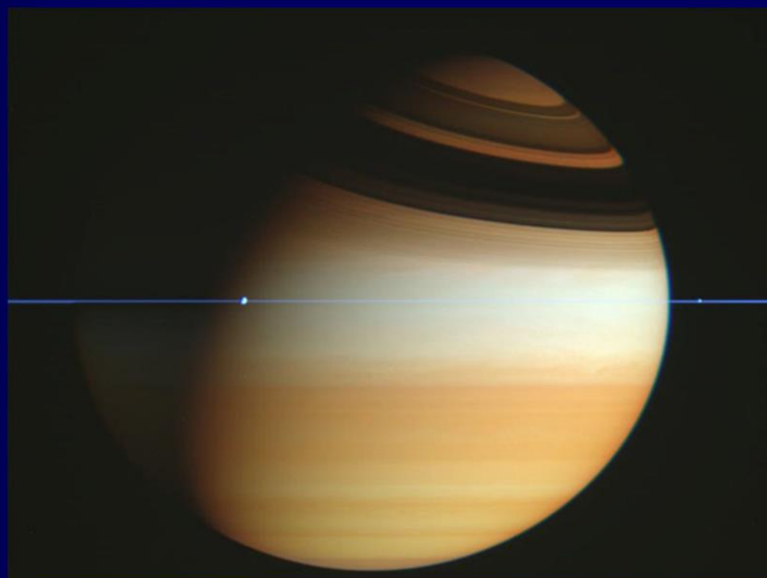
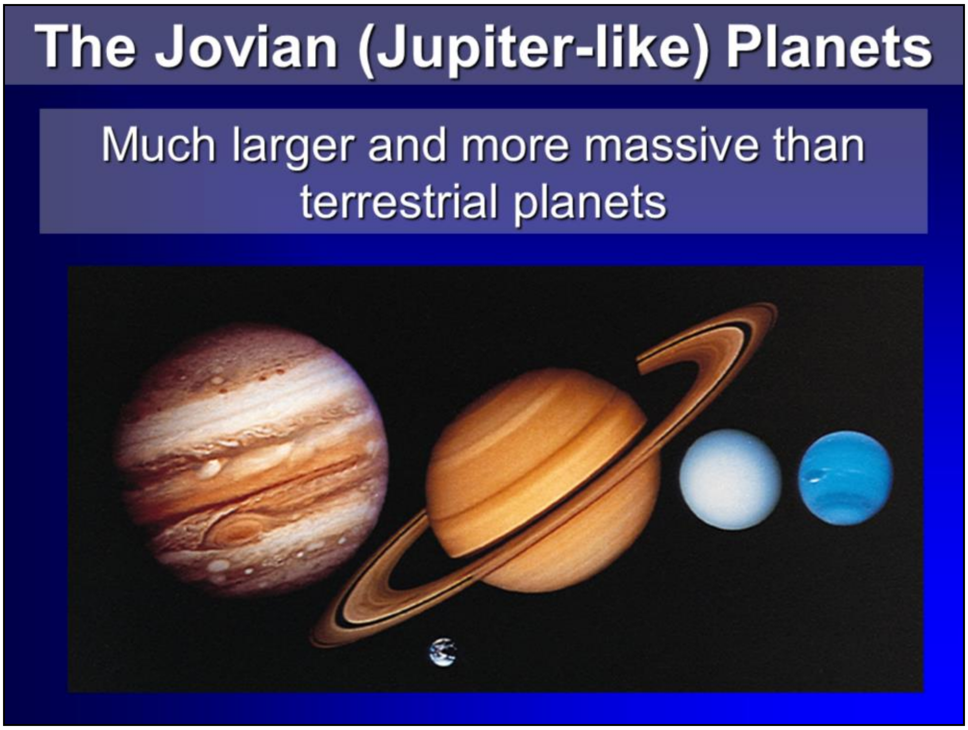
The Jovian Planets





Much larger and much more massive than the terrestrial planets, although not necessarily as dense

Composed mostly of H, He, and H compounds

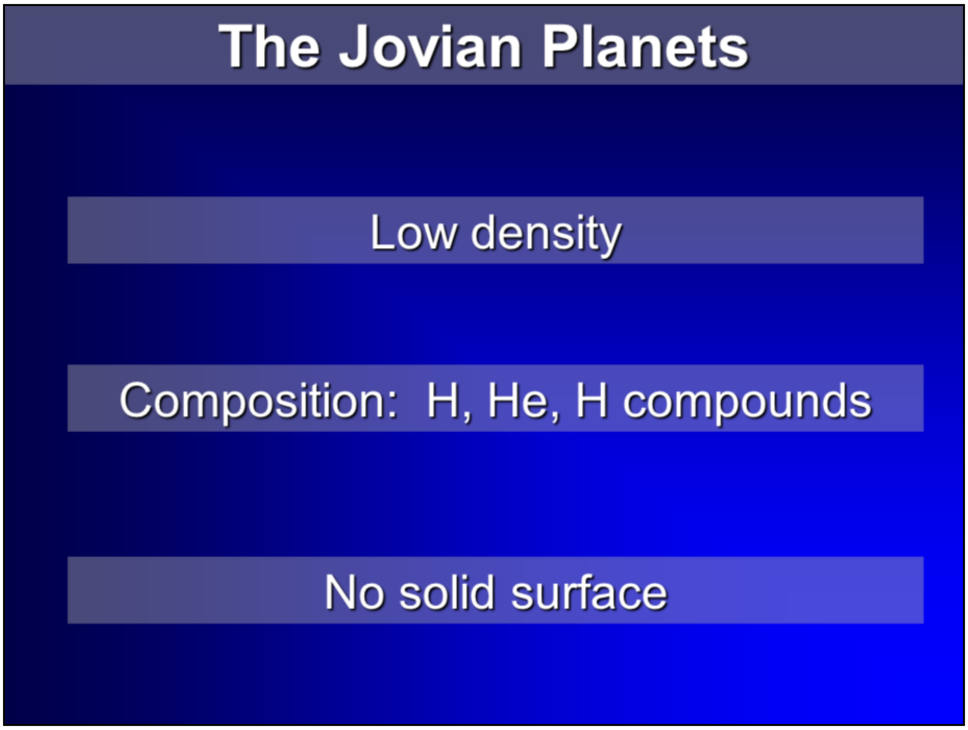
No solid surface

Fast rotation rates, therefore Slightly squished in nature

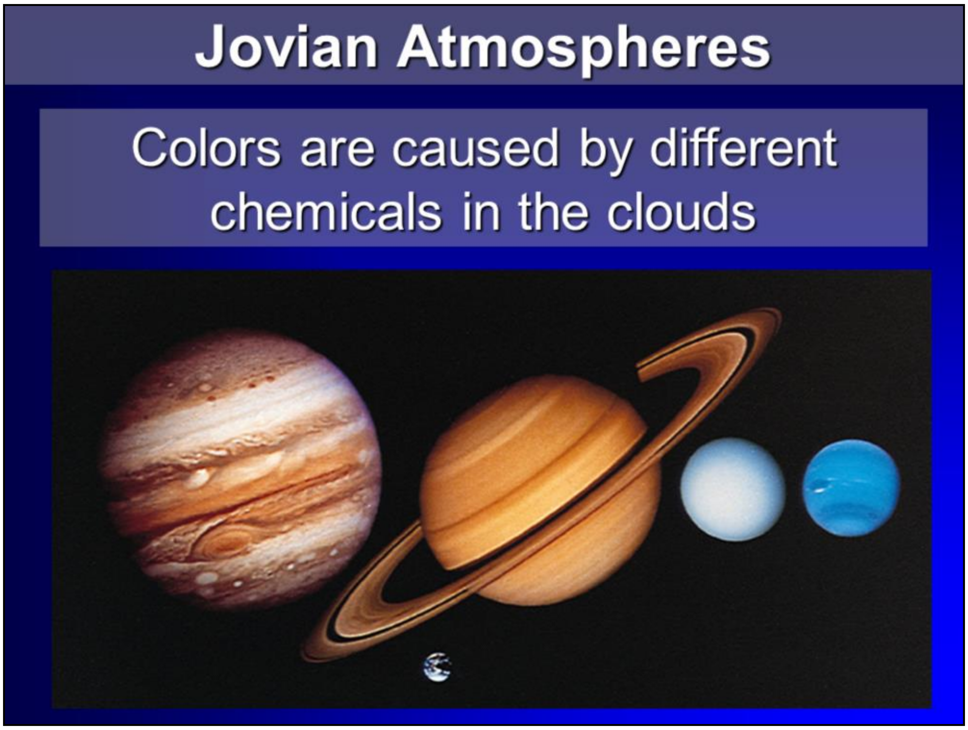
Many moons

- Over 100 combined
- Captured asteroids and comets
- Some similar to terrestrial planets

All have rings



Though it is possible that the stuff at the center of Uranus & Neptune are solid… hard to say for sure.



Different colors caused by different chemicals condensing into clouds (these are *trace* amounts)

White-yellow: Ammonia (NH_3)

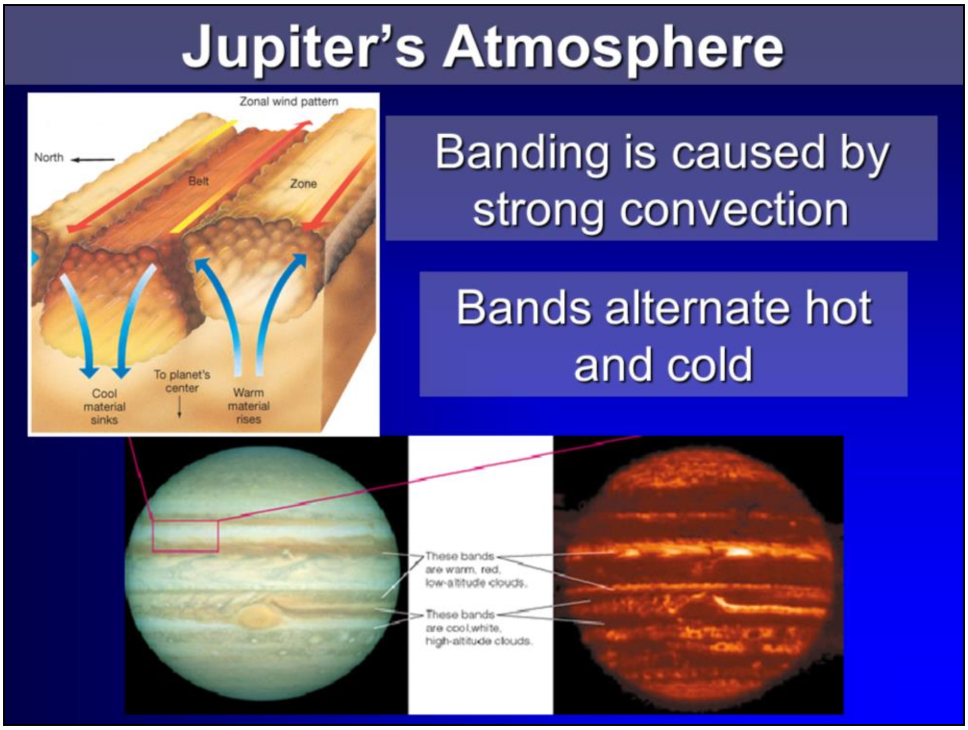
Blue-green: Methane (CH_4)

