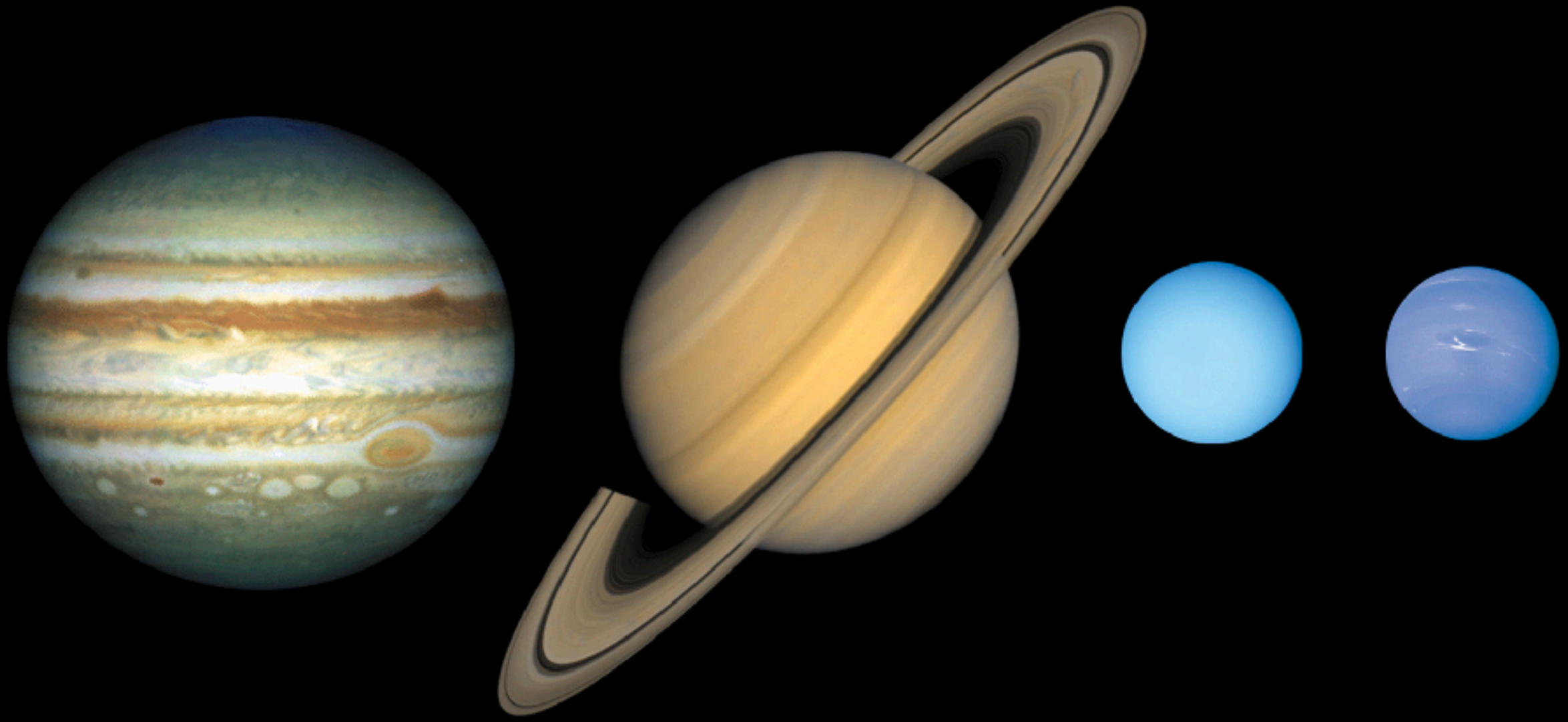
# The Giant Planets

Chapter 11

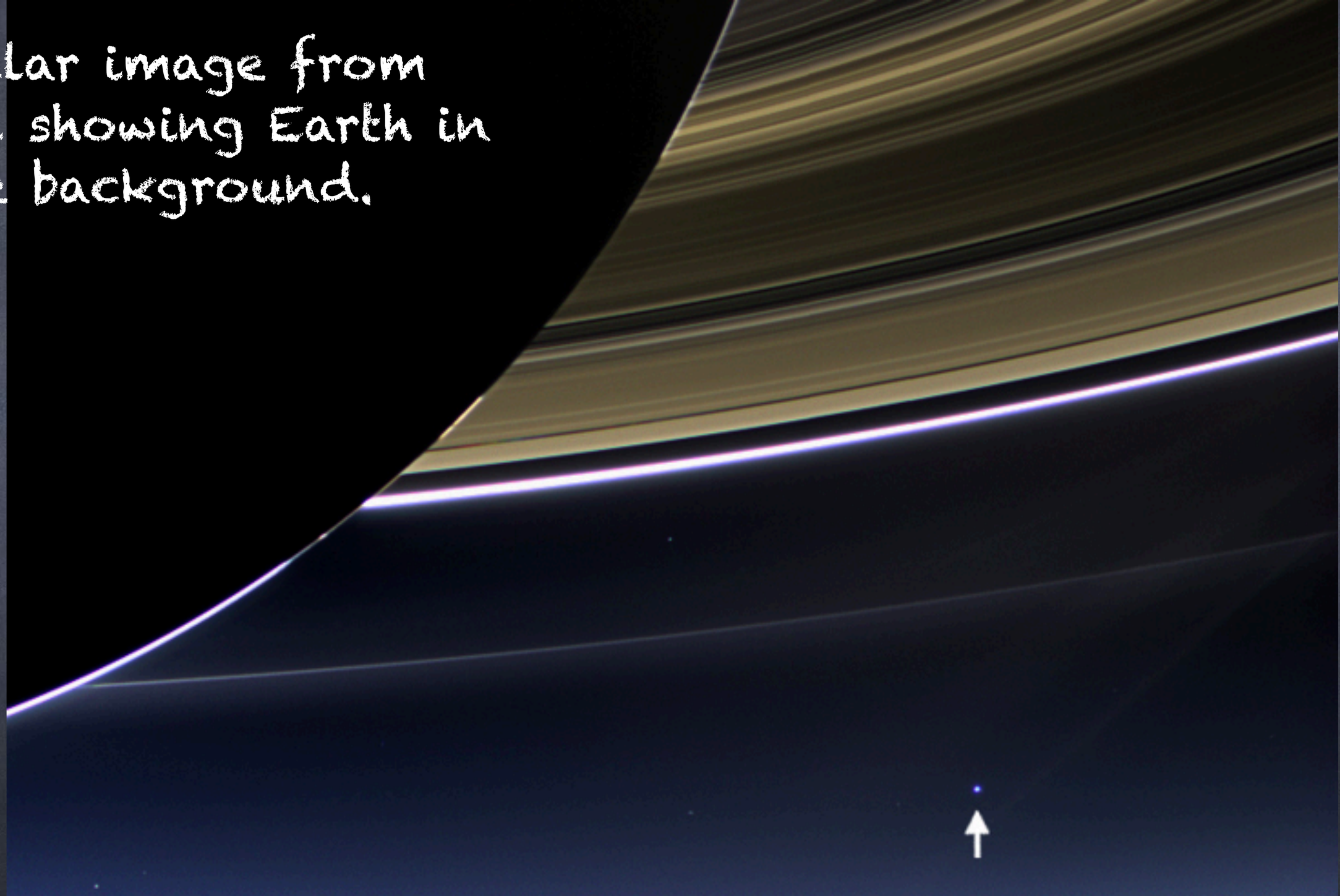


# The Giant Planets

- The giant planets have vastly more mass than the inner planets. Jupiter by itself has more mass than all the other planets combined.
- These planets are primarily composed of gas, hydrogen and helium. We categorize other elements as ices (water ice, $H_2O$, but also methane, $CH_4$, and ammonia, $NH_3$) and rock (metals and silicon).
- Most of what we know about the outer planets comes from visiting spacecraft. But while Jupiter has been visited 9 times and Saturn 4, Uranus and Neptune have only been visited by the Voyager 2 spacecraft.

https://www.jpl.nasa.gov/video/details.php?id=1215

Popular image from Cassini showing Earth in the background.



# Basic Properties

| Planet | Distance (AU) | Period (years) | Diameter (km) | Earth Masses | Density (g/cm³) | Rotation Period (hours) |
