Detecting Extra Solar Planets

The Extrasolar Planet Count

Currently, 288 stars have been discovered to have planets. Some of these have more than one, so a total of 380 planets have been discovered as of today.

Over 90% of these have been discovered using the Doppler effect. The rest were found using either astrometry (wobbles), or transits (periodic changes in stellar brightness).

You can keep up with the current extrasolar planet count at the Jet Propulsion Laboratory's PlanetQuest web site:

http://planetquest.jpl.nasa.gov

Detecting Extra Solar Planets

The first planet ever detected outside our solar system was discovered in 1995 by Swiss astronomers Michel Mayor and Didier Queloz.

By observing the spectra of star 51 Pegasi, the were able to detect very tiny, very regular Doppler shifts in the colors of light it was emitting. These shifts are caused by the gravity of a very large planet causing the star to wobble slightly.

The planet itself is too dim to see directly, but the influence it has on the star is observable.

51 Pegasi: the first extrasolar planet

The star 51 Pegasi is very similar to the Sun, just a little more massive and a little bit brighter. The planet, called 51 Pegasi b, is about half Jupiter's mass, but is 10 times closer to its star than Jupiter is to our Sun.

If fact, at that distance, the planet really ought to be boiling away into nothing from the heat of the star. The existence of 51 Pegasi b is forcing astronomers to re-think our theories of how solar systems form.

Detecting Extra Solar Planets

In order understand how astronomers can detect planets around stars that are many light years away from us, we need to learn about some of the tools astronomers use:

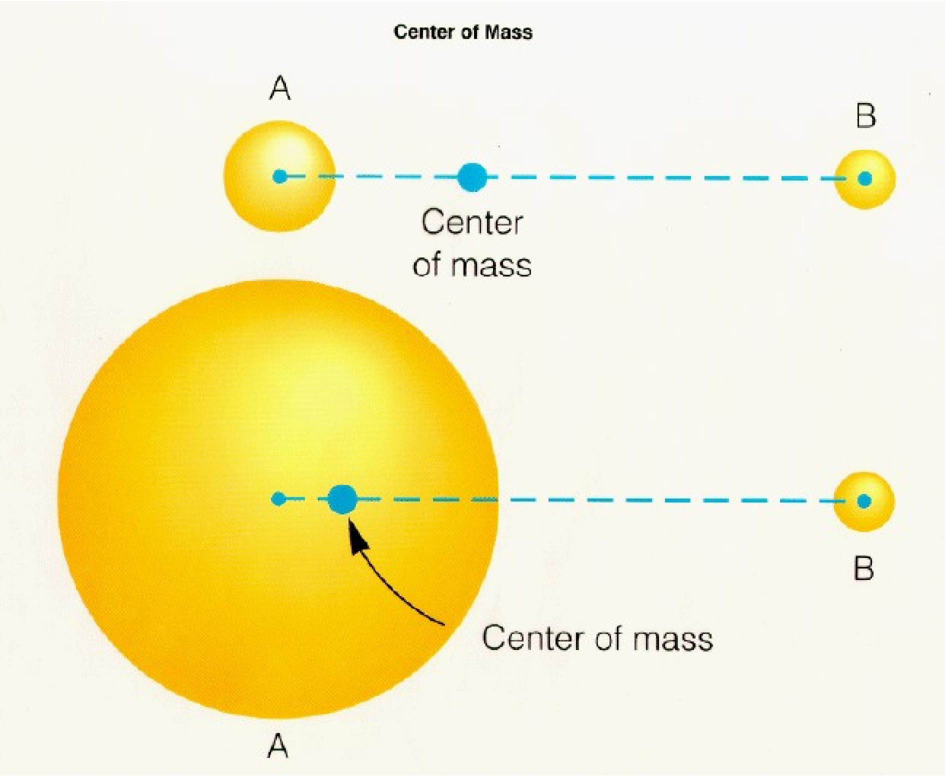
1) Gravity

2) Light

3) the Doppler effect

You can't see extra solar planets directly (yet!) because they're too faint, but you can still tell they are out there because of how they influence their own Suns. The three tools above show us how.

