Astronomy 400A: Homework 6

You may collaborate on all problems this week.

1. In class we showed that the mass accretion rate onto a forming protostar from a collapsing protostellar core is
$$\dot{M} \sim \frac{c_s^3}{G}. \tag{1}$$
   (a) For typical conditions in the interstellar medium estimate c_s, and use this to estimate $\dot{M}$.
   (b) Inferred lifetimes for protostars surrounded by collapsing envelopes are $\sim 10^5$–10^6 years. Is this consistent with the inferred mass accretion rate?
   (c) Measured mass accretion rates onto protstars are $\sim 10^{-7}$ $\mathrm{M}_\odot$ yr^{-1}. This traces material that is falling from the inner regions of a disk onto the protostar, rather than the global infall rate estimated above. Assuming material is added to the disk at the global infall rate but subtracted at the protostellar accretion rate, estimate how long it would take for such a disk around a 1 $\mathrm{M}_\odot$ star to become gravitationally unstable. You may assume that the disk height, H is a constant fraction of the radius: $H/R = 0.1$.
   (d) Using your answers from parts (b) and (c), what do you infer about the accretion onto protostars?

2. The "ice-line" or "snow-line" is the stellocentric radius in a protoplanetary disk where the temperature becomes low enough for water vapor to condense into ice. While the condensation temperature depends on pressure, assume that in a protoplanetary disk, $T_{\mathrm{condense}} = 150$ K.
   (a) Estimate the radius of the ice-line around a 0.2 $\mathrm{M}_\odot$ main-sequence star.
   (b) Estimate the radius of the ice-line around a 1 $\mathrm{M}_\odot$ main-sequence star.
   (c) Compute the stellocentric radius in the solar system where water can exist in liquid form on the surface of a planet.
   (d) Compare your answers from parts (b) and (c). What does this imply for the formation of habitable planets?