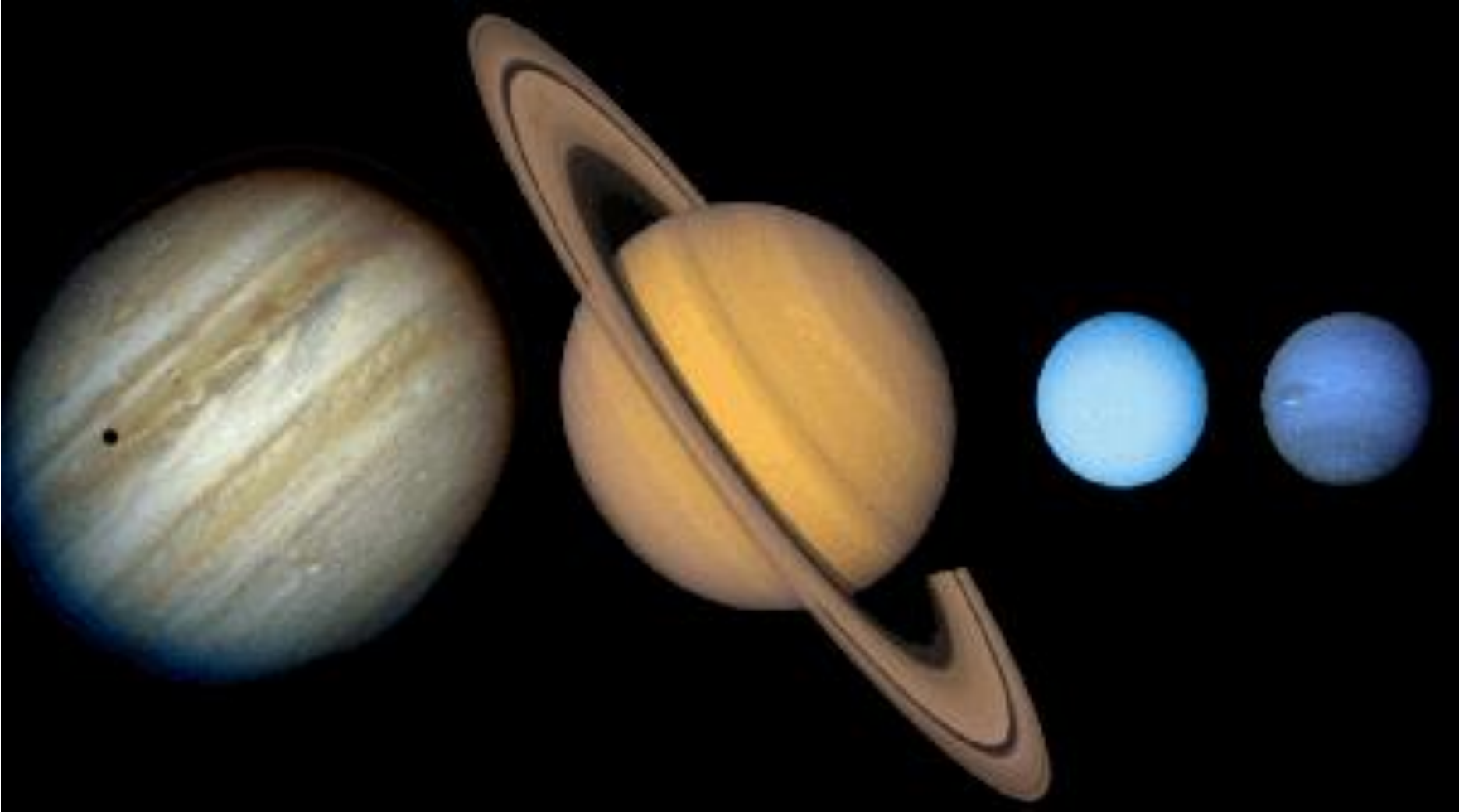


The Essential Cosmic Perspective

Lecture 11
The Structure and
Atmospheres of the
Outer Planets
October 8, 2018

Bennett
Donahue
Schneider
Voit

Jovian Planets

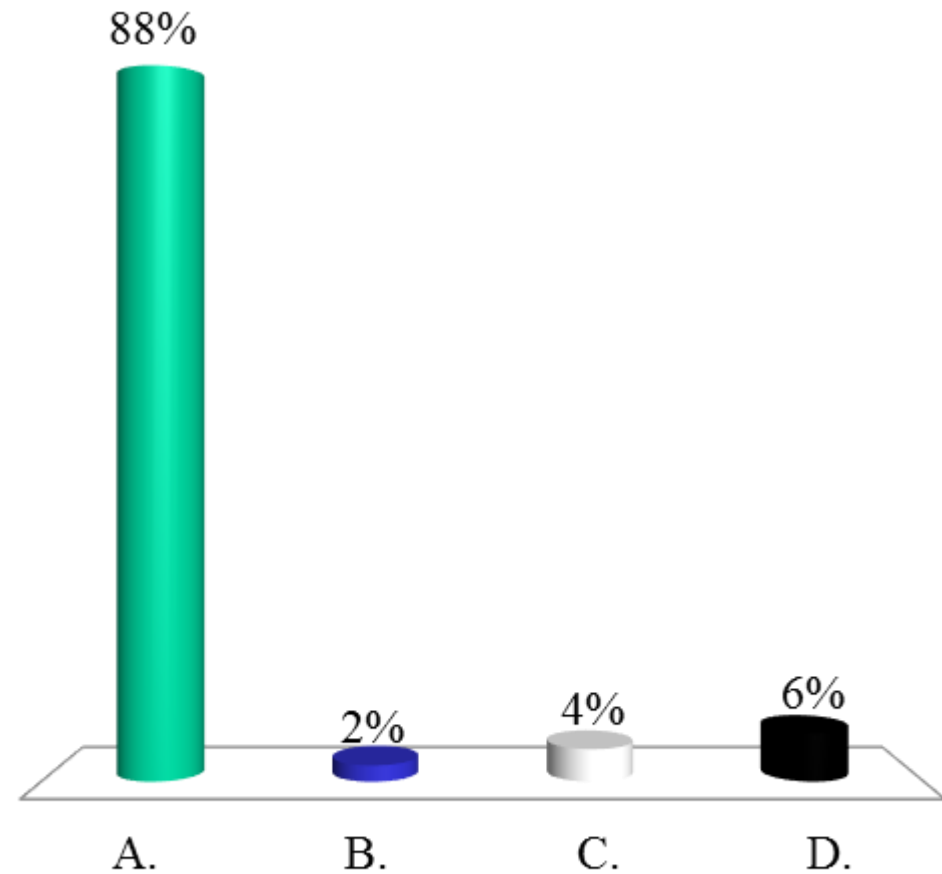


Jovian Planets -- Basic Information

	Jupiter	Saturn	Uranus	Neptune
Distance	5.2 AU	9.5 AU	19 AU	30 AU
Spin Period	10 hrs	10.5 hrs	17 hrs	17 hrs
Orbital Period	12 years	29.5 years	84 years	164 years
Radius (R_{\oplus})	11	9	3.9	3.9
Mass (M_{\oplus})	300	100	14.5	17
Eccentricity	0.05	0.06	0.05	0.01
Moons	79	62	27	14

Saturn's orbit distance is 9.5 AU. How much more sunlight does Earth receive than does Saturn?

- A. 90 times
- B. 9.5 times
- C. 29 times
- D. 19 times



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Saturn's orbit distance is 9.5 AU. How much more sunlight does Earth receive than does Saturn?

A. 90 times

$$S_{\text{Saturn}} = \frac{S_{\oplus}}{r^2} = \frac{S_{\oplus}}{(9.5 \text{ AU})^2}$$

B. 9.5 times

C. 29 times

$$S_{\text{Saturn}} = \frac{S_{\oplus}}{90.25} \Rightarrow S_{\oplus} = \boxed{90S_{\text{Saturn}}}$$

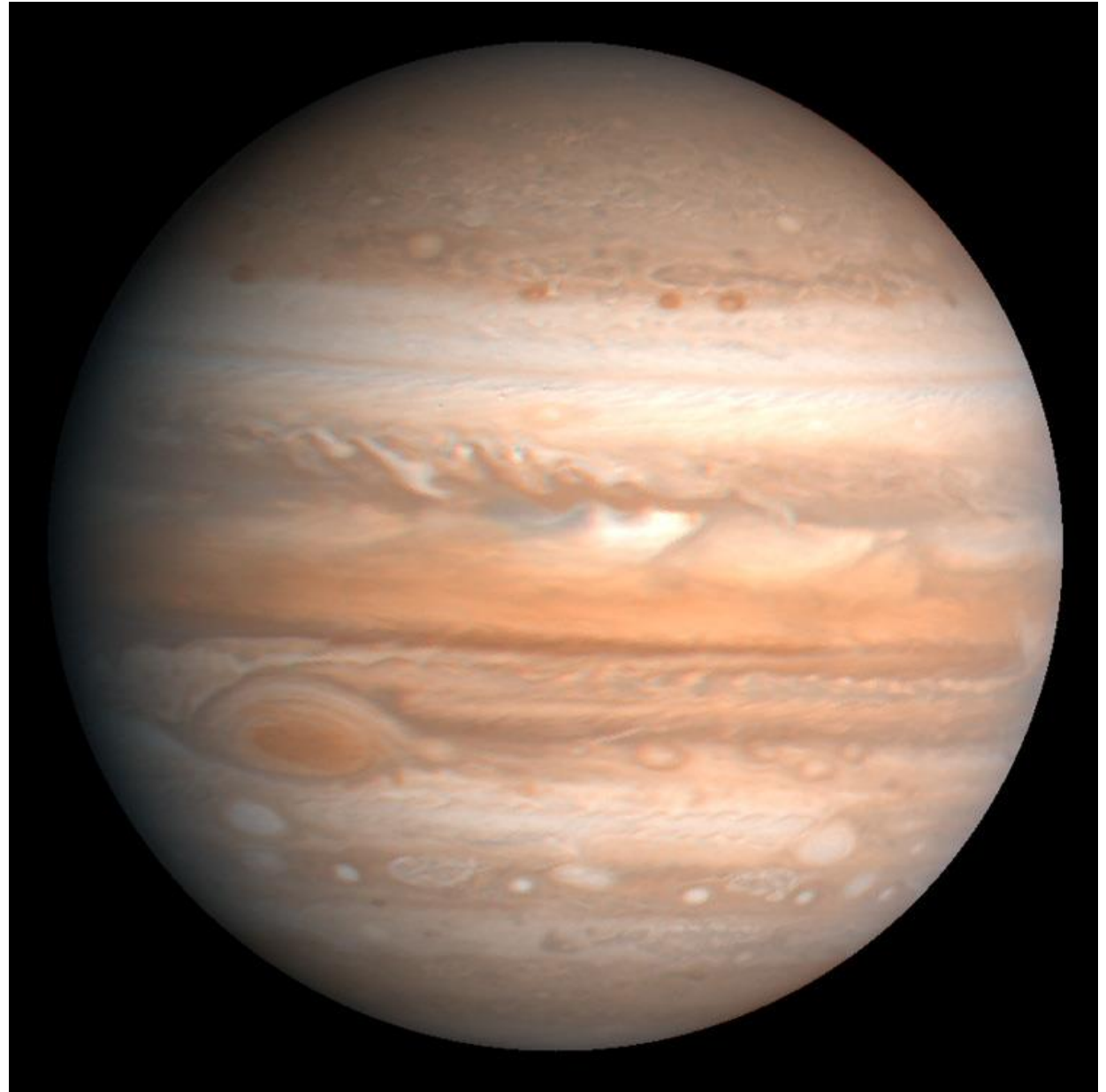
D. 19 times

Atmospheres of Jovian Planets

- Composition
 - Mainly H₂, some He
 - Trace amounts of methane, ammonia, water vapor, sulfur compounds.
 - Trace elements provide coloring of planets.
- Internal Heat
 - All Jovian Planets except Uranus give off more heat than received from Sun.
 - Left over gravitational energy.
 - Heat drives weather
 - Why not Uranus??

