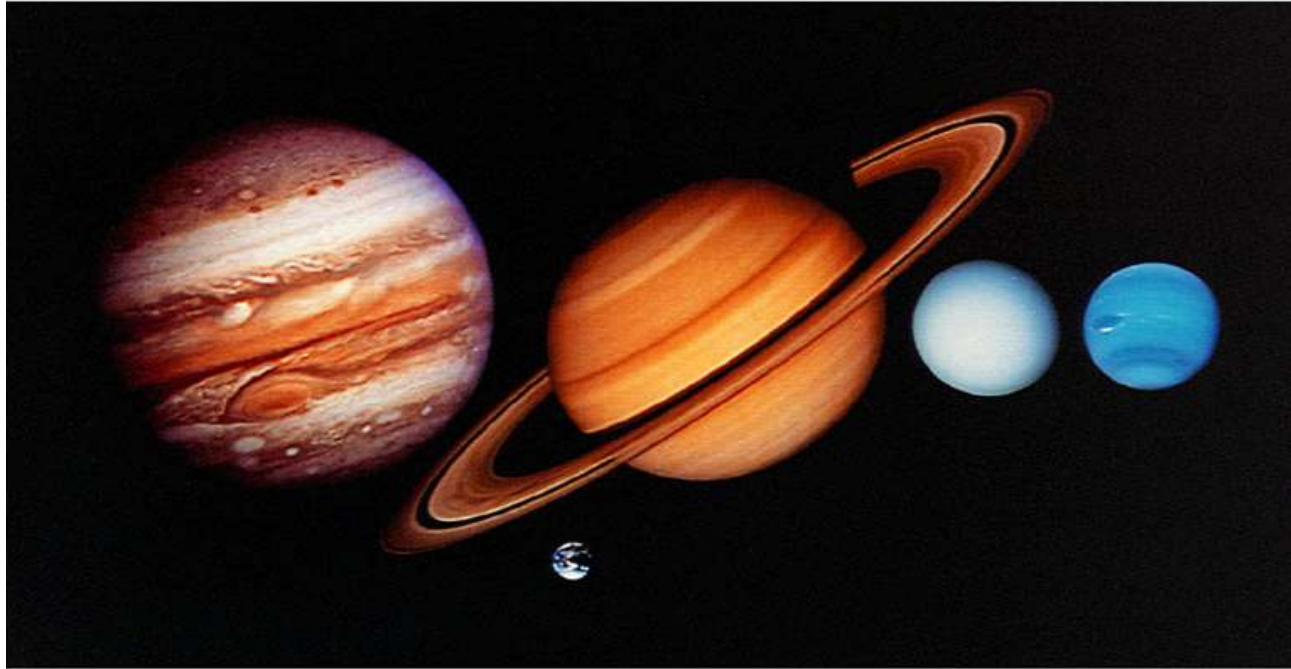




Jovian Planets - Different than Terrestrial Planets



- Bigger & more massive
- Lower density, different composition
- All have rings
- All have many moons

A Different Kind of Planet

- **What is the weather like on jovian planets?**
- **What are jovian planets like on the inside?**
- **What are jovian planets made of?**

What is the weather like on jovian planets?