|---|---|---|---|---|---|---|
| Jupiter | 5.2 | 11.9 | 142,800 | 318 | 1.3 | 9.9 |
| Saturn | 9.5 | 29.5 | 120,540 | 95 | 0.7 | 10.7 |
| Uranus | 19.2 | 84.1 | 51,200 | 14 | 1.3 | 17.2 |
| Neptune | 30.0 | 164.8 | 49,500 | 17 | 1.6 | 16.1 |

# Appearance and Rotation

- Jupiter and Saturn have bands of different colors which are clouds mostly of ammonia. Neptune has methane clouds and Uranus has no obvious cloud layer.
- We can measure the motion of these clouds, but that isn't the real rotation rate of the planet. Instead the rotation times are from measuring the magnetic fields of the planet. Note that for something not made of rock and metal rotation is not as straightforward a concept.
- All of the giant planets rotate quickly compared to Earth, and they are much bigger so their outer layers are moving much faster. The biggest planets rotate the fastest.

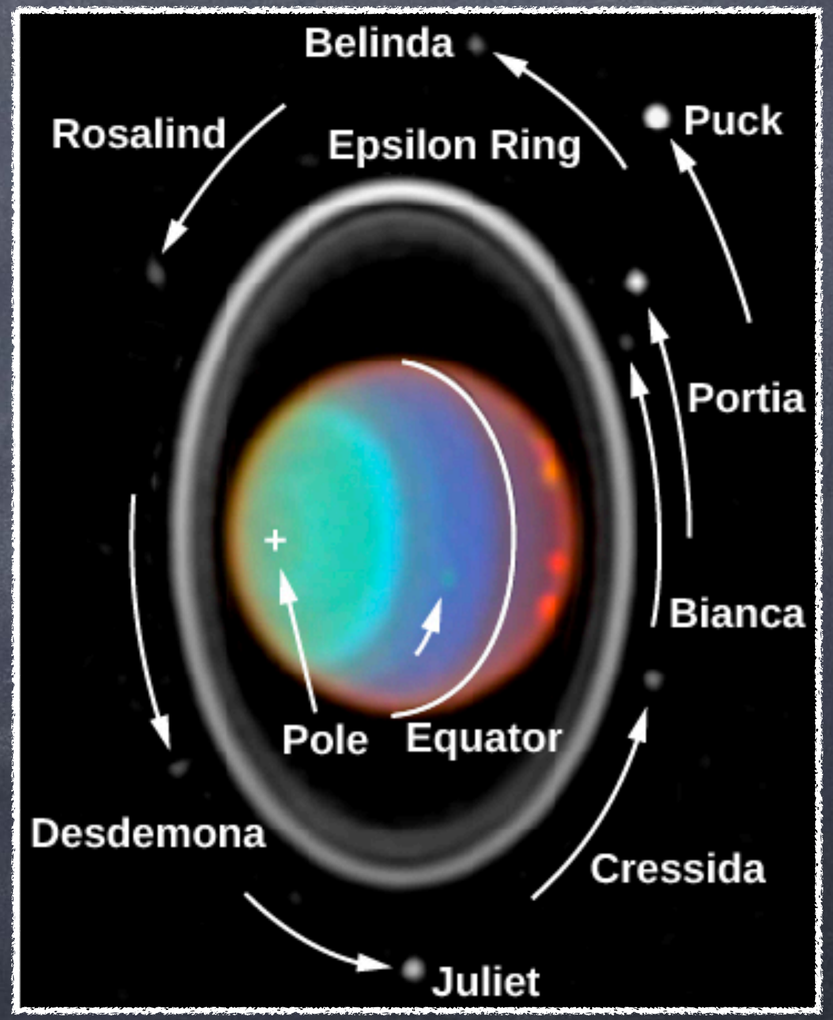
https://www.youtube.com/watch?v=QND_NtNFAvI