Atmosphere of Jupiter

[Motion of the clouds](#)

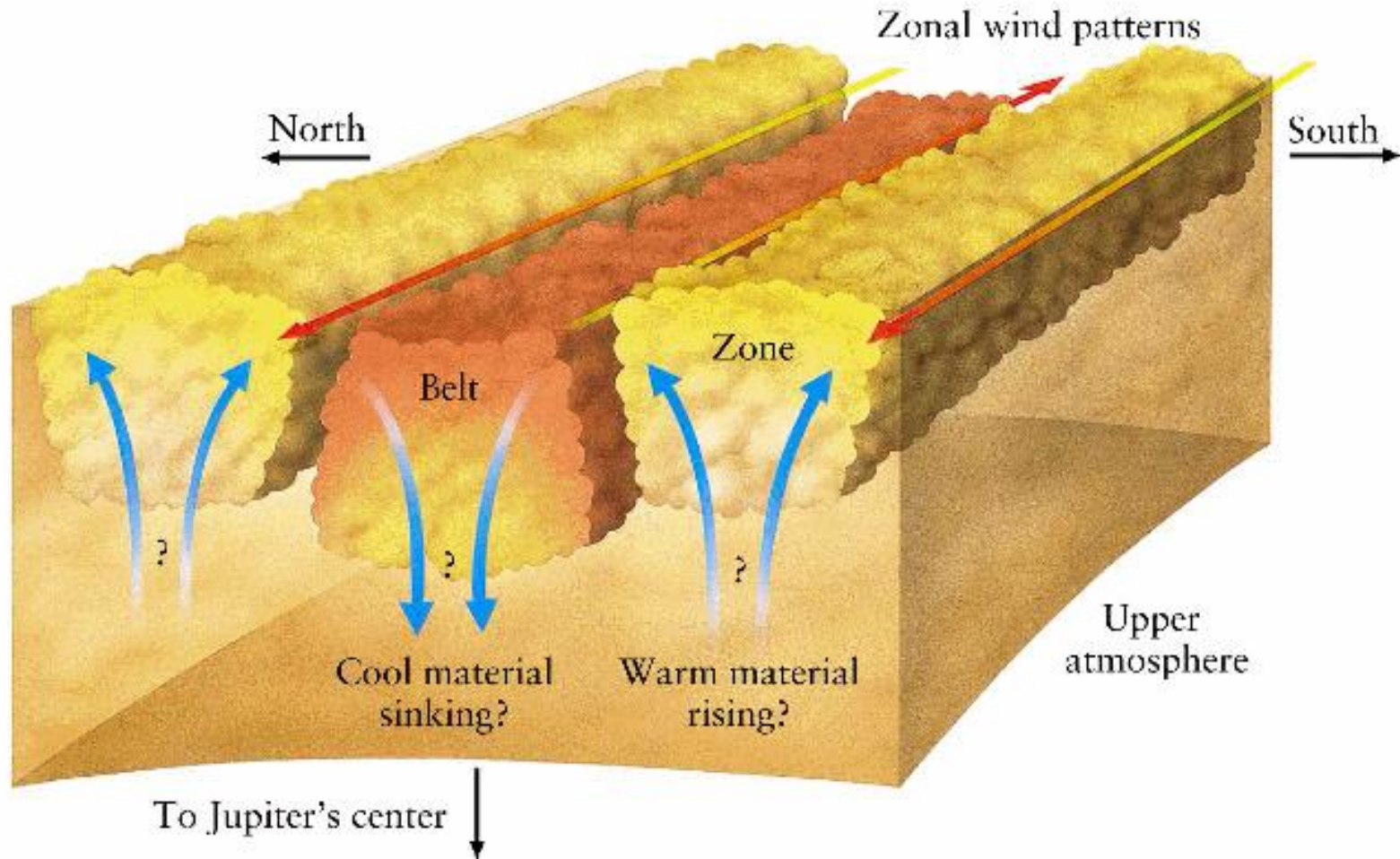


Composite of Voyager 2
images taken in June
1979 and compiled in
1990.

[Click here](#) for more info

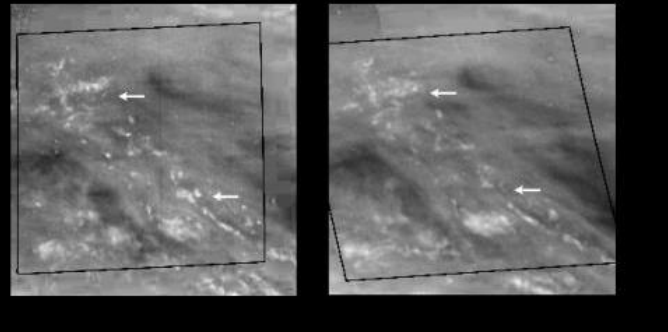
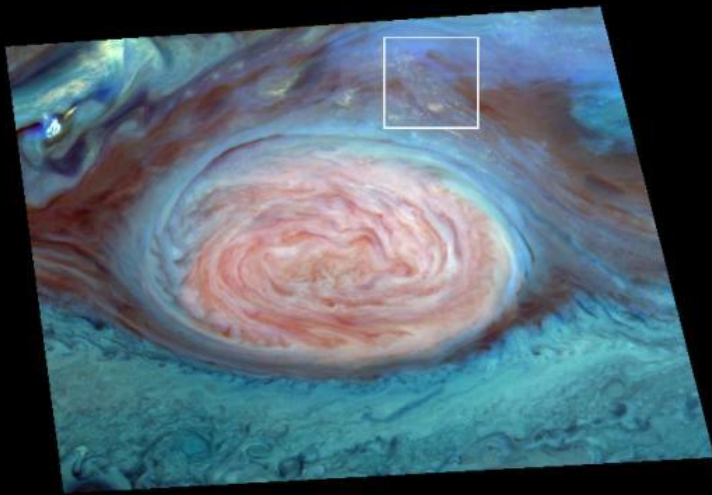
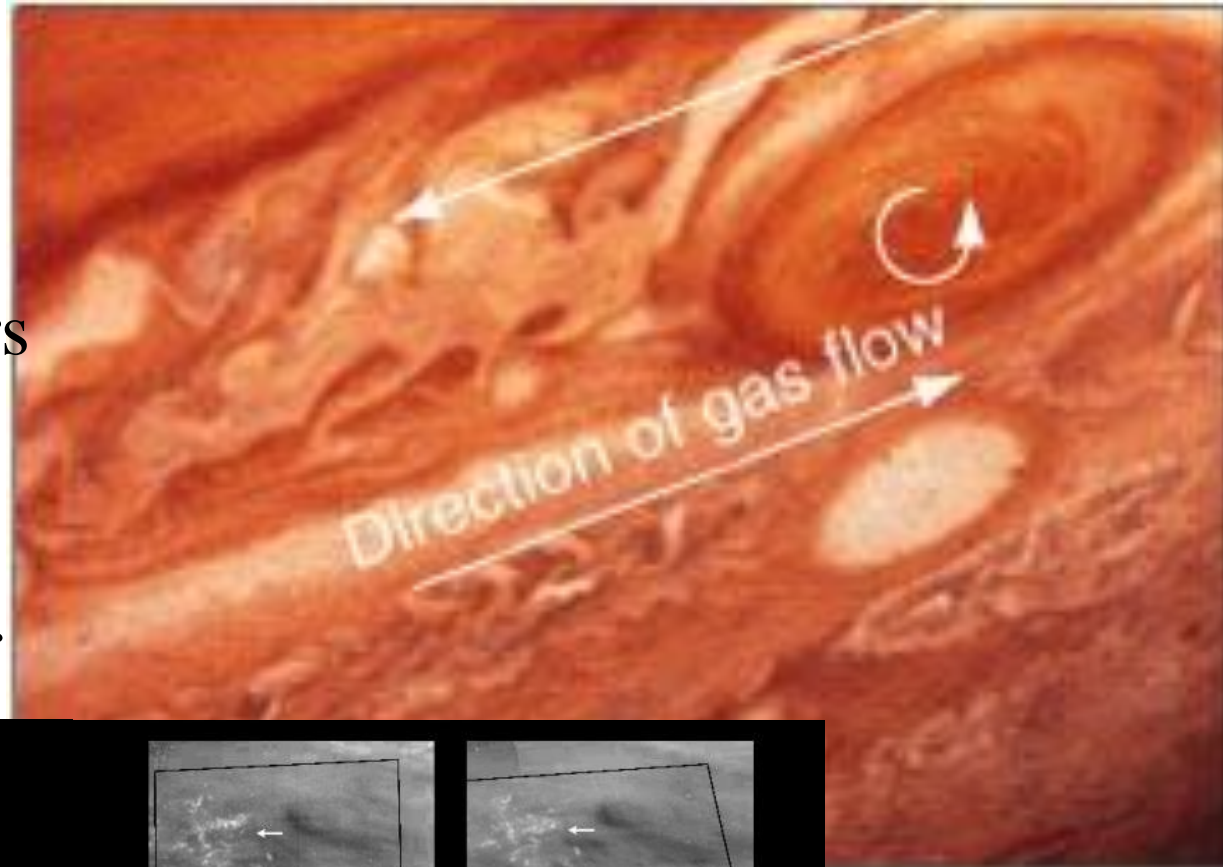
Atmospheric Features of Jupiter

- Zones and Belts
 - banded appearance from convection in atmosphere.
 - **Zones** -- bright bands, warmer material rising(?).
 - **Belts** -- Dark bands, cool material sinking(?).



