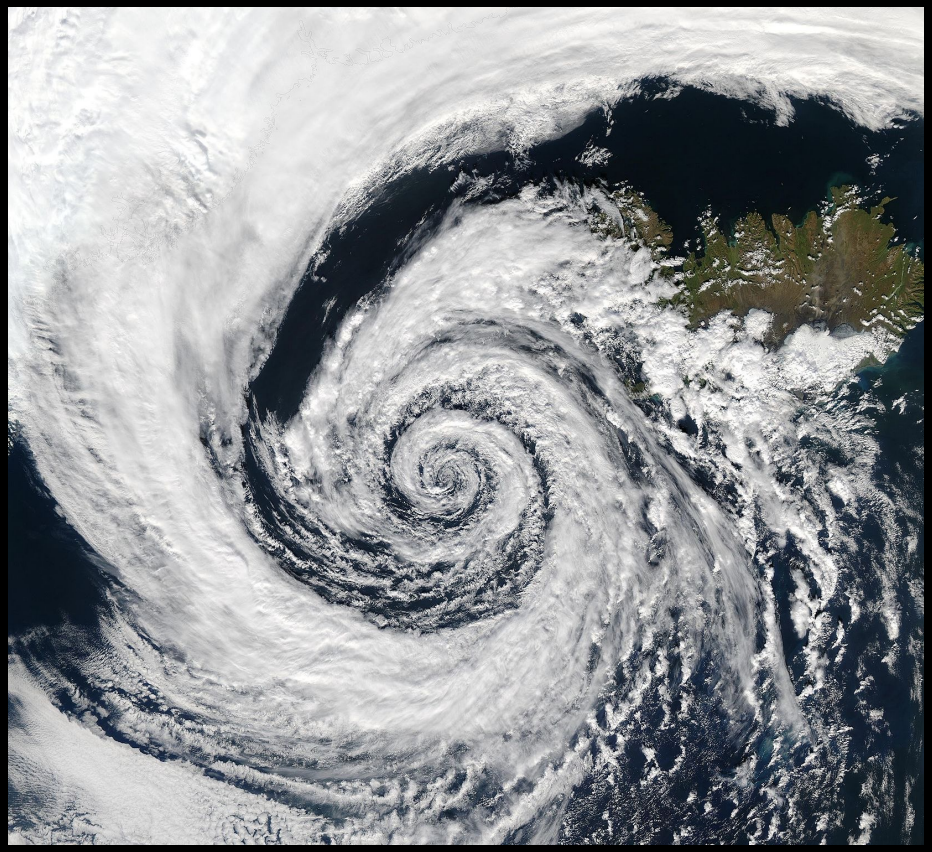


Swirling Storm…

Coriolis force causes deflection of winds (compare to Earth!)



Anticyclone (high pressure)



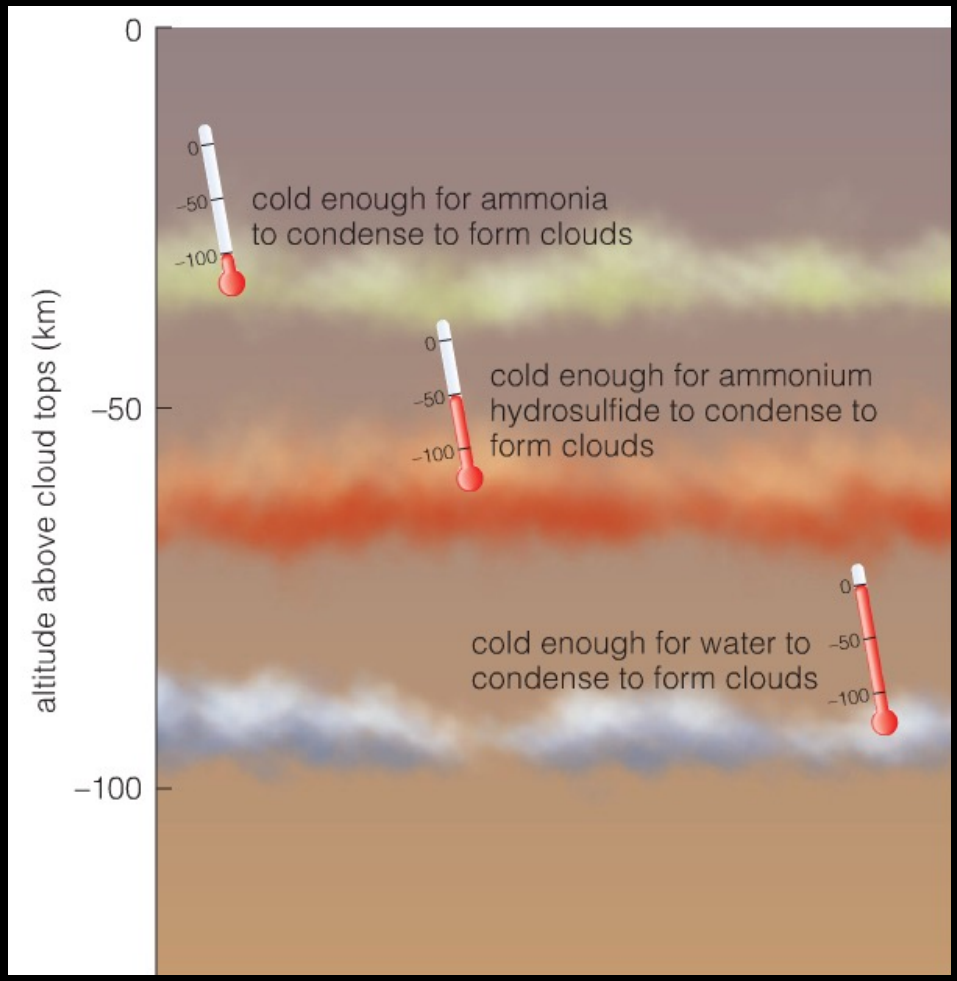
Cyclone (low pressure)

Layers of clouds

Different volatiles condense at different temperatures, forming colorful layers of clouds in Jupiter's atmosphere:

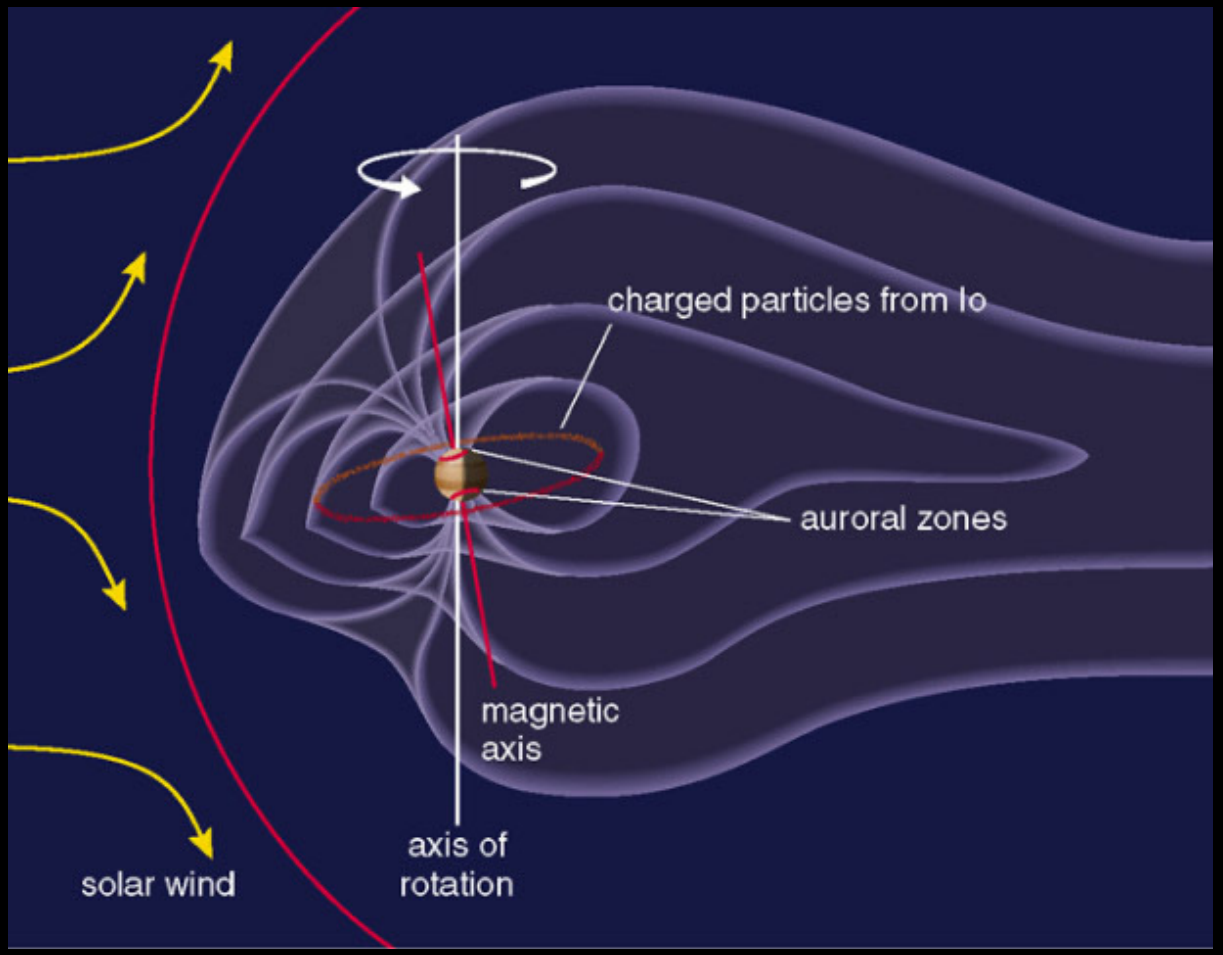
- High: frozen ammonia crystals, white/yellow.
- Middle: ammonium hydrosulfide, ~50 km below, red/brown.
- Low: Water clouds, ~100 km below.

All these compounds have been found by spectroscopic observations from Earth, and confirmed by the Galileo probe.