# Seasons

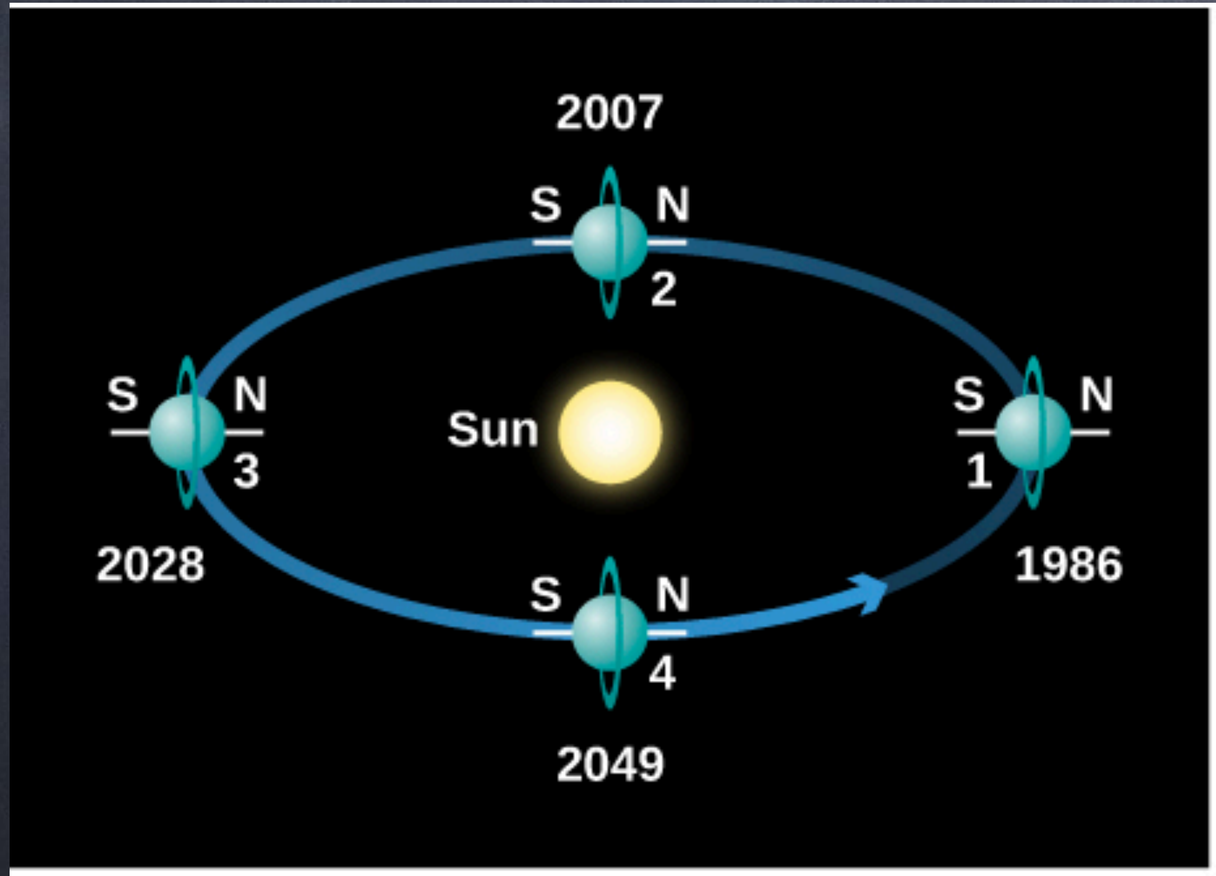
- The giant planets will have seasons if their axis is tilted with respect to their orbit around the Sun.
- Jupiter is only tilted by 3° so no seasons.
- Saturn is tilted by 27° and Neptune is by 29° so they both have seasons like Earth and Mars.
- Uranus is a special case because it is titled by 98°. Uranus is close to perpendicular to every other planet.