The Great Red Spot

- Large storm
- 2 times size of Earth
- At least 300 years old
- smaller storms not as long lived.



<http://photojournal.jpl.nasa.gov/catalog/PIA00506>

Thunderstorm on Jupiter

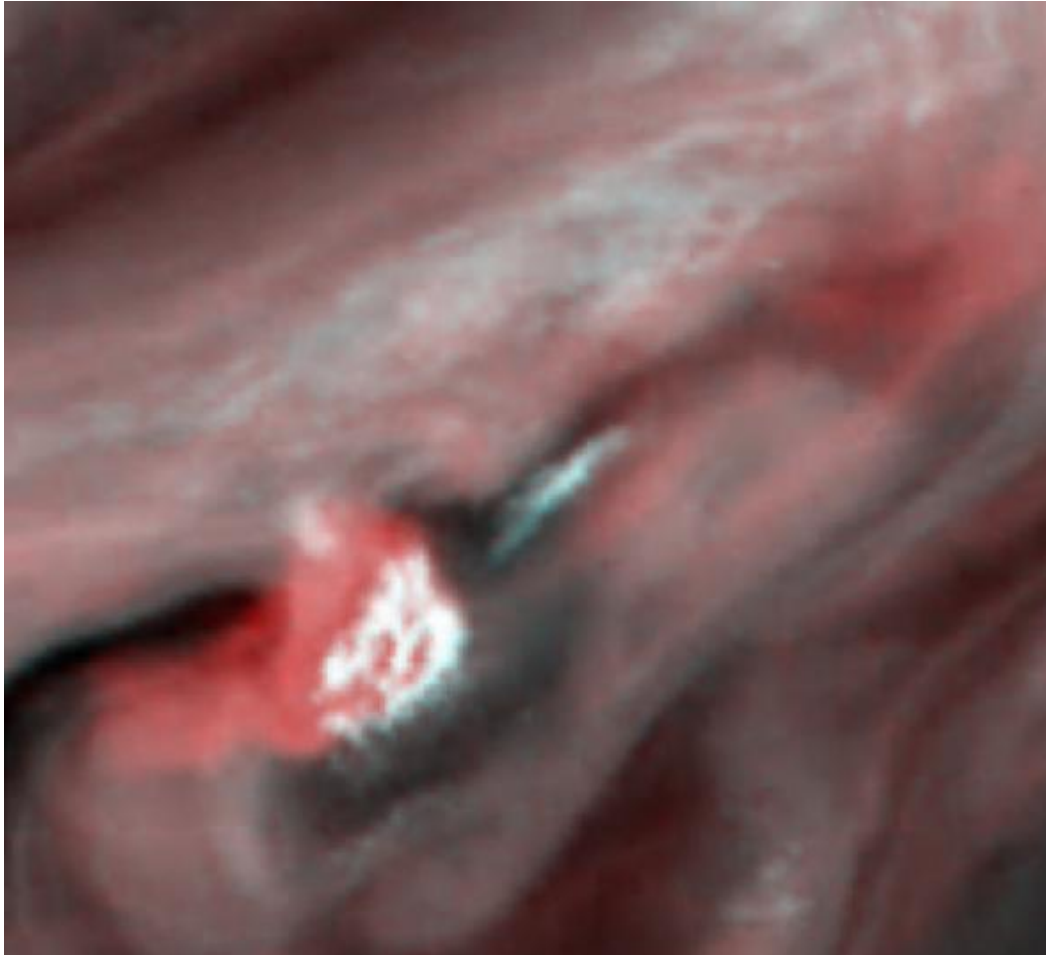
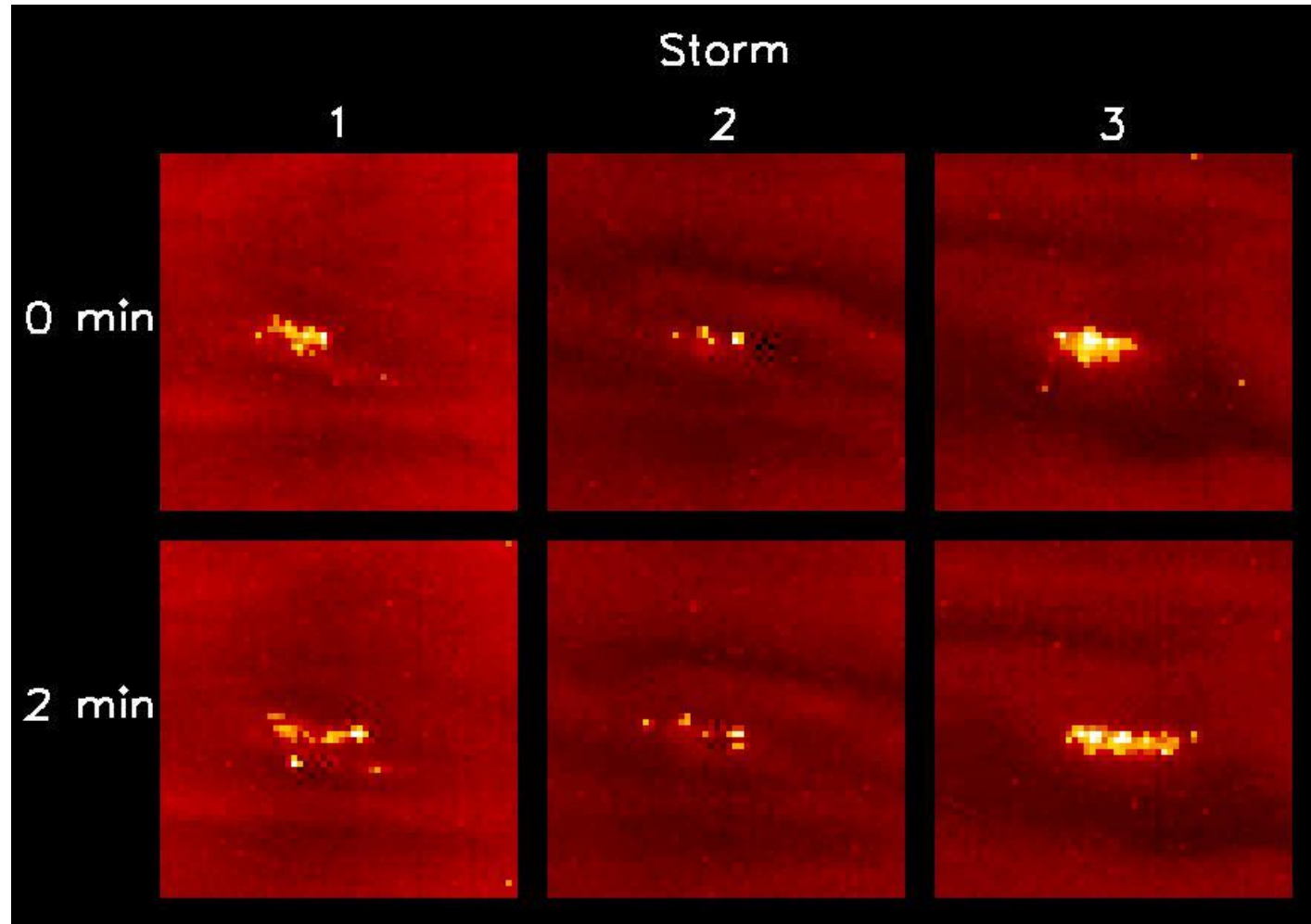


Photo taken by NASA's Galileo spacecraft on June 26, 1996. The top of the storm is white, and its very deep reddish base extends toward the left. The storm is 1000 km across and 75 km tall, some 5 times wider and four times taller than the largest Earth storms.

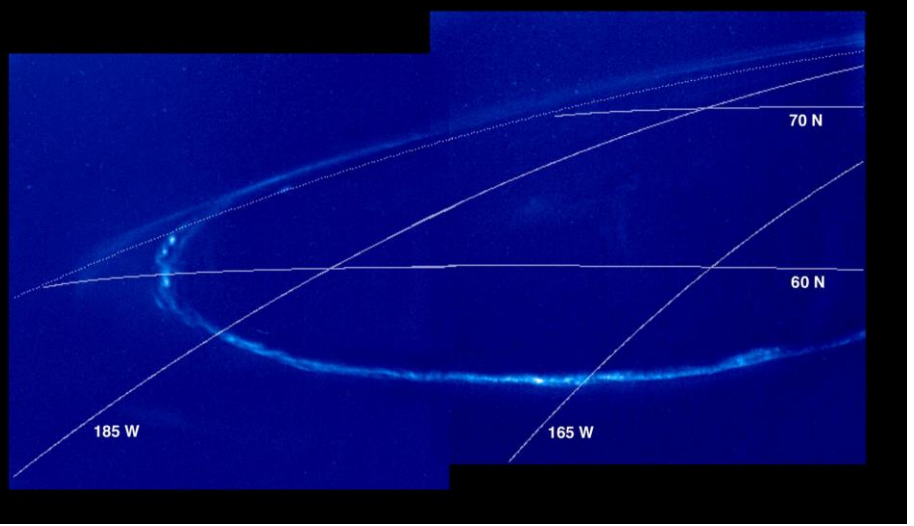
<http://photojournal.jpl.nasa.gov/catalog/PIA01639>

