Star and Planet Formation Mini-Course
Assignment 1, due Wednesday, March 26

1. Estimate the mass below which an object becomes a brown dwarf rather than a star. It may be easiest to work as follows.

   (a) What are the central pressure and density as a function of mass and radius? Here, you should use the fact that the object will be completely convective, which means its central pressure and density are known functions of mass and radius.

   (b) Ignoring nuclear fusion, what sets the maximum central temperature a contracting object obtains? And what is its value? (A sensible estimate suffices.)

   (c) What central temperature is required for fusion to balance the object's luminosity? Here, you should not just use a "magic" minimum temperature for fusion, but estimate it by calculating how much energy is generated. You are allowed, however, to assume "known" the effective temperature for calculating the luminosity (just guesstimate a value from observed or theoretical HRDs; it is rather tricky to derive).

2. Estimate the run of temperature in accretion disks, and use those to calculate spectral energy distributions.

   (a) Calculate the run of effective temperature with radius, $T_{\rm eff}(r)$, for a solar mass star accreting at the rate of $\dot{M} = 10^{-6} M_\odot/{\rm yr}$. Assume that the stellar radius is three times that of the sun, and that the disk is optically thick so that it emits as a black body.

   (b) Using your expression for $T_{\rm eff}(r)$, calculate the spectral energy distribution (SED) L_ν, where L_ν has units erg/s/Hz, for the disk. Do this for wavelengths between 1000 Å and 1000 μm. Similarly, calculate the emission from the stellar photosphere, assuming the temperature you found in 1(c) above. Make a plot of both SEDs and their sum, i.e.., plot on a log-log plot the quantity νL_ν versus ν. Identify the "infrared excess" with a (possibly hand written) label on the plot.

   (c) Now assume that the mass accretion rate is so low that the accretion power is negligible, but that the disk is still optically thick. This is dodgy at the longer wavelengths, but we will not worry about that here. Recalling the illustration of disk illumination in Ray's talk on Tuesday, calculate the flux striking the disk at radius r. In doing this calculation, it will be sufficient to consider that the stellar emission arises from a point source a distance R_* above the center of the disk, where R_* is the stellar radius given in part a) above. Assume that this flux is thermalized, and calculate $T_{\rm eff}(r)$

   (d) Calculate the SED for this "passive" disk. Comment on the similarities and differences with the SED calculated in part (b).