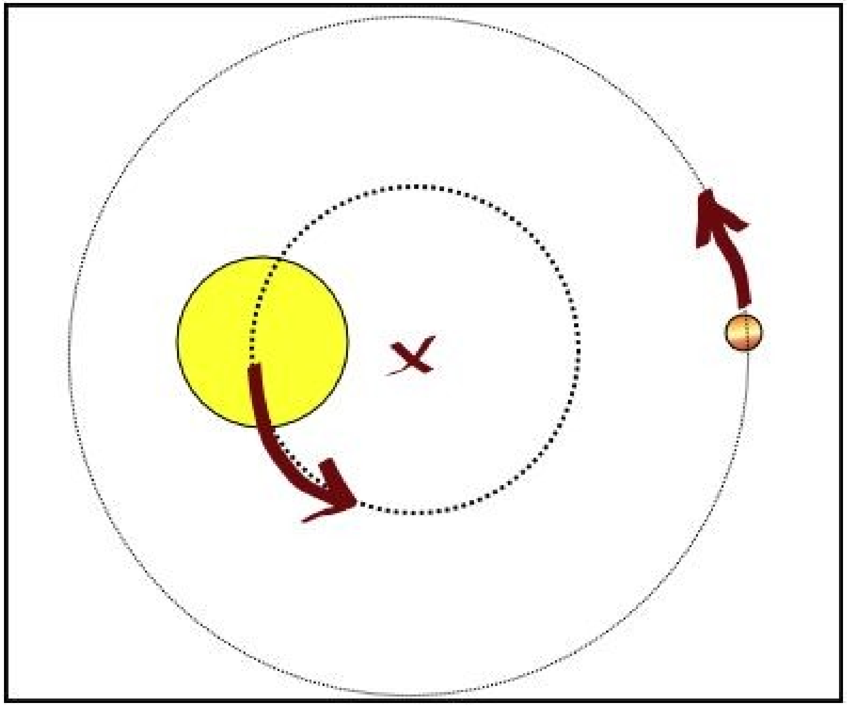
Gravity



When a planet gravitationally orbits a star (like Earth around the Sun), it really orbits the *center of mass* of the combined two objects. The center of mass is kind of like the average location of matter in the two objects. When one object is much more massive than the other, the center of mass may be inside the bigger object.

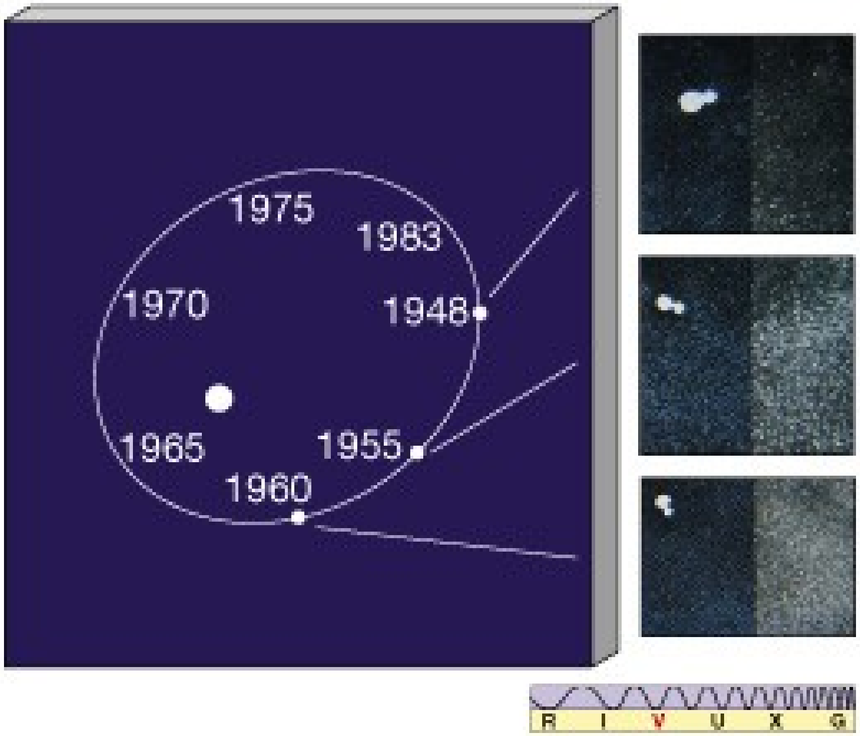
Center of Mass

Gravity



This picture exaggerates the effect to make it easier to see, but it does work just this way – both the planet *and the star* orbit around their common center of mass. The heavier the planet, the more the center of mass moves away from the star, and the more obvious the movement of the star becomes. Having planets far from the star also increases the motion.