Lightning on Jupiter

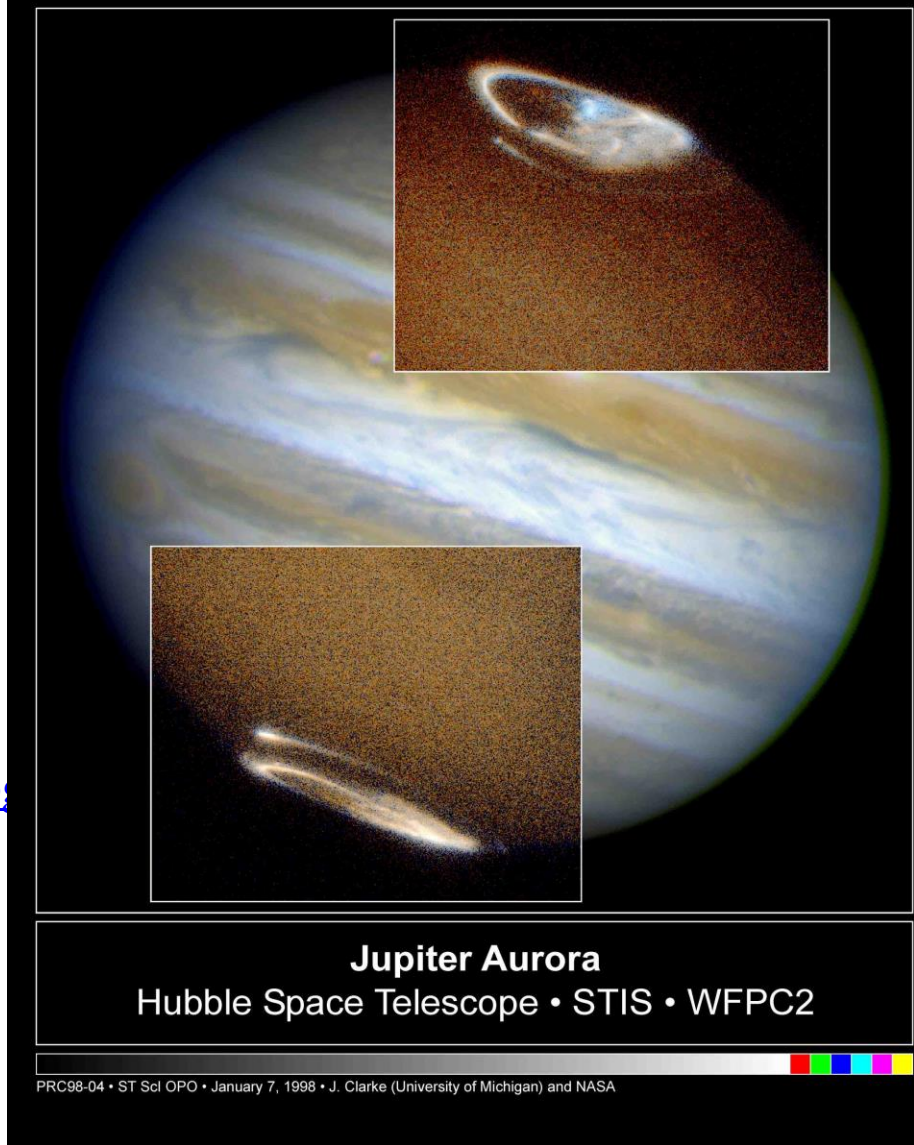


<http://photojournal.jpl.nasa.gov/catalog/PIA01636>

Aurora on Jupiter



<http://photojournal.jpl.nasa.gov/jpeg/PIA01097.jpg>



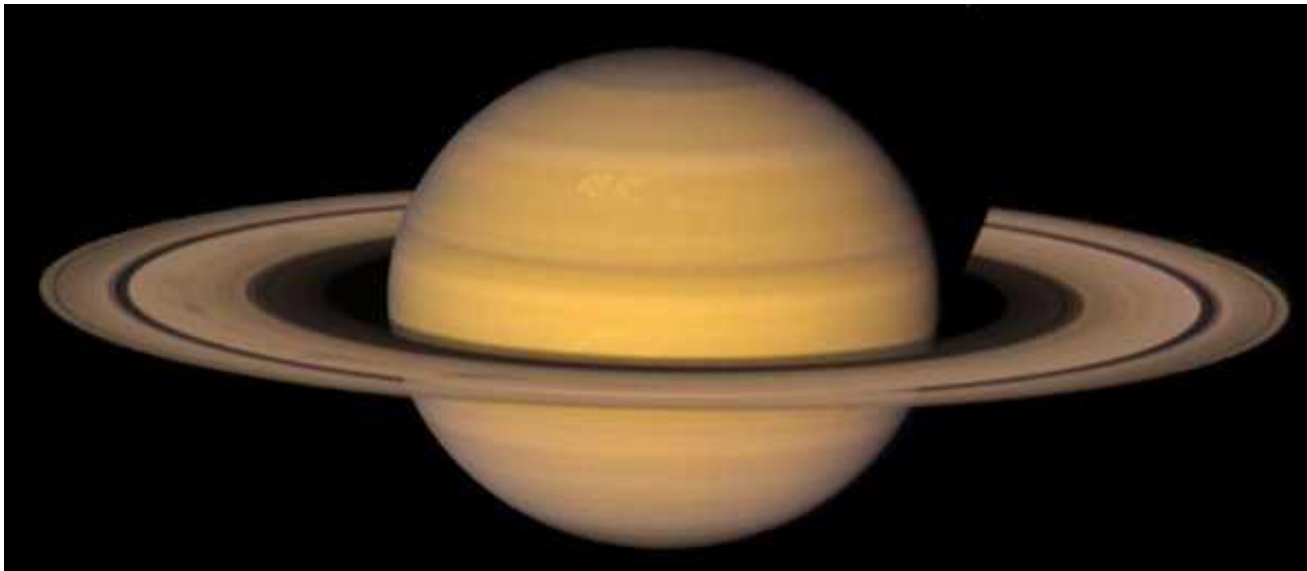
Jupiter Aurora
Hubble Space Telescope • STIS • WFPC2

PRC98-04 • ST ScI OPO • January 7, 1998 • J. Clarke (University of Michigan) and NASA

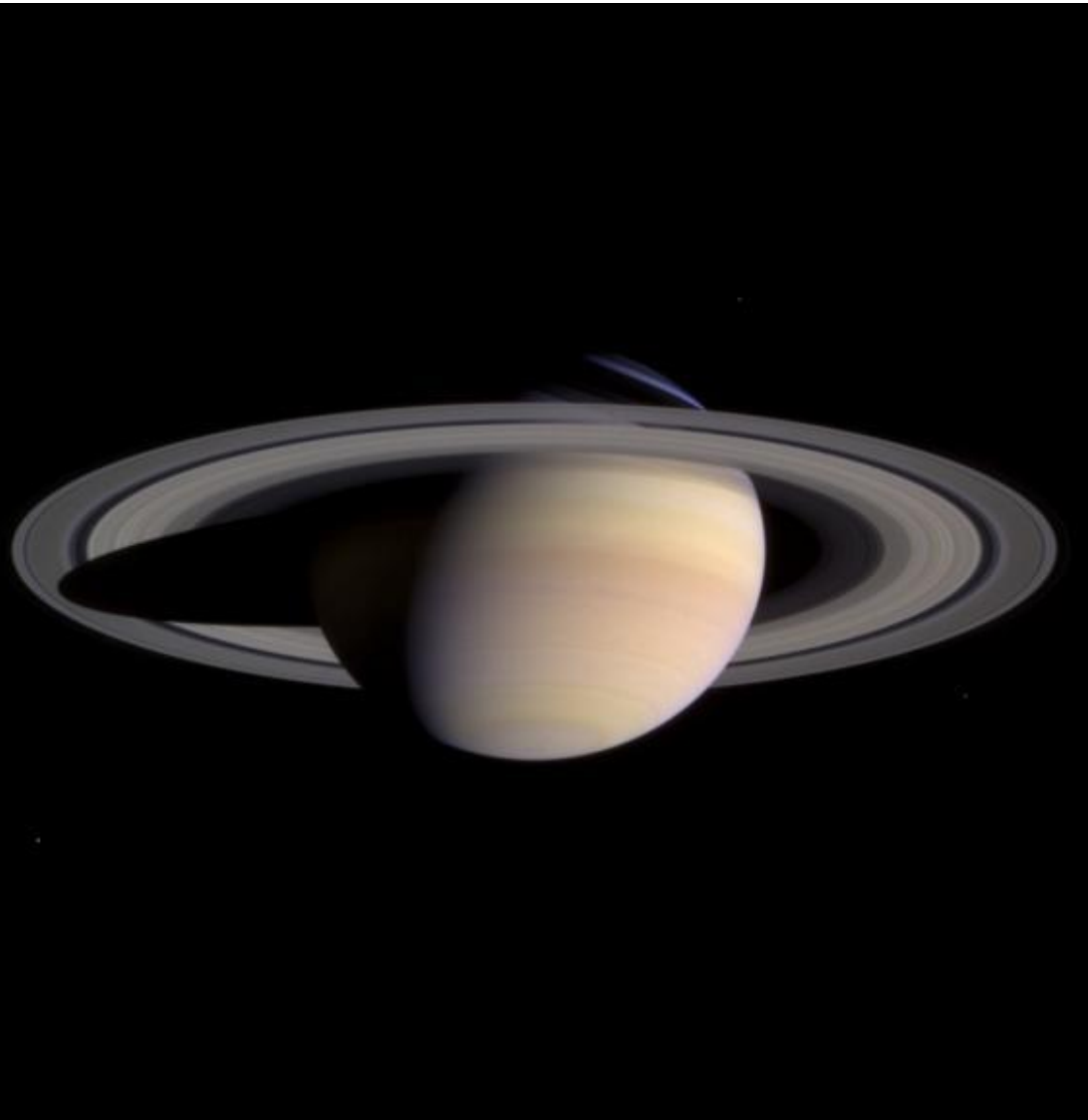
<http://hubblesite.org/newscenter/newsdesk/archive/releases/1998/04/image/a>

Atmospheric Features of Saturn

- Zones and Belts are less vivid
 - Cooler temperatures produce thicker haze over bands, dimming colors below.
- Storms
 - not as strong as on Jupiter
 - less long lasting