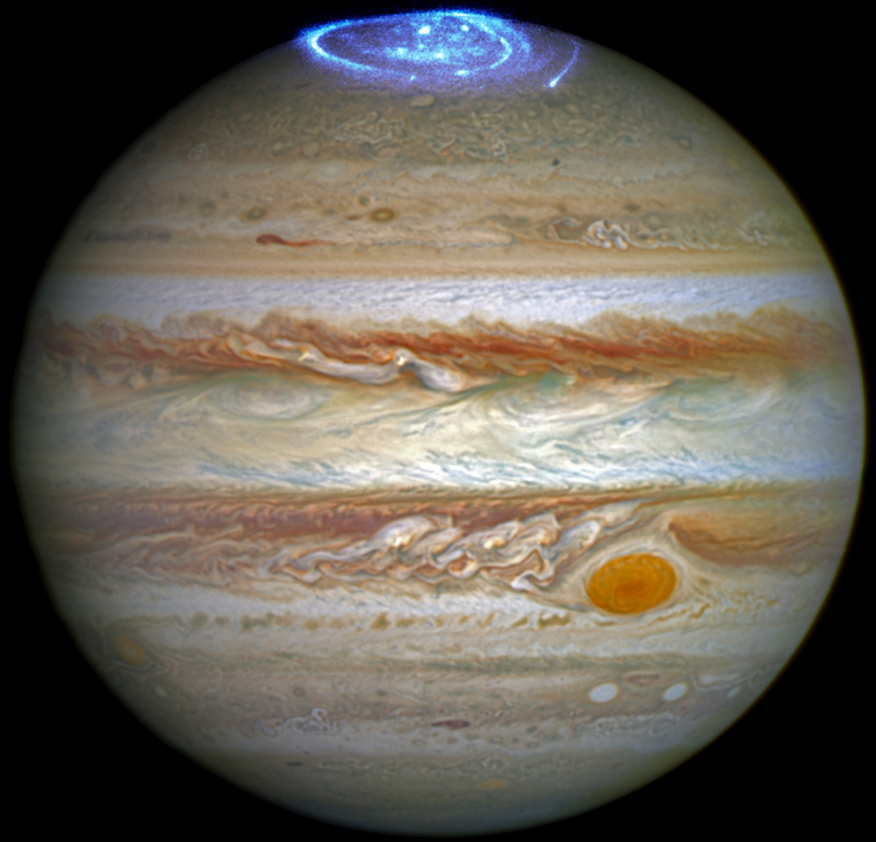
Jupiter's Magnetosphere

Jupiter's magnetosphere enormous compared to Earth!



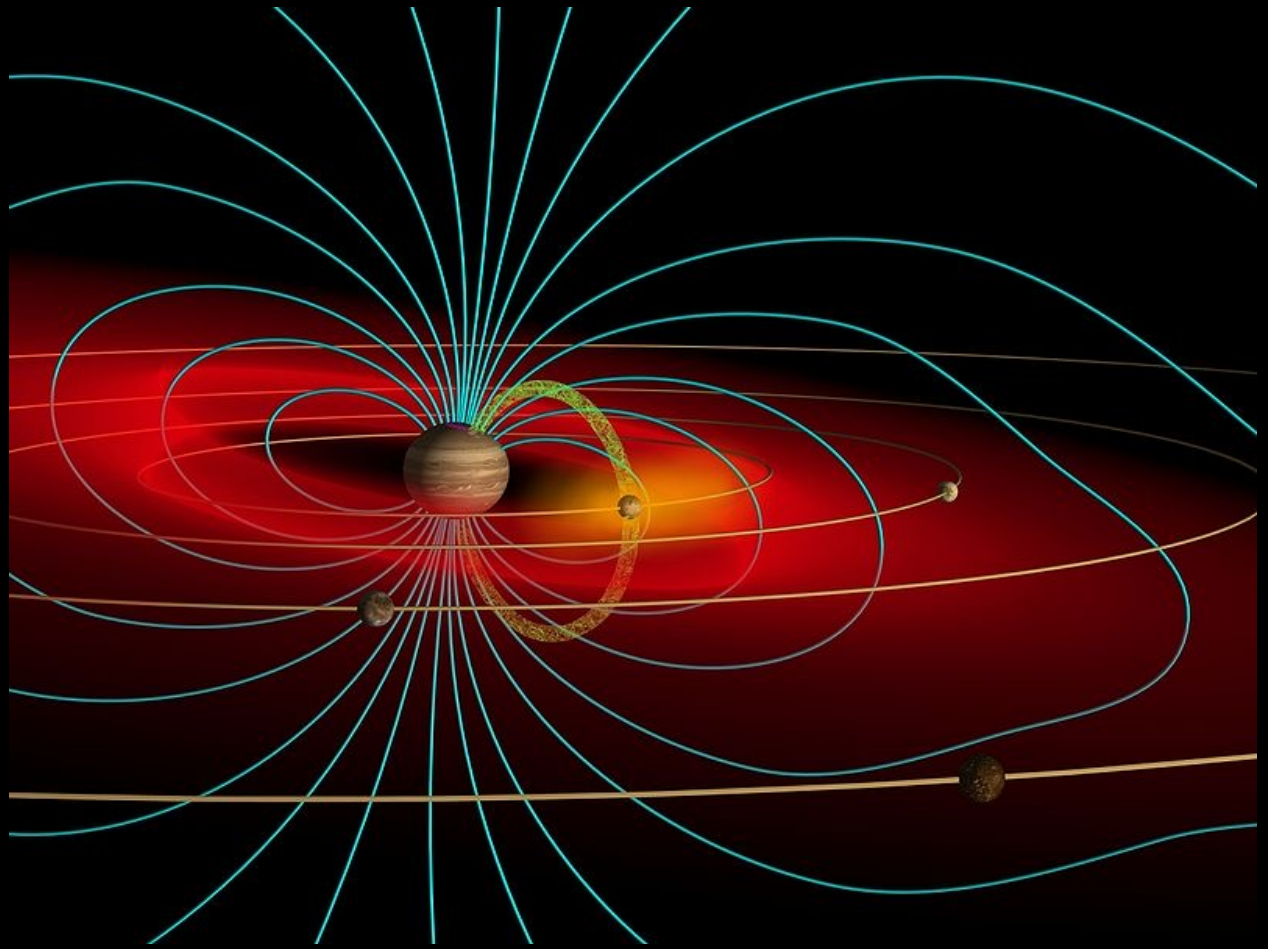
Jupiter's Aurora

Lots of electrical currents and particles raining down on Jupiter's atmosphere (composite image in visible + UV).



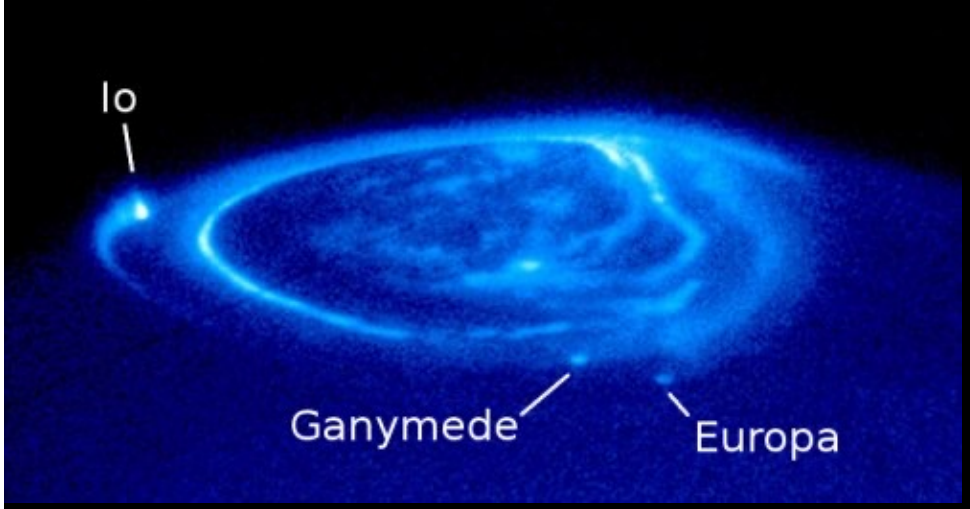
Jupiter's Magnetosphere

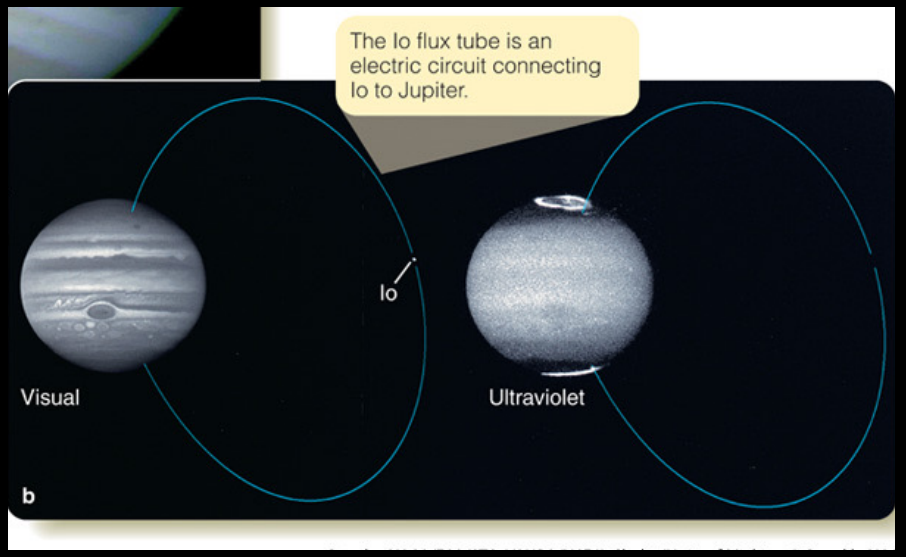
Particles supplied by volcanic eruptions on Io.



Jupiter's Aurora

- "Footpoints" of Galilean moons can also be seen. What would cause an electrical connection between a moon and its planet?