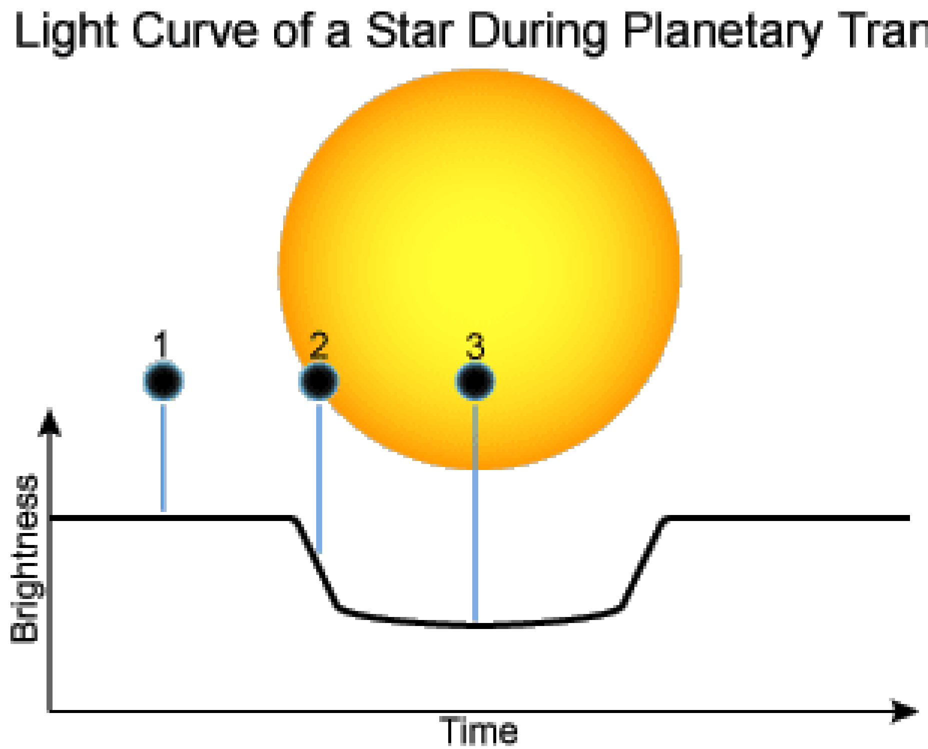
Gravity



When the planet is massive enough, it tugs on its sun enough that astronomers can see the sun moving around and around in its orbit, even though the planet is too faint to be seen. This kind of work is called *astrometry.* It works best when the planets are close to their stars, and very massive.

If the star system is too far away (more than 10 light years for Jupiter-type planets in Jupiter-type orbits) the movement of the star is too small to detect.

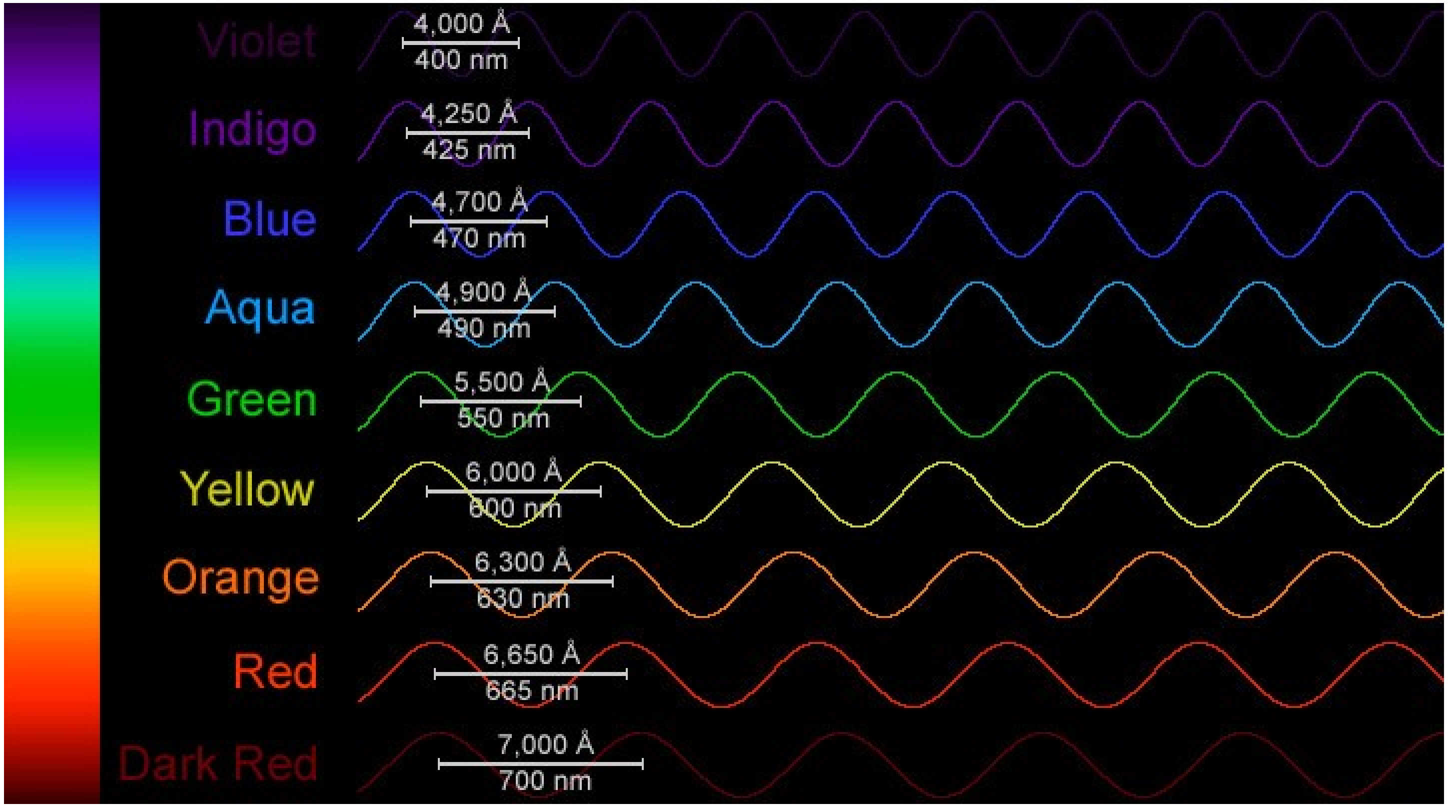
Light



Extrasolar planets have also been detected when they *transit*, or cross in front of their star as seen from the Earth. This is basically like a solar eclipse, only the planets don't cover much of their sun when they cross, so instead of blocking all of the light, they only block some of it. The lightcurve is a graph of the star's brightness versus time, and extrasolar planets show up as dips in the curve. About 20 planets have been discovered this way.

