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1 Star Formation

Gas in galaxies comes in multiple "phases". It's still a gas, just a broad range with particular characteristics. They have different ρ & T with comparable P. Hot, low ρ gas is mostly in the form of Hot ISM. Stars form from **cold molecular clouds**. What are the conditions for a cold molecular gas cloud to collapse?

$$\begin{aligned}
|U| &\geq |K| \\
\frac{GM}{R^2} &\gtrsim \left|\frac{dP}{dr}\right| \\
\text{self gravity of cloud} &\gtrsim \frac{3}{2}NkT \\
&\approx \frac{M}{m_p}kT
\end{aligned}$$

If $M \gtrsim \frac{RkT}{Gm_p}$, then it will collapse.

$$\begin{aligned}
\rho &\approx \frac{M}{R^3} \\
R &\sim \left(\frac{M}{\rho}\right)^{1/3} \\
M^{2/3} &\gtrsim \frac{kT}{Gm_p\rho^{1/3}} \\
&\boxed{M \geq \left(\frac{k}{Gm_p}\right)^{3/2}\frac{T^{3/2}}{\sqrt{\rho}}}\text{ , Jeans Mass} \\
\frac{GM^2}{R} &\geq \frac{MkT}{m_p} \\
\frac{GM^2}{R} &\geq c_s \\
if\frac{1}{\sqrt{G\rho}} &\leq \frac{R}{c_s}\text{ , then } t_{FF} < t_{sound}\text{, and it will collapse}
\end{aligned}$$

Stars are more prone to collapse if they have lower T and higher ρ. Stars form from cold molecular clouds because they are the most unstable.

$$\begin{aligned}
M_J &\approx 50M_\odot\frac{\left(\frac{T}{10K}\right)^{3/2}}{\left(\frac{\text{n}}{100\text{ cm}^{-3}}\right)^{1/2}} \\
R_J &= \left(\frac{M_J}{\rho}\right)^{1/3} \\
&\approx 3\text{ pc}\frac{(T/10K)^{1/2}}{(n/100\text{ cm}^{-3})^{1/2}}
\end{aligned}$$

If a star has $M > M_J$ and $R < R_J$, then it will collapse. The collapse time is $\sim \frac{1}{\sqrt{G\rho}} \sim 10 \text{ Myr} \left(\frac{n}{100 \text{ cm}^{-3}}\right)^{-1/2}$. Why don't we have tons of $50 M_\odot$ stars? In reality, most of them are roughly $0.3 M_\odot$.

$$\begin{aligned}
\rho a &= -\frac{dP}{dr} - \rho \frac{GM}{R^2} \\
&\sim \frac{P}{R} - \frac{GM^2}{R^5} \\
&\propto \frac{nT}{R} \\
&\propto \frac{MT}{R^4}
\end{aligned}$$

2 Actual Collapse

Initially, the gas cools rapidly and since photons easily escape cloud, $T \sim$ roughly constant, isothermal at around $10K$. $P \propto \frac{M}{R^4}$, & gravity $\propto \frac{M^2}{R^5}$. As radius decreases,