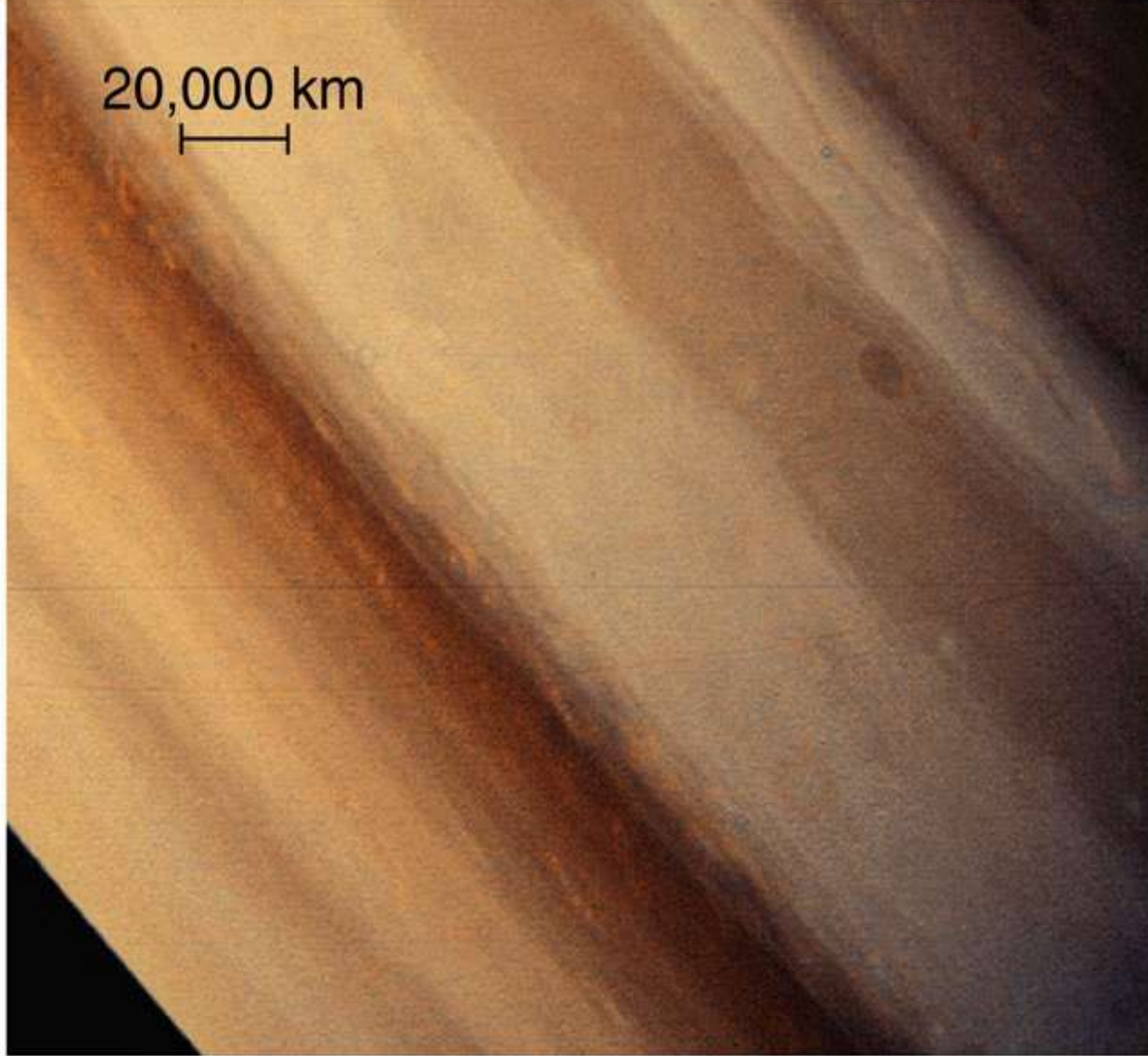
Colorful surface features reveal:

- Clouds of different compositions
- Wind speeds
- Storms, some long-lived



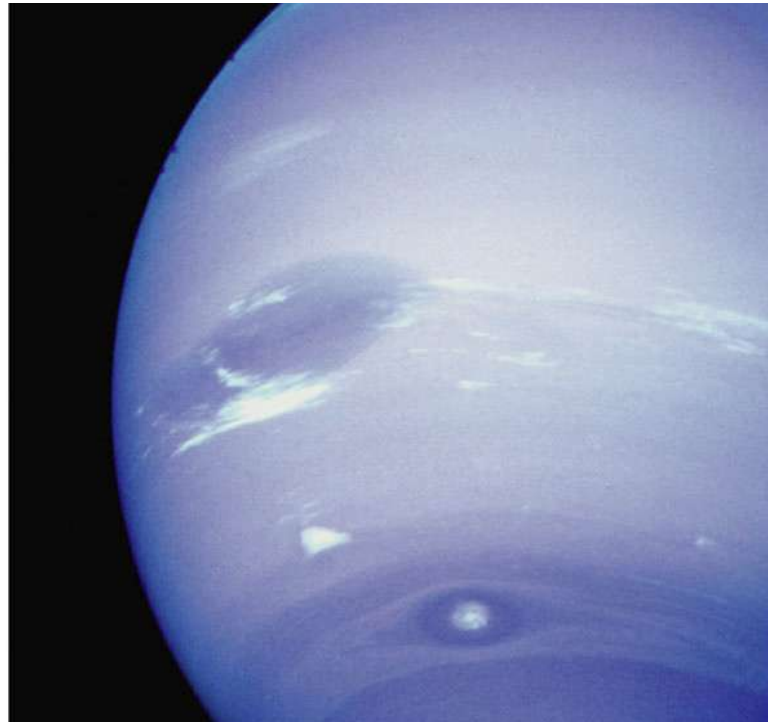
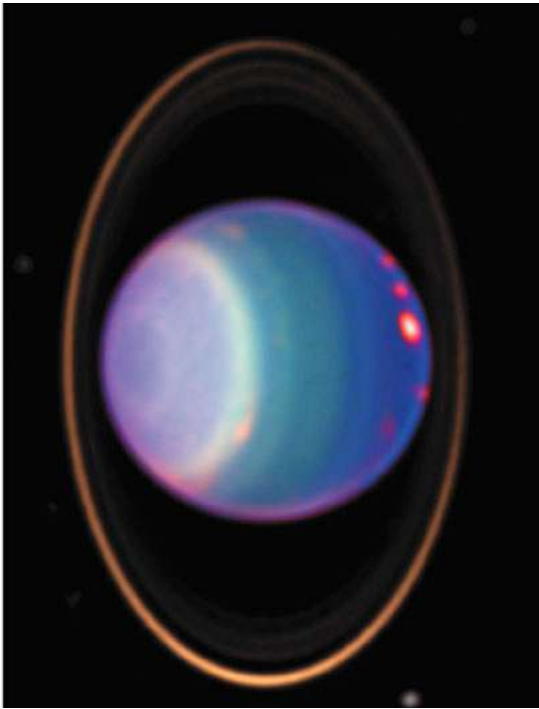
Jupiter's colors

- Red, brown colours are light reflected from a layer of ammonium hydrosulphide clouds (chemistry uncertain).
- Ammonia, the highest coldest cloud layer, reflects white.