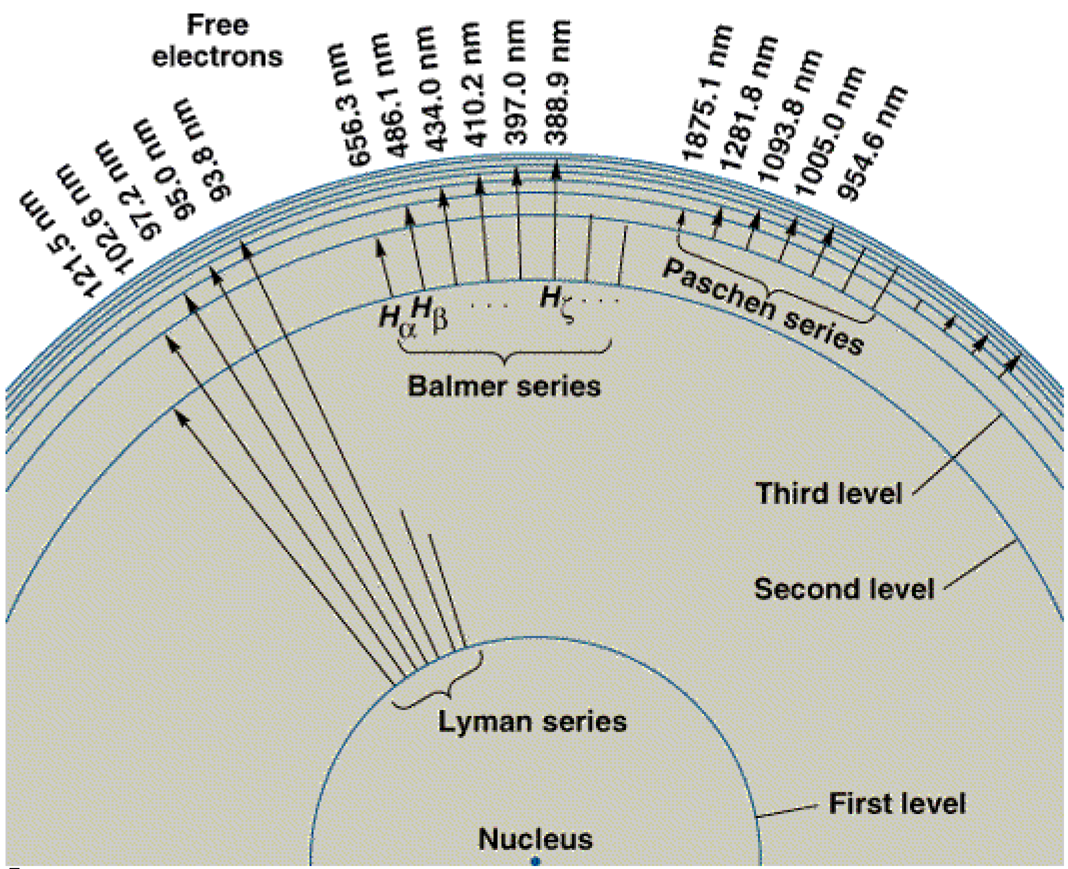
Transit Applet

Light

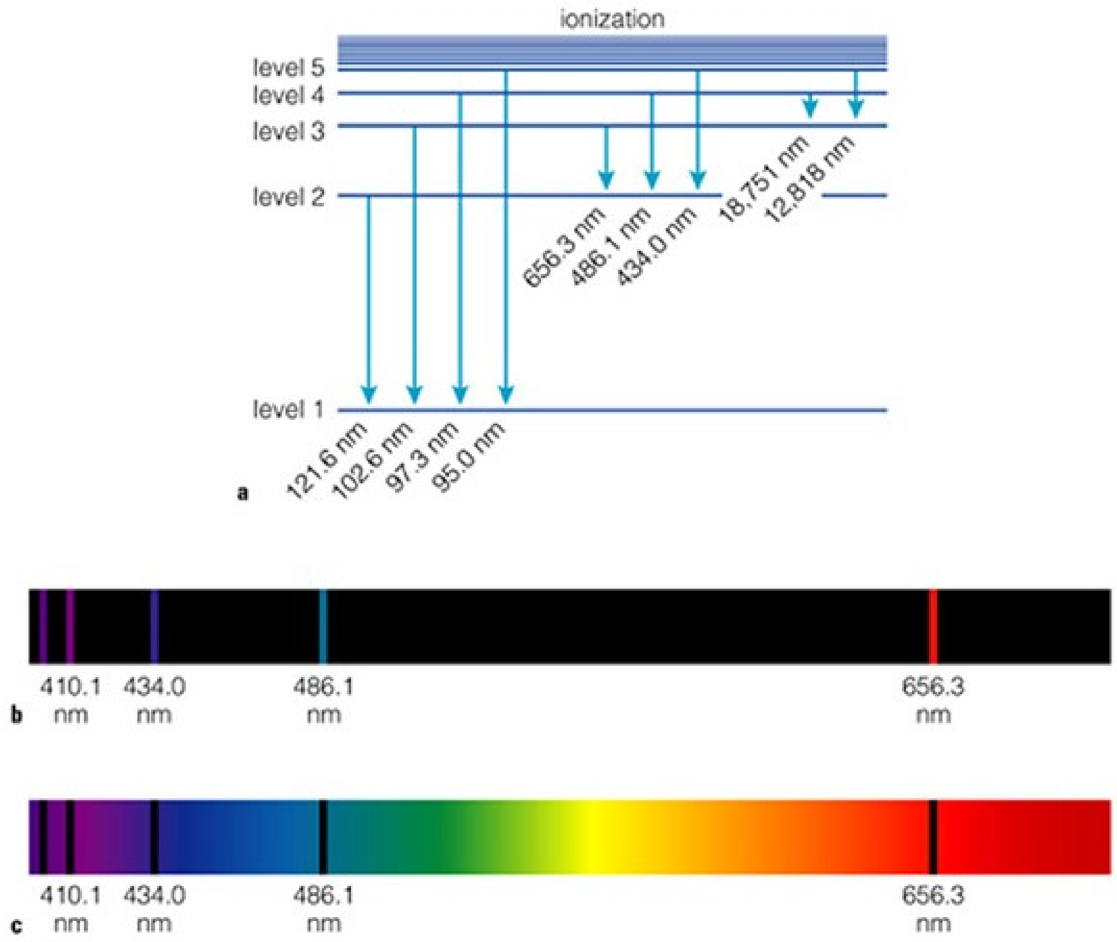


Astronomers can also detect the presence of planets by measuring very accurately the colors of light being emitted by their suns, and looking for regular, periodic changes in the colors.

The color of light is just how our brains interpret light waves of different wavelengths.

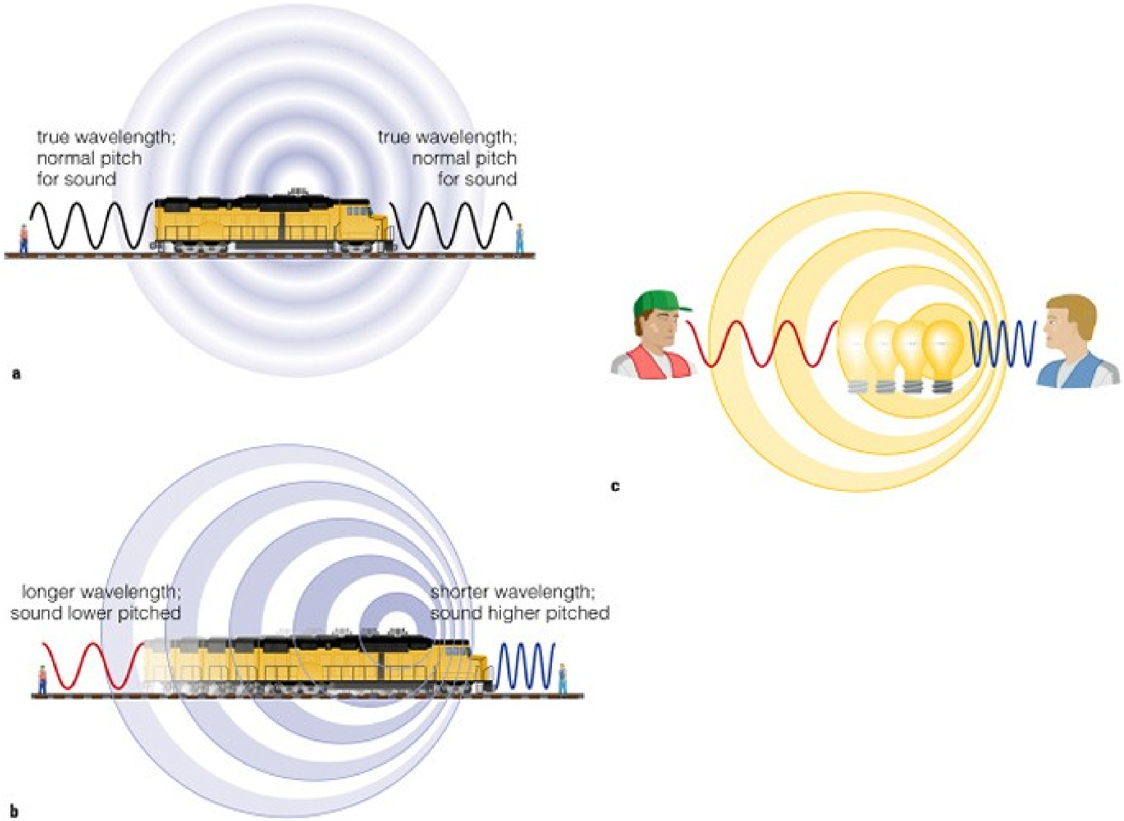


The atoms of hydrogen in the outer layer of stars can absorb, store, and release energy by moving their electron closer to the nucleus *(this means less energy)* or further away from the nucleus *(this mean more energy)*. This energy becomes rays of light of specific colors that are either absorbed or emitted. Astronomers use a spectrograph to measure the exact wavelengths of these colors.