White: Water (H_2O)

Brown-rust: Ammonium Hydrosulfide (NH_4SH)

Atmosphere temperature and condensation points for each chemical explain planet colors

Uranus and Neptune are cold enough to form methane clouds which absorb red light and reflect blue light

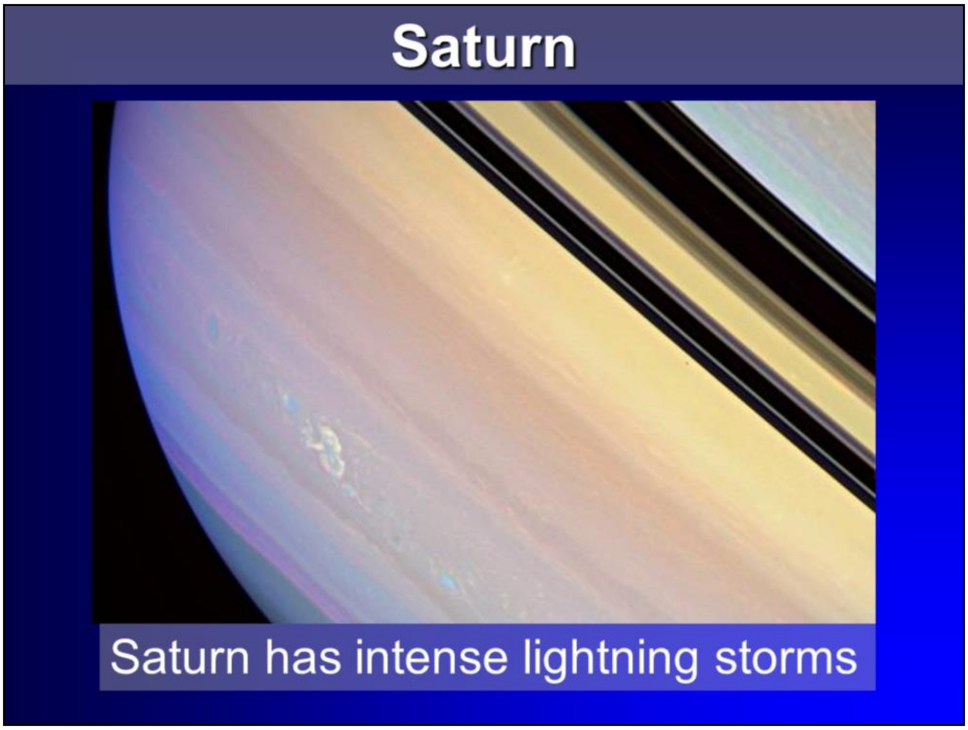


Severe winds within the troposphere, 300 miles an hour as measured by Galileo probe

Bands and zones created by strong convection

The great red spot is a giant hurricane – 2.5 times the diameter of Earth! It's been going on for over 400 years now.

Note: Jupiter (and Saturn and Neptune) actually emits more light than it receives!! This is because it's still undergoing gravitational contraction.

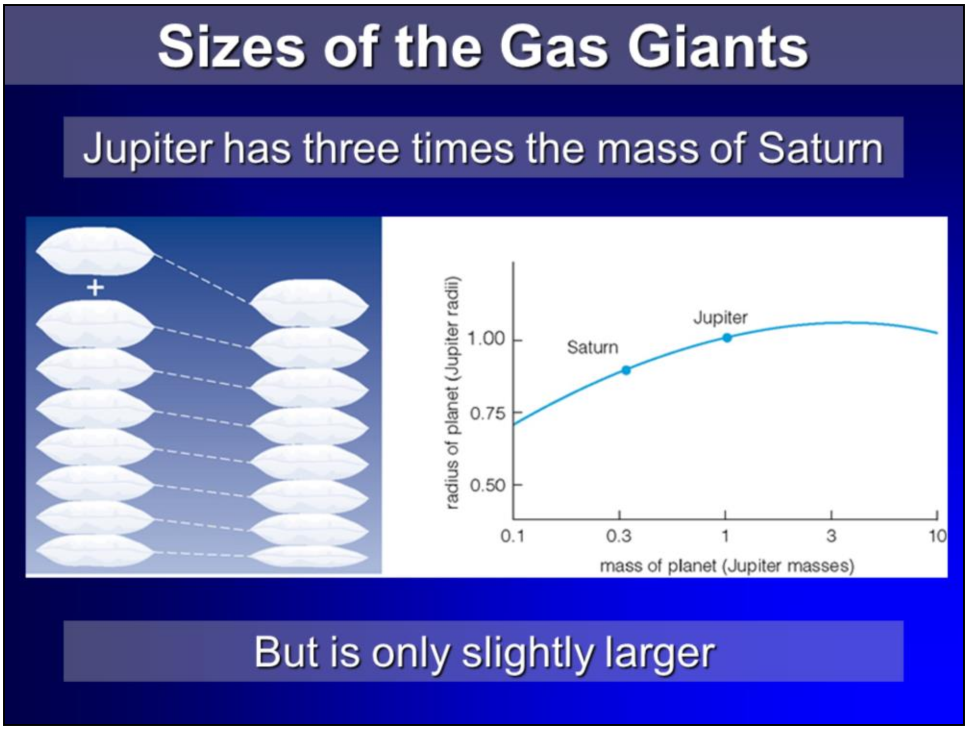


Saturn isn't as dense as Jupiter because it has less gravity

Also, its clouds are thicker due to less gravity; they get compressed less at the altitude that clouds form.

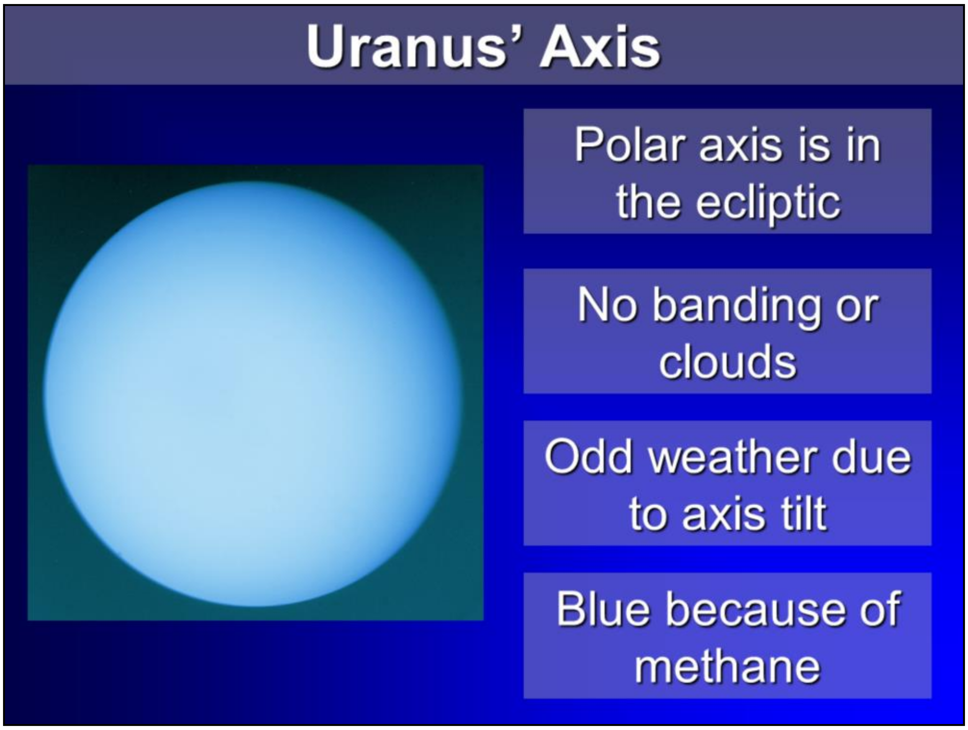
Like Jupiter, Saturn also emits more light than it receives; probably because He droplets are still condensing and raining down (sort of like differentiation, in a way)

Saturn has powerful lightning storms, ten thousand times stronger than on Earth, that occur in huge, deep thunderstorms columns nearly as large as the entire Earth. The storms occasionally boil up to the planet's visible surface.



Jupiter has 3 times the mass of Saturn but it is not much larger

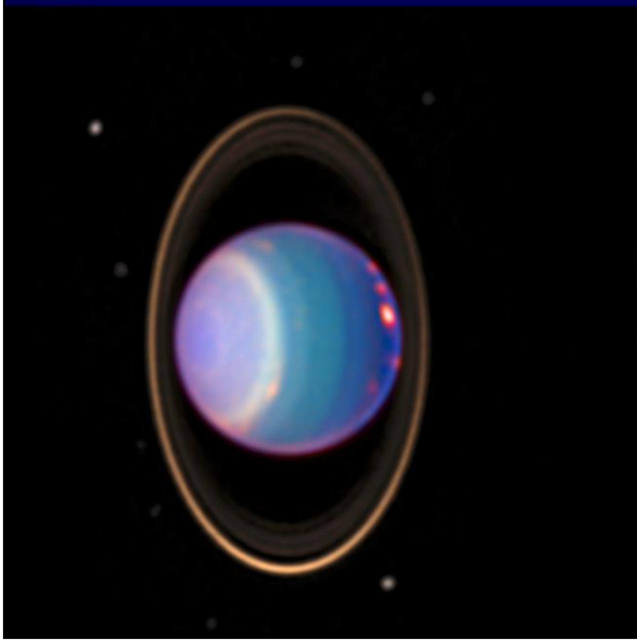
- Increasing the mass doesn't really increase the size because the added weight compresses the planet more
- Jupiter is about as big as planets can get
- Increasing Jupiter's mass would actually shrink the size