Saturn's Colors

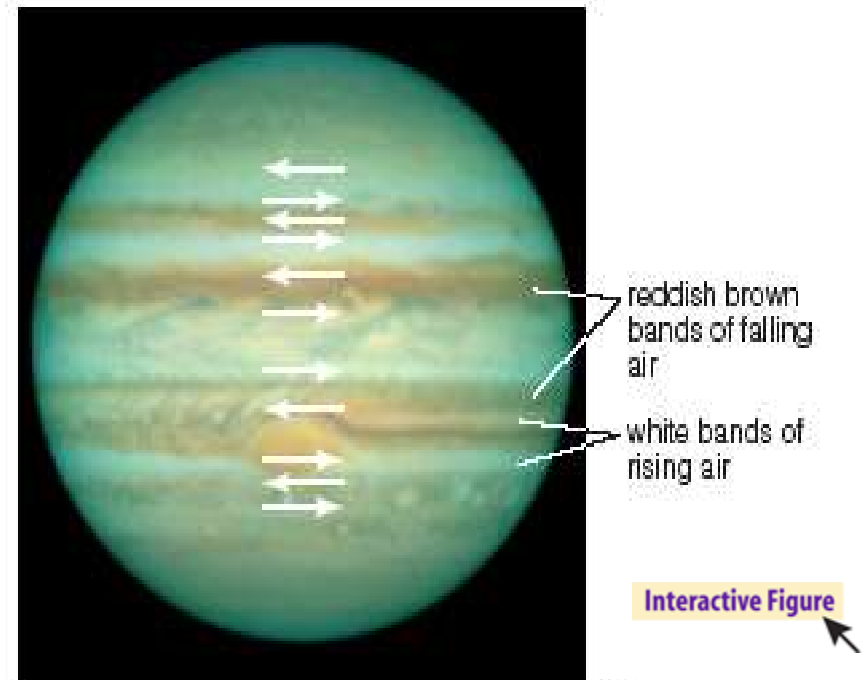
Saturn's layers are the same, but atmosphere is colder and sunlight weaker. Thus, red/brown clouds are deeper in the atmosphere, making overall colours more subdued.



Uranus (left) and Neptune (right): upper layers of atmospheres are cold enough that methane condenses. Methane gas absorbs red light and reflects blue light; Neptune has more methane so it looks bluer.