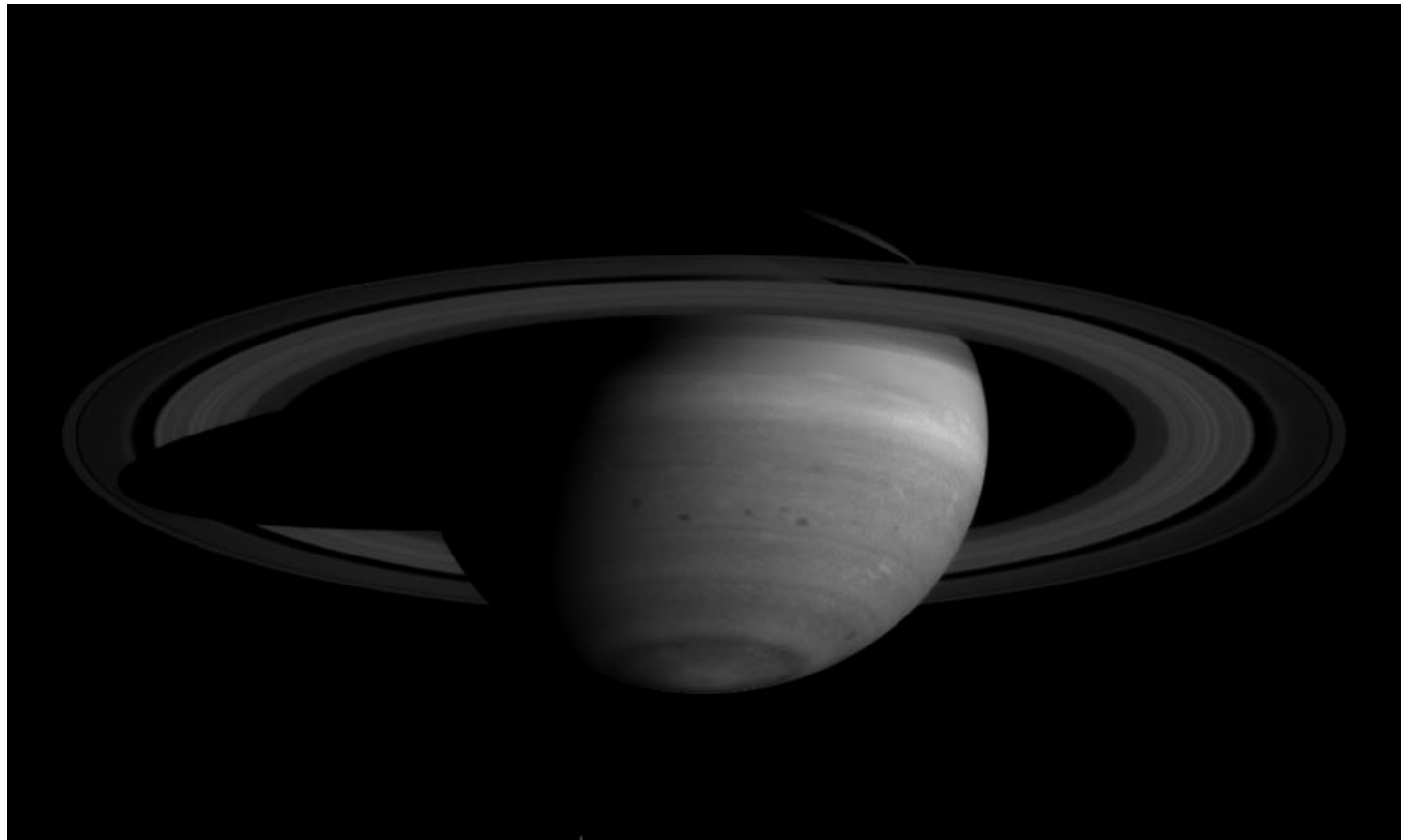
Saturn from Cassini



- Arrived July 2004
- 4 year mission
- 70 orbits, many pix
- Huygens probe landed on Titan January 2005
- Photo taken March 27, 2004.
[Click here](#) for more information