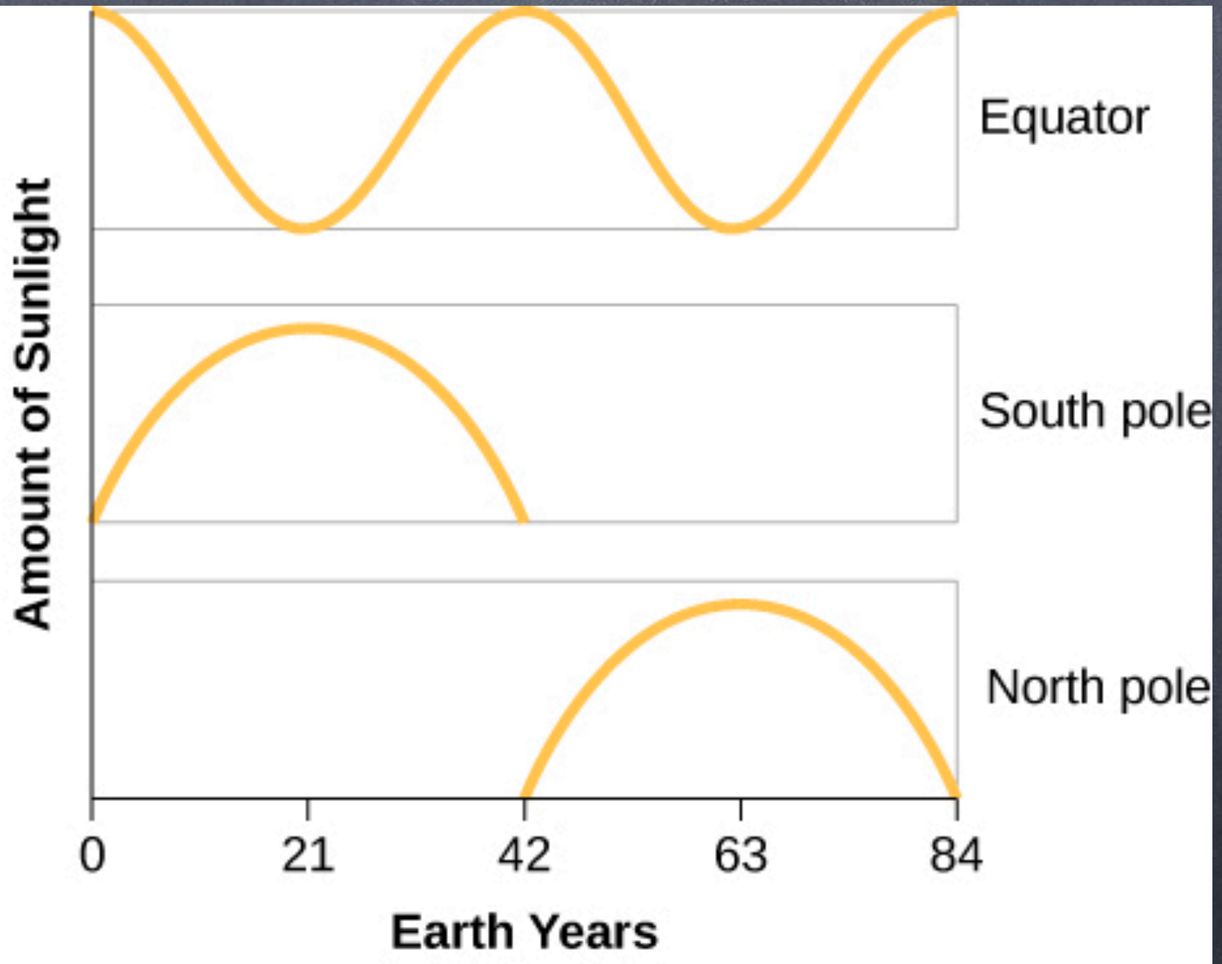
# Uranus on its side

- Uranus, its rings and its moons all rotate together on their side.
- What caused this is unclear, maybe impact with a large object.
- The resulting seasons are extreme. On the pole one would have 42 years of light followed by 42 years of darkness.
- On the equator the Sun goes from being due north on the horizon to over head, to due south.



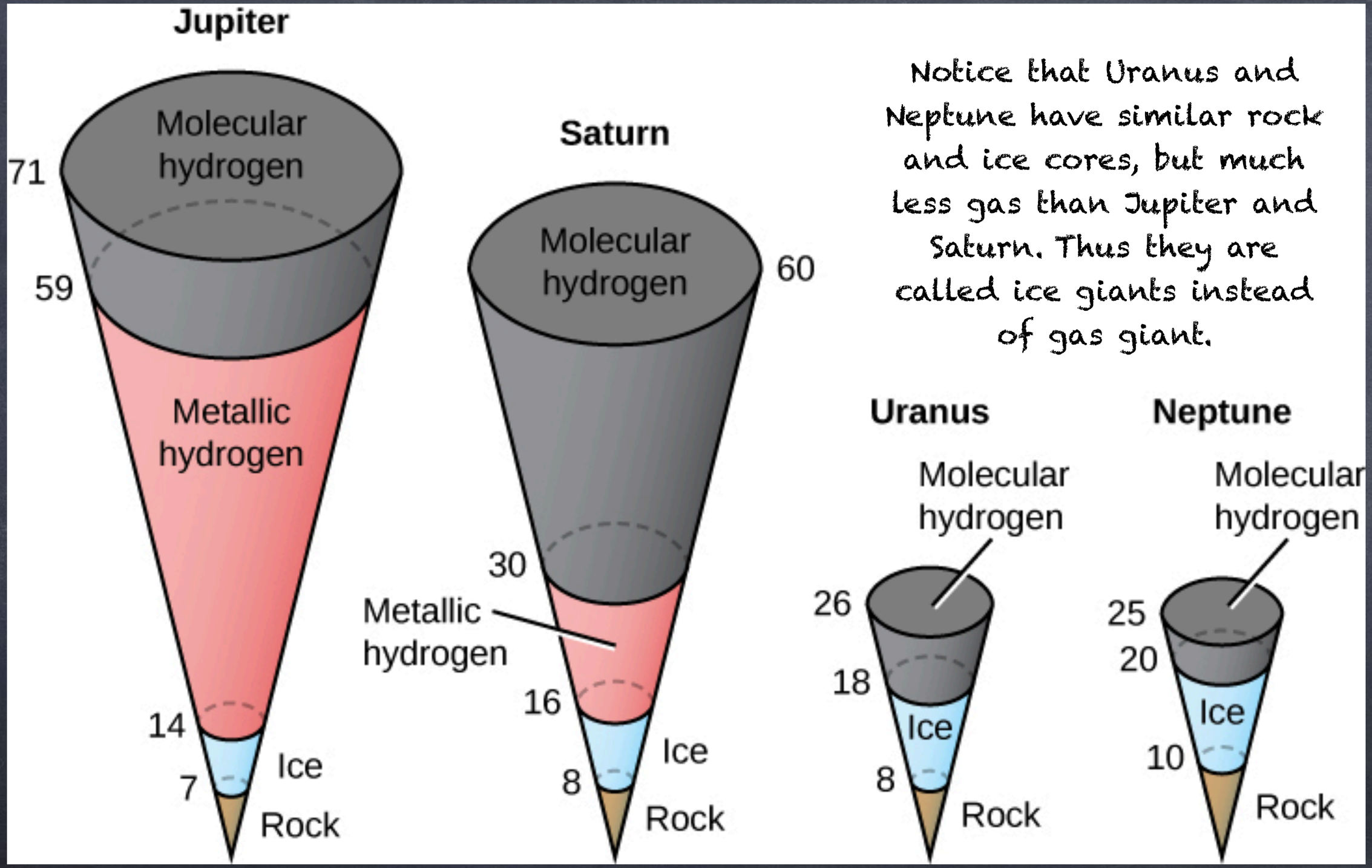
# Sunlight on Uranus.
# This strange arrangement is why weather on Uranus is different than the other giant planets.