These are the most common colors emitted or absorbed by hydrogen atoms in the outer layers of stars.

The Doppler Effect



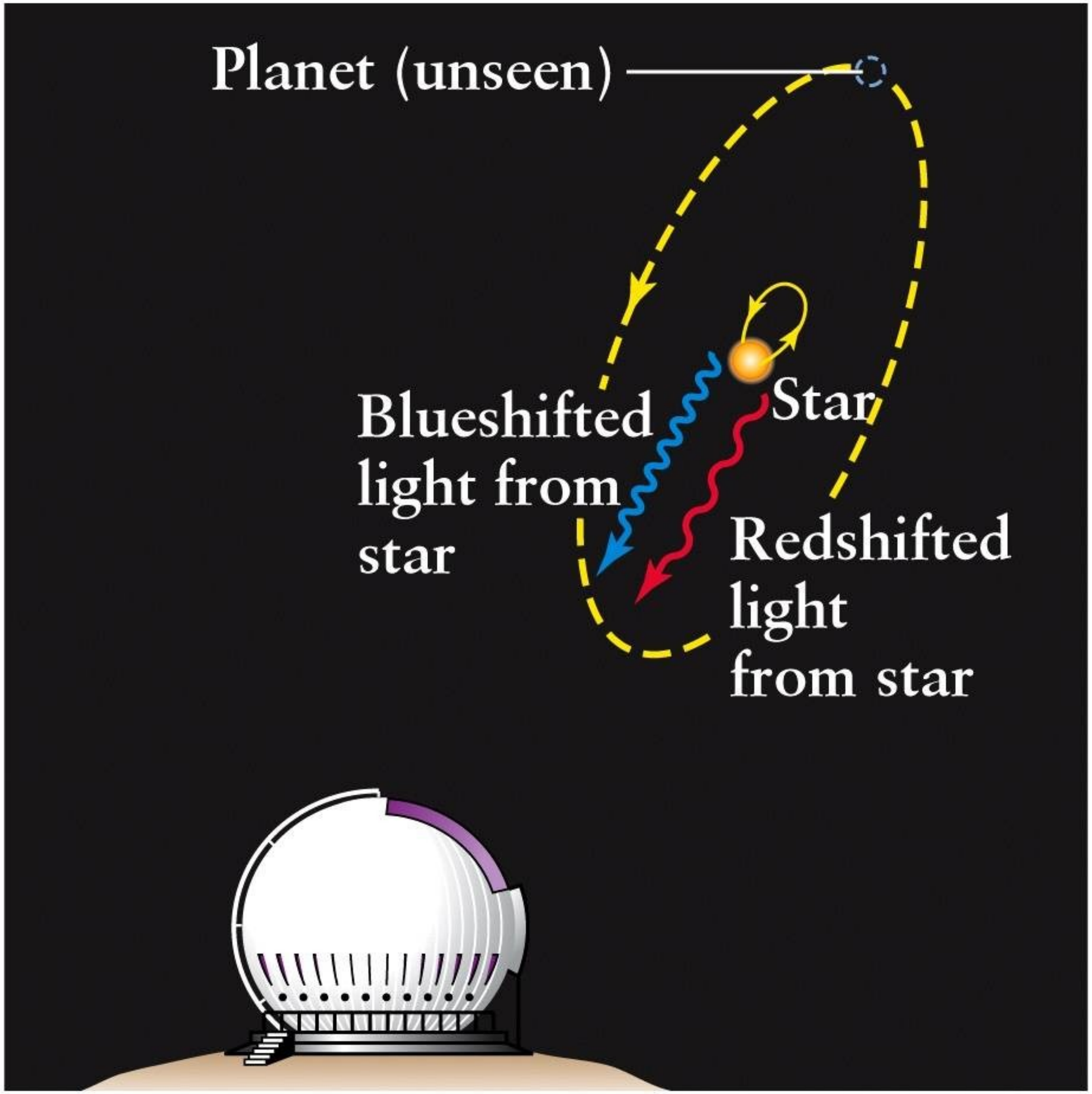
$$v = \lambda – \lambda_0/\lambda_0 \ \text{x}\ c$$

λ = observed wavelength;