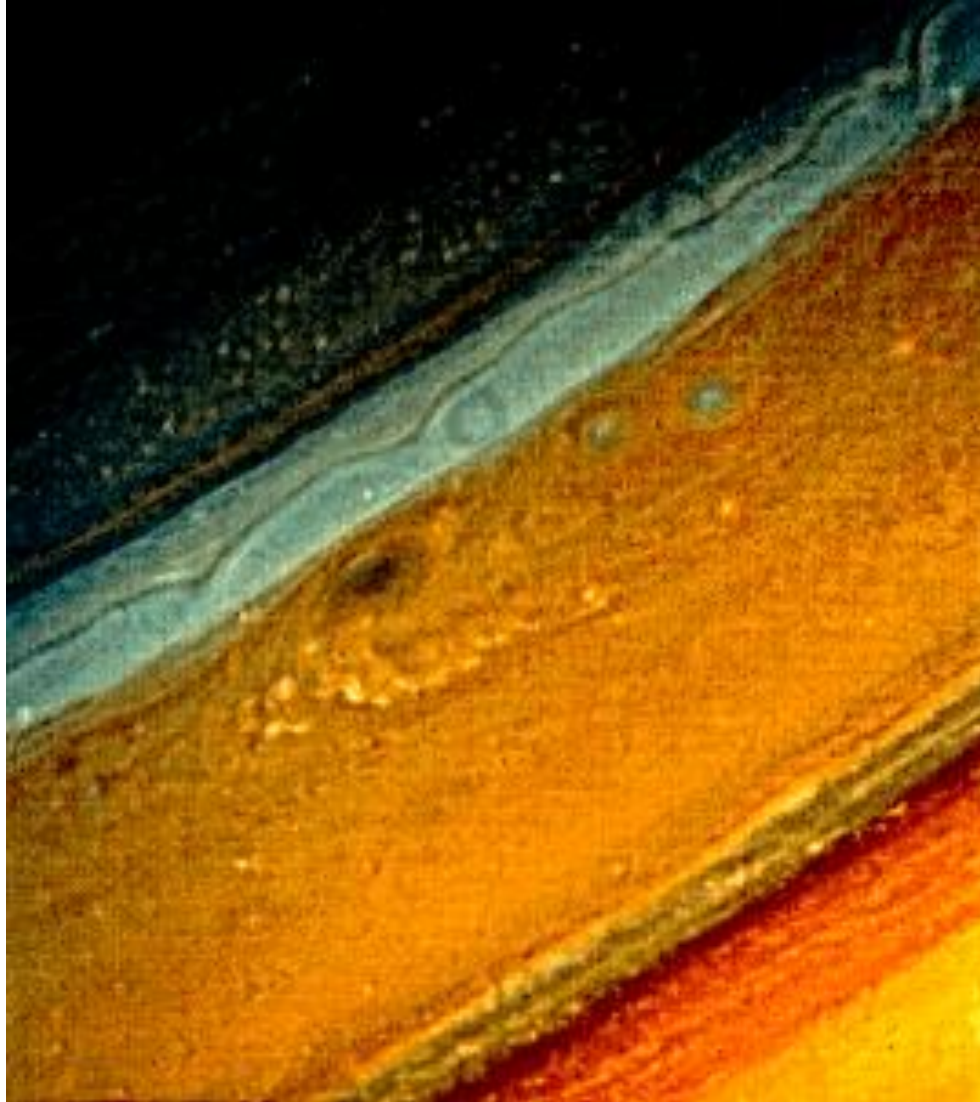
saturn.jpl.nasa.gov/index.cfm

Motion of Saturn's Atmosphere

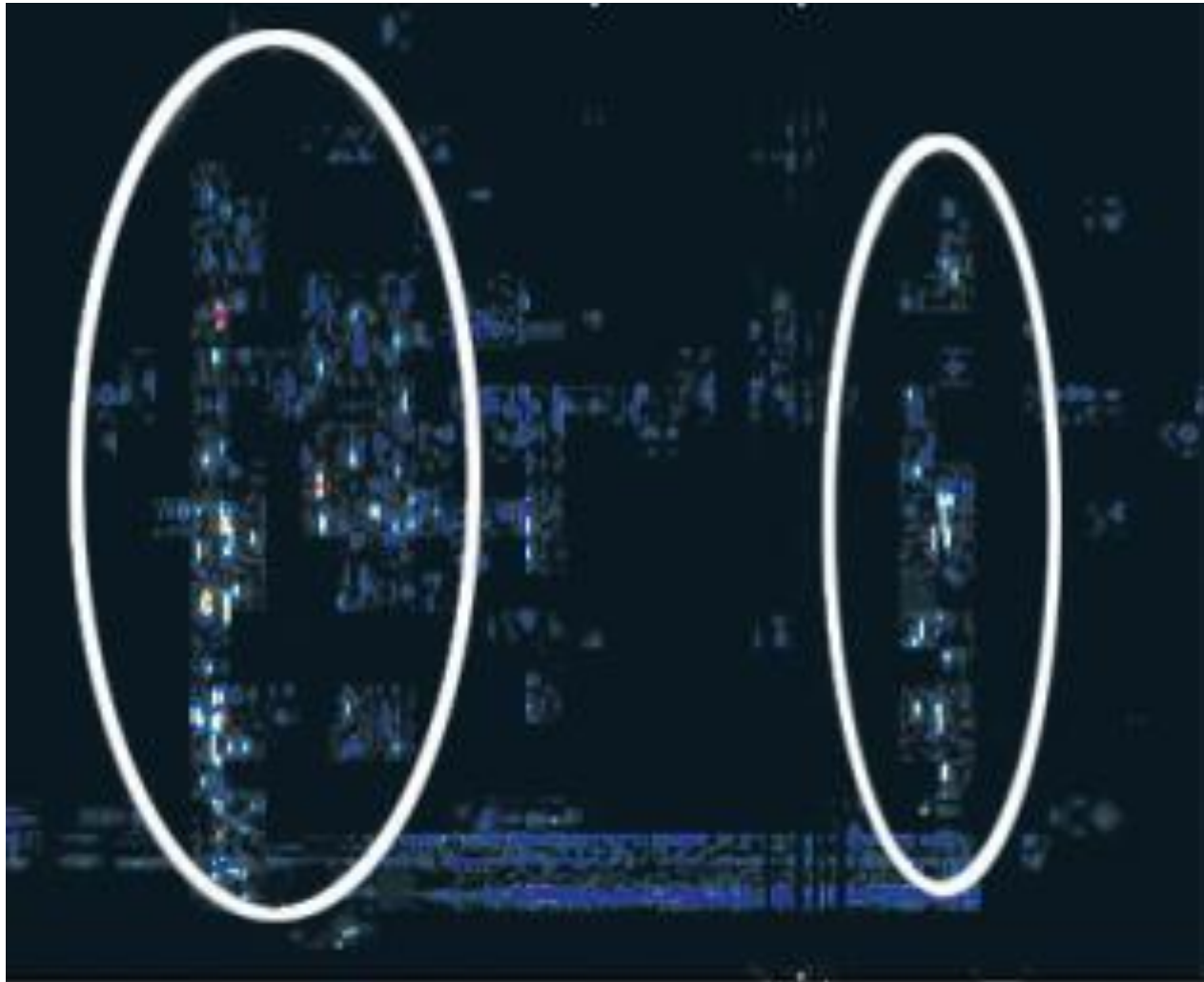


<http://photojournal.jpl.nasa.gov/animation/PIA06082>

Saturn -- Close Up



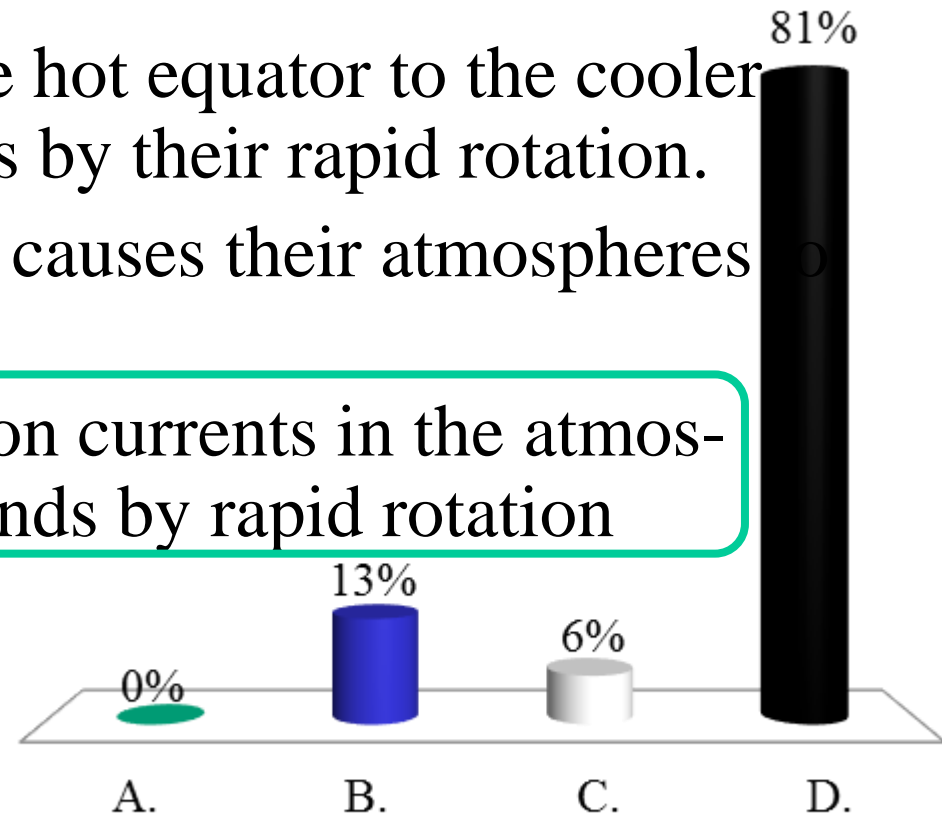
Lightning on Saturn – Radio Data (Cassini Mission)



<http://photojournal.jpl.nasa.gov/catalog/PIA06417>

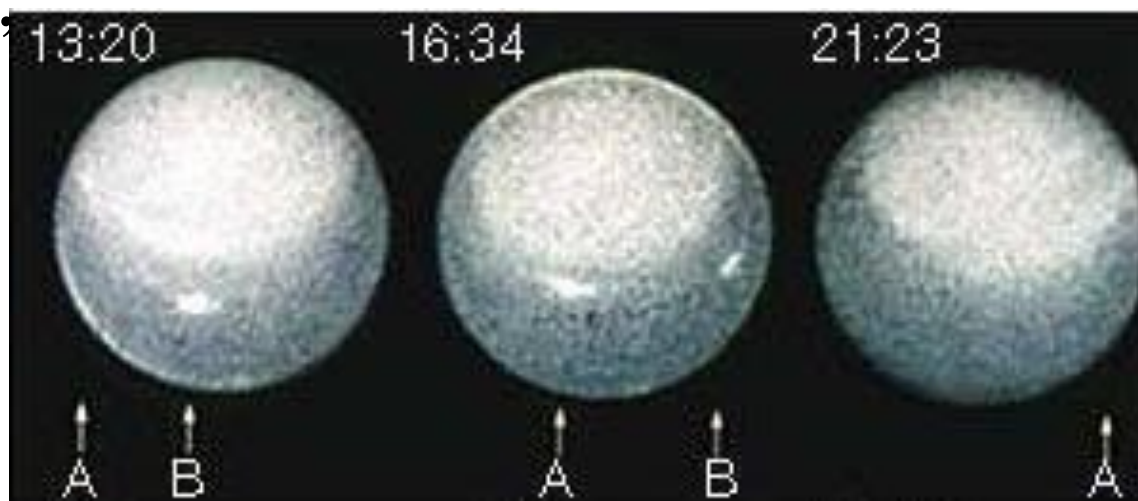
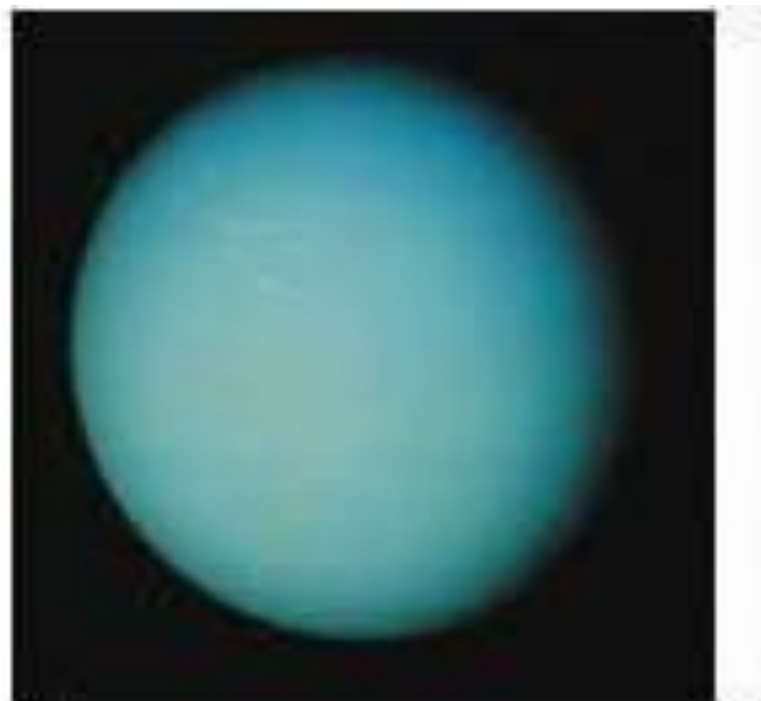
Jupiter and Saturn both show spectacular bands on their surfaces which appear to be very stable. Which of the following best explains these bands?

- A. Their rotation causes rapid eastward winds that are broken up by a deep rocky mantle.
- B. The flow of gasses from the hot equator to the cooler poles is stretched into bands by their rapid rotation.
- C. Their strong magnetic field causes their atmospheres to flow in bands.
- D. Rising and falling convection currents in the atmospheres are stretched into bands by rapid rotation

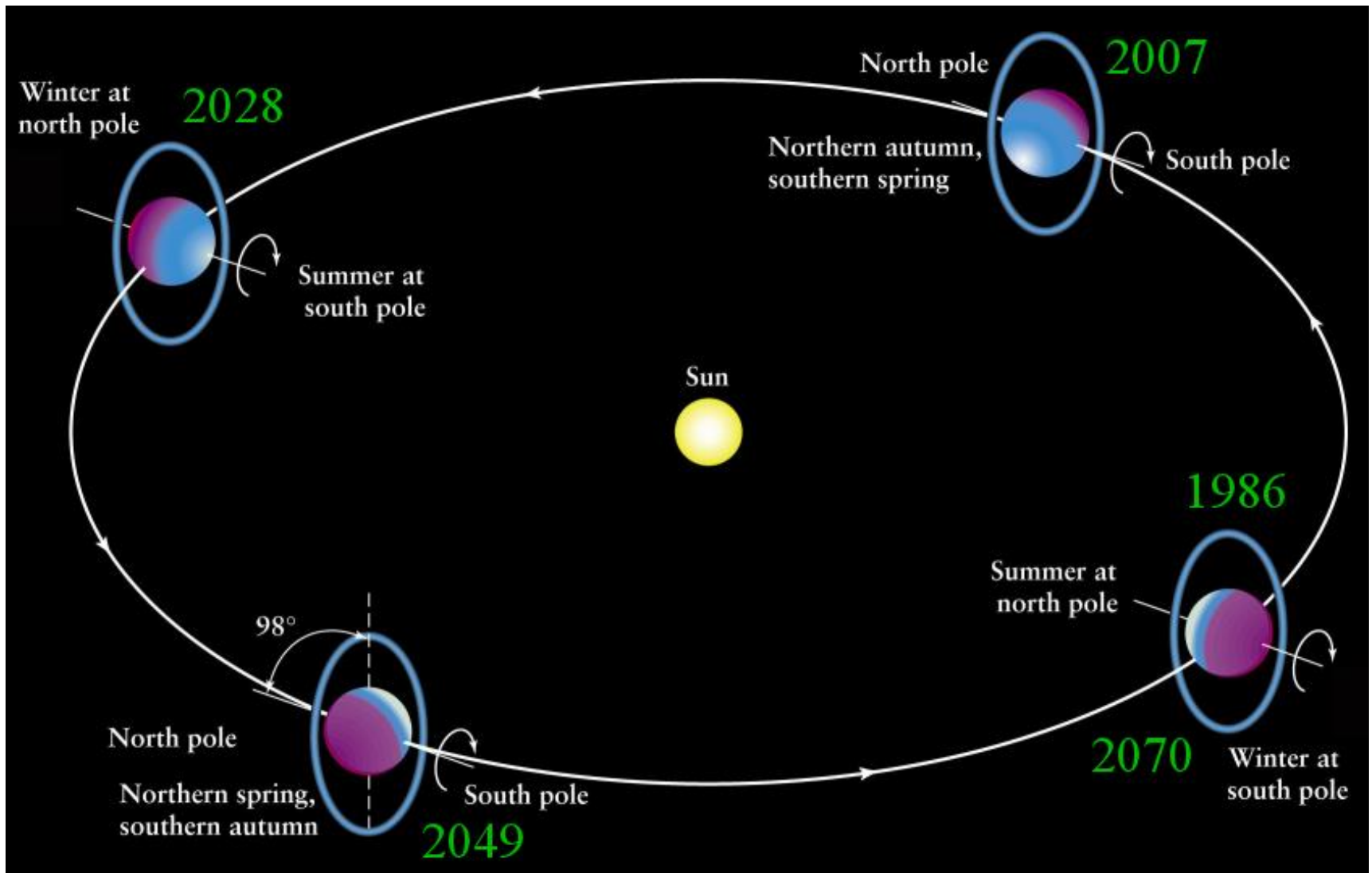


Atmosphere of Uranus

- Discovered by William Herschel in 1781 by accident.
- Blue-green/blue due to methane.
- Cold makes haze, hiding detailed features below.
- Very featureless