# Composition and Structure

- Although we can not see into any of the giant planets we can try to guess their structure based on what we understand about how elements behave under pressure.
- The pressure at the center of Jupiter probably reaches 100 million that of Earth's atmosphere and a density of 31 g/cm$^3$. Earth's center is 4 million and 17 g/cm$^3$.
- Under these conditions hydrogen acts like a metal, conducting electricity. Even a few thousand km below the cloud layer the pressure is high enough to make hydrogen a liquid on Jupiter and Saturn.
- Uranus and Neptune don't have high enough pressure to make metallic hydrogen.
- All the giant planets also have rock and ice in them. By this we mean the elements that make rock and ice, but at temperatures and pressures where they will not be rock or ice.

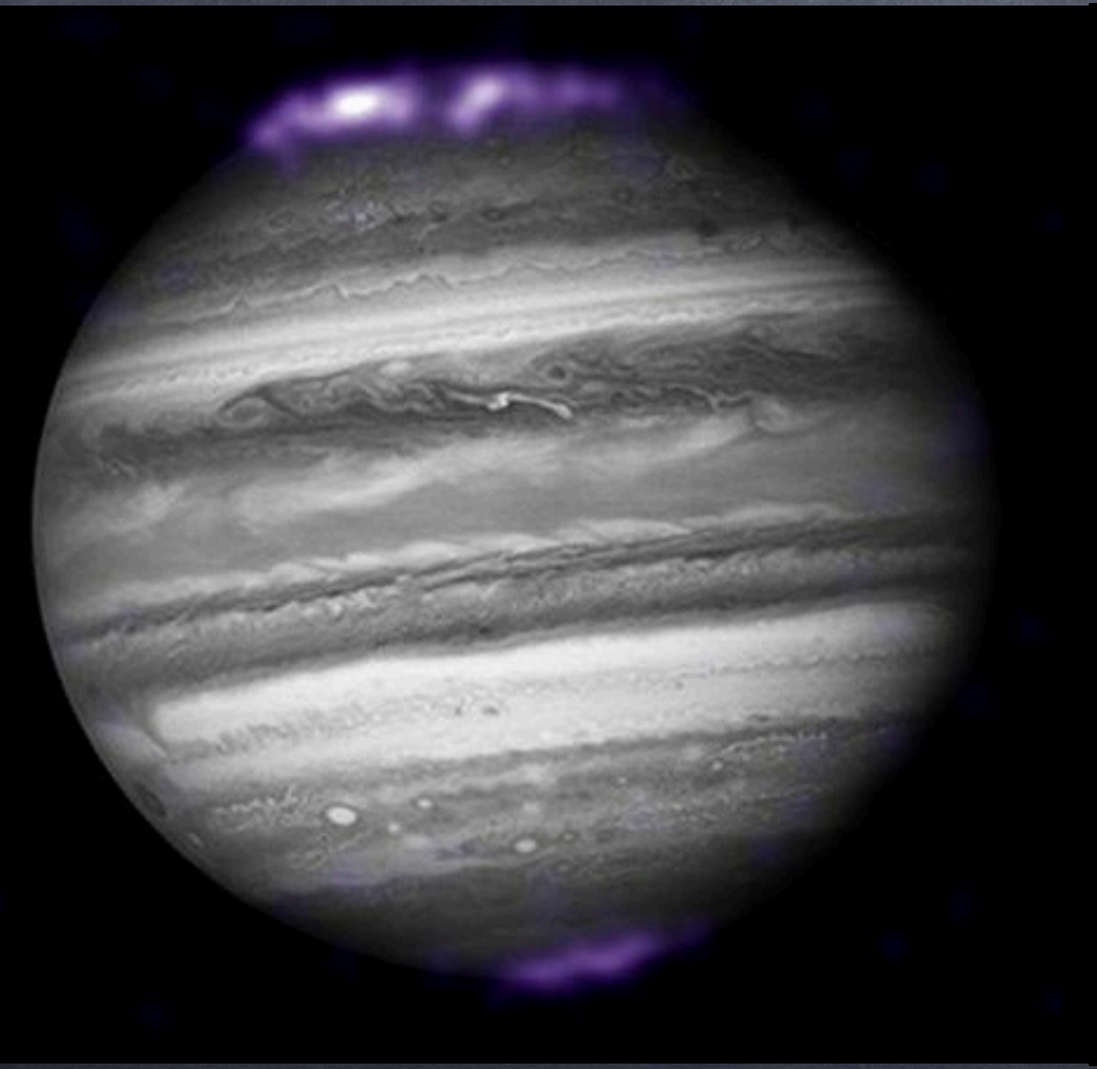