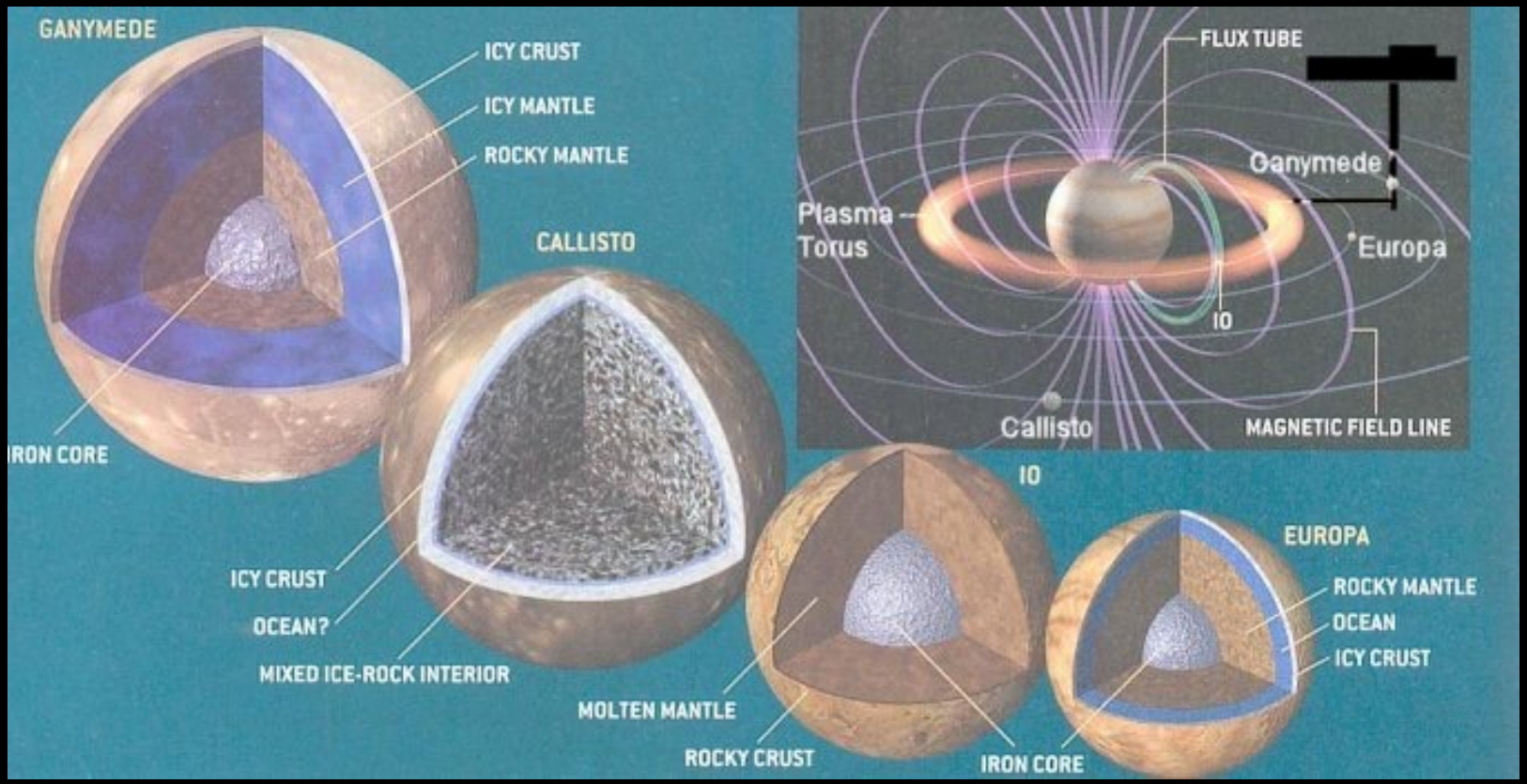




Jovian moons

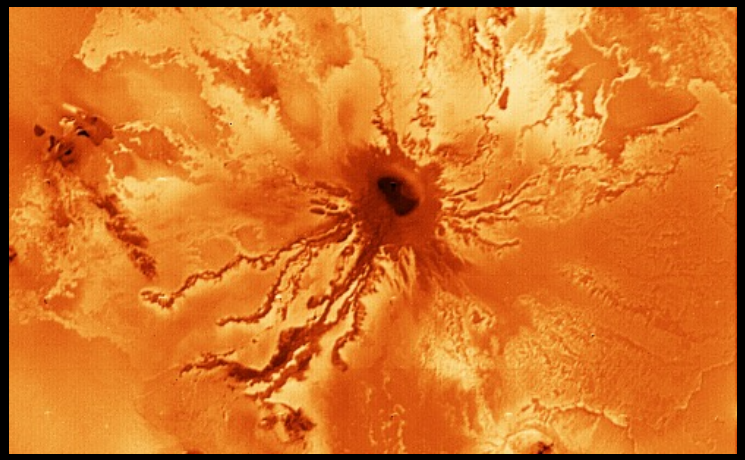
Jovian moons

- Jovian moons formed in the outer solar system where rocky and icy planetesimals formed.
- The largest ones are made of rocks & ice with an iron core.



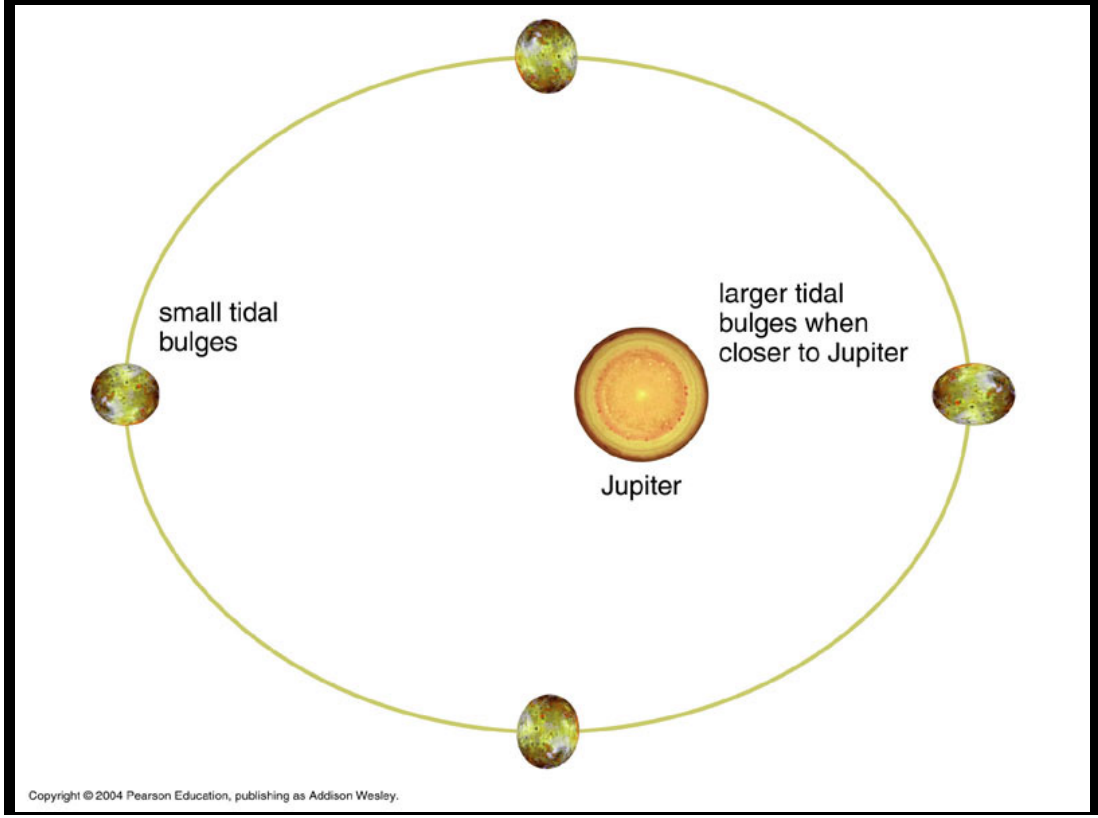
Io

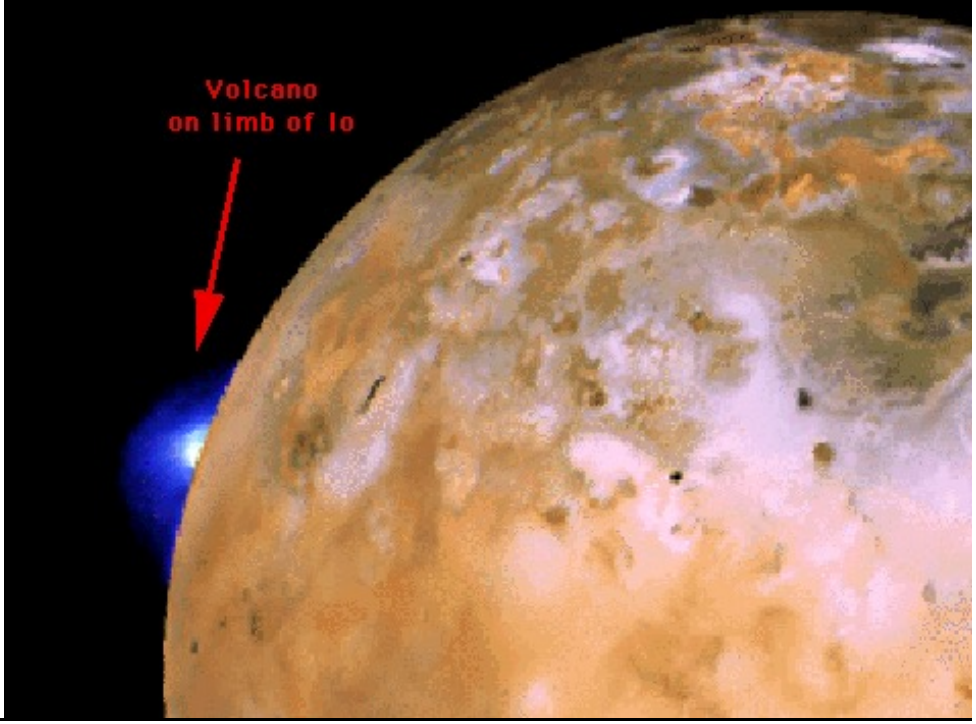
- 3600 km in diameter (slightly larger than our Moon).
- 400 active volcanoes: the most geologically active object in the solar system!
- Temperatures in Io's volcanoes exceed 3,500 °F; we see evidence of active plumes.
- Mercury, Earth's Moon, and Mars have all lost their internal heat during the last several billion years.



Tidal Heating at Io

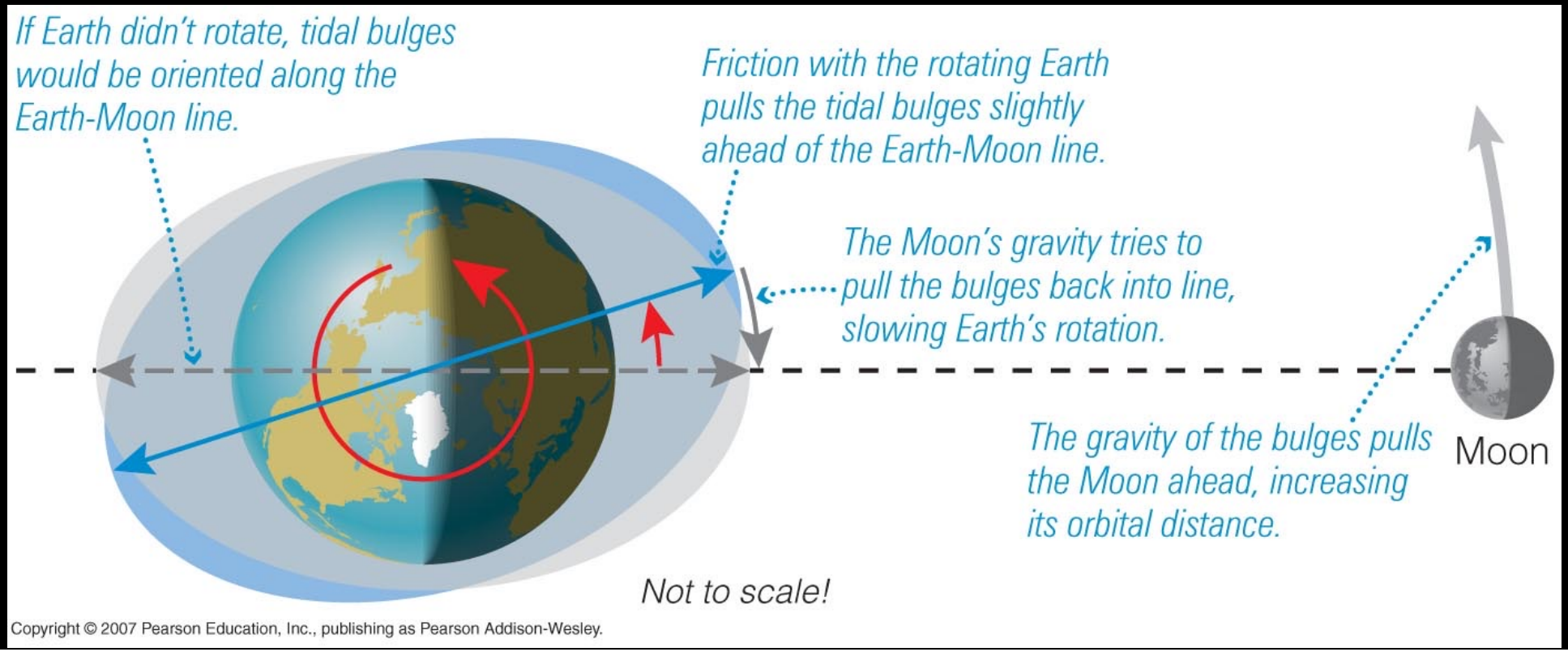
- Io's global volcanism is caused by **tidal heating**.
- Proximity to Jupiter and elliptical orbit push and pull on Io, generating internal friction.