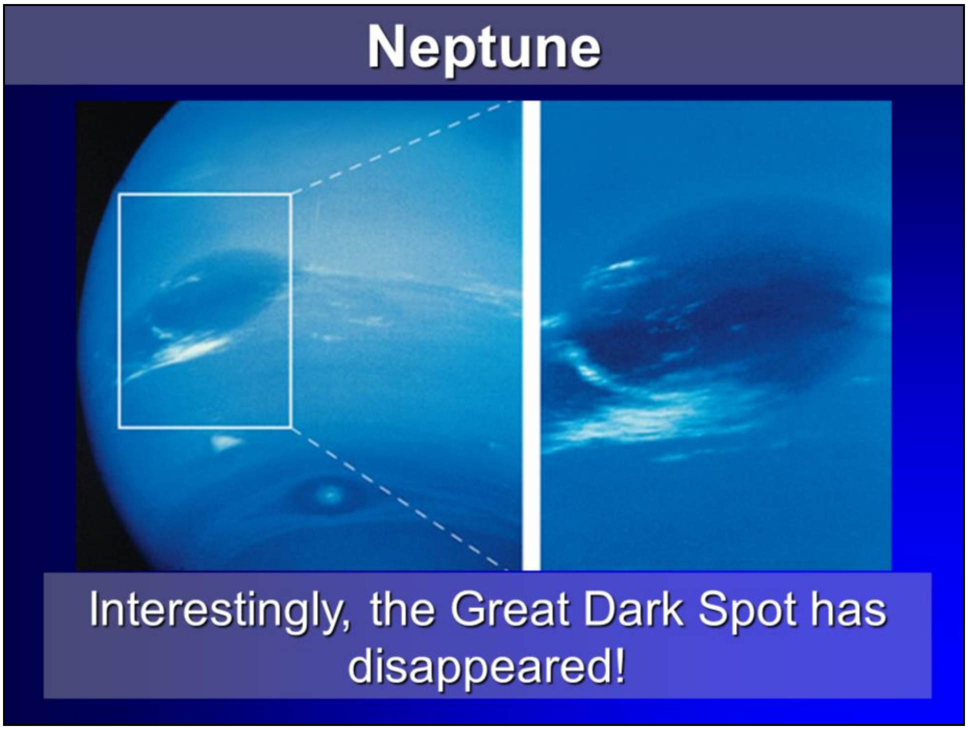
Uranus' rotation axis tilt leads to extreme seasons

- No storms
- No clouds or banded structure seen in 1986 when N pole facing Sun
- HST saw storms in 1998, perhaps because the S hemisphere is warming up

Uranus



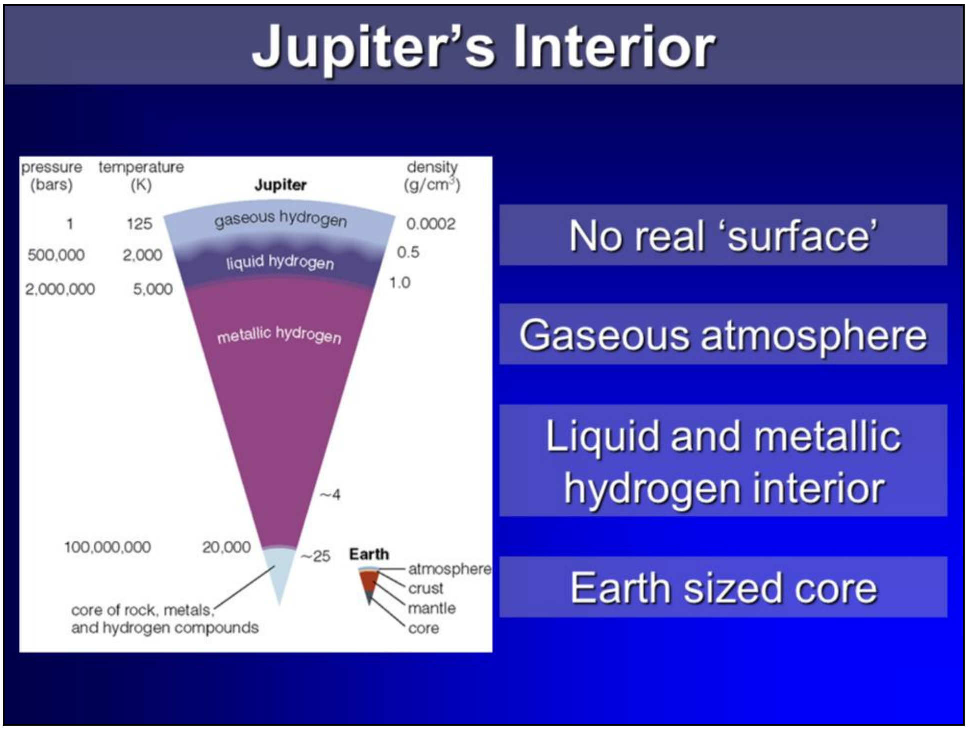
But in the IR, we do see storms and bands!



Neptune's winds go the wrong way around – opposite its rotation!

They're also really fast, at 2,000km/h!

Neptune also emits more light than it receives… we don't know why, as it does not appear to be contracting still. Maybe the methane insulates it?

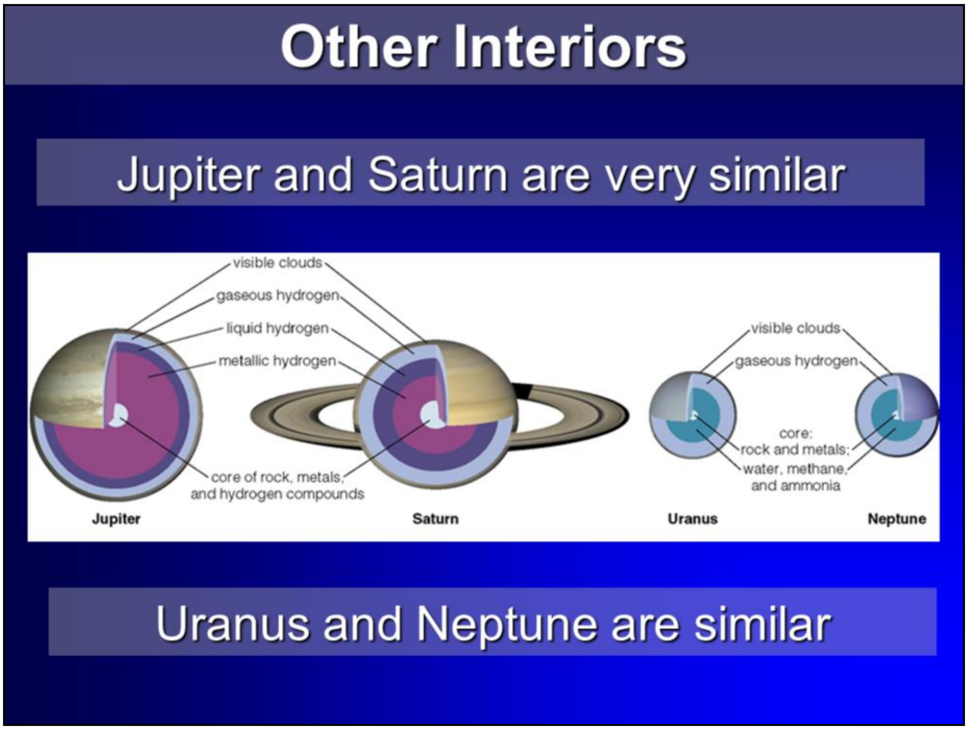


Temperature, density, and pressure all increase with depth

Jupiter's core is slightly larger than the Earth, but 10 times as massive and 5 times as dense due to the intense pressure from the material stacked on top of it

Metallic Hydrogen

Hydrogen molecules share the same electrons



The cores of all Jovian planets appear roughly the same

Composition: rock, metal, hydrogen compounds

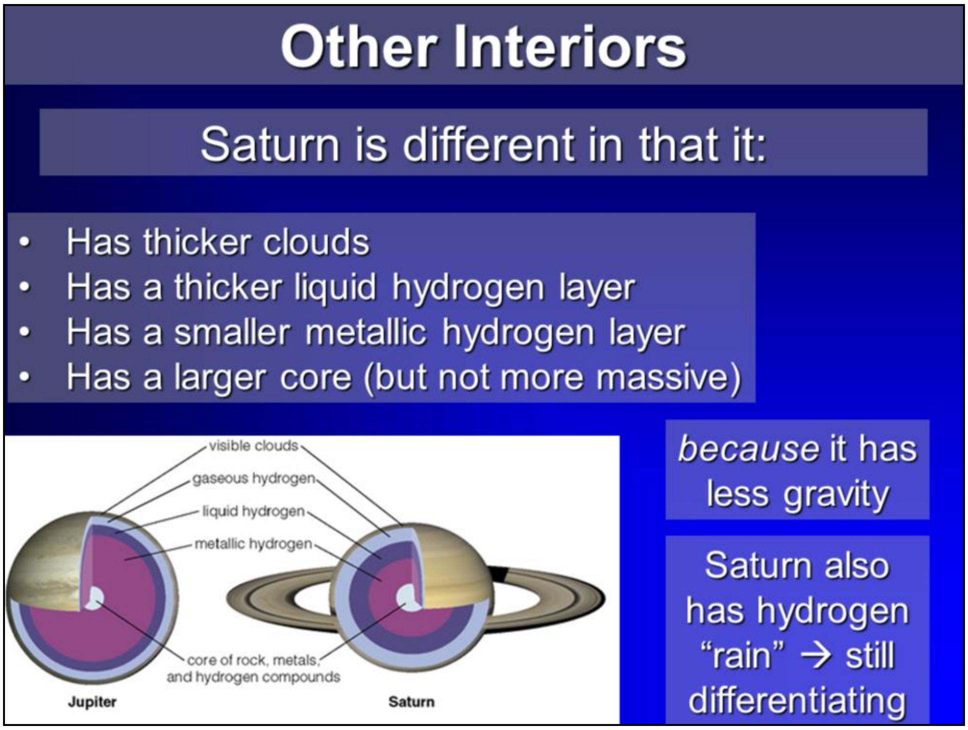
- Small rocky cores were probably the seeds of accretion (~10 times as massive as Earth)

Uranus and Neptune captured less matter from the solar nebula than Jupiter and Saturn

- Accretion of planetesimals took longer
- Had less time before material was cleared out by the solar wind

Only Jupiter and Saturn have metallic hydrogen

Jupiter, Saturn, and Neptune emit more light than they receive from the sun: Jupiter is still contracting; Saturn is still differentiating (see next slide); not sure what's going on with Neptune and Uranus.