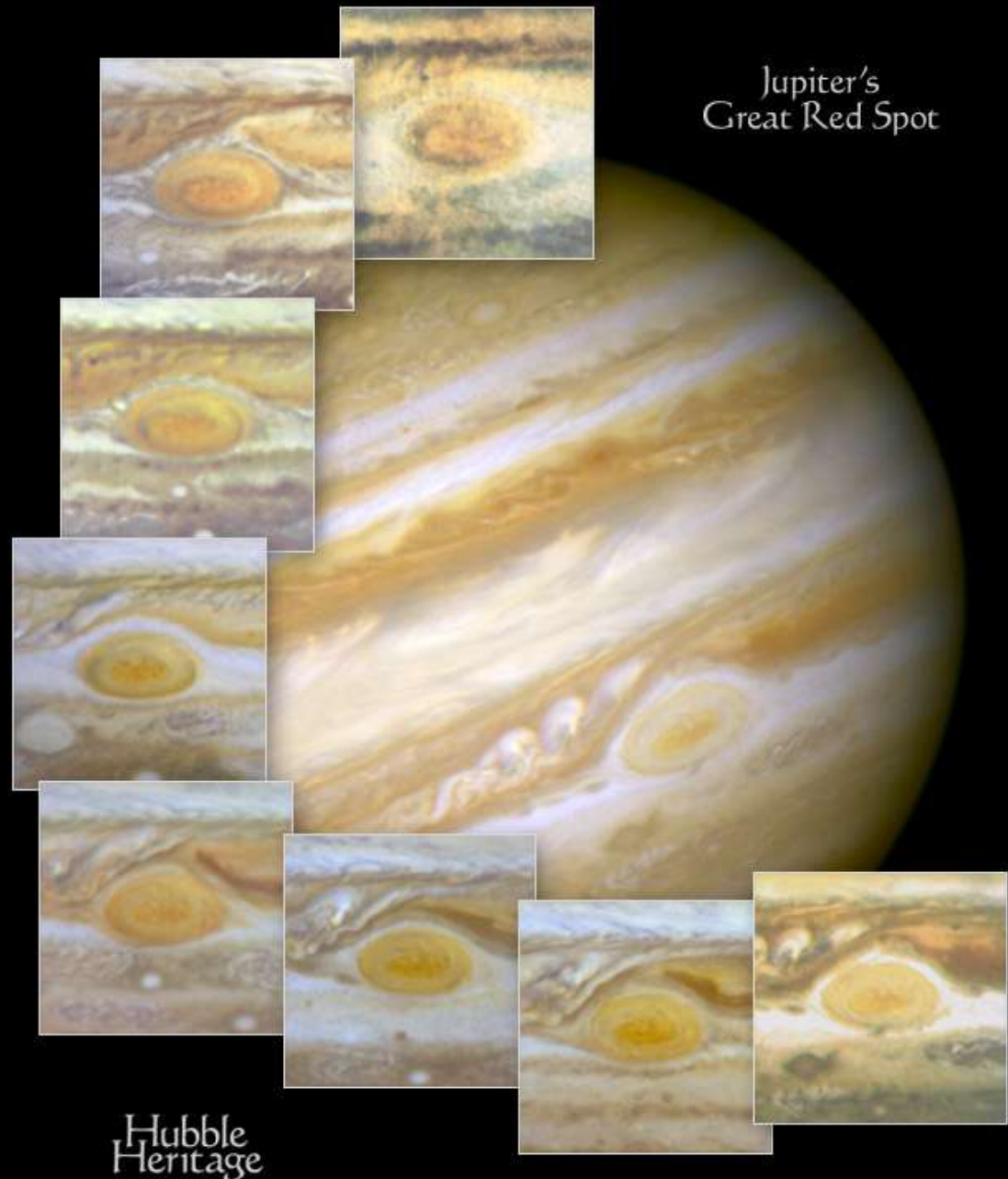
Jupiter winds and storms

- Earth's rotation makes storms 'spin'.
- Jupiter's fast rotation stretches storms into bands that surround the planet.
- High east/west winds (up to 400 km/hr)



Jovian planets do change!

- Jupiter's great red spot changes color
- Saturn had a huge storm in 1994
- Uranus has extreme seasons over an 84 Earth year cycle
- Neptune's great dark spot vanished within 6 years



Additional heat source for Jovian planet storms?

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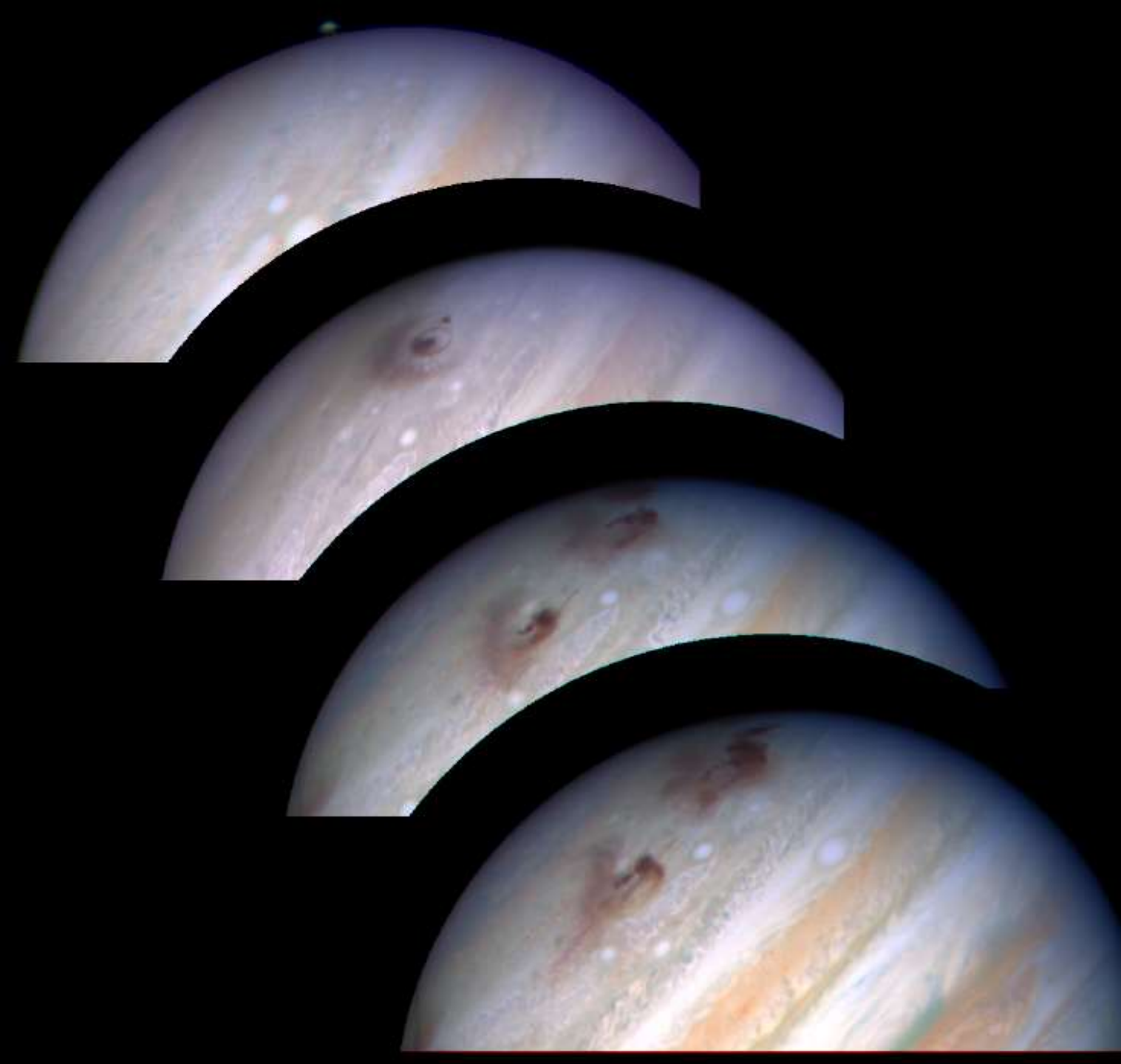
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- Jupiter, Saturn and Neptune radiate more heat than they receive from the Sun --- they are still cooling off from their formation 4.5 billion years ago!
- Jupiter: insulated by its large size.
- Saturn: helium sinks to center, releases energy.
- Neptune: insulated by its large methane content?
- Uranus has cooled off from its formation; storms driven by extreme seasonal changes?