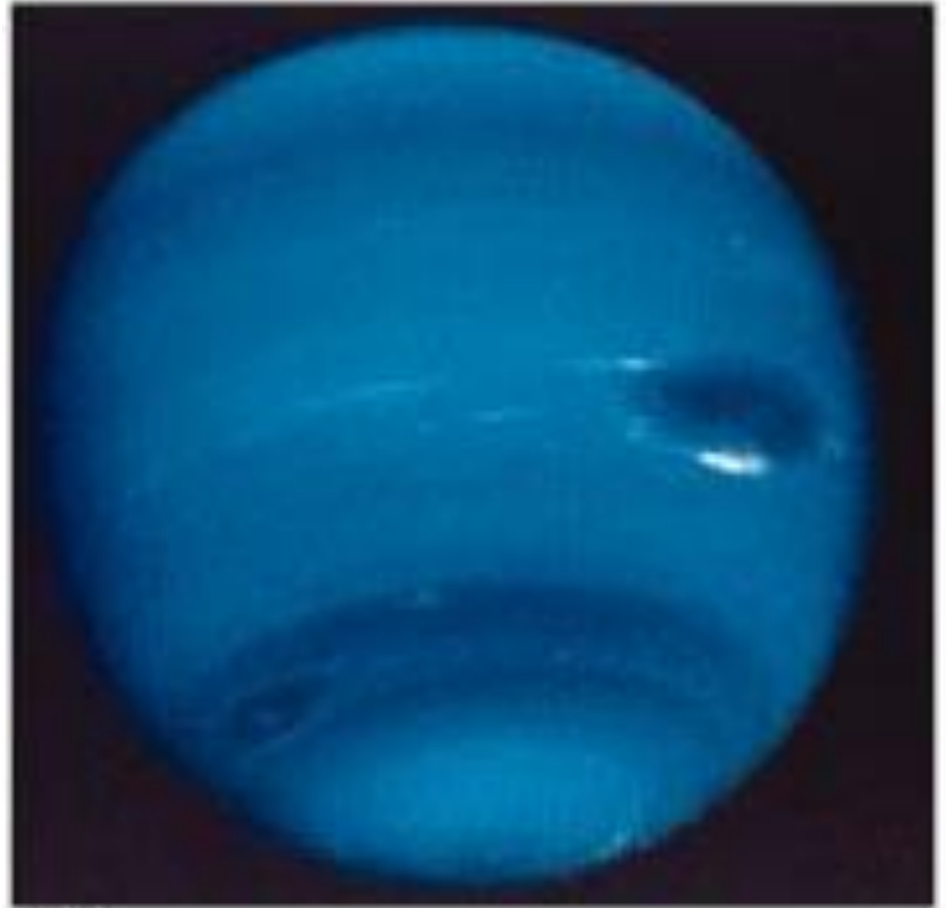


- Uranus is tilted on its side (98°)
 - Pole almost points towards Sun.
 - Causes drastic seasons.
 - Why on its side? Possible collision.



Atmosphere of Neptune

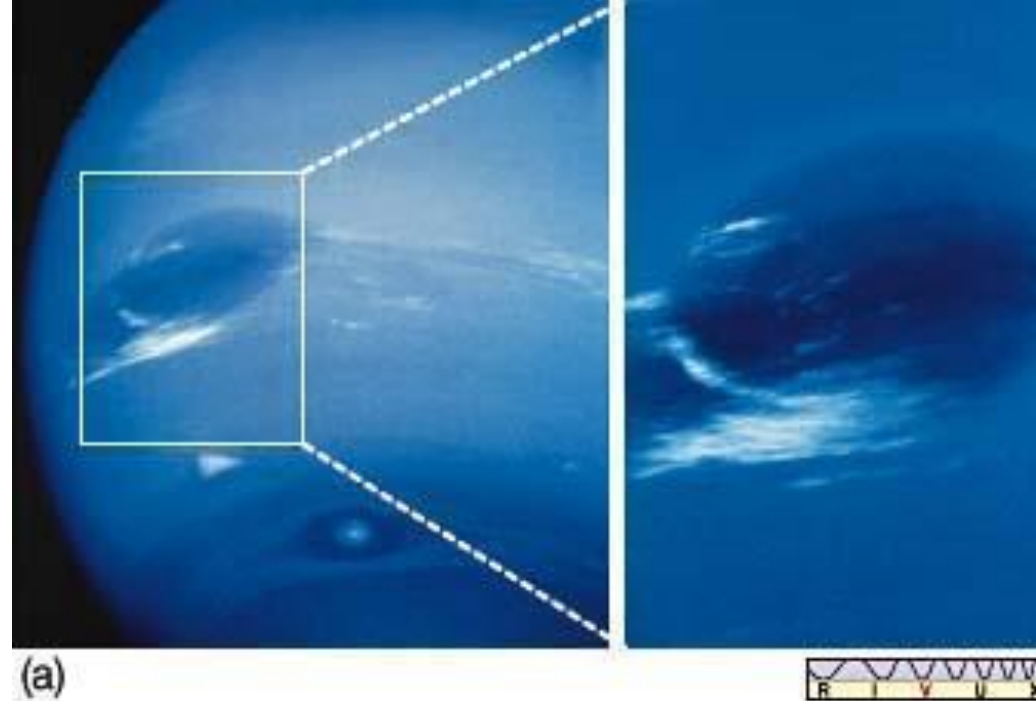
- Predicted by Adams and Le Verrier (1845)
- Blue due to methane.
- Cold makes haze, hiding detailed features below.
- More structure in Atmosphere.
- Has storm systems
- Great Dark Spot



(b)

Atmosphere of Neptune

- Great dark spot highlighted by white methane ice clouds
- Banded structure suggests belts and zones something like Jupiter.



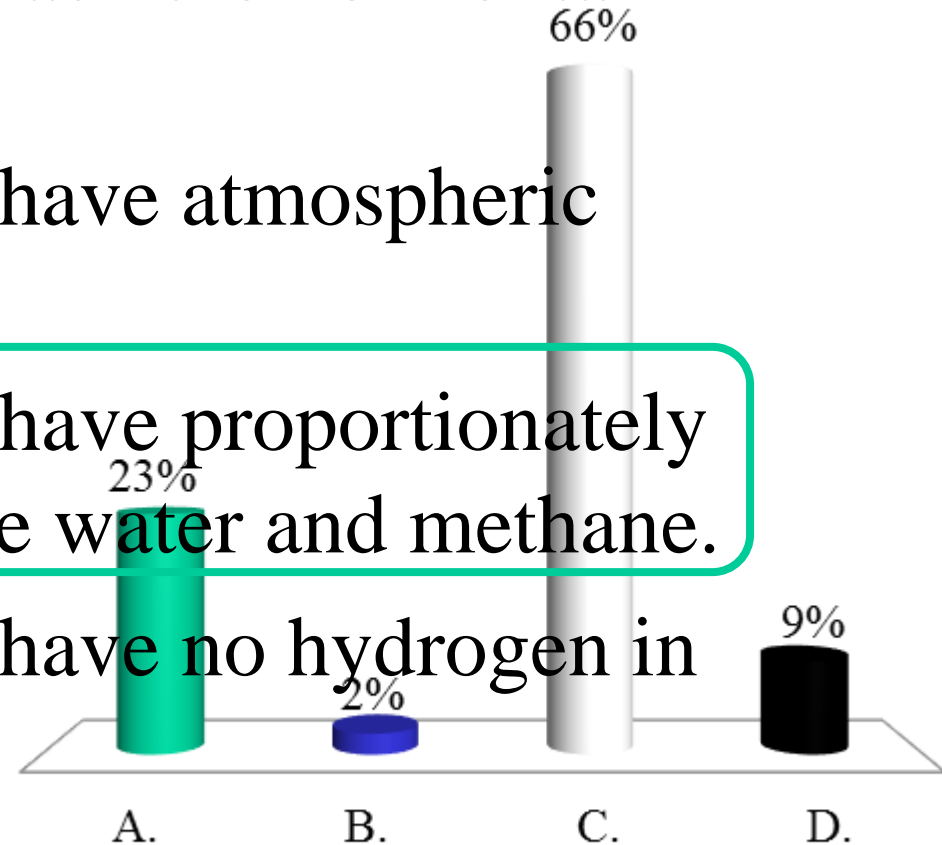
How are the atmospheres of Uranus and Neptune different from those of Saturn and Jupiter?

A. Uranus and Neptune lack the horizontal bands.

B. Uranus and Neptune have atmospheric storms.

C. Uranus and Neptune have proportionately more heavy gases like water and methane.

D. Uranus and Neptune have no hydrogen in their atmospheres.



Inner Structure of Jovian Planets

	Jupiter	Saturn	Uranus	Neptune
Density (kg/m ³)	1300	700	1200	1700
Magnetic Field	20,000 x Earth's	1,000 x Earth's	100 x Earth's	100 x Earth's
Inner Structure	Atmosphere	Atmosphere	Atmosphere	Atmosphere
	Liquid H	Liquid H	Liquid H	Liquid H
	Liquid Metallic H	Liquid Metallic H	Ammonia / Water "slush"	Ammonia / Water "slush"
	Rocky Core	Rocky Core	Rocky Core	Rocky Core

Clues to Composition

- **Density** -- for all Jovian planets it is less than 2000 kg/m^3 , suggesting composition of gas and “ices”.
- **Spectroscopic information** – composition is mainly hydrogen and helium.

Clues to Composition -- Magnetic Field

- All much larger than Earth's
 - All have rapid rotation
 - But not much metal
 - instead, liquid gas and “ices” create magnetic field
- Jupiter and Saturn -- Metallic hydrogen in interior
 - H_2 acts like a metal, but only when the gravitational pressure is high enough. This requires a large mass.
- Uranus and Neptune -- Water and ammonia “slush”
 - Mass and thus gravitational pressures are not large enough to make metallic hydrogen

Structure of Jupiter and Saturn

- **Atmosphere:** H₂ gas at about 300 K
- **Mantle:** Hydrogen gas turning to liquid as you go deeper, then behaving like a metallic liquid below 20,000 km
- **Core:** rocky, three times as massive as Earth, but smaller in size due to tremendous pressure. Surrounded by a shell of liquid water, carbon dioxide, methane, and ammonia “ices”.