λ_0 = rest wavelength

v = object velocity

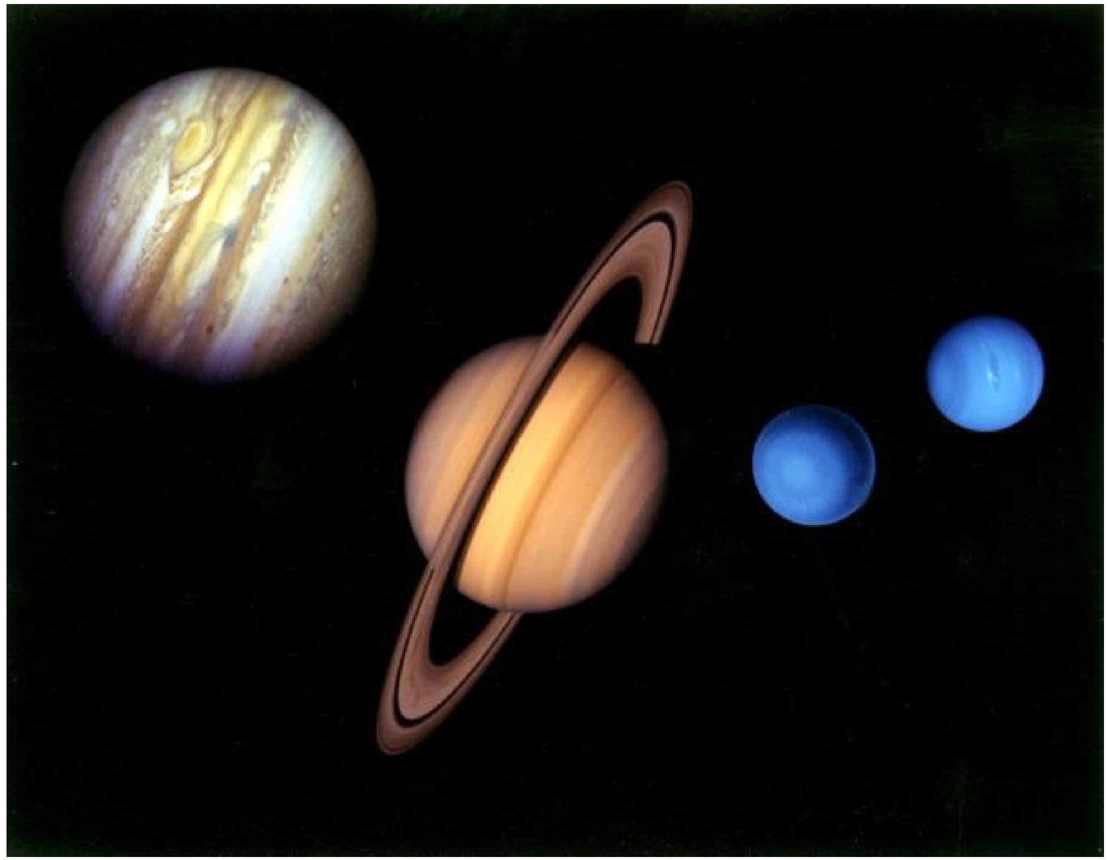
c = speed of light


Planet (unseen)
Star
Blueshifted light from star
Redshifted light from star

c

Spectroscopic Binary Applet

What are the Extrasolar Planets Like?

