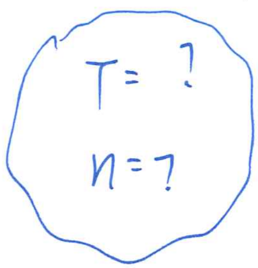
Last time we completed our discussion of the star formation process for typical, Milky way stars. Now we move our attention to the first stars.

Formation of the First Stars

→ Star formation of primordial gas.

H / He only



The first step in triggering star formation is gravitational instability, i.e. having a gas cloud more massive than the Jeans mass M_J:

$$M_J = 1 M_\odot \left(\frac{T}{10K}\right)^{3/2} \left(\frac{n}{10^5 cm^{-3}}\right)^{-\frac{1}{2}}.$$

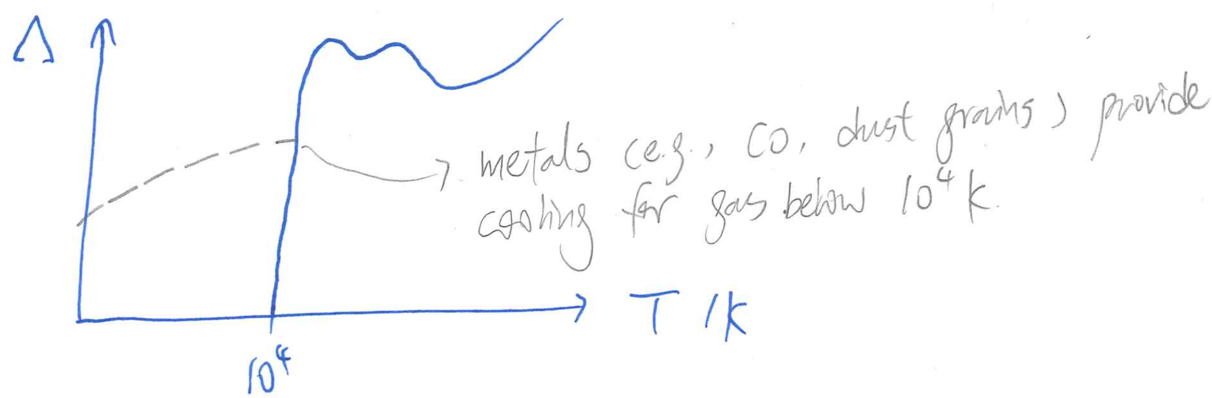
What should be T and n in the gas clouds that formed the first stars?

We don't have observations like we do for milky way stars.

In this lecture, we'd like to estimate both T and n in the primordial gas cloud with our physical understanding 03-31-2016

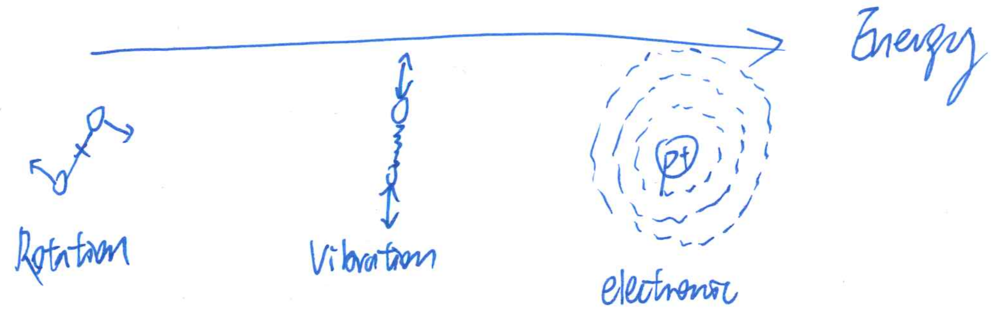
Recall that our previous theory of star formation stems from the fact that the cloud can cool efficiently.

$$\text{cooling rate} = \frac{\Delta E}{\Delta t \cdot \Delta V} \equiv \Lambda$$



Only way to cool H/He gas at $T < 10^4$ K

→ molecular H, i.e. H_2.



rotational kinetic energy $E_{rot} = L^2/2I$ 03-31-2016

$$L = \hbar\sqrt{J(J+1)} \qquad \hbar = h/2\pi$$

$$I = mr^2 = 2m_H \cdot a_0$$

Bohr radius $\sim 10^{-8}$ cm.

H_2 → symmetric, requires $\Delta J = 2$ in QM transition of rotational states.

· NOTE : can even excite lowest energy H_2 level with $T_{min} \simeq 200$ K.

Q : What about number density n?

A : We can have an estimate of n by considering the collisional de-excitation of H_2. In effect, if a gas cloud has a density higher than some critical value n_{crit}, excited H_2 molecules would share the energy with other colliding particles before they have a chance to release a photon. ——— insufficient cooling.

"Critical" density for collisionally de-exciting :

$$n_{crit} \sim 10^4 \ cm^{-3}.$$

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