

Astr 423, Spring 2019

Homework 5: protostars

1 Initial phase of protostar evolution

Assume a protostar of 1 solar mass, made of pure H. Initially, the gravitational energy of the collapse is used to dissociate and ionize the molecular gas. Estimate the radius of the protostar, in solar radii, when most of the gas throughout the protostar is ionized.

We will define the following quantities:

Mass and radius of the protostar M and R .

Dissociation energy of the H_2 molecule: $\epsilon_d = 4.5$ eV.

Ionization energy of H atom: $\epsilon_i = 13.6$ eV.

2 Reaching quasi-hydrostatic equilibrium

After the ionization is complete throughout most of the protostar, the temperature begins to rise and the increase in pressure quickly forces hydrostatic equilibrium. We can take the potential energy calculated in Section 1. Calculate the average internal temperature when equilibrium is reached (think in terms of the virial theorem). Does this temperature depend on the protostar's mass?

Hint: when calculating the thermal energy, remember that the gas has been ionized, and the electrons contribute as much as the protons, because of the equipartition of energy.