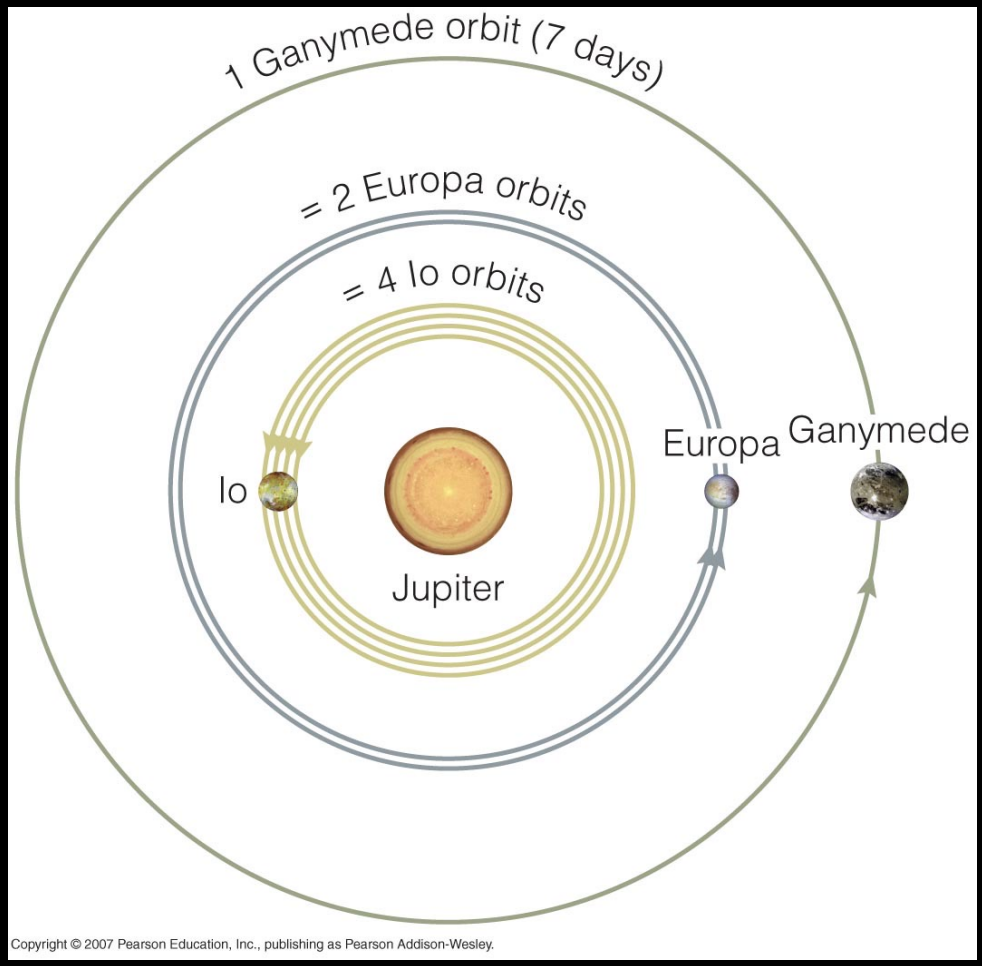
Tidal friction

- Tidal friction slows down the moon's rotation and causes the moon to move farther out.
- Similarly, planet's gravity slows down the moon's rotation till the same face of the moon is always facing the planet (synchronous rotation, all 4 Galilean moons)

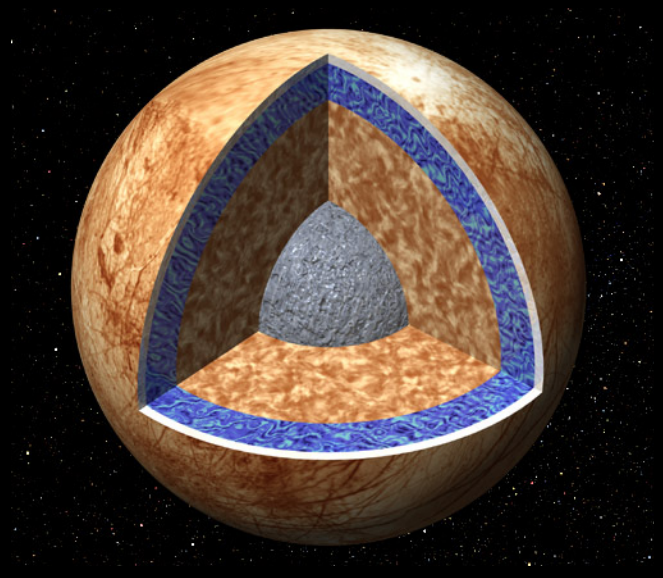


Orbital Resonance

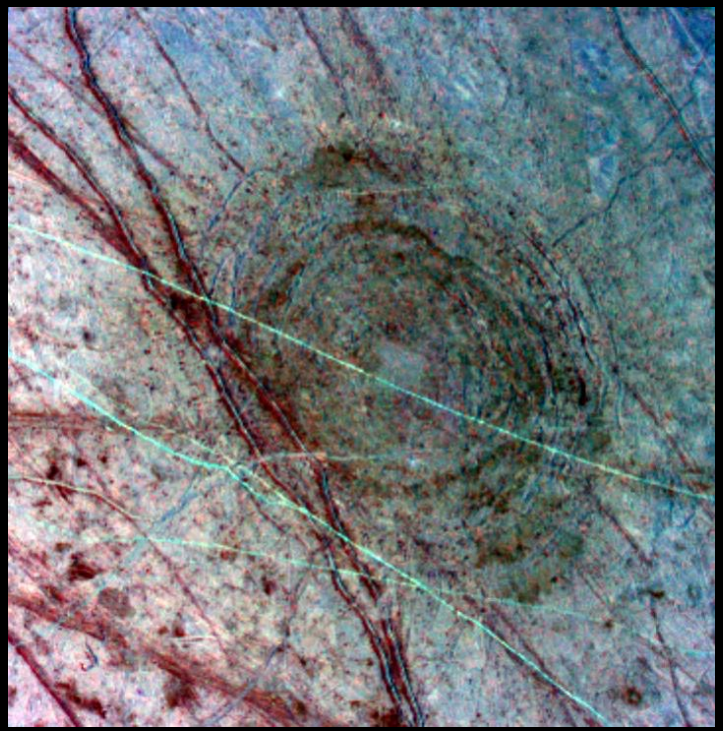
- Ganymede completes one orbit for each 2 Europa orbits and 4 Io orbits: all three satellites line up once every 7 days, tugging on one-another.
- Tug distorts Io's and Europa's orbits into ellipses, amplifying tidal heating from Jupiter.

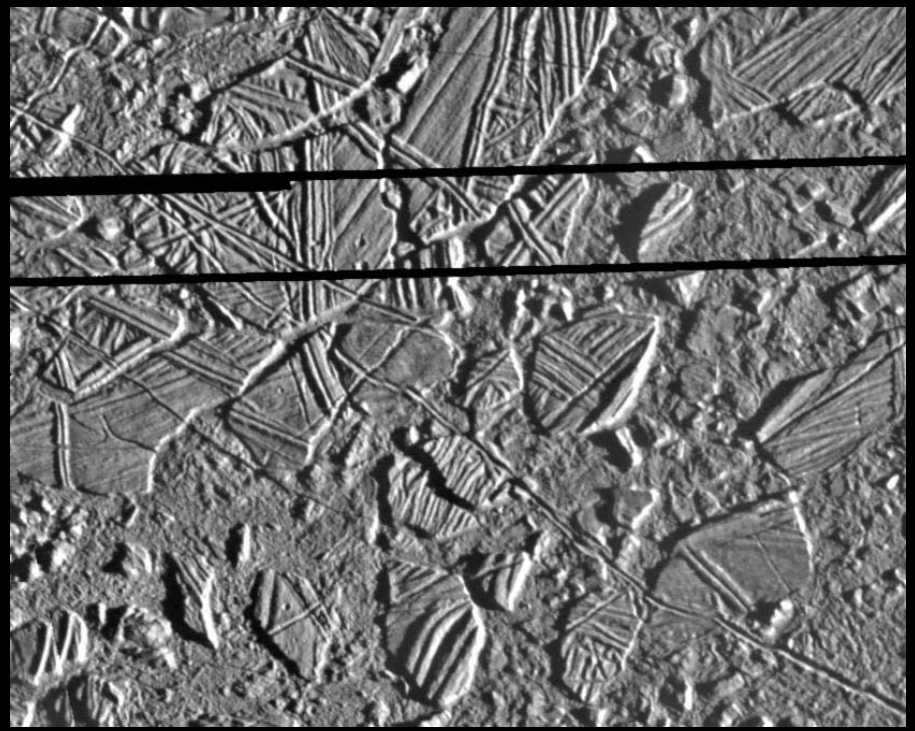


Europa



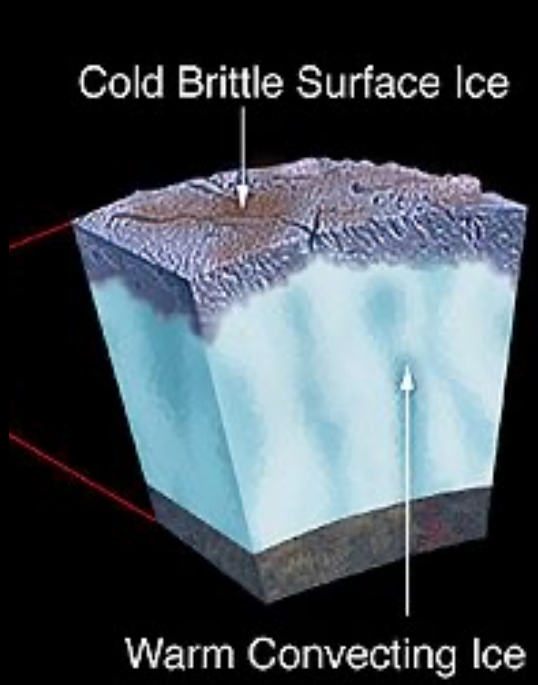
- Very few impact craters on Europa (those that remain are already overlaid by new fractures).
- Surface also shows regions that have "rafted" across.
- Under-surface ocean?

