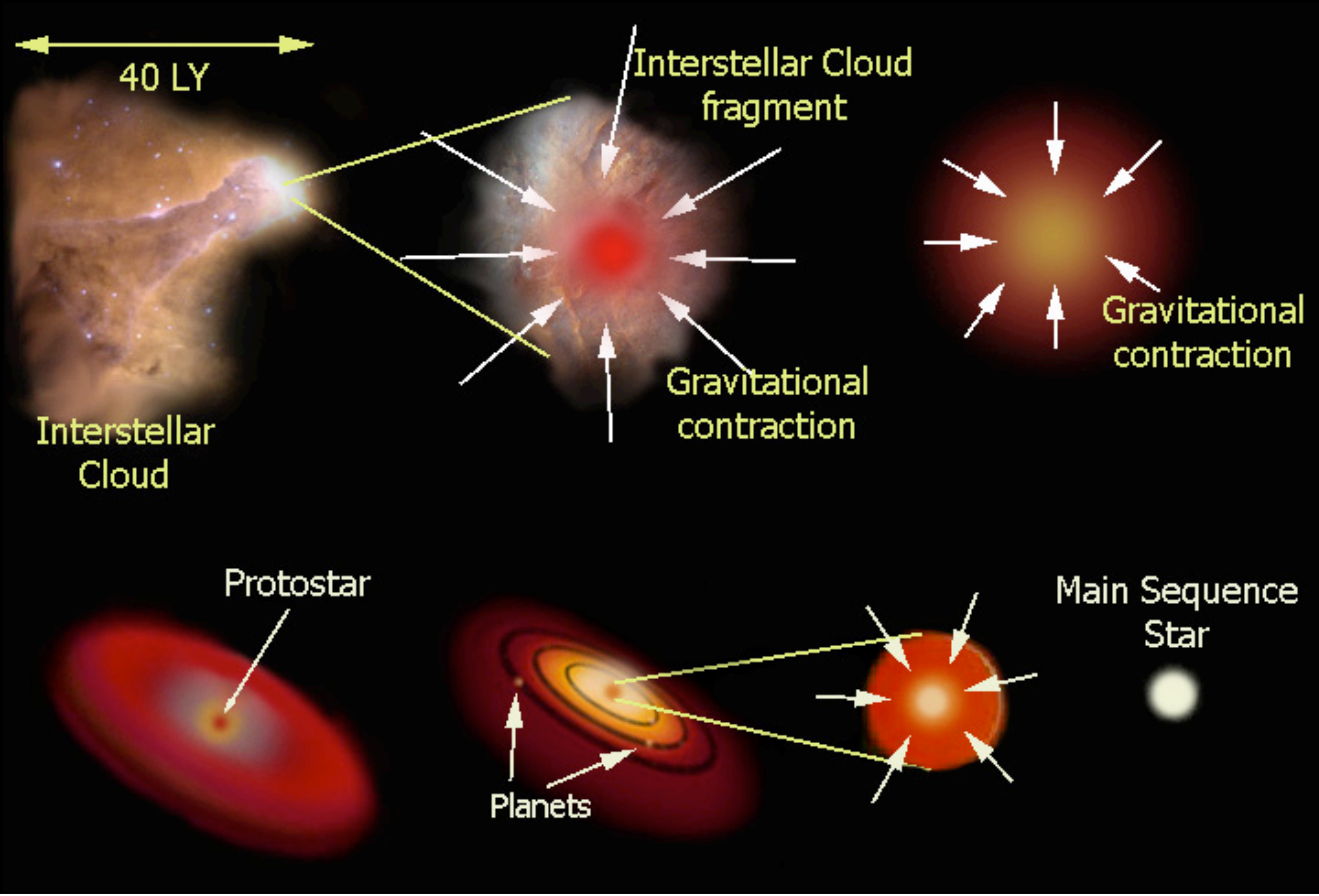
La naissance des étoiles

Questions

- ❉ Echelles de masses?
- ❉ Echelles de tailles?
- ❉ Echelles de temps?