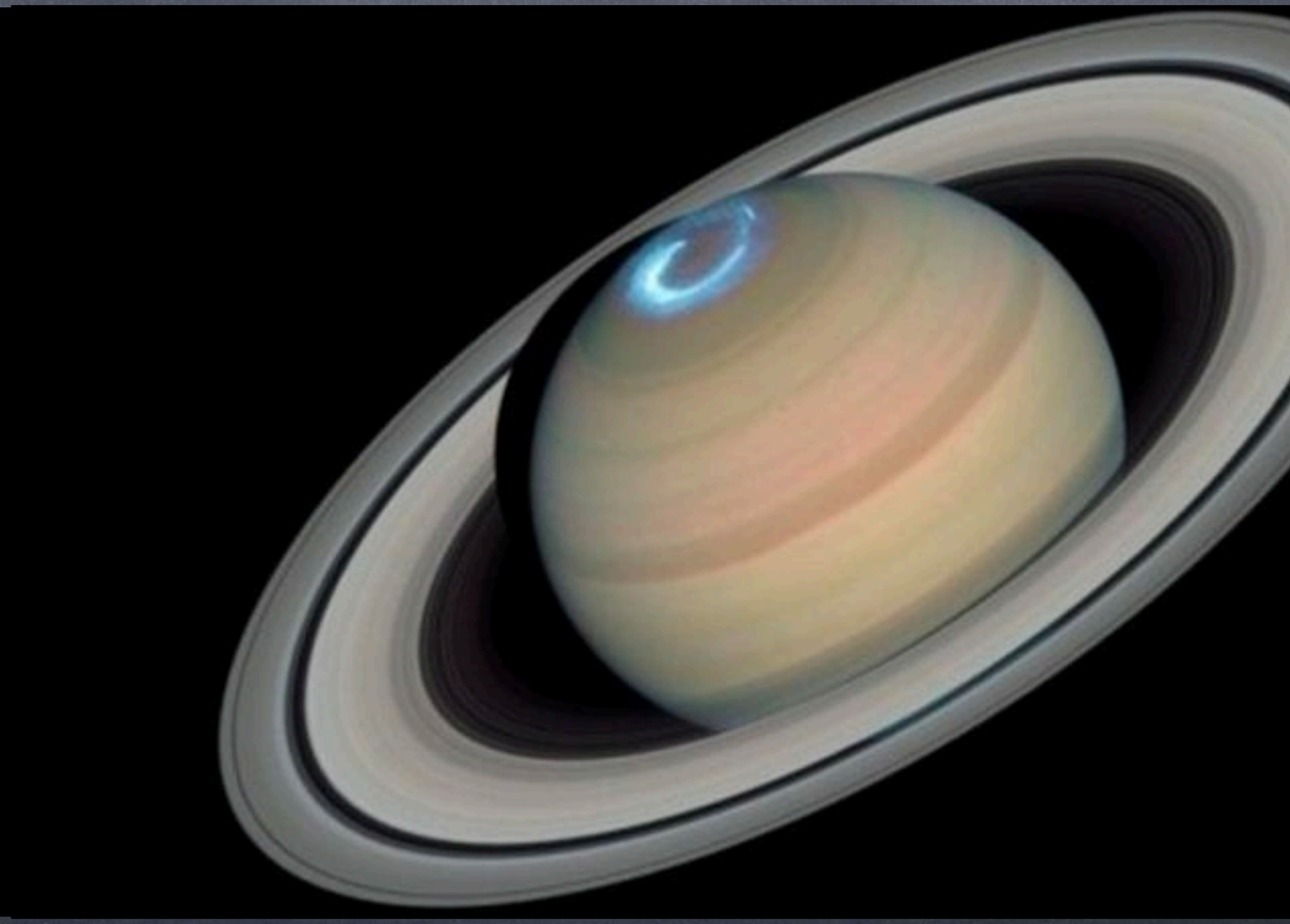

Notice that Uranus and Neptune have similar rock and ice cores, but much less gas than Jupiter and Saturn. Thus they are called ice giants instead of gas giant.

# Magnetic Fields

- Each of the outer planets has a magnetic field. The area around the planet dominated by this field is called the magnetosphere. The magnetospheres extend millions of kilometers into space.
- In each magnetosphere charged particles are spiral around and emit radiation. If they travel down to planets clouds layer they create aurora borealis (northern lights).
- The magnetic poles are misaligned by 60° and 55° for Uranus and Neptune. We basically don't understand what is happening on these planets.

# Aurora borealis on Jupiter and Saturn





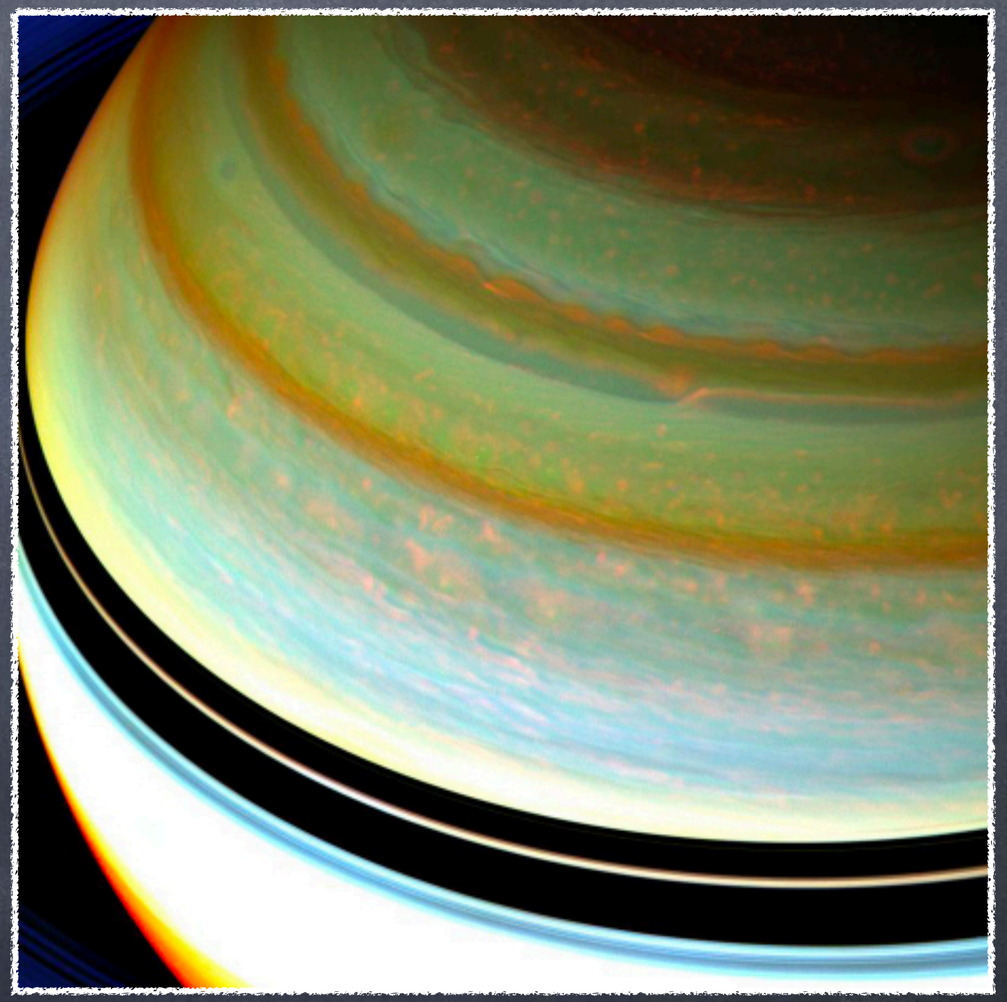
https://www.youtube.com/watch?v=e0tqmrZn6kY