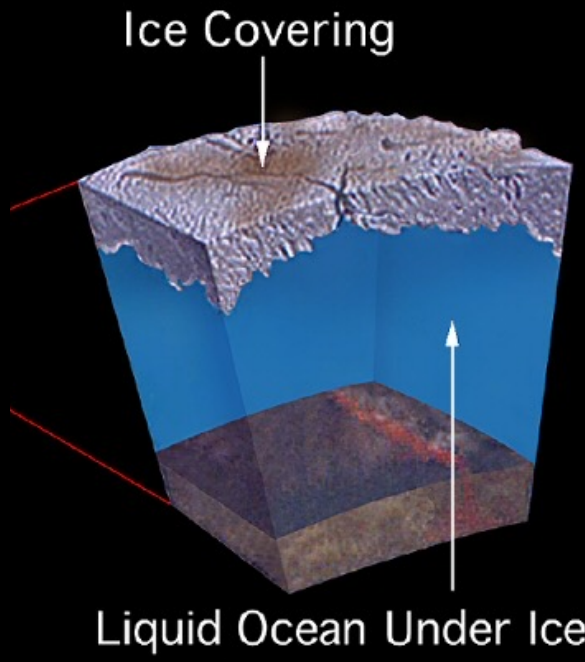




Life on Europa?

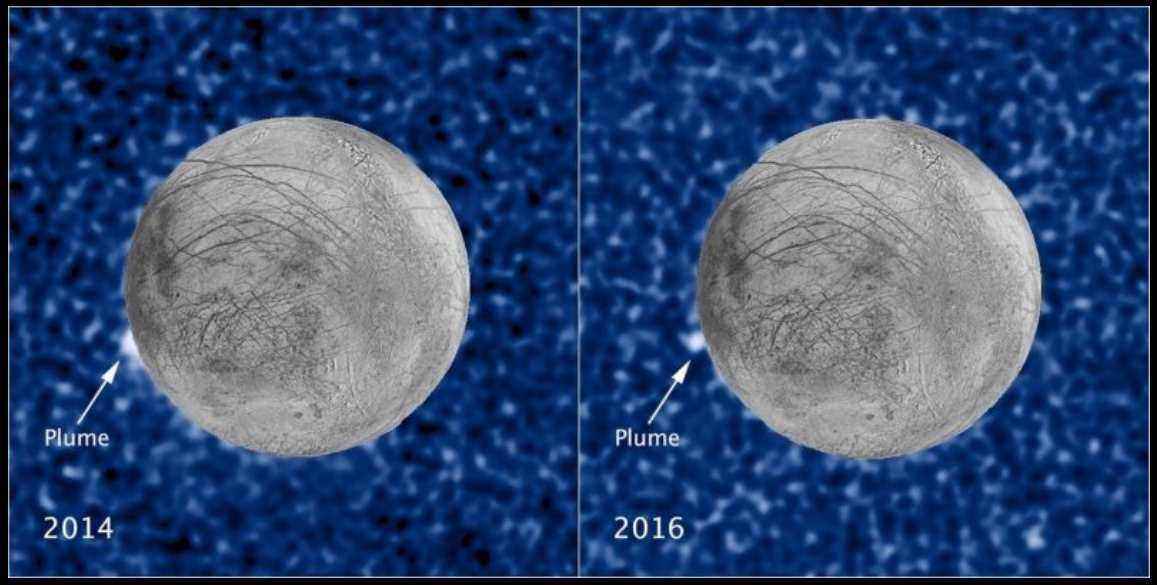
- Beneath ~10km of ice, there may be either ice or an ocean of liquid water (latter is more likely, because Europa conducts current).
- This ocean is in contact with the rocky mantle, providing minerals and possibly building blocks for life.





Liquid water???

- Hubble Space Telescope has detected plumes of water shooting off the surface of Europa!



Ganymede

- Largest moon in the solar system: 5,268 km diameter.
- Composed of equal parts water ice and rock.

question for you

How often does Jupiter rise as seen from Europa?

A. It depents where the observer stands.
B. Once every 10 hours.
C. Once every 12 years.
D. Never.

question for you

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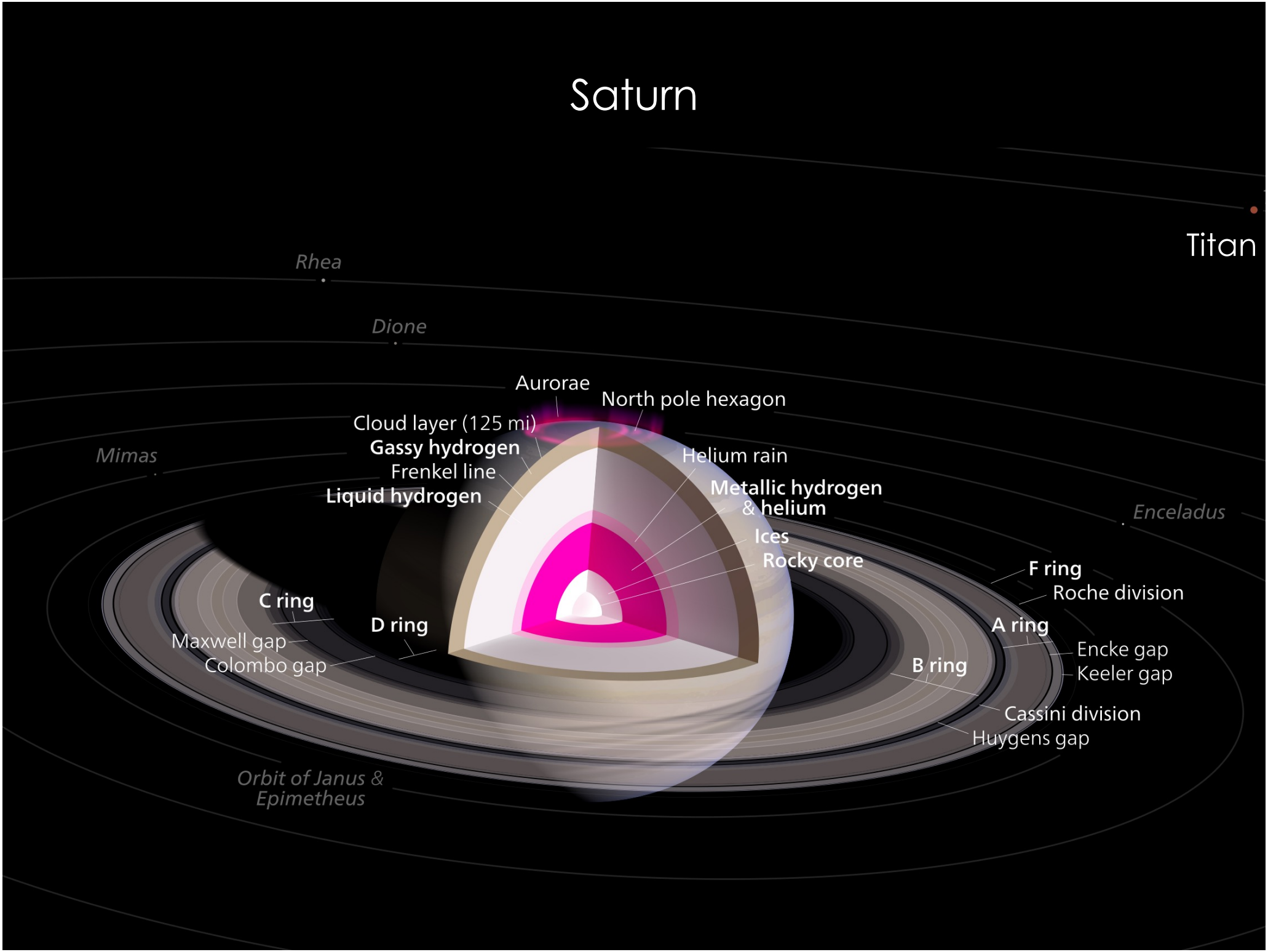
Saturn