- In 1994, comet Shoemaker-Levy 9 [yes, these two amateur astronomers have found 9 comets together] passed close enough to Jupiter that Jupiter's gravity tore it apart into dozens of fragments.
- website: [movie of the impact of Fragment A.](#)

Comet P/Shoemaker-Levy 9 (1993e) • May 1994





- Comet SL9 impact fireball (top) and resulting dark impact 'bruises' on Jupiter

An impact site from above

- Dark regions: small particles from comet, high up in atmosphere
- Different models of Jupiter's atmosphere made different predictions for the effects of the impacts; by studying the actual effects, we improve our understanding of Jupiter's atmosphere.



What are jovian planets made of?

- Jupiter & Saturn: almost all Hydrogen & Helium, very little metal & rock (*less dense*)
- Uranus & Neptune: <50% Hydrogen & Helium, the rest ices (water, methane, ammonia), with some metal & rock (*more dense*)

Why are they different if they formed at the same time out of the same cloud of gas and dust?

Jovian planet formation

- Beyond about 2 AU from the Sun, water stayed frozen even when the solar system was forming.
- Inside this ‘frost line,’ planetesimals only formed from rock & metal (0.4% and 0.2% by mass).

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- The Jovian planets then accreted atmospheres of hydrogen/helium (98%), but why did Jupiter & Saturn accrete more H/He than Uranus & Neptune?

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- So Jupiter formed first and captured the most gas.

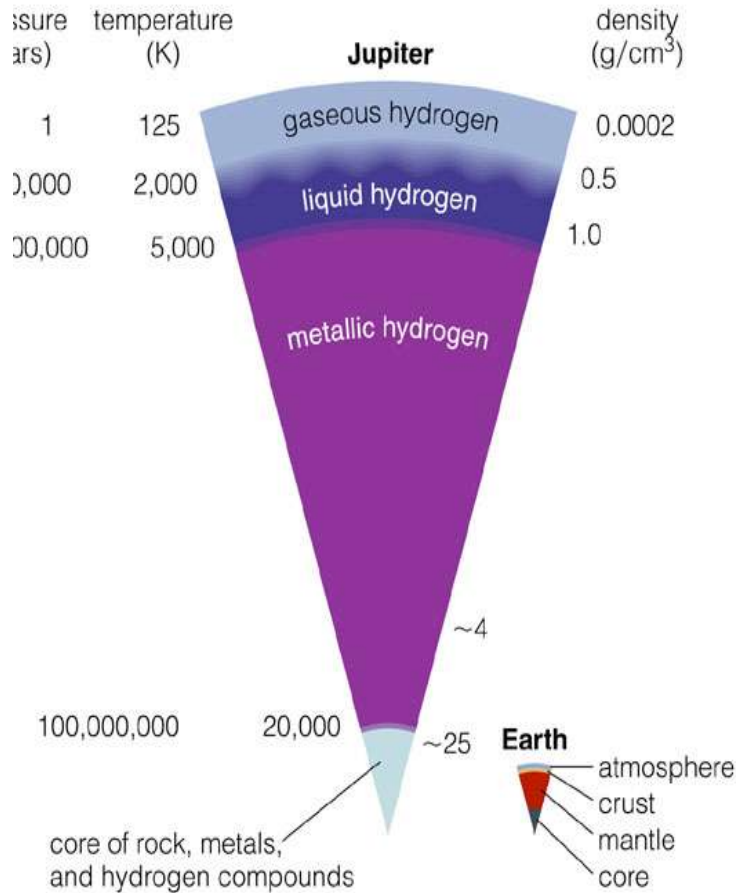
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- *This theory predicts the most massive giant planets will be closest to their parent stars. That's not true in general, so the theory is an oversimplification.*

What are Jovian planets like on the inside?