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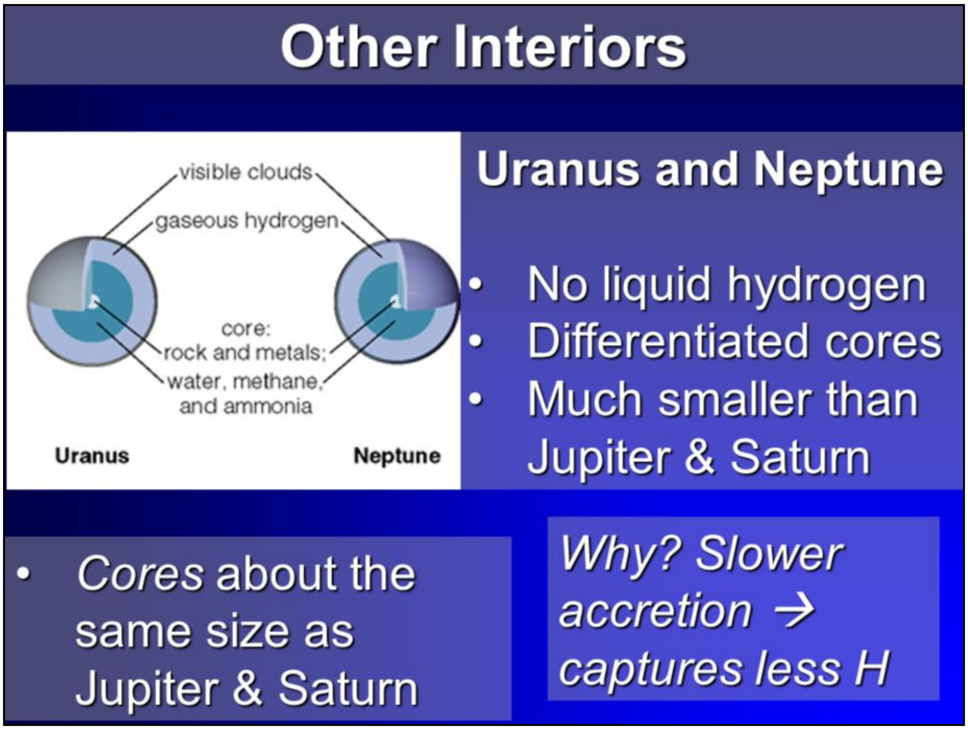

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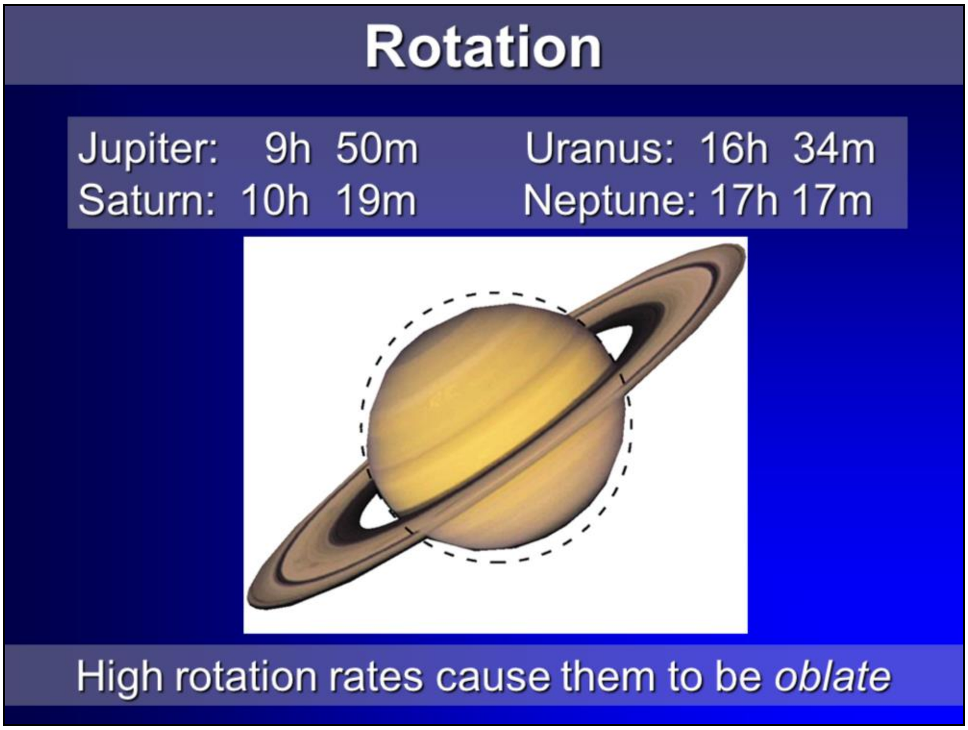
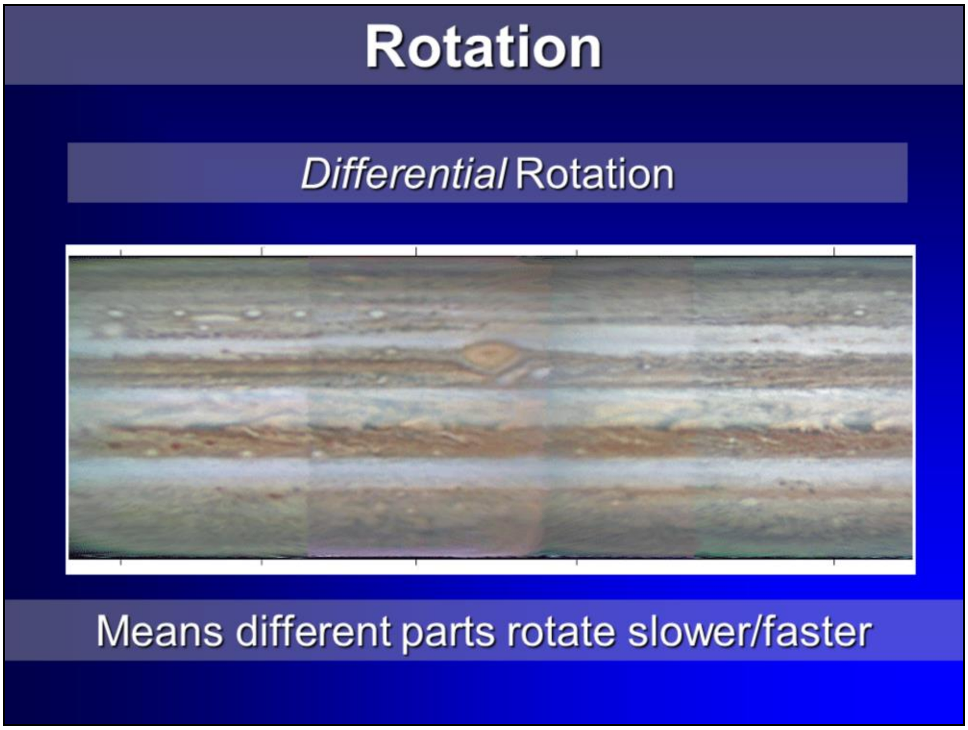
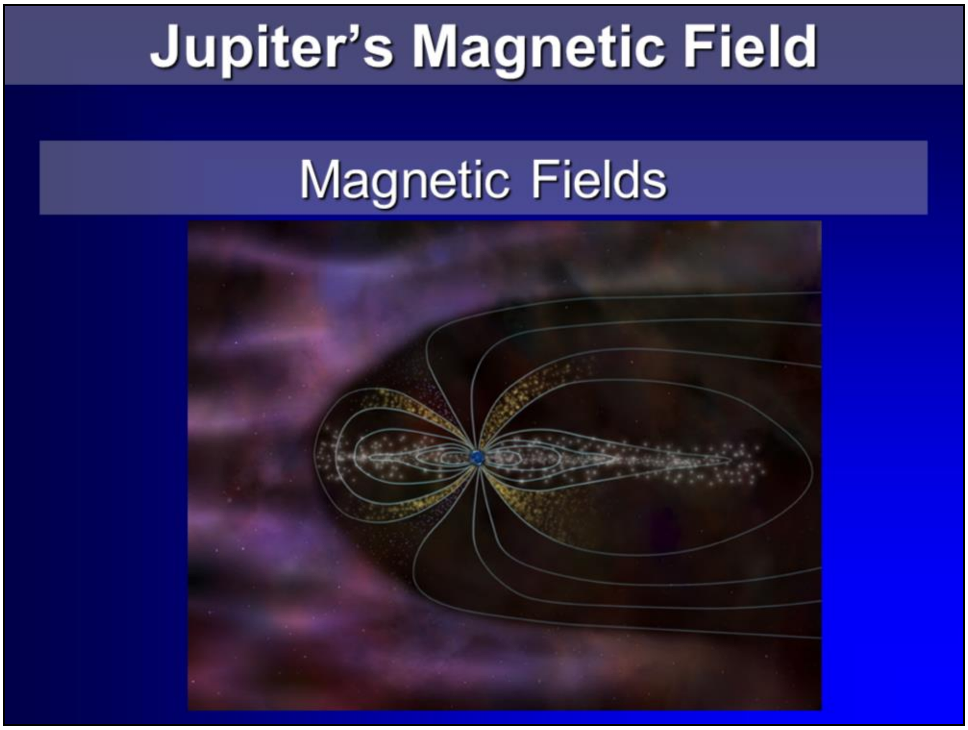


Just like pre-solar nebula spin into a disk… rapidly rotating planets spin (slightly) into a disk

Jupiter completes one rotation in 9.8 hours. Saturn 10.23 hours



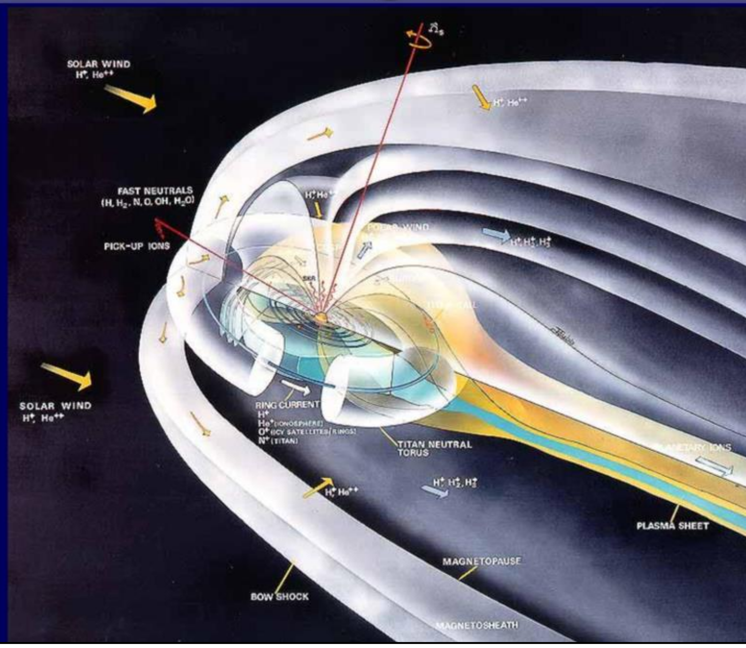
Jupiter has some pretty fast winds



Plasma sheet in the plane of Jupiter's orbit, due to ions that are trapped by the magnetic field. Io (and Europa a little) put out atoms into the Jovian environment. Neutral ones get trapped in a torus around the moon; ions often make it to Jupiter causing the aurora.