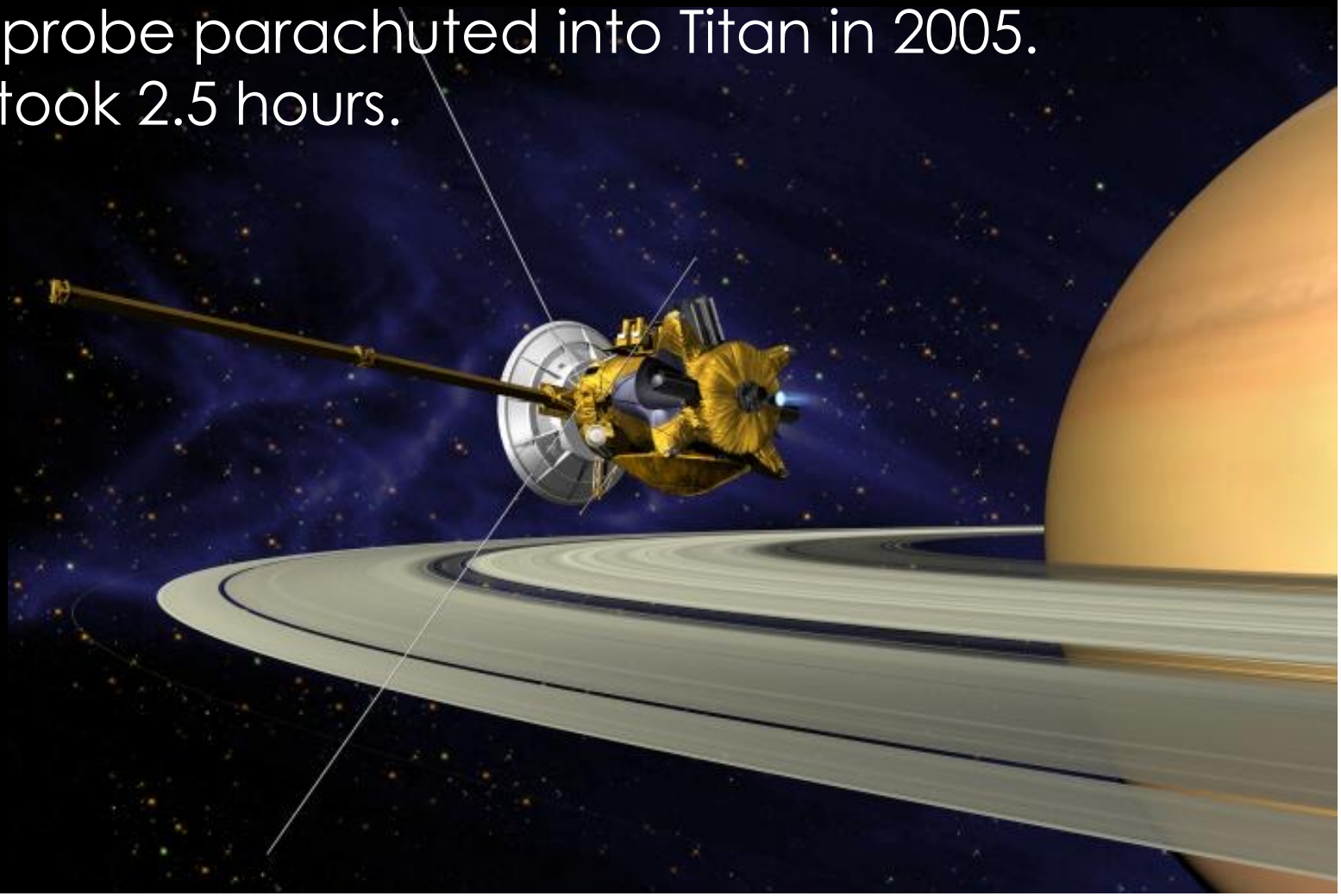
Saturn

- Second largest planet in solar system
- Perihelion and aphelion: 9.024 AU – 10.086 AU
- Orbital period: 29.46 years
- Radius 54,000 – 60,000 km
- ~100x more massive than Earth
- 82 known satellites


Saturn
Titan
Rhea
Dione
Aurorae
North pole hexagon
Cloud layer (125 mi)
Gassy hydrogen
Frenkel line
Liquid hydrogen
Helium rain
Metallic hydrogen
& helium
Ices
Rocky core
Mimas
Enceladus
F ring
Roche division
C ring
D ring
A ring
Maxwell gap
Colombo gap
Encke gap
Keeler gap
B ring
Cassini division
Huygens gap
Orbit of Janus &
Epimetheus

Cassini-Huygens

- Cassini spacecraft reached Saturn and entered orbit in 2004. Mission ended in 2017.
- Huygens probe parachuted into Titan in 2005. Descent took 2.5 hours.



question for you

Why is Saturn less dense than Jupiter?

A. It's less massive and less compressed.
B. Jupiter has a very different composition, with more heavy elements.
C. Saturn has an internal source of heat that "puffs" it up.
D. Both B and C.

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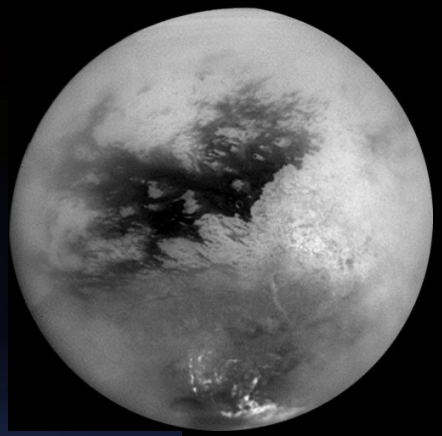
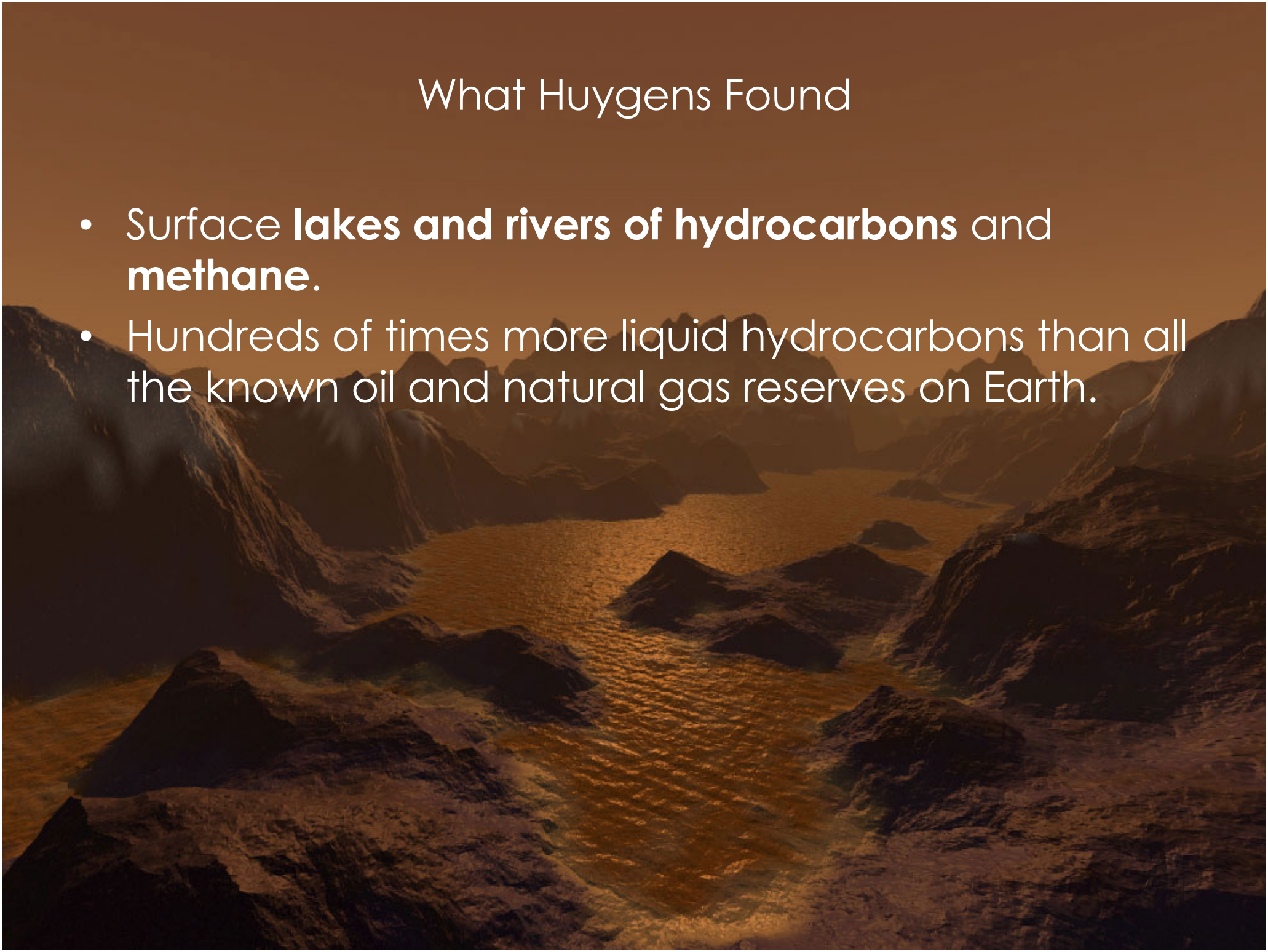
Moons of Saturn

Titan has an atmosphere!



- Larger than Mercury, Titan was discovered by Huygens in 1656.
- Atmospheric composition: 98.6% nitrogen, remainder is methane and hydrocarbons.
- Surface: -200 C.