# Clouds on Jupiter

- The different colors in Jupiter's and Saturn's clouds are caused by different temperatures and thus different molecules freezing to form the clouds.
- Saturn has less color because there is less temperature change in the cloud layer.
- The spots are storms, like a hurricane on Earth.

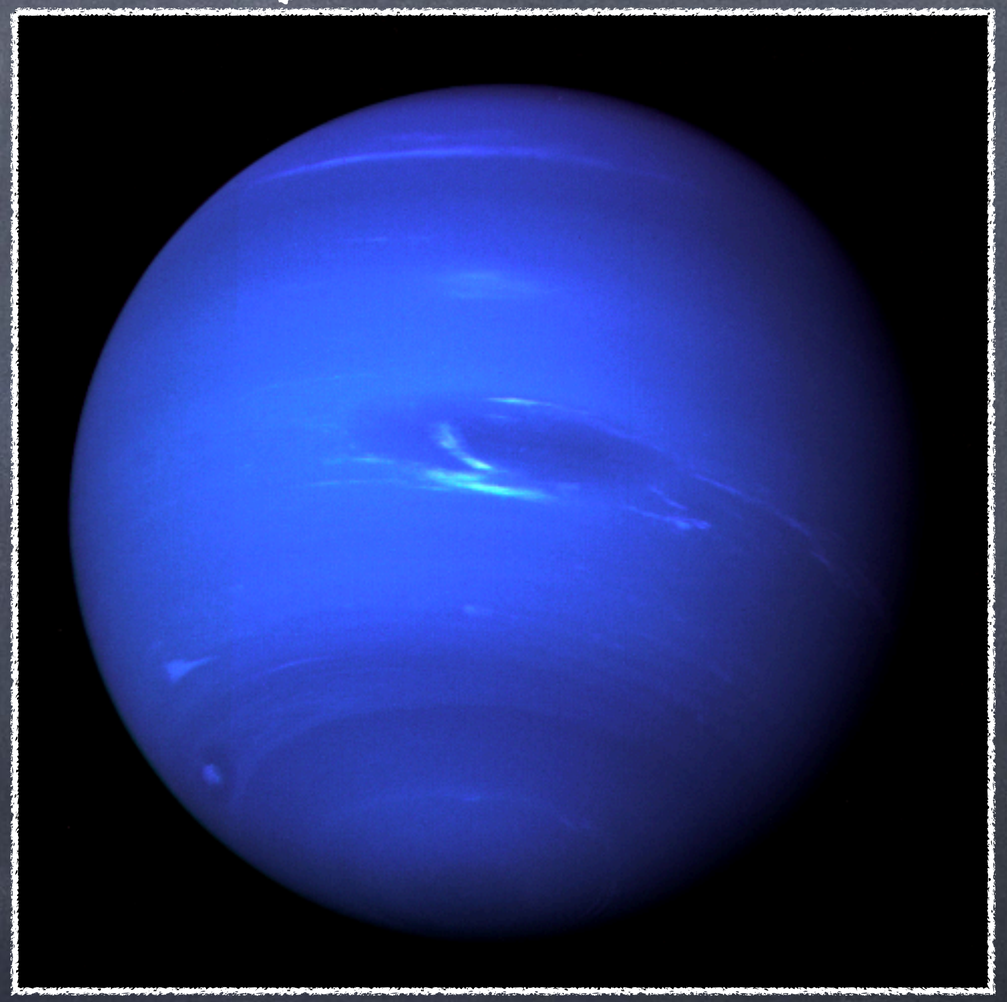
# Clouds on Saturn

- Saturn actually looks very similar to Jupiter if the color contrast is increased.
- This is not a true color image, but the physical nature of the bands is real.