Effondrement d'un nuage interstellaire



Critère de Jeans

$$E_{cin} \approx \frac{3}{2} kT \times \frac{M}{\mu}$$

$$E_{pot} \approx -\frac{3}{5} \times \frac{GM^2}{R}$$

système en effondrement (i.e. lié) si:

$$\boxed{E_{cin} + E_{pot} \leq 0}$$

soit…

critère de Jeans:

en masse:

$$M \geq M_J \sim 3.7 \left(\frac{kT}{G\mu} \right)^{3/2} \cdot \frac{1}{\sqrt{\rho}}$$

AN:

$$M_J \sim 6 \times 10^4 \, \frac{T^{3/2}}{\sqrt{n}} \, M_{\text{Soleil}}$$

Valeurs typiques:

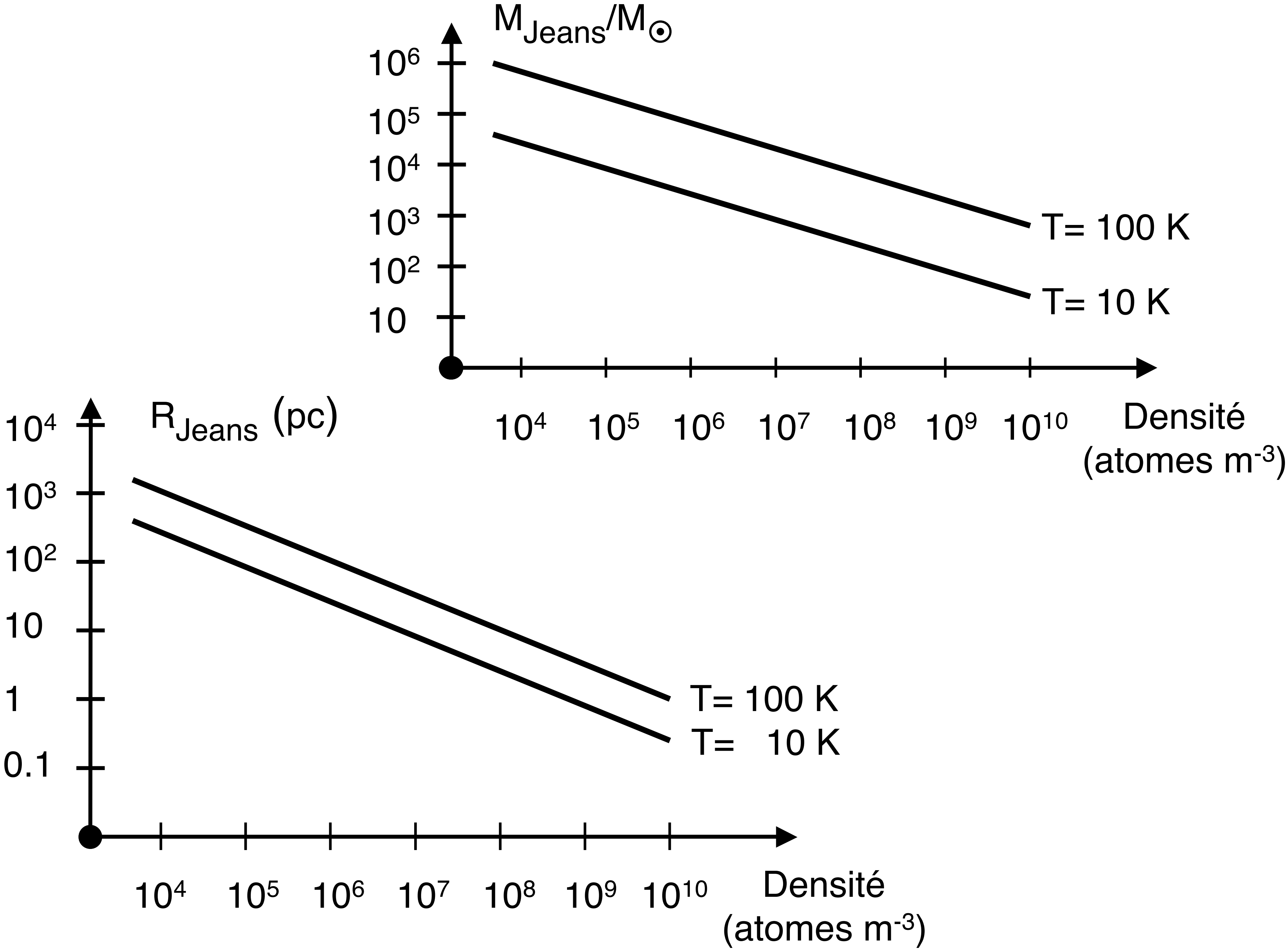
$$\left.\begin{array}{l} T \sim 20-100K \\ \bar{n} \sim 10-10^{6} m^{-3} \end{array}\right\} \Rightarrow M_{J} \sim qqs \quad 10^{3} M_{Soleil}$$

⇒ les étoiles naissent en groupe

NB. Problème de hièrarchie dans la fragmentation ⇒ notion de IMF (Initial Mass Function).

