Lecture 17:
Baryons and Photons Part II
Galaxies and Stars

Dr. James Mullaney

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1 The fragmentation of molecular clouds

- As we saw in Lecture 14, the Jean's mass is given by:

$$M_J = \frac{4\pi}{3}\rho\lambda_J^3 \tag{1}$$

- Where:

$$\lambda_J = c_s \left(\frac{\pi c^2}{G\bar{\epsilon}}\right)^{1/2} \tag{2}$$

- Which, for Giant Molecular Clouds, which have typical densities of $\sim 10^{-15}$ and temperatures of $\sim 20K$ corresponds to about:

$$M_J \approx 15\ M_\odot \left(\frac{\rho}{10^{-15}\ \mathrm{kg\ m^{-3}}}\right)^{-1/2} \left(\frac{T}{20\ \mathrm{K}}\right)^{1/2} \tag{3}$$

  where the $\rho^{-1/2}$ and $T^{1/2}$ come from the combination of c_s with ρ.

- Since clouds of lower mass than the Jean's mass are pressure supported, then this seems to imply that GMCs should stop collapsing at 15 $M_\odot$. So, how come we see stars of smaller masses?

- It is basically because the molecular cloud is able to release energy via thermal emission.

- If we assume isothermal emission (i.e., it stays at 20 K), then since $M_J \propto \rho^{-1/2}$. As the cloud releases energy, and collapses due to gravity, its density increases and its Jean's mass decreases.

- Eventually, the 15 $M_\odot$ cloud will become unstable (since it's more massive than its Jean's mass) and fragment into two (or more clouds).

- These two (or more) clouds will go through the same process. Cooling and splitting over and over.

- What stops this cooling and splitting from continuing *ad infinitum*?

- It's to do with that constant, isothermal 20 K we assumed. In order to maintain that isothermal temperature, the clouds must continuously radiate energy away (otherwise they'd heat up as they contracted as gravitational energy is converted into heat energy).
- But since the ability to radiate is propertional to area (think σT^4 - it's per unit area), as the clouds get smaller and smaller, they get less able to radiate the heat away.
- And eventually they stop collapsing.
- Depending on the geometry and kinetics of the clouds, different clouds will stop collapsing at different sizes, created the Initial Mass Function.