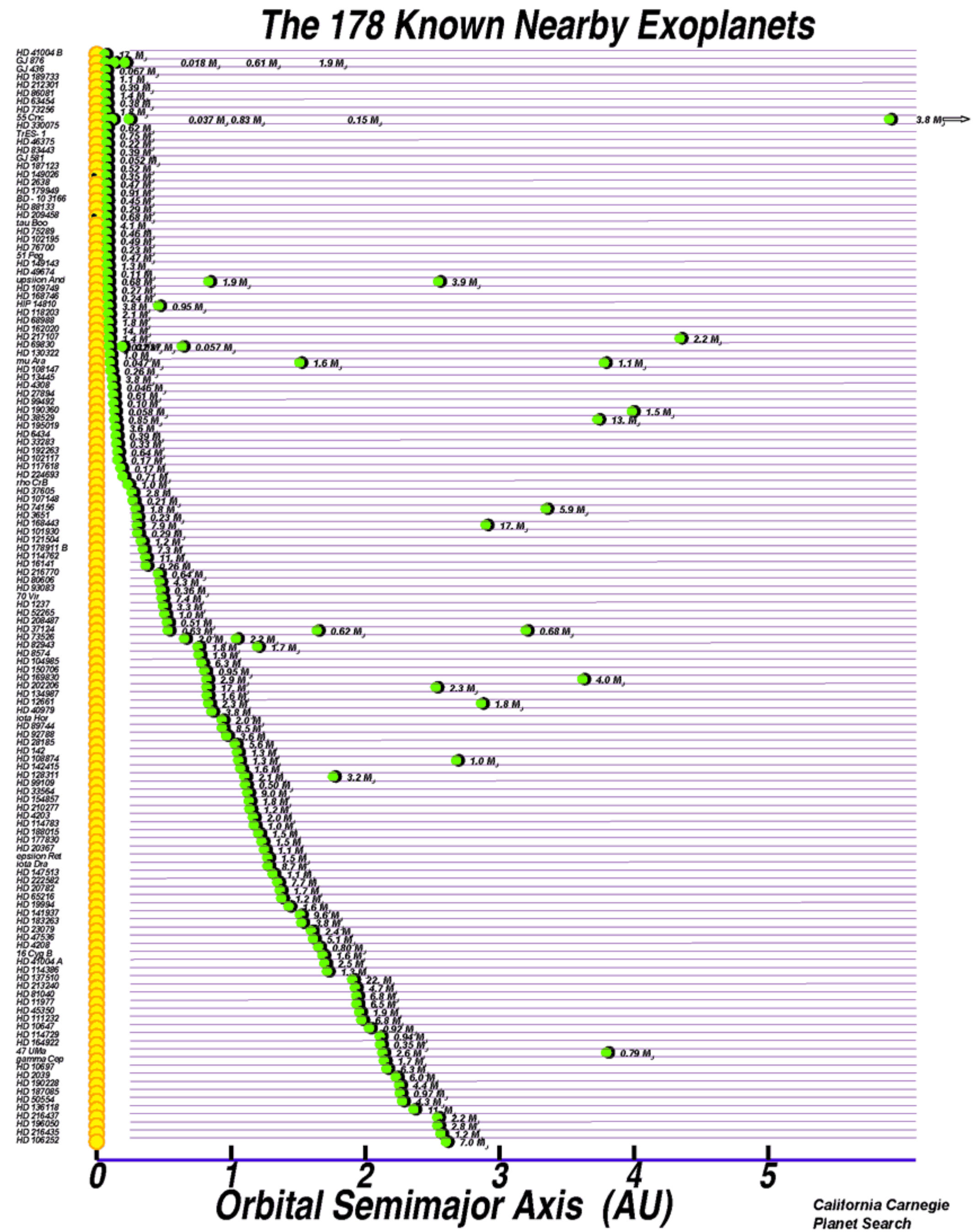


The short answer is that they are almost all gas giants, like Jupiter and the others. We don't think that there are only gas giants out there, but that the astrometry and Doppler shift methods work best at detecting massive planets that can strongly influence their suns with their gravity.

This graph shows the orbital distances of all the known extrasolar planets that are within 600 light years of the Earth, as of Jan. 2008.

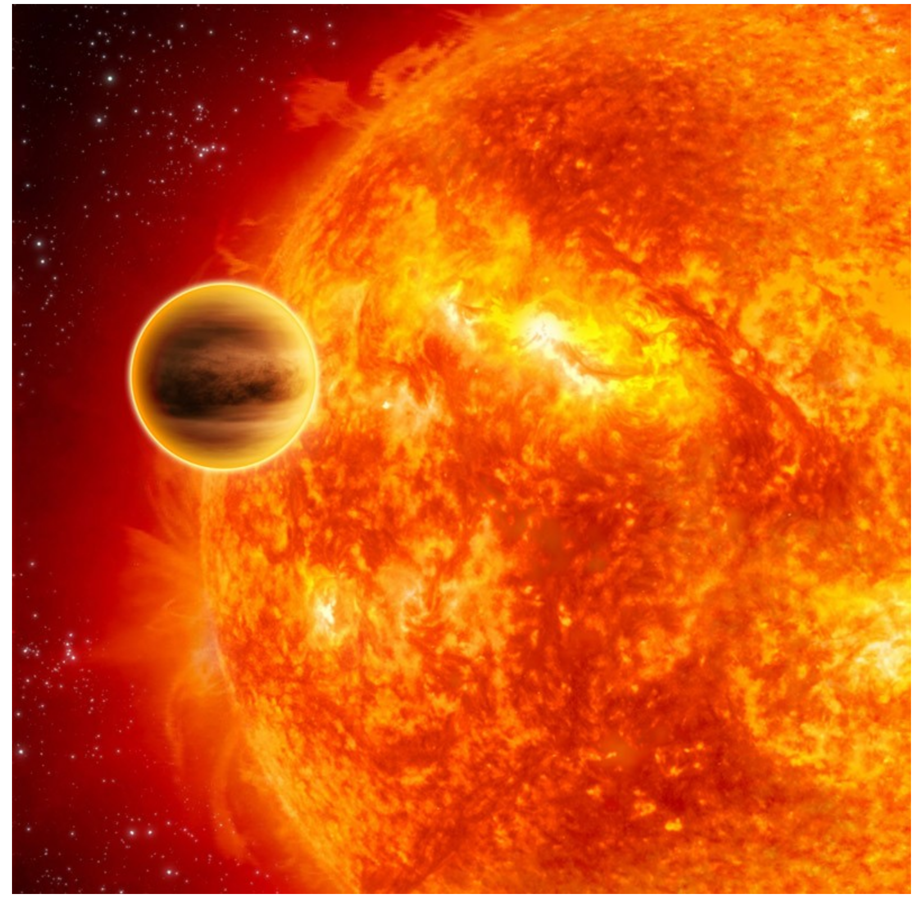
Notice how they are all really close! These are all gas giants, yet some are closer to their stars than Venus and Mercury are to our Sun.

These are called "Hot Jupiters.



Hot Jupiters

Our Solar System has no hot Jupiters – all our gas giants are at 5 A.U. from the Sun or more. Hot Jupiters tend to have elongated elliptical orbits, not nearly circular ones like we see near Earth.



They are so close to their stars that they can be 1000 C or hotter. Astronomers think that they probably started much farther away, and gradually closed in on their stars.

The inward motion of these planets probably shoots any inner rocky planets down into the star, or off into interstellar space.