Ay 20 # 21 - Star - formation

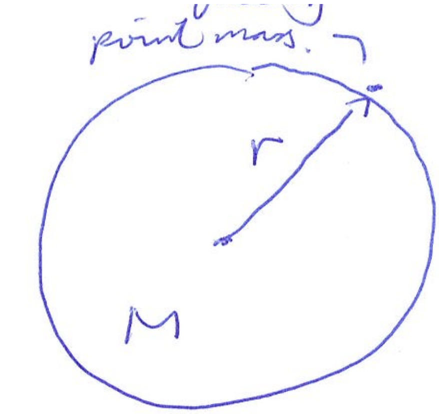
Stars form upon the collapse & fragmentation of molecular clouds. What fraction of the mass of the Milky Way is in these ~5000 clouds?

* Physical conditions: $T \sim 20\,K$, $n \sim 10^2\,cm^{-3}$, sizes between few - 100 pc. Primarily H_2 gas, dust opacity @ BB peak. (dust to gas ratio is ~ 1:100 by mass).

* Collapse occurs when the gravitational forces exceed pressure balance (i.e., hydro equilibrium). This is described by the Jeans instability. We want the cloud to collapse before it "knows" about it...

Free-fall time t_{ff} < Sound crossing time t_s.

At r, the acceleration is



$$\ddot{r} = -\frac{GM(r)}{r^2}.$$

$$= -\frac{4}{3}G\pi\rho r$$

Then, $r(t) = R\cos\left(t\sqrt{\frac{4}{3}G\pi\rho}\right)$,

and $t_{ff} \sim \frac{\pi}{2\sqrt{\frac{4}{3}G\pi\rho}} \sim \frac{1}{\sqrt{G\rho}}$.

The sound crossing time is

$t_s \sim \frac{R}{c_s}$, where the sound speed

is $c_s = \sqrt{\frac{\partial p}{\partial \rho}}$. For an isothermal gas,

$$p = \frac{\rho kT}{\mu m_H} \Rightarrow c_s \sim \sqrt{\frac{kT}{\mu m_H}},$$ and

the Jeans criterion is

$$\frac{1}{\sqrt{G\rho}} < R\sqrt{\frac{\mu m_H}{kT}}.$$

Scales larger than the Jeans length

$$R_J = \sqrt{\frac{kT}{G\rho\mu m_H}}$$ will collapse.

The resulting collapsed objects will have masses larger than the Jeans mass

$$M_J = \frac{4}{3}\rho\pi R_J^3 .$$ What happens on $R < R_J$?

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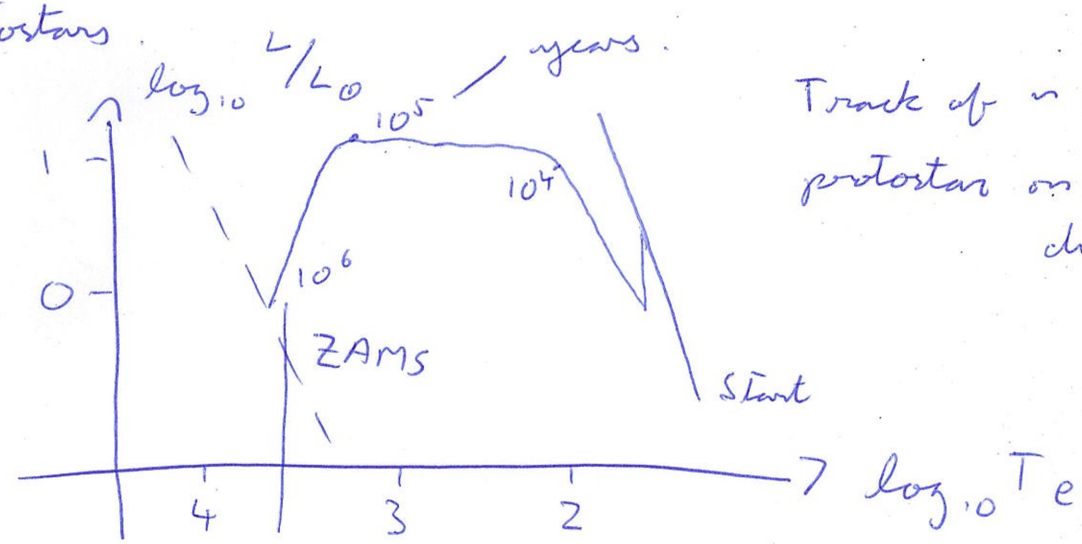
* Protostars.



Hayashi track.

Track of $\sim 1\, M_\odot$ protostar on H-R diagram.

Protostars evolve through various regimes of temperature and luminosity, as dust ($T > 10^3 K$) and H_2 ($T > 2 \times 10^3 K$) are dissociated.

Young stellar objects (YSOs):

Class 0 : only $\lambda > 20\,\mu m$.

Class I : $\alpha_{2.2-20\mu m} > 0.3$, $\alpha = \frac{d \log(\lambda F_\lambda)}{d \log \lambda}$

Class II : $-0.3 > \alpha > -1.6$ (SED).

Class III : $\alpha < -1.6$.

The lifetimes increase logarithmically from $10^4 - 10^7$ yr.

There is a rich phenomenology of inflows, outflows, and jets! e.g., T Tauri stars ($\sim$ Class II).

Energy / opacity sources:

- $T < 1000K$: shocks inside star $\rightarrow$ dust opacity
- $T \sim 1000K$: dust destroyed $\rightarrow$ $\tau = 2/3$ surface shrinks $\rightarrow$ T_{eff} & L rise.
- $T \sim 2000K$: H_2 dissociates, unstable to further collapse $\rightarrow$ core forms and accretion continues $\rightarrow$ H^- opacity $\rightarrow$ convective envelope $\rightarrow$ burning is triggered.