Jupiter's magnetic field is VERY strong, due to the spinning metallic hydrogen at its center.

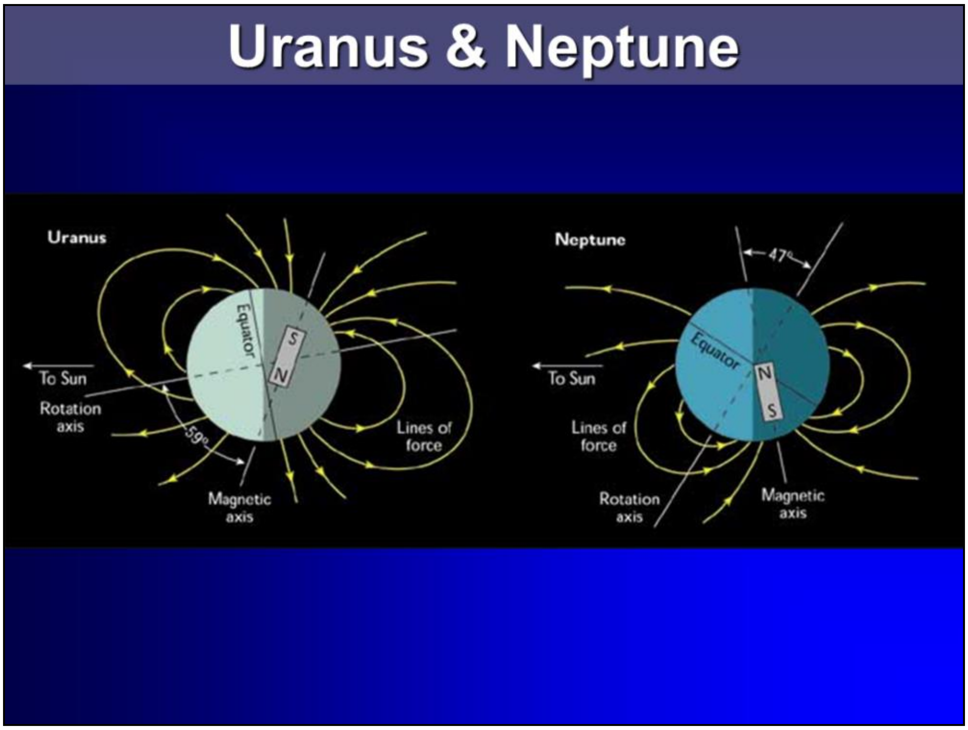
Saturn's Magnetic Field



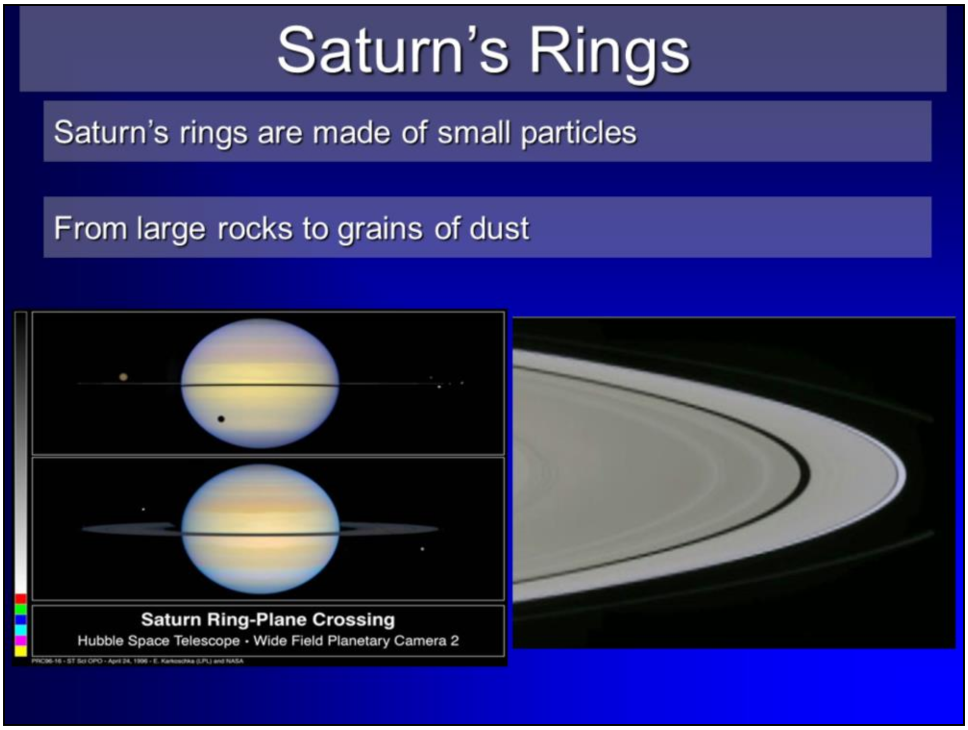
Saturn's magnetic field is similar to Jupiter's. There is a neutral torus around Titan, a plasma sheet, etc.

It was expected that a large amount of neutral Nitrogen would escape from Titan's atmosphere; we don't see that though. So is less Nitrogen escaping than expected, or is it somehow being removed? We don't know yet, but we're trying to find out!

Uranus and Neptune have smaller magnetic fields.



Uranus and Neptune have weird magnetic fields. Neither are aligned with the spin axis. With Uranus, the extreme tilt and strange seasons likely come into play. Neither of the magnetic field axes pass through the center of the planet. Since there is not a metallic hydrogen core, the process of generating the magnetic fields is poorly understood; it's entirely possible that it's generated at higher altitudes, such as in the water-ammonia ocean at the center.



Easily visible through a telescope

Consist of many small particles

From large rocks to tiny dust grains

Mostly made of water ice

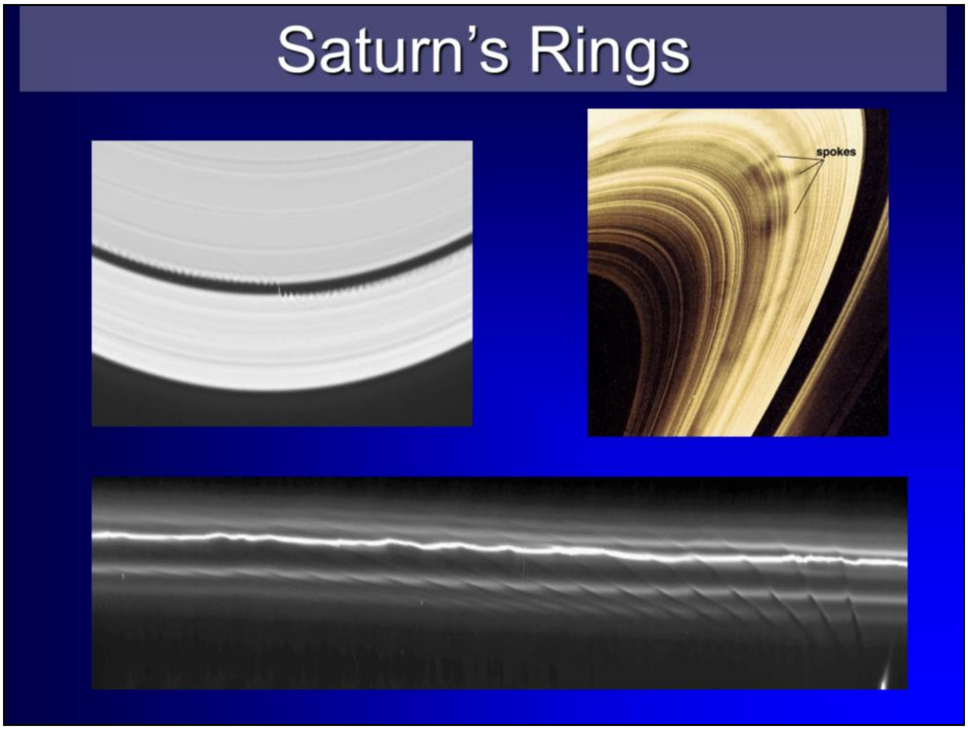
The brighter rings consist of more material, so they reflect more light. Darker rings have less material

Very thin due to constant collisions

A few meters thick, 270,000 km in dia.

Invisible when viewed edge on

Your book notes that the rings are pretty young and so must be replentished. In fact, we DO see moons being ground apart, and even reforming, in the rings.



Aside from the rings, we see gaps and ripples

Gravitational interaction with moons inside the rings push particles into specific orbits

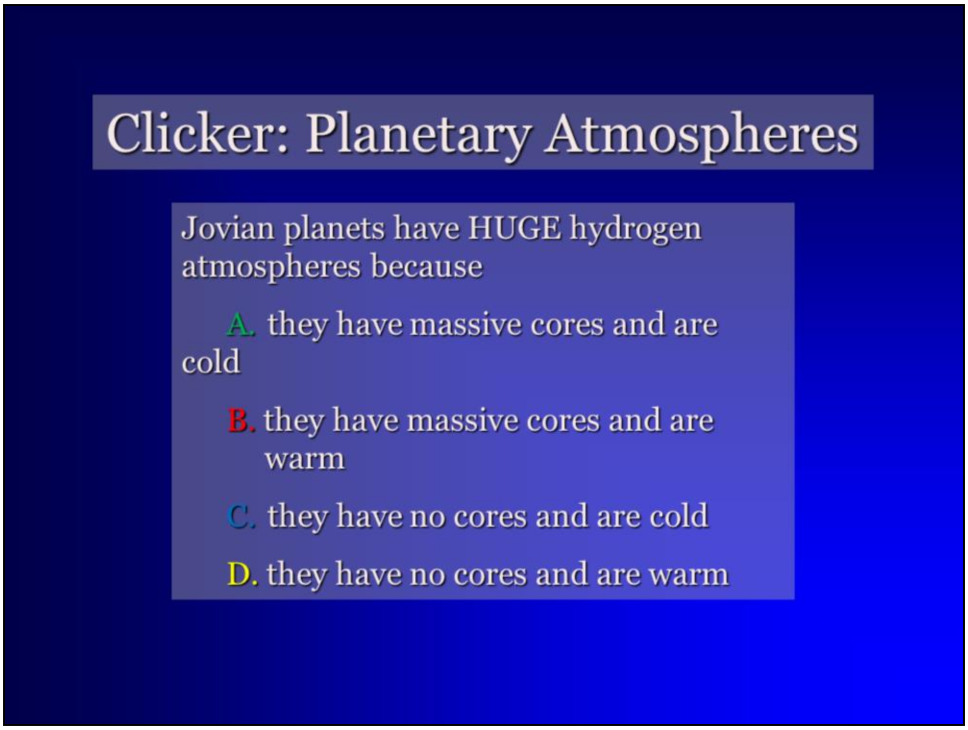
clear gaps

Interaction with larger, distant moons can clear gaps and form ripples.