NB'. critère de Jeans en *rayon*: effonderment pour R ≥ R_J, où:

$$R_{J} \sim 9 \times 10^{3} \frac{T^{1/2}}{\bar{n}^{3/2}} \quad pc$$

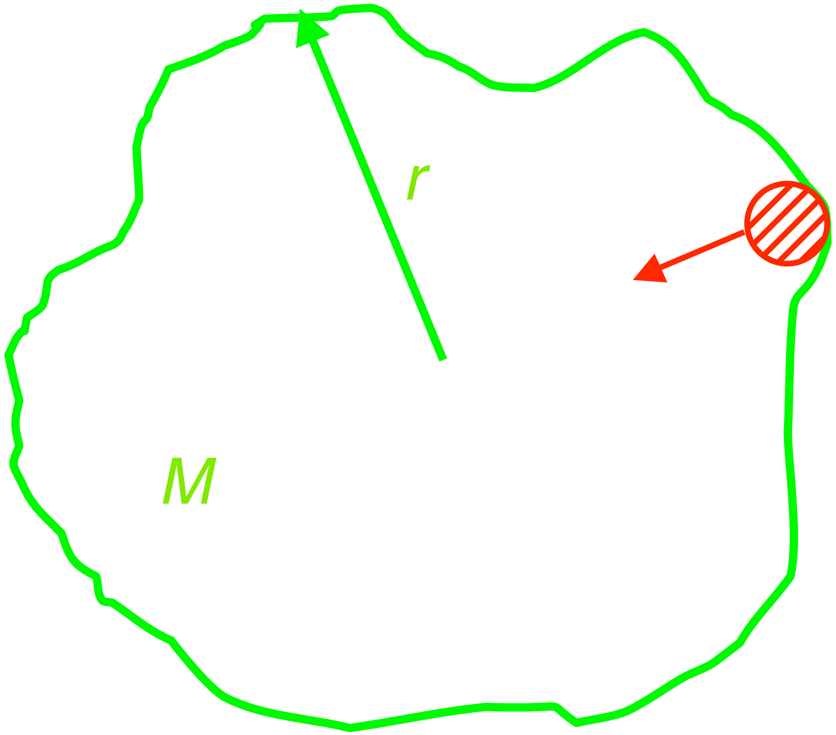


$M_{Jeans}/M_{\odot}$
10^6
10^5
10^4
10^3
10^2
10
T= 100 K
T= 10 K
10^4 10^5 10^6 10^7 10^8 10^9 10^{10}
Densité
(atomes m^{-3})
R_{Jeans} (pc)
10^4
10^3
10^2
10
1
0.1
T= 100 K
T= 10 K
10^4 10^5 10^6 10^7 10^8 10^9 10^{10}
Densité
(atomes m^{-3})

Temps de chute libre

Combien met le nuage pour s'effondrer?

En l'absence de barrière (au début…):