- No solid surface: gas->liquid->molten core.
- Layers under high pressure and temperatures.
- Cores (about 10 Earth masses) made of hydrogen compounds, metals & rock
- The layers are different for the different Jovian planets.

Layers inside Jovian planets



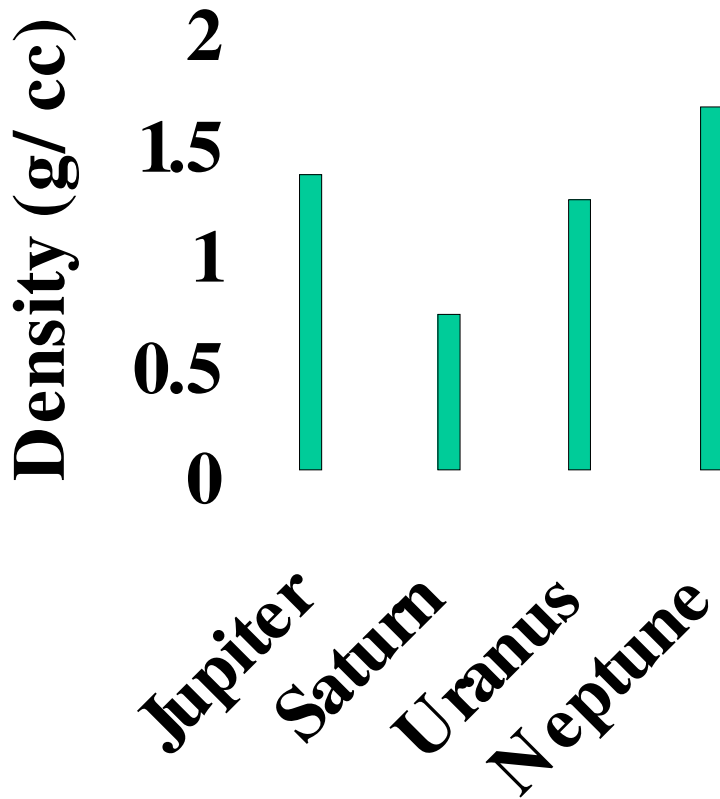
Notes: [Density of liquid water is $\sim 1\text{g/cm}^3$.]

Liquid metallic hydrogen conducts electricity.

Core is molten hydrogen compounds, metals, rocks. But not in a form you'd recognize... **10 x the mass of Earth inside a volume the size of Earth.**

Jupiter

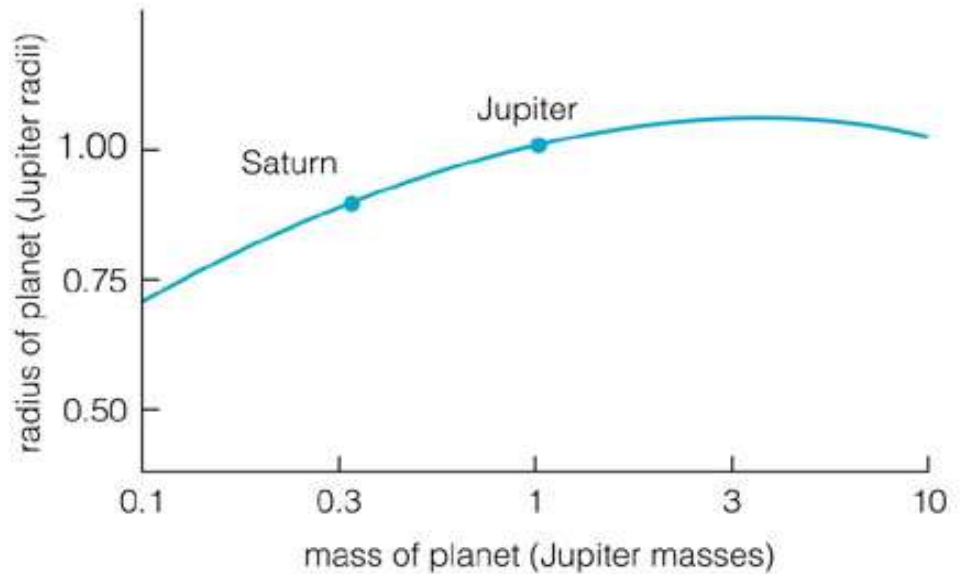
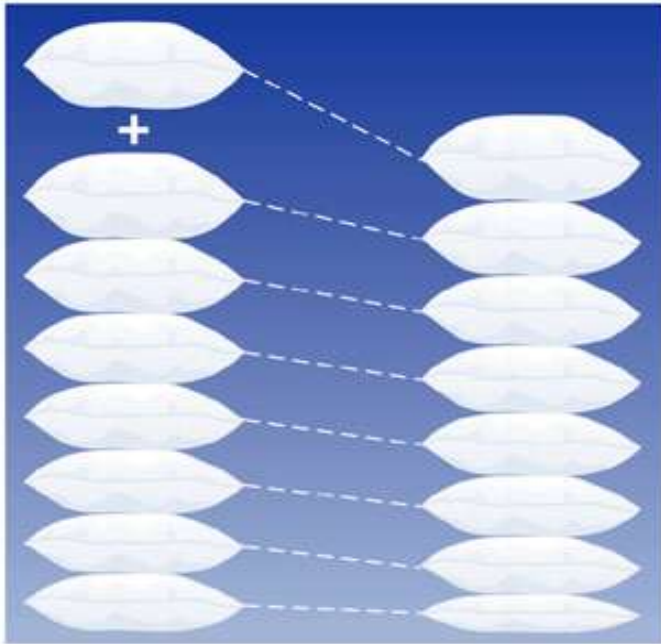
Density Differences