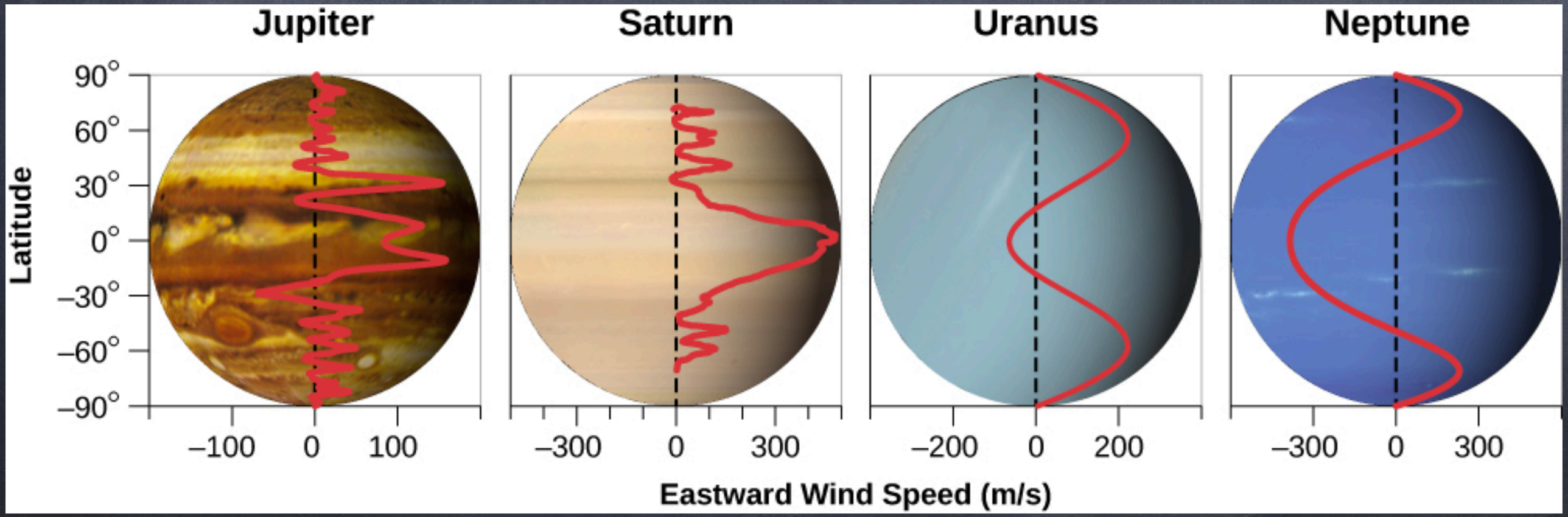


# Uranus and Neptune

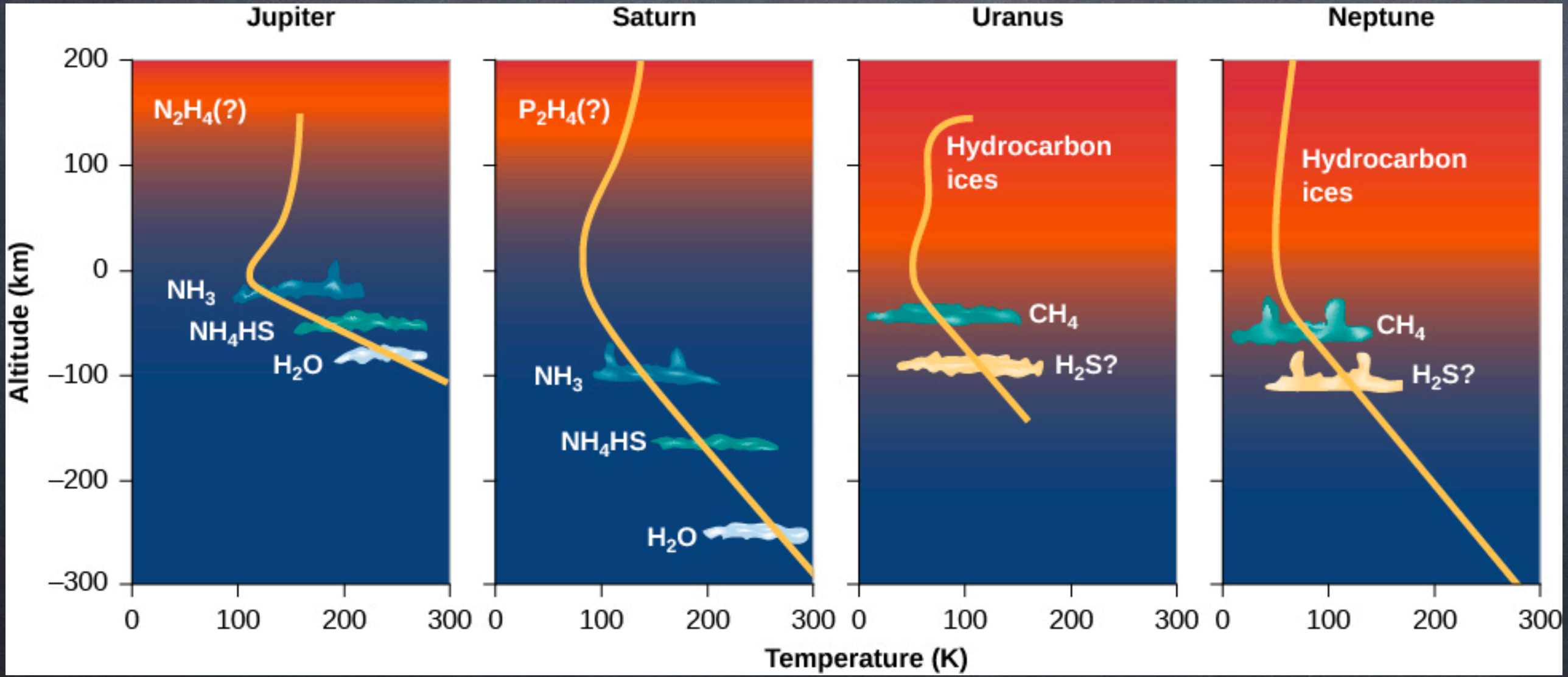
- Uranus has no obvious cloud structure. Its unusual seasons might be the reason for this.
- Neptune has clouds though they don't offer as much color contrast.



The bands on Jupiter and Saturn are caused by the wind going in different directions. This has associated temperature changes which gives different clouds with different colors.



# Giant Planet Atmospheres



# Giant Storms on Giant Planets

- Storms on the giant planets are much like storms on Earth, just much much bigger.
- The largest, Jupiter's Great Red Spot has been around for at least 300 years and is the size of the Earth.
- Neptune's Great Dark Spot, is 10,000km long.
- On these planets storms will last much longer because they reason they end on Earth is when they come over land. No land, means the storms strength is not interrupted.

# Jupiters Great Red Spot

- This storm is larger than Earth. Unlike storms on Earth is a high pressure region, not a low pressure region.
- It has shrunk in the past few decades, so we may witness the end of this storm in our lifetimes.