

PROBLEM SET 1 – Exoplanets

Distributed: 8 February 2010

Due: Thursday, 4 March 2010 at the start of class

Star and planet formation

1. Stars are born when fragments of an interstellar nebula (molecular cloud) collapse due to a gravitational instability known as the Jeans criterion. This criterion can be expressed as a mass, so that the Jeans mass M_{Jeans} is given by

$$M_{\text{Jeans}} \text{ (in } M_{\text{Sun}}) \sim 45 T^{3/2} n^{-1/2}$$

where T is cloud temperature (in K) and n is number density (in particles per cm^3).

- (a) Derive this expression, assuming the cloud has a uniform temperature and density and that it is composed entirely of hydrogen.
 - (b) What is the Jeans mass for a cloud of temperature $T = 30 \text{ K}$ and number density $n = 10^{11} \text{ m}^{-3}$.
2. Estimate how long it will take for a cloud fragment to collapse into a star, as a function of the initial number density of the nebula.
 3. Before the star becomes a star, it is not radiating thermonuclear energy, but converting gravitational potential into thermal energy. What is the average luminosity (in units of L_{Sun}) of the protostellar cloud as it collapses?

The habitable zone

If a planet is to harbor LAWKI (Life As We Know It) then it must be able to have liquid water at or near its surface. Any planet whose orbit relative to its star allows the presence of liquid water is said to be in the "habitable zone".

4. Estimate the equilibrium temperature of a planet's surface as a function of its distance from its parent star, and any other relevant parameters of the star and the planet (e.g., star's luminosity, planet's radius and albedo). Be careful to point out any approximations or assumptions and justify their validity.
5. Generate your own plot of the boundaries of the habitable zone as a function of spectral type for main sequence stars. Is there a limit (or are there limits) on stellar spectral type beyond which we would not expect to find simple or complex life even on a planet orbiting in its habitable zone? Why or why not?