Density = mass \div volume

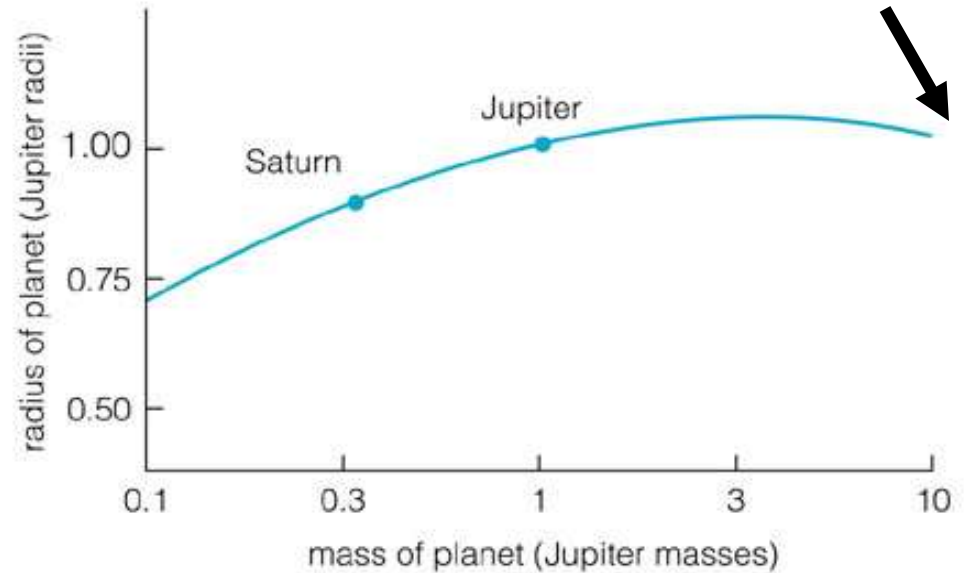
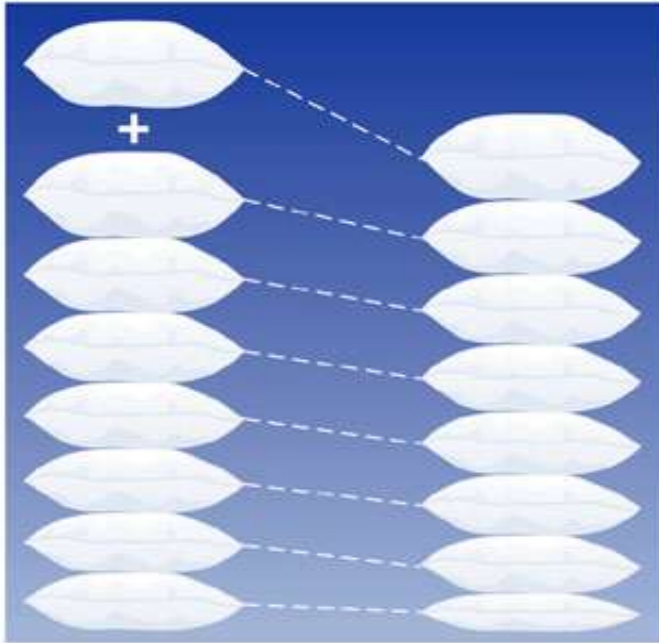
Uranus and Neptune are denser than Saturn because they have proportionately less Hydrogen and Helium (the lightest elements).

But that explanation does not explain why Jupiter is denser than Saturn.



- Jupiter and Saturn are nearly the same size
- But Jupiter is 3x more massive than Saturn

More massive planets
could even be smaller!