Dark patches called 'spokes' appear and disappear but origin is unknown

Perhaps they might be particles of dust drawn out by Saturn's magnetic field

Origin of rings is probably a moon destroyed by tidal forces



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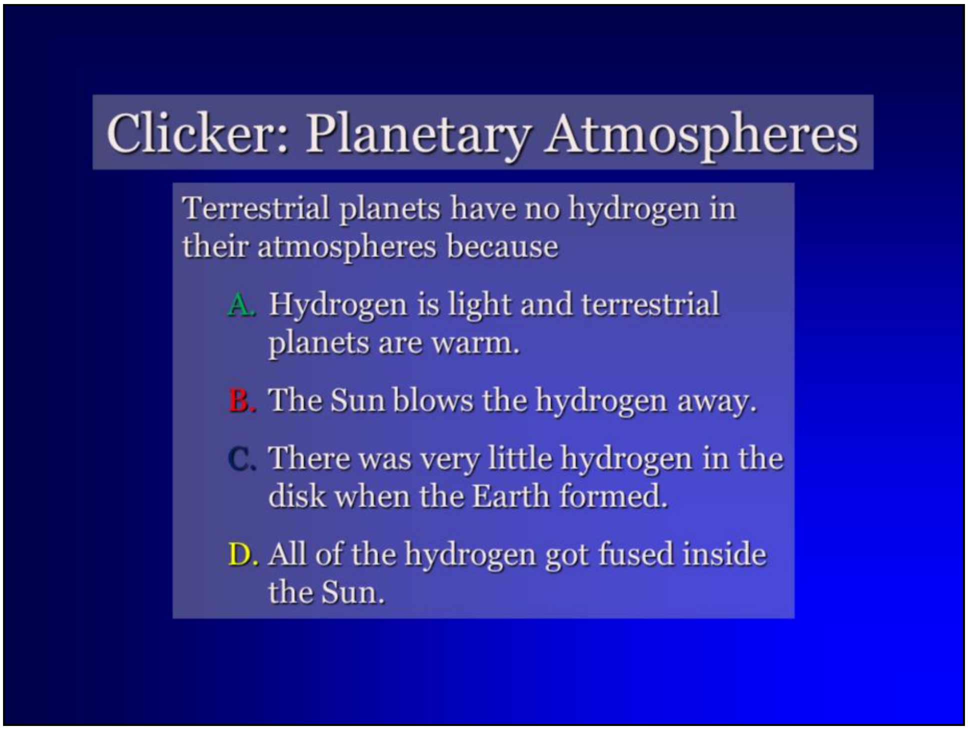
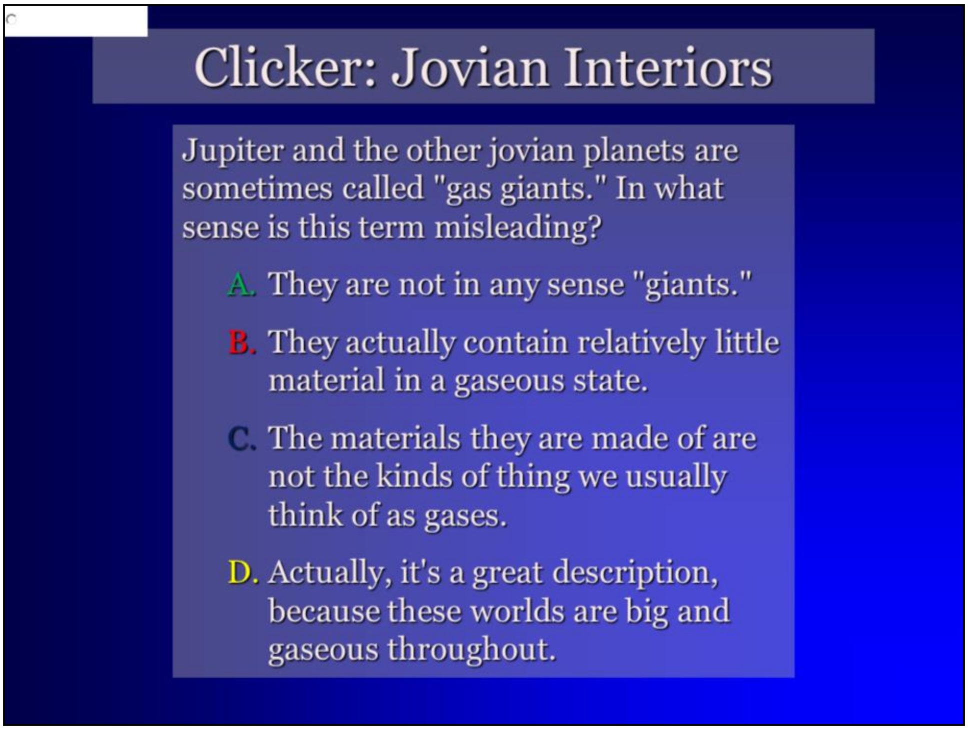
It’s cold where Jupiter forms. And, the jovian cores are BIG.

So, hydrogen isn’t moving very fast. It doesn’t exceed the escape velocity.



A.

It’s too warm here, and terrestrial planets aren’t very massive.
So, hydrogen exceeds the escape velocity.



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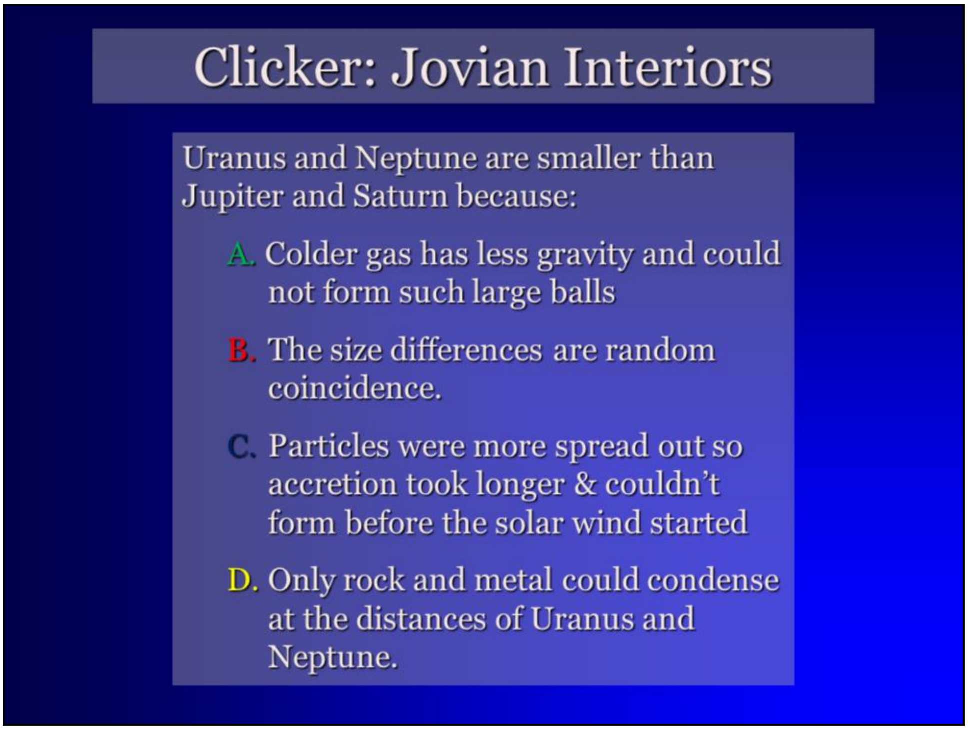

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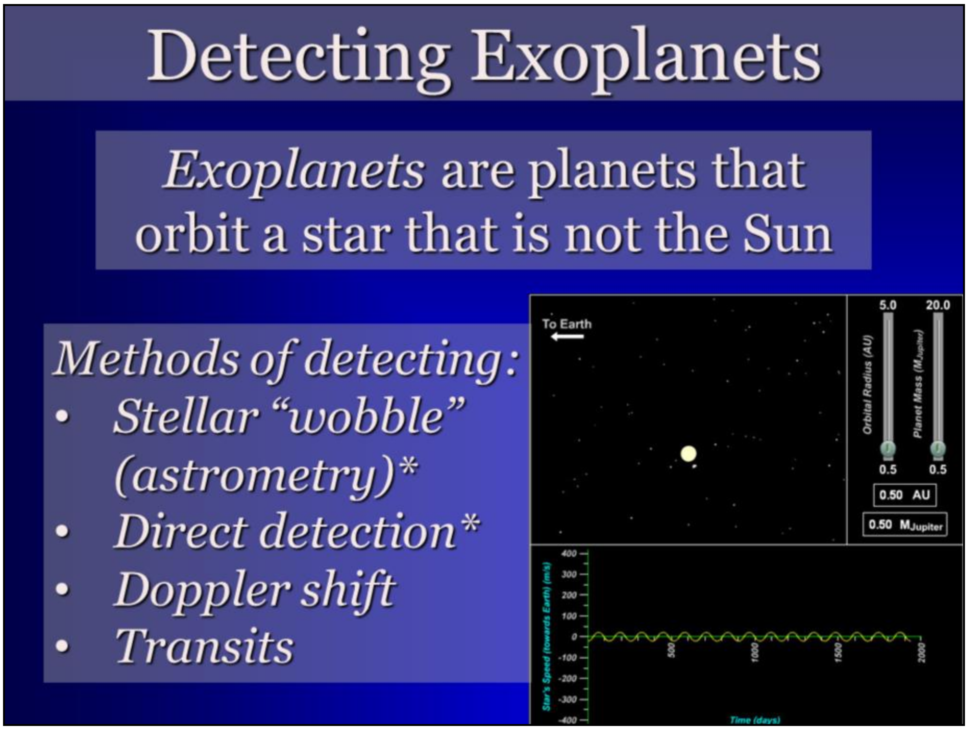
So, hydrogen exceeds the escape velocity.

What are the things that life needs to exist?