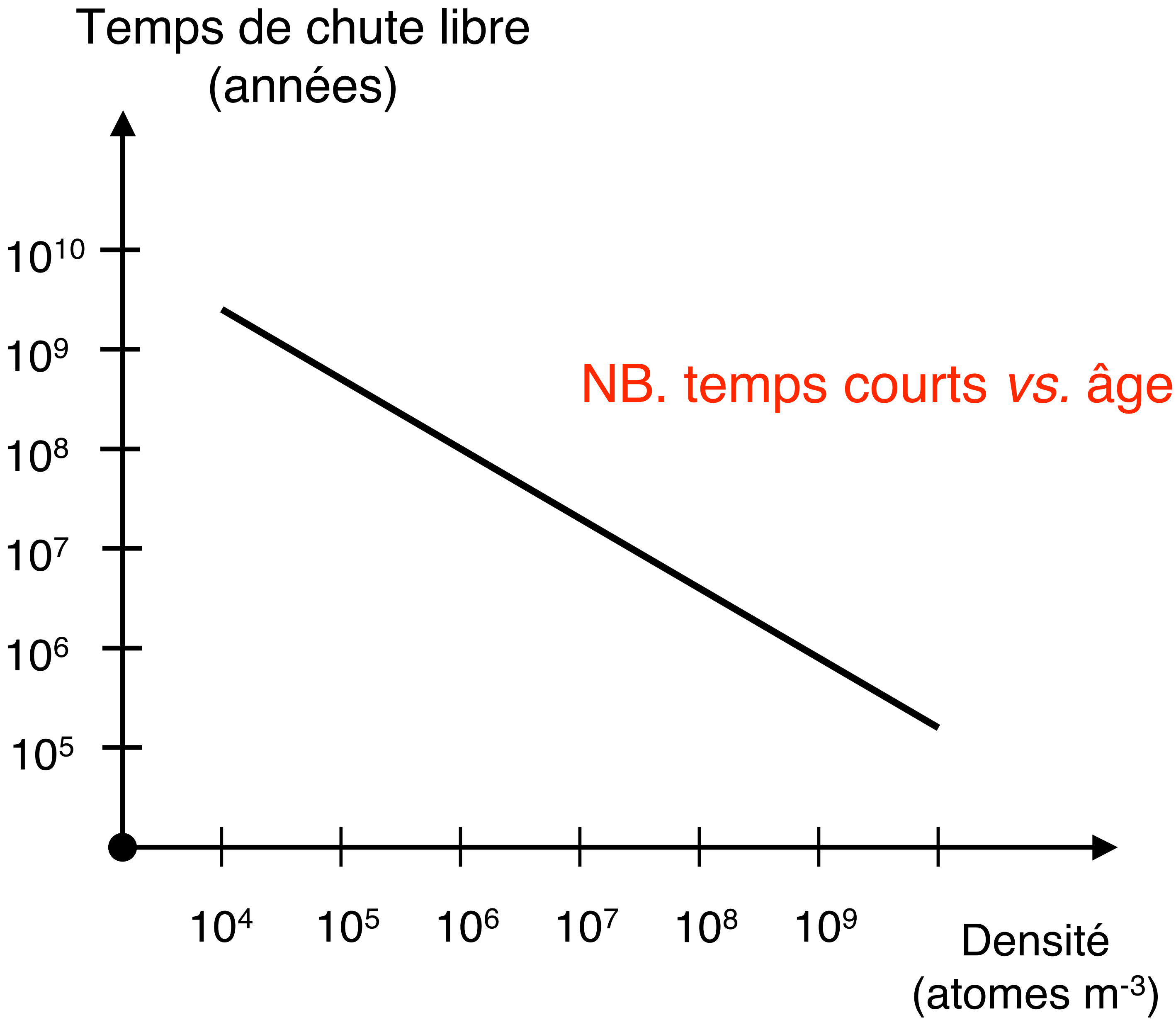


$$g = -\frac{GM}{r^2}$$

Temps de chute libre: $\frac{1}{2}|g|t_{cl}^{\ 2} \sim r$

où: $g \sim G\bar{\rho}r$

$$t_{cl} \sim \frac{0.3}{\sqrt{G\bar{\rho}}}$$



NB. temps courts *vs.* âge Galaxie!

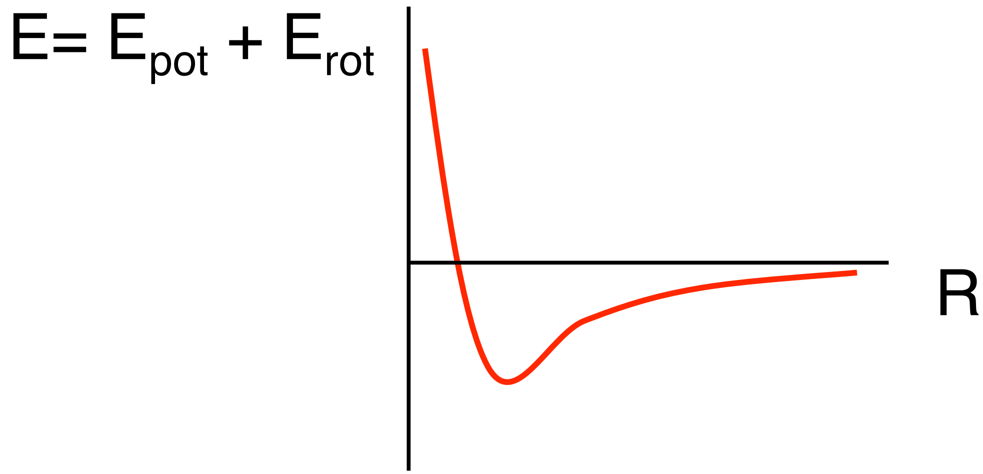
Barrière rotationnelle

$$\begin{cases} E_{pot} \sim -\dfrac{3}{5}\cdot\dfrac{GM^2}{R} \\ E_{rot} \sim \dfrac{1}{2}\cdot I\omega^2 \end{cases}$$

où: $$\begin{cases} H = I\omega = cste \\ I \sim MR^2 \end{cases}$$

(*H:* moment cinétique, *I:* moment d'inertie)

$$\Rightarrow \begin{cases} E_{pot} \propto -\dfrac{1}{R} \\ E_{rot} \propto +\dfrac{1}{R^2} \end