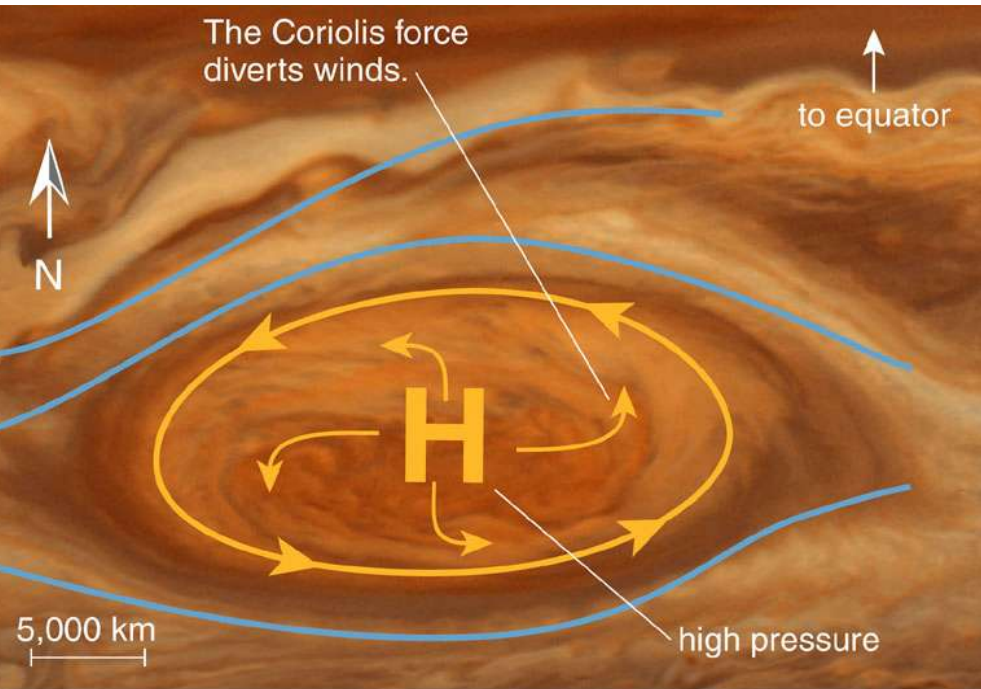


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What have we learned?

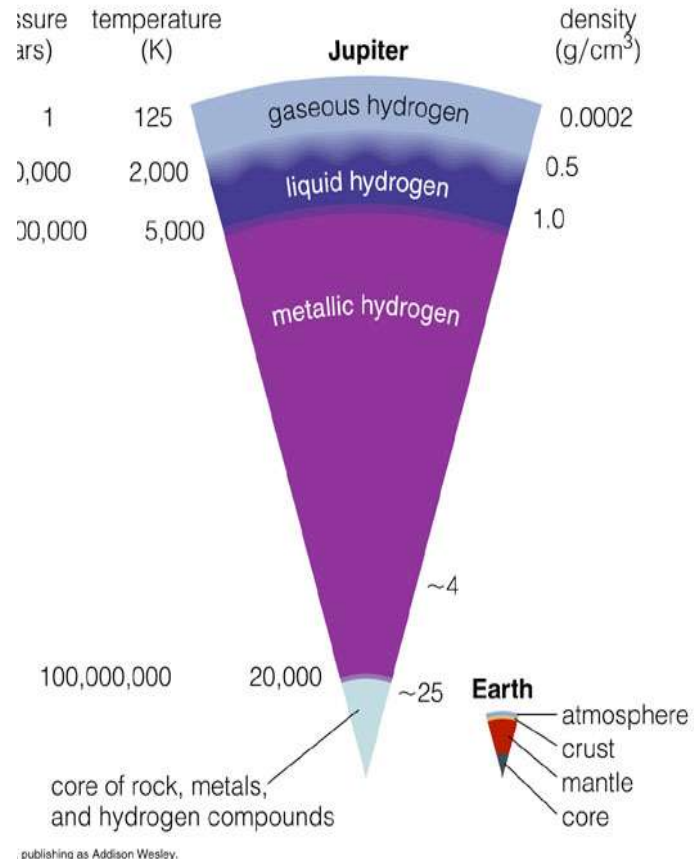
- **What is the weather like on jovian planets?**

- The jovian planets all have multiple cloud layers (which help create the colors of the planets), fast winds, and large storms. Some storms, such as the Great Red Spot, can last for centuries or longer.



What have we learned?

- What are jovian planets like on the inside?
- The jovian planets have layered interiors with very high internal temperatures and pressures. All have a core about 10 times as massive as Earth, consisting of hydrogen compounds, metals, and rock. They differ mainly in their surrounding layers of hydrogen and helium.



What have we learned?

- **What are jovian planets made of?**
- Jupiter and Saturn are made almost entirely of hydrogen and helium
- Uranus and Neptune are made mostly of hydrogen compounds mixed with metal and rock.
- All four planets started from ice-rich planetesimals of about the same size but captured different amounts of hydrogen and helium gas from the solar nebula, depending on their location in the nebula.