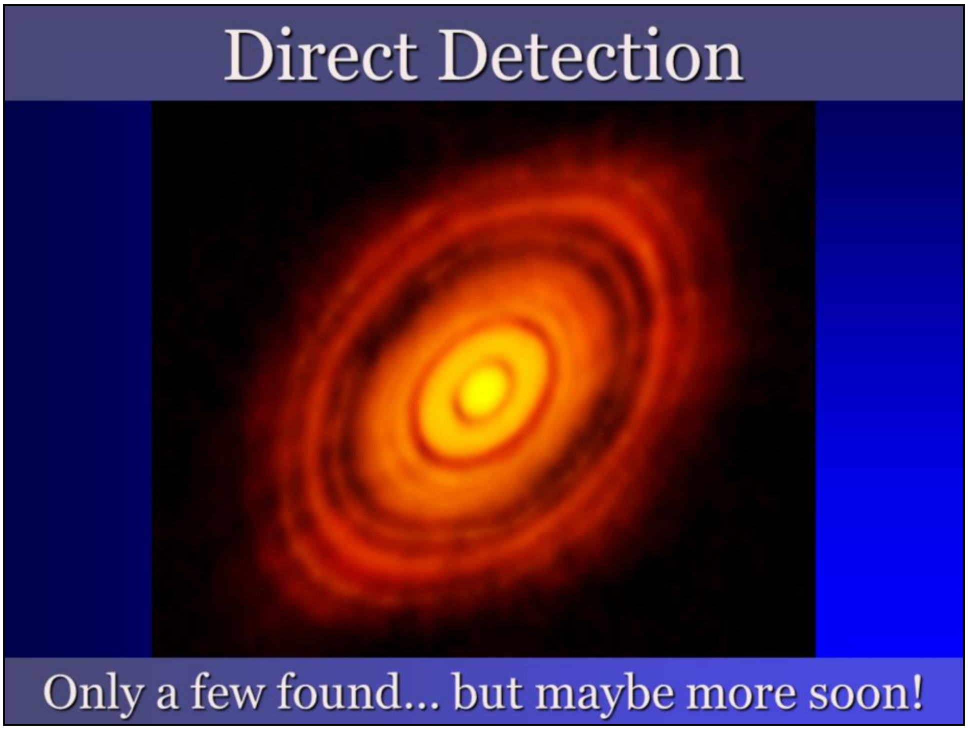
Are each of these *necessary*, or can we get around them somehow?

If we want to find life, where should we look?



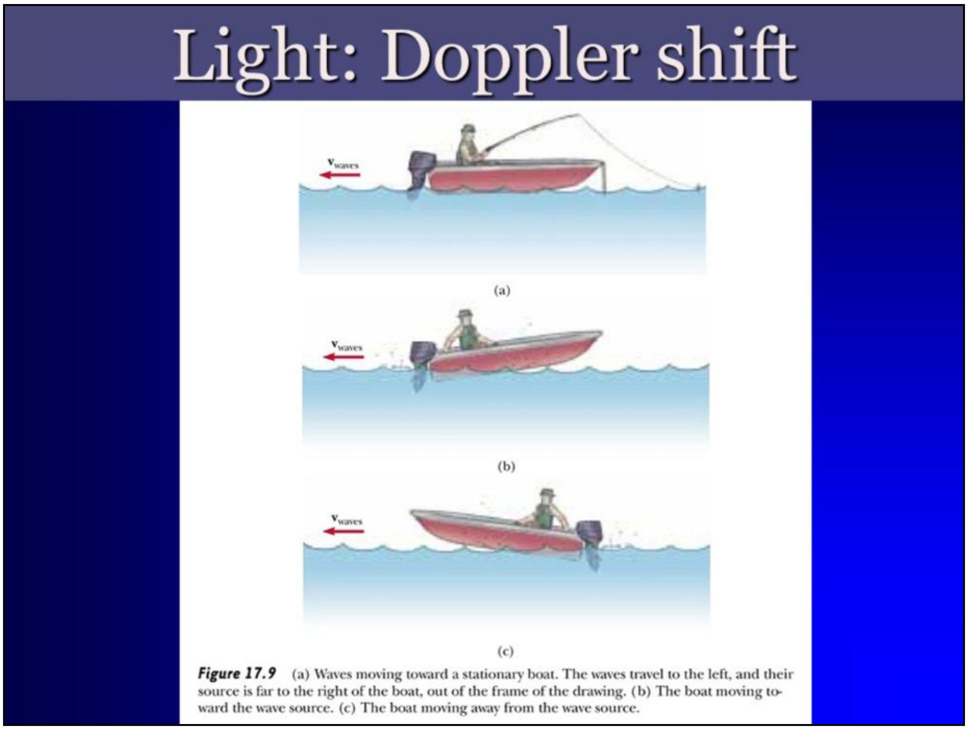
Mostly, we can only see the effect that they have on their parent stars.

Really big planets (Like the size of Jupiter) can cause a significant wobble in the star… but this can be hard because it's best if they are far from their star, which makes the wobble take a long time. Best for nearby stars, and only works in rare cases. The GAIA mission that the European Space Agency (ESA) is running is currently working on doing this accurately.



It's VERY HARD to detect extra solar planets directly. Rare cases only….

As the Alma telescope comes online this will become easier – but most likely will focus on the planetary systems already detected. This is a *proto*planetary disk, one of the first ones imaged! Look at those gaps! Just like we predicted!



We can detect that wobble through the **Doppler Effect**.

The absorption lines in the star shift back and forth as the star wobbles first away from us and then towards us.

So let's talk about Doppler shift (we will need it for other things as well).

If you think about waves on a lake, the water waves move at a constant rate

When you move TOWARDS the waves, the frequency with which you get hit in the head INCREASES

When you move AWAY from the waves, the frequency with which you get hit in the head DECREASES

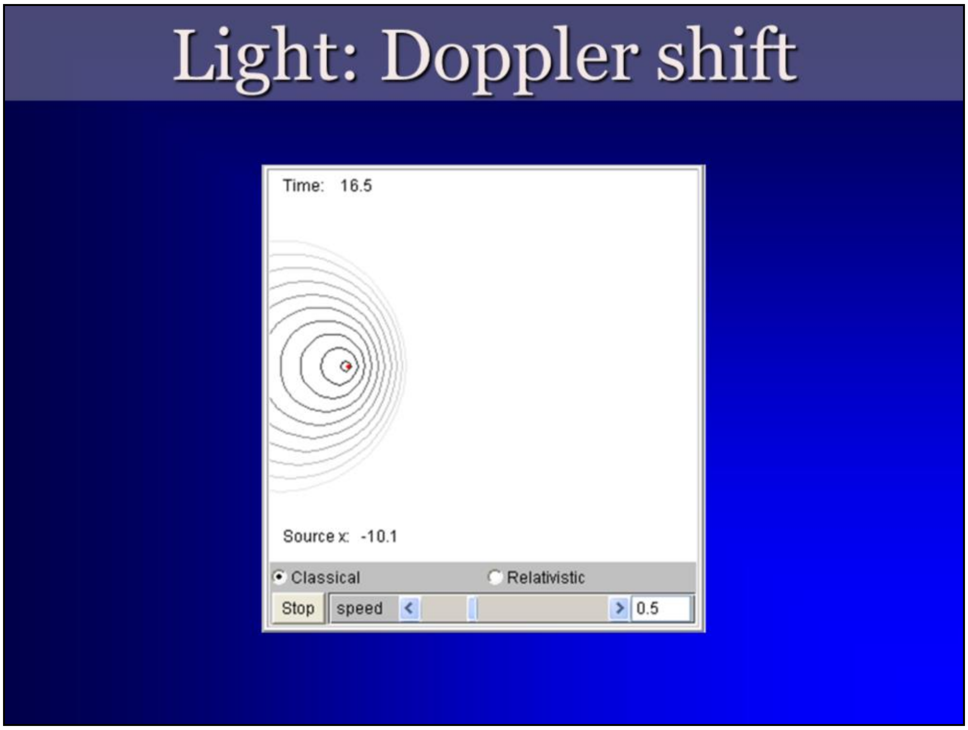
Another analogy:

A baseball machine shoots baseballs at a constant rate…

When you run TOWARDS the machine, the frequency with which you get hit in the head INCREASES

When you run AWAY from the machine, the frequency with which you get hit in the head DECREASES

It doesn’t matter if it’s the machine moving (the thing generating the waves) or if you’re moving; it’s the RELATIVE velocity that matters.

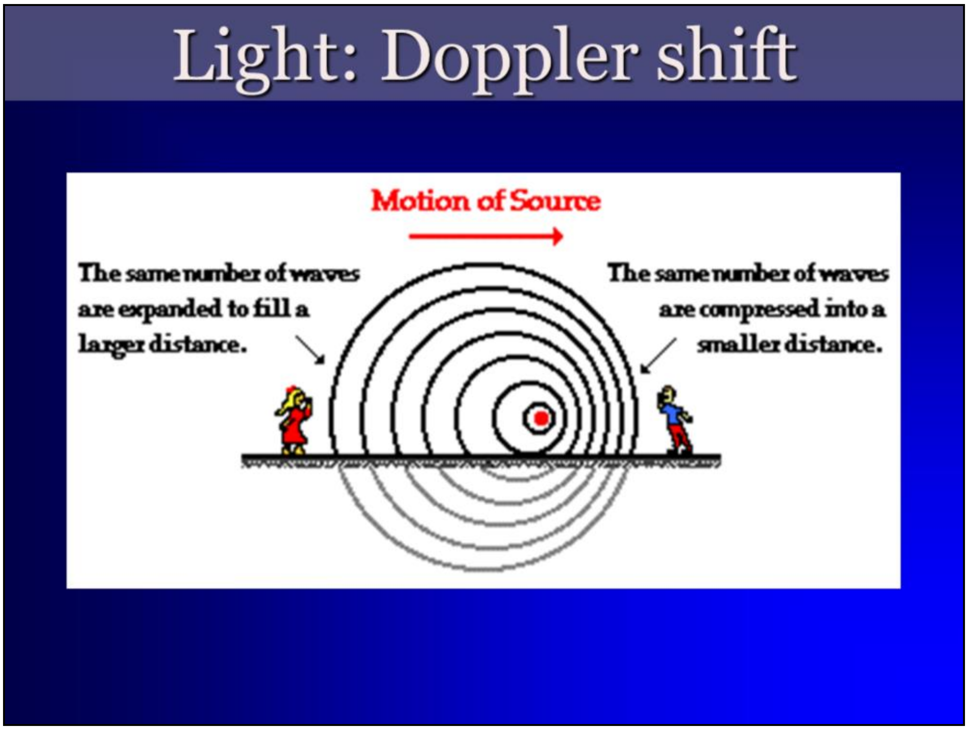


Notice in this example the people are stationary and the wave source is moving, as opposed to the boat/baseball examples.

Either one could be the case, the end result is the same.

