Topics: Other planetary systems: exoplanet detection and properties

Reading:

- Review the first two sections of of Ch. 12 in Ryden and Peterson.
- Read secs. 3 and 4 of Ch. 12 in Ryden and Peterson (pp. 294 - 306).
- Go to exoplanets.org – try making plots with the plot-making tool on their website.

Summary of work to submit:

- To prepare for Tuesday's class, email Prof. Cohen your plot of planet mass vs. semi-major axis. It is your choice of how to plot these quantities. In your email, include a sentence or two about how your plot compares to Fig. 12.9a in the textbook (it's up to you to decide what's most relevant to comment on). Note what year the textbook was published in your comparison.

Overview:

It is truly remarkable that we can detect and measure the properties of exoplanets. The reading for this class starts out by showing how hard/impossible the obvious ways of detecting exoplanets are to use. The basic problem is that planets are dim and stars are bright. It's also a problem that planets are light and stars are heavy. It turns out that while it's hard to detect the brightness of a planet that's a million times dimmer than its host star, it's easy to measure the Doppler shift of something moving a millionth the speed of light (or even 10^8 times less...well, maybe not easy, but doable). And it also turns out that transits are much more common that people had assumed (because there are a lot more planets with small orbits than we expected). The Doppler shift (radial velocity) method gives the planet's mass while the transit method gives its radius. Combining these give a planet's density, with associated information about its possible composition. It's truly remarkable that we're able to find out so much information about exoplanets that we still can't see. Many measured exoplanet systems are different than our Solar System, often with close-in planets – sometimes Jovian planets – that likely formed further out and migrated inward (it is assumed).

Commentary on the reading, viewing, and other preparation:

The beginning of section 3 gives you a good opportunity to review blackbody radiation and the Planck function. Why is the brightness contrast between star and planet more favorable in the infrared? At a basic level, recognize that the surface flux scaling as the fourth-power of temperature is about the *wavelength integrated* flux. If you pick a particular wavelength, the contrast will be different. We haven't learned about the "Rayleigh Jeans limit" but you can look it up in Ch. 5. It quantifies the relative advantage a colder object has in competing with the brightness of a hotter object, if you look at long wavelengths.

Note that the very small handful of directly detected exoplanets are very young, and therefore still hot from the heat of their formation, and so are quite bright in the infrared. (This is not mentioned in the textbook; you can look up HR 8799 on the web.)

Astrometric detection – seeing the host star move in response to the gravitational force of the planet – is also prohibitively difficult because the signal is so small. Recall that the center of mass of the Sun-Jupiter system is barely outside the surface of the Sun!

Radial velocity detection: make sure you're clear in your own mind about how the velocity that's measured is that of the host star. Pay careful attention to the math (and physics) by which Kepler's third law turns into eqn. 12.20. Note that we haven't learned about *stellar spectral types* but suffice it to say that you can infer a star's mass from the detailed appearance of its spectrum. You can look up an estimated mass of a star from its "spectral type" in the appendix of the textbook.

Note also the issue of the *inclination* of the orbit. Make sure you understand Fig. 12.6. But recognize that if a transit is also observed then we know that $i \approx 90$ degrees and so that inclination ambiguity is removed.

Transits are valuable in that they easily give the planet's radius (as a ratio of the star's radius which, again, can be inferred from the star's spectral properties). Eqn. 12.22 gives the radius. The information associated with the shape and timing of the light curve (as described in Fig. 12.7 and the associated text), while correct, cannot in practice be used to determine the planet's radius (because there's no guarantee the planet goes right across the middle of the star).

Problem 1

Using the plot-making tool at exoplanets.org, make a plot of mass vs. semi-major axis for all currently confirmed exoplanets. Comment on how our knowledge has changed since the textbook was written.

Send Prof. Cohen your plot and brief commentary by 10 AM on Tuesday.