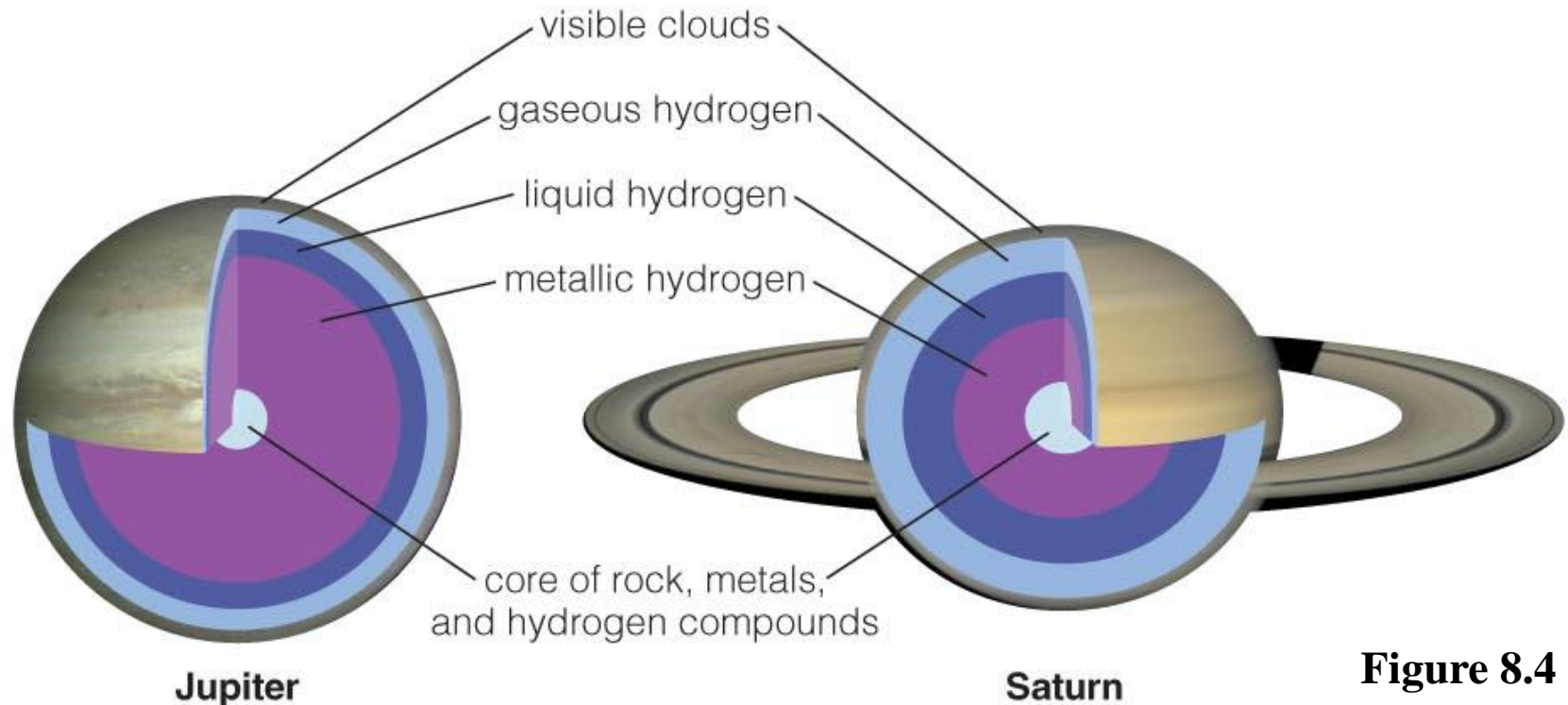
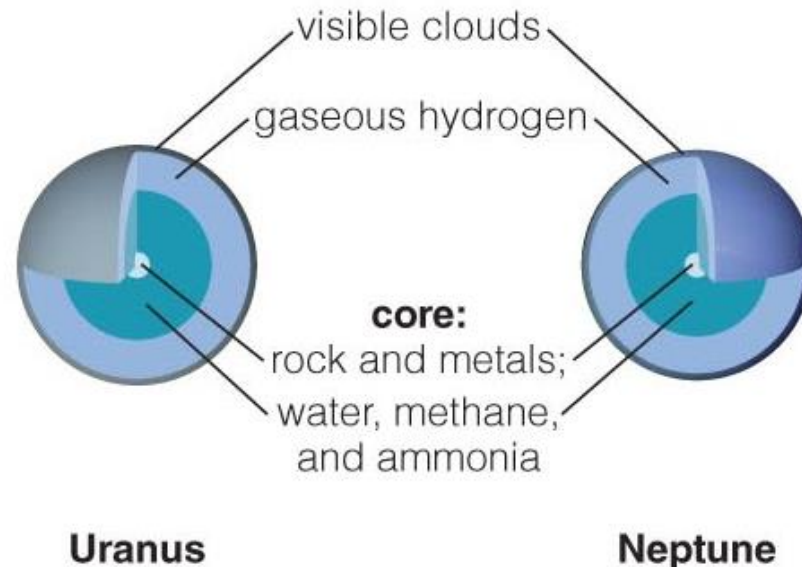


Figure 8.4

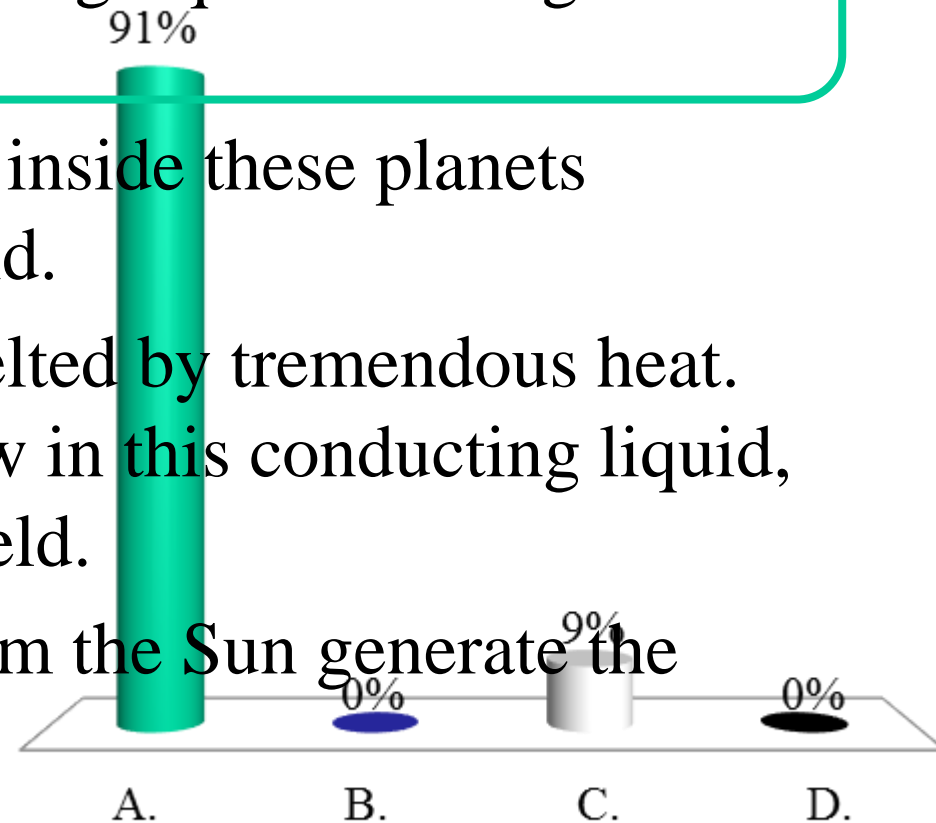
Structure of Uranus and Neptune

- NOT like Saturn and Jupiter
 - **Atmosphere:** Thin, mostly H_2 with traces of methane
 - **Mantle:** Dense gaseous H_2 and helium outer mantle
 - Compressed water & ammonia “slush” inner mantle
 - **Core:** Rock, metals, hydrogen compounds. About the same mass as Jupiter and Saturn’s cores.



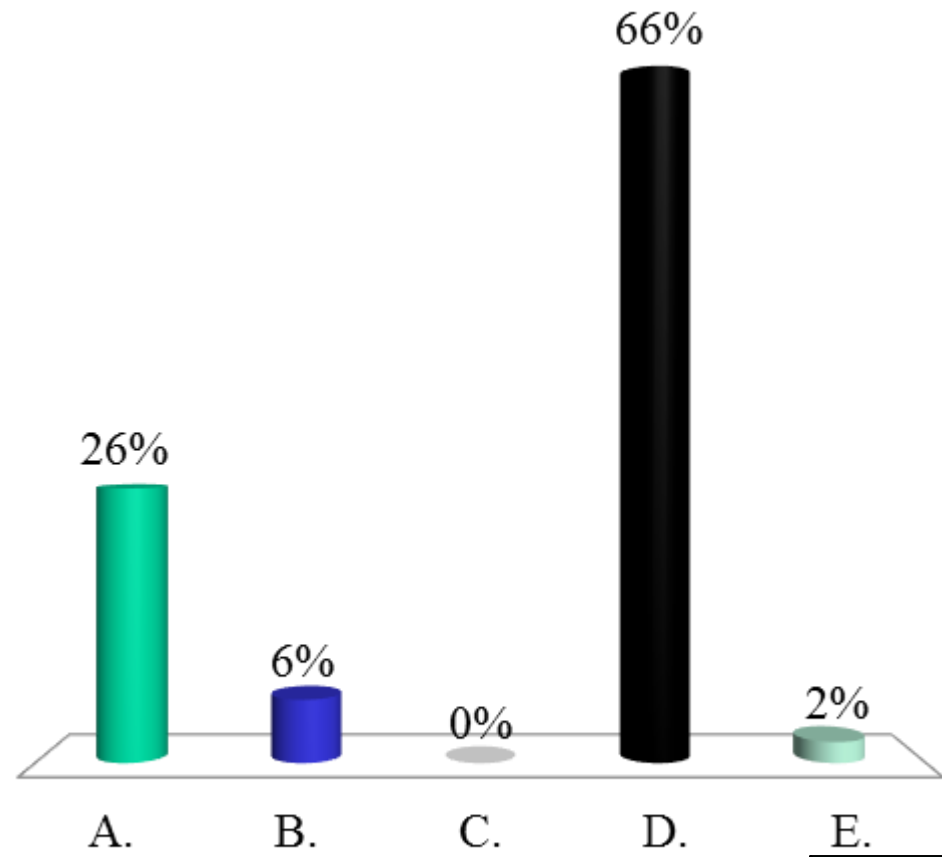
What is the origin of the magnetic fields of Jupiter and Saturn?

- A. The thick hydrogen layer is under so much pressure that it becomes a conducting liquid able to generate a magnetic field.
- B. The large iron core deep inside these planets generates a magnetic field.
- C. The large iron core is melted by tremendous heat. Electric currents can flow in this conducting liquid, generating a magnetic field.
- D. Solar winds captured from the Sun generate the strong magnetic field.



Astronomers think that the inner cores of the Jovian planets are composed mainly of

- A. hydrogen.
- B. methane.
- C. water.
- D. rock and iron.
- E. liquid helium.



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