ASTR 3710: Problem Set #1

(due in class Thursday September 12th)

1. The innermost three planets of the Kepler 11 system have the orbits and masses given below:

Planet	Mass / M_{Earth}	Orbital radius / AU
b	4.3	0.091
c	13.5	0.106
d	6.1	0.159

   (a) Planet c has a mass similar to that of Neptune in the Solar System. In constructing the Minimum Mass Solar Nebula, Weidenschilling (1977) multiplied the mass of Neptune by a factor of 70 in order to derive the mass of Solar composition material that would have been sufficient to form the planet. Assuming that Kepler 11c is physically similar to Neptune, follow the MMSN procedure to estimate the surface density (in g cm^{-2} or kg m^{-2}) of the Kepler 11 disk at the location of planet c.
   (b) How does the value you estimated in part (a) compare to an inward extrapolation of the MMSN surface density profile?

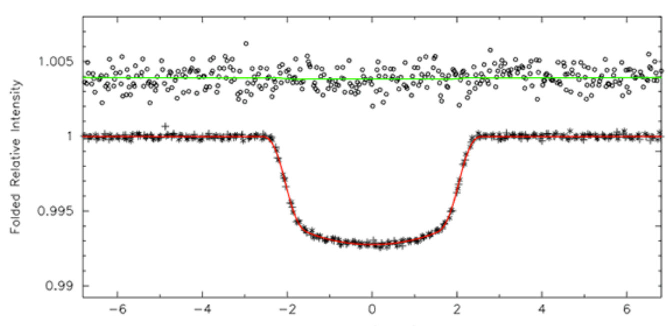
2. Astronomical observations of disks around other stars have been interpreted as indicating a shallower mass profile than the $r^{-3/2}$ of the MMSN. Consider a profile:

$$\Sigma(r) = kr^{-1}$$

   where k is a constant.

   (a) If the surface density at 1 AU is 10^3 g cm^{-2}, determine the value of k.
   (b) Integrate the surface density (taking note of the differential area of the disk at different radii) to determine the mass between 0.1 AU and 100 AU. Quote an answer in Solar masses.

3. The data below (red curve) shows a transit light curve obtained from the Kepler satellite:



If the planet is orbiting a star with the same radius as the Sun, estimate the planet's radius. What type of planet is it likely to be?

4. Suppose that a transiting planet has a very large moon whose radius is half that of the planet. Sketch the transit light curve you would expect to observe as the planet and its moon pass in front of their star (note any assumptions you need to make to answer this question).

5. A planet is detected orbiting a Solar mass (and radius) star using the radial velocity technique. The observations show that the orbital period P = 10 days, and that the semi-amplitude of the radial velocity signal is 100 ms^{-1}.

   (a) Calculate the radius of the orbit, assuming it is circular.
   (b) Calculate the minimum mass of the planet.
   (c) Explain why the mass is only the minimum mass, and not the true mass.
   (d) Subsequently, the planet is observed to transit. What can you say about the mass knowing this additional information?
   (e) The transit depth is observed to be f = 0.01. Using this information, along with the radial velocity data, calculate the mean density of the planet.