(In fact, Newton says that you can't really tell which is moving unless one is *accelerating*. If velocities are constant than each one can claim it is stationary and the other is moving.)

http://www.fisica.uniud.it/~deangeli/applets/Multimedia/Waves_java/Doppler/doppler.htm

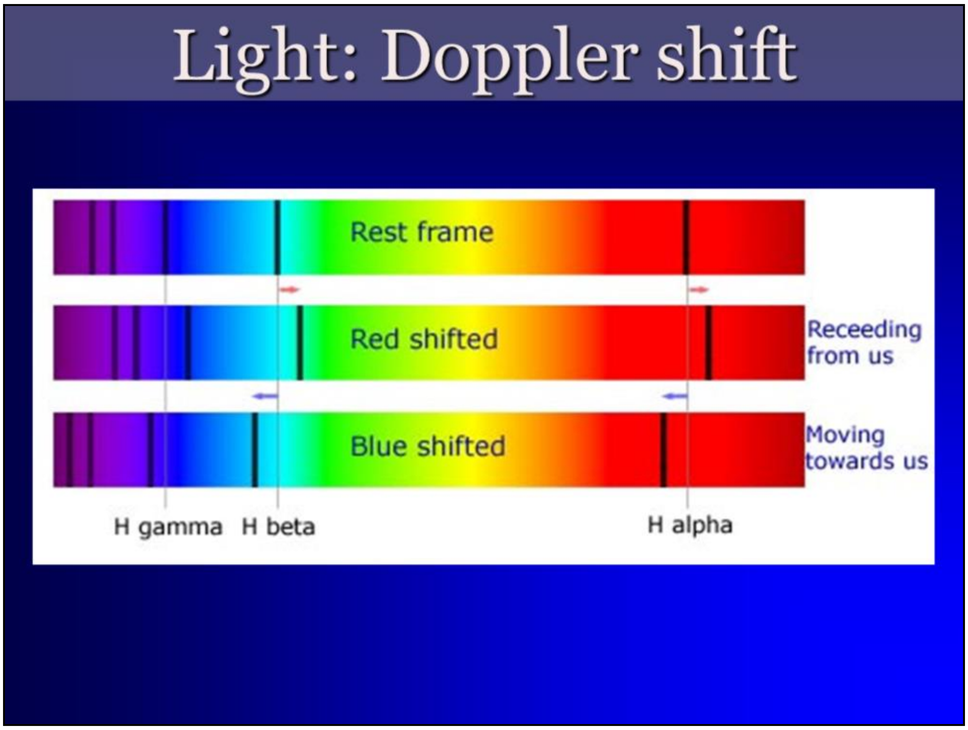


The person on the left sees a longer wavelength (redder light)

The person on the right sees a shorter wavelength (bluer light)

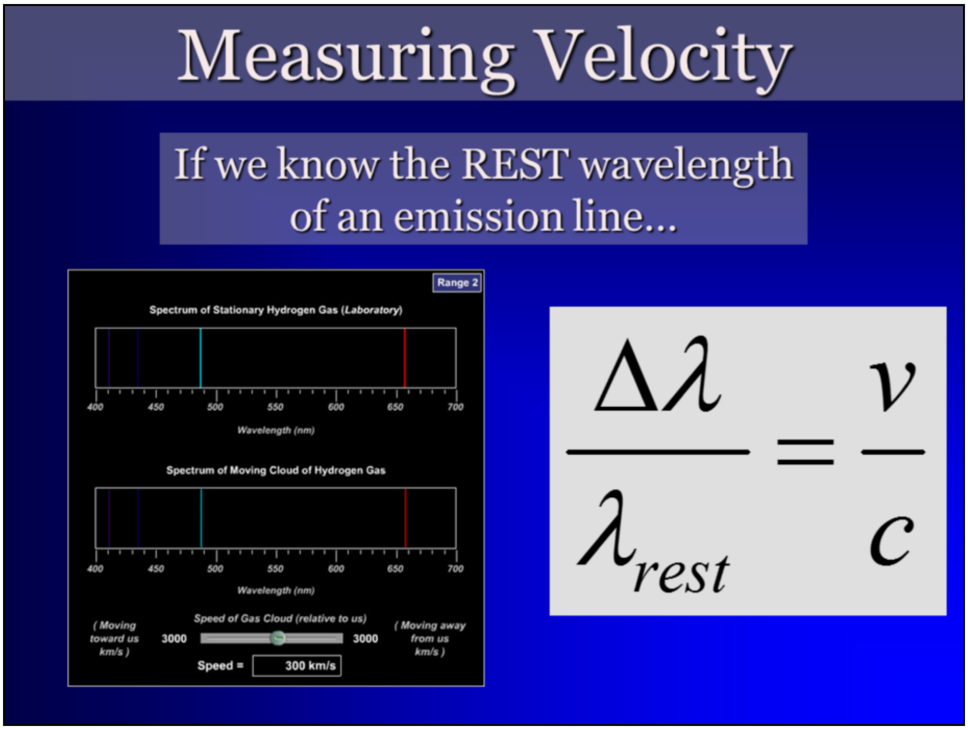
Redder/bluer are relative to the source's emitted light (the source sees itself at rest/not in motion so emits like it were stationary).

Image from The Physics Classroom: http://www.physicsclassroom.com/class/sound/Lesson-3/The-Doppler-Effect-and-Shock-Waves



In terms of spectra, this is what we see.

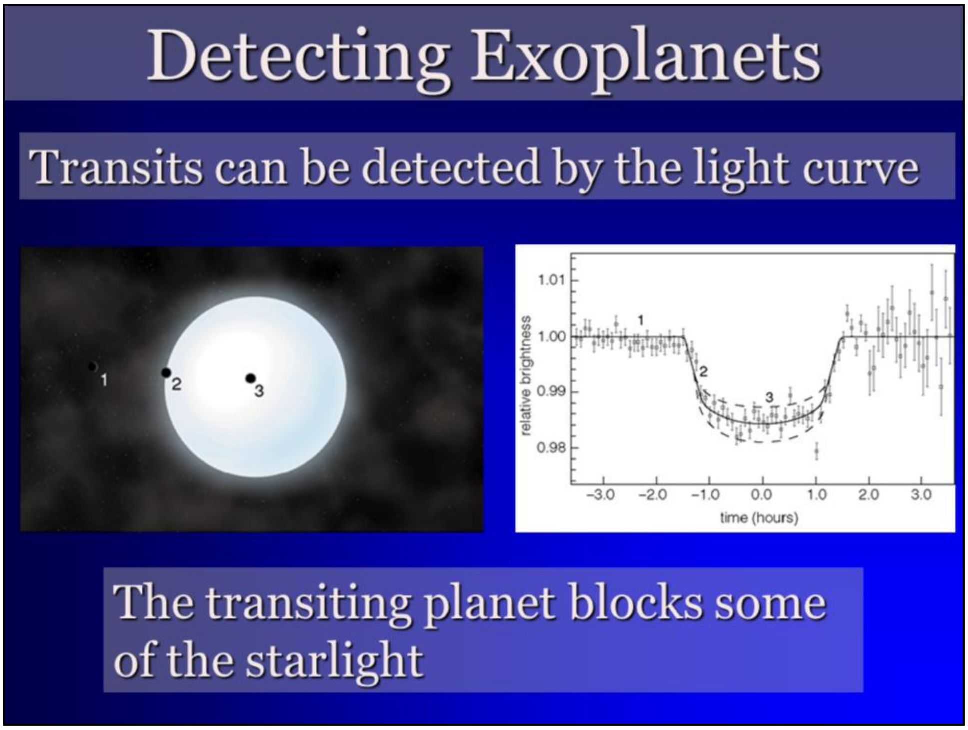
Image from http://www.atnf.csiro.au/outreach/education/senior/astrophysics/spectra_info.html



if we know the REST (not moving toward or away from us) wavelength we can calculate the VELOCITY…

file:///U:/Astro/Powerpoints/CP_InteractiveFigs/IF_5.22_doppler_shift_emission_line.html

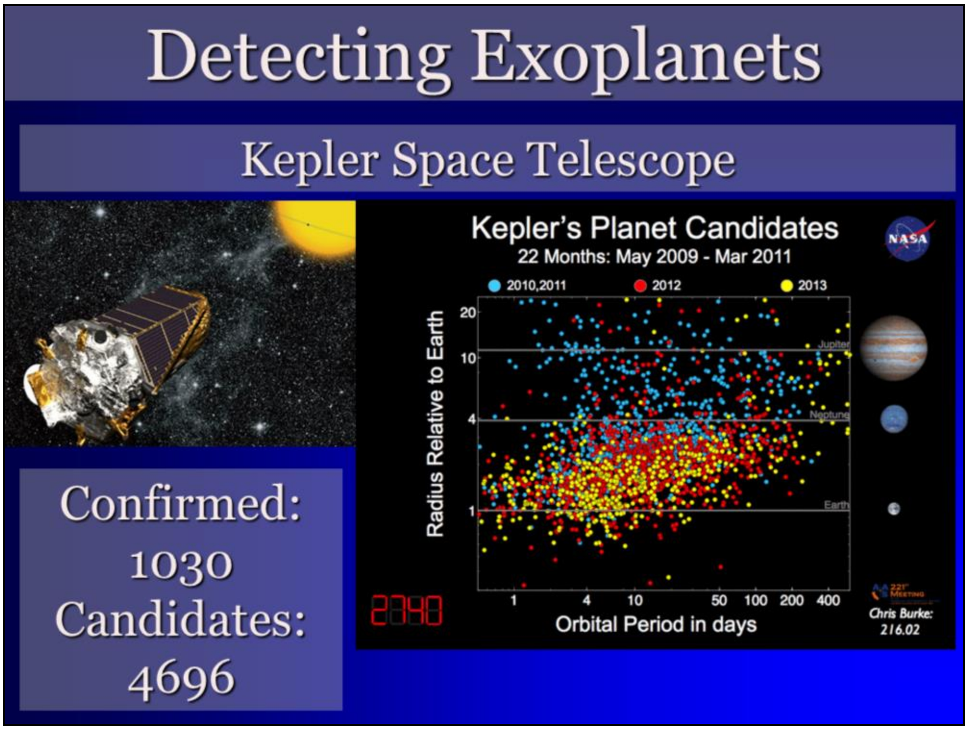
file:///U:/Astro/Powerpoints/CP_InteractiveFigs/IF_5.23_star_motion_doppler_effect.html



We can also, if we are very lucky and happen to see a planetary system aligned juuuust right, see the starlight dim slightly as the planet passes in front of it.

This method favors big planets close to the star.

Show:
file:///U:/Astro/Powerpoints/CP_InteractiveFigs/IF_13.5_planetary_transits.html



These are only the ones that have more than one transit seen, and only from Kepler data. There are others detected as well (not just with Kepler) as well.

Life…