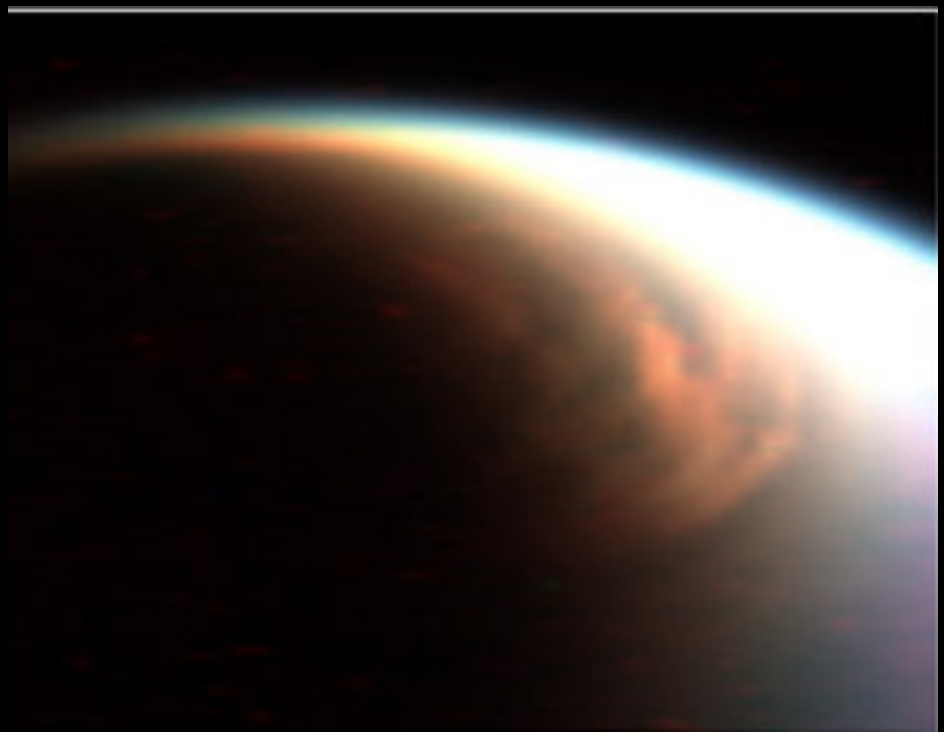
What Huygens Found



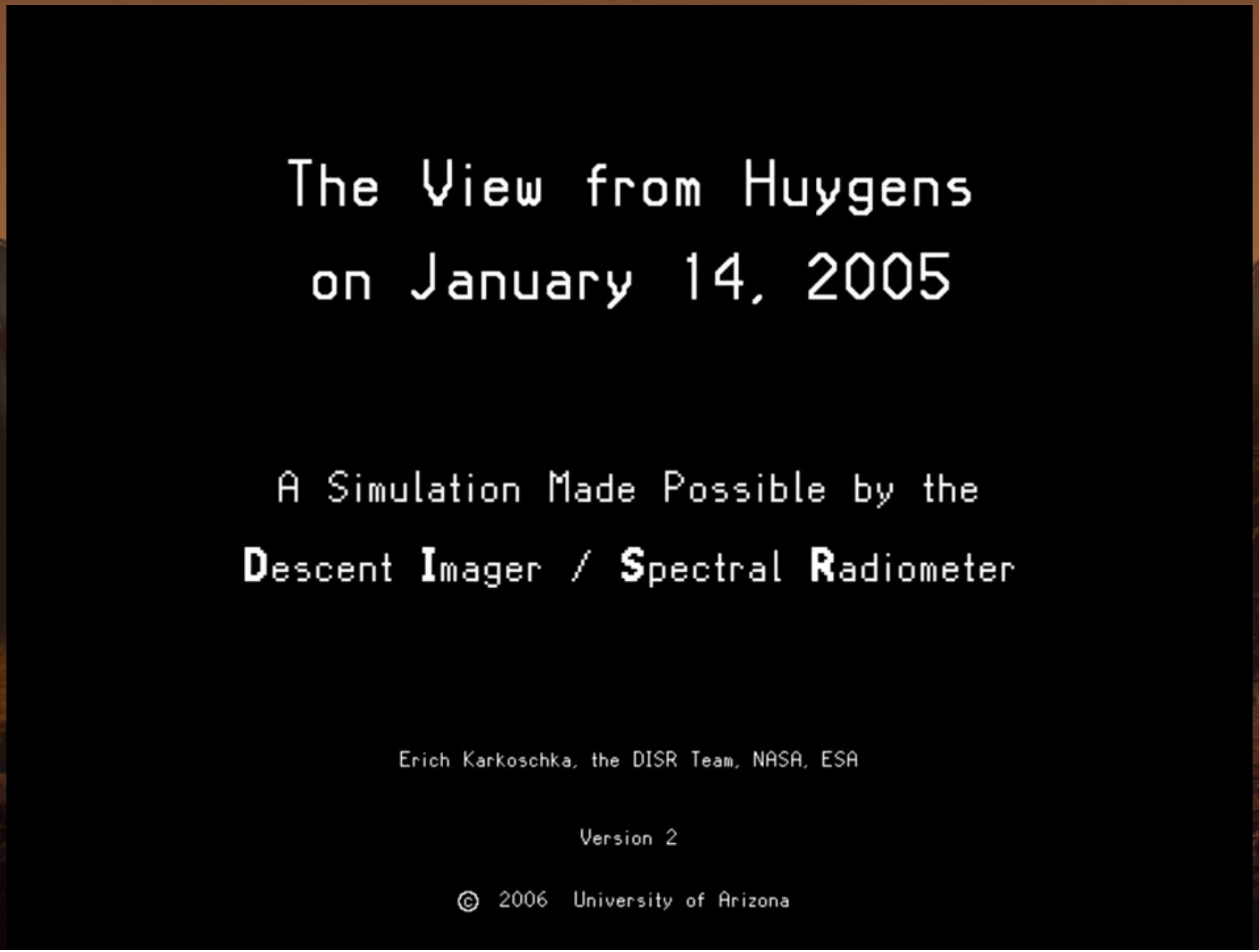
- Surface **lakes and rivers of hydrocarbons** and **methane**.
- Hundreds of times more liquid hydrocarbons than all the known oil and natural gas reserves on Earth.

How did the atmosphere form?

- Ammonia can be broken down by solar radiation to give nitrogen.
- Breakdown of methane gives hydrocarbons.
- Need a reservoir of methane and a methane cycle.

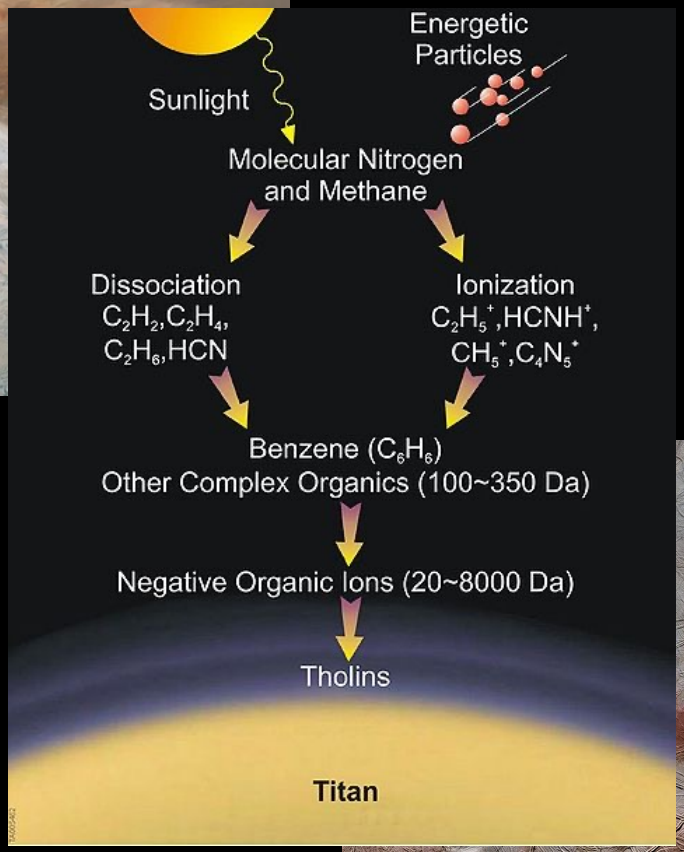


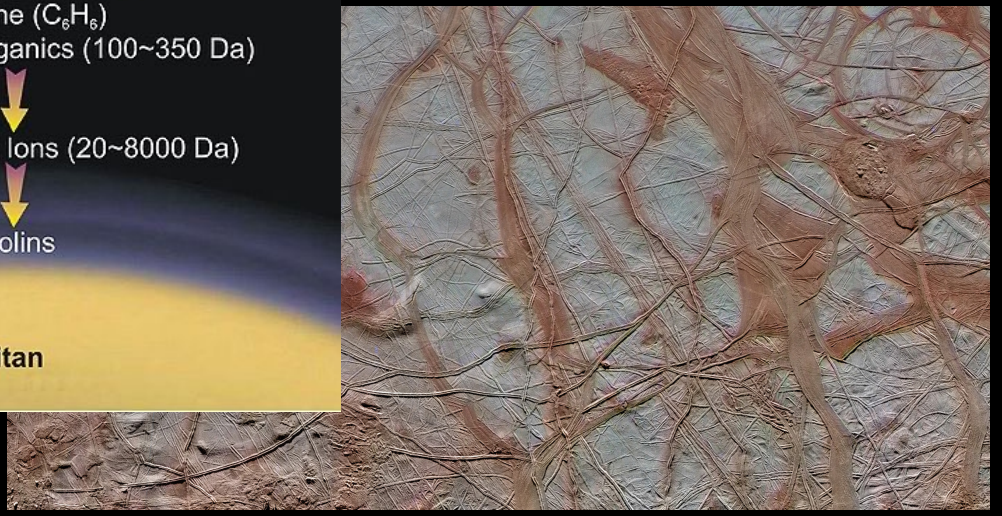
The Huygens descent



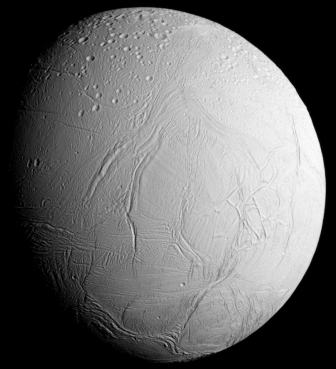
Tholins

Dunes of "tholins" cover vast areas of Titan's surface and give red-ish color to various features on the outer Solar System objects.





Enceladus



- Enceladus is geologically active: Cassini has detected geysers (or **cryovolcanoes**) of liquid water and ice in the southern hemisphere.
- In 2015, Cassini flew through water plumes on Enceladus.

question for you

How is it that Mercury doesn't have an atmosphere, the Moon doesn't have an atmosphere, but Titan does?

A. Titan has more gravity than Mercury and the Moon
B. It's much colder at Titan, so gases don't move as fast.
C. Mercury and the Moon did have atmospheres, but these were stripped away by giant collisions.
D. Titan's magnetic field protects the atmosphere.

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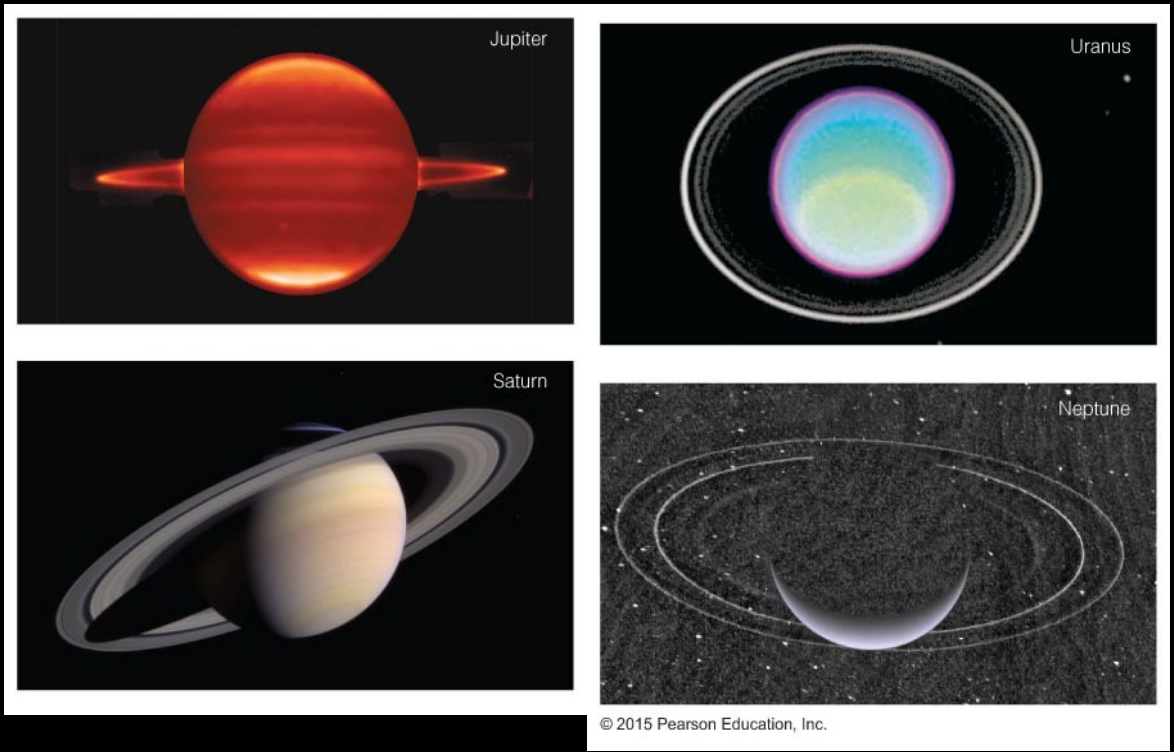
Saturn’s rings

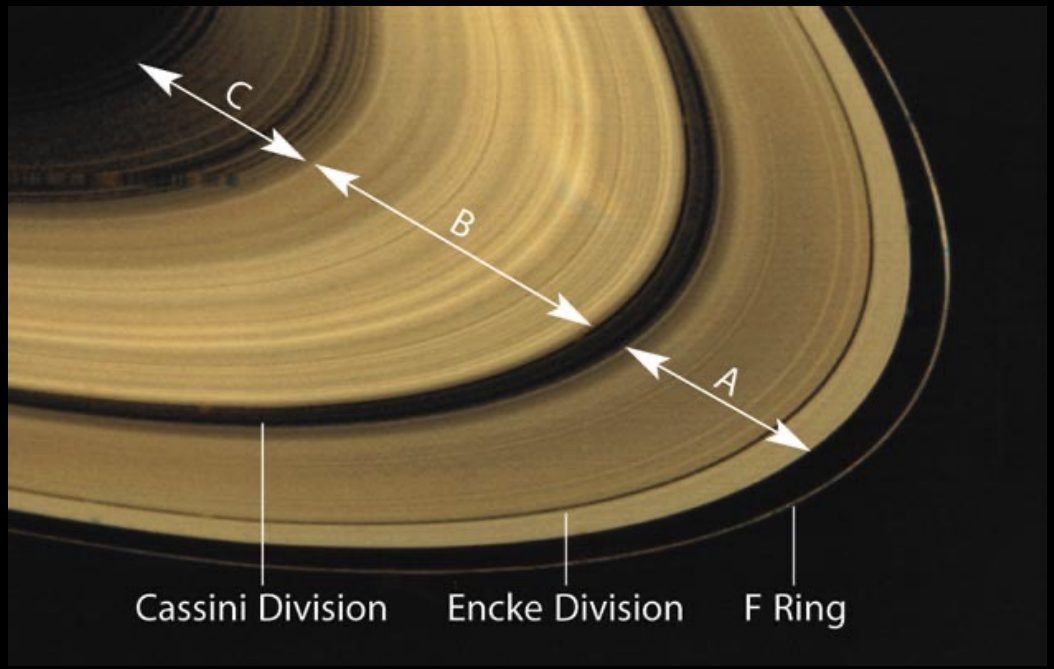
The rings of Jovian planets

- All four Jovian planets have rings.
- The particles in the rings have to be continually replenished.



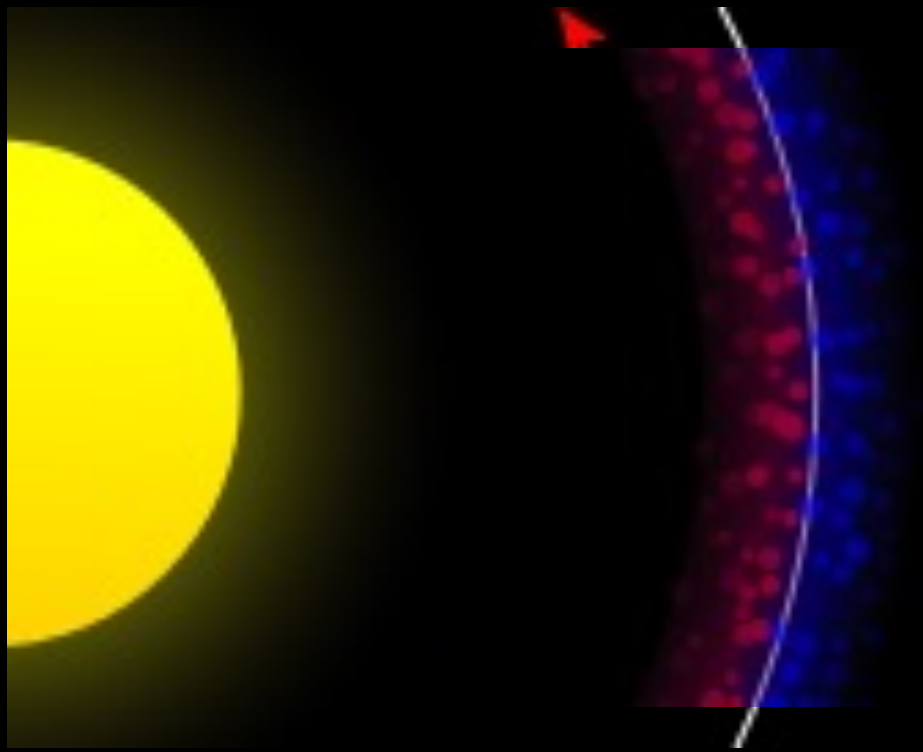
The rings of Saturn

- Giovanni Cassini (1675) noted several rings with gaps in between, most notably Cassini Division.
- Each gap is a home to a moon of Jupiter called the **shepherd moon**.
- Rings are **tens of meters in thickness**, and made of **water ice** particles, most 1 meter accross.
- Ring system is newer than 100 million years and will dissapear in ~100 million years.



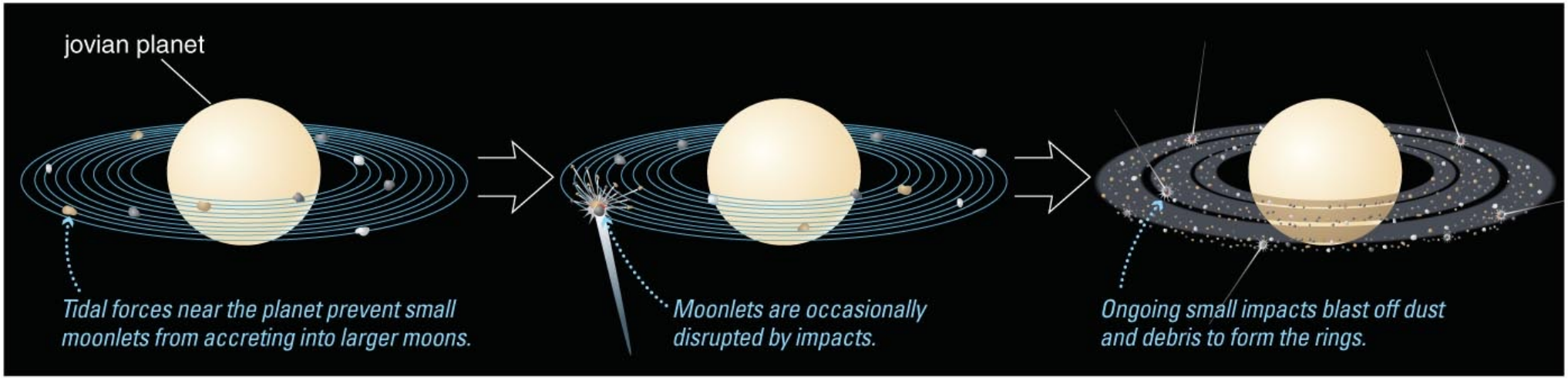
How are rings formed?

- The **Roche Limit** of a planet is the distance at which the tidal forces the planet exerts on the moon exceed the gravitational forces holding the moon together.



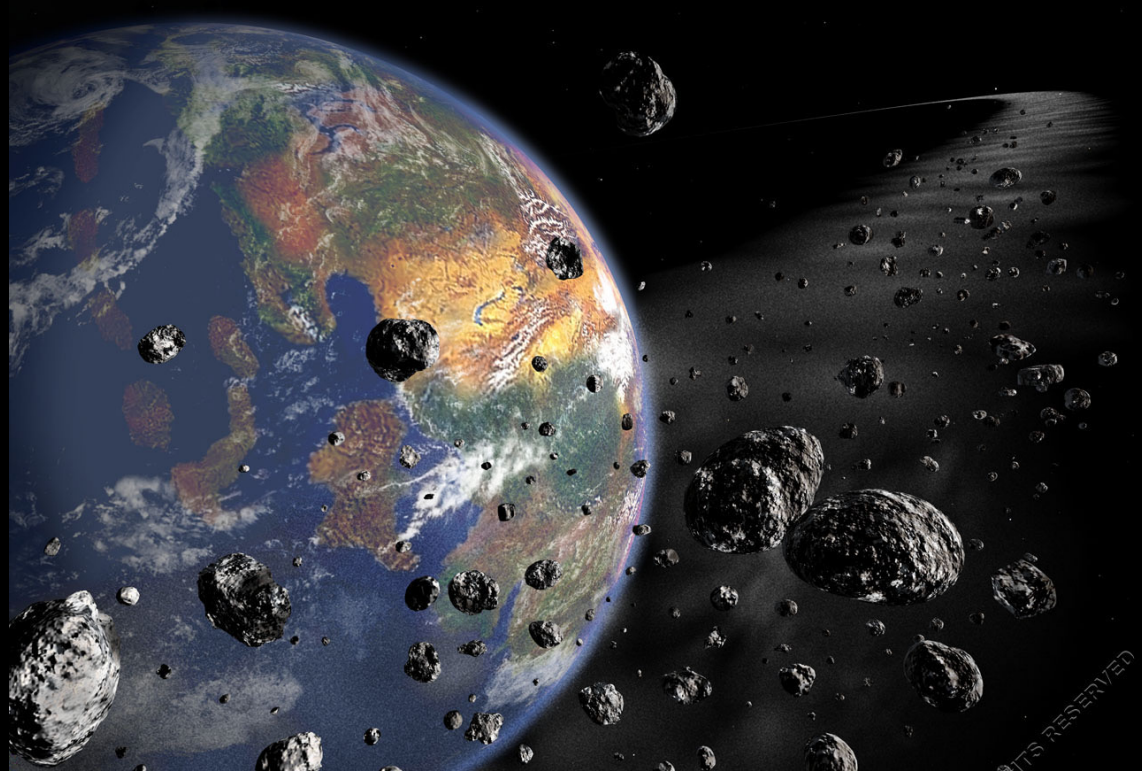
The rings of Jovian planets

- All four giant planets have moons within the Roche limit that continually supply ring material.



Why don't terrestrial planets have rings?

- The Roche limit for Earth is between 9,000 – 18,000 km from its center (Moon is at 384,000 km).
- Phobos and Deimos are well outside Mars' Roche limit.
- Terrestrial planets have few or no moons, and would not be able to continually replenish rings.



Cassini's Grand Finale

What did we learn in Chapter 22?

- Jovian planets are less dense than terrestrial planets.
- Jovian planets are primarily composed of hydrogen and helium (Jupiter and Saturn), with the addition of ices for Uranus and Neptune.
- Sizes of Jupiter and Saturn similar because increased mass simply compresses the interior of the planet and just makes it denser.
- Pressures and temperatures in Jupiter's interior very high.
- Different colors of Jupiter's clouds are due to condensation of different molecules at different depths.

What did we learn in Chapter 22?

- Interiors of Io and Europa heated due to tidal heating and orbital resonance.
- Europa has global ocean of water under its icy surface.
- Ganymede must have a fluid interior since it has a magnetic field.
- Saturn's rings are very thin (tens of meters) and composed of small pieces of rock and ice.
- Titan has an atmosphere of nitrogen and can hold onto this atmosphere because at very low temperatures gases move very slowly.

What did we learn in Chapter 22?

- Huygens probe found lakes of hydrocarbons on the surface of Titan.
- Enceladus also has global ocean beneath its surface.
- Planetary rings are formed when small moons stray too close to the planet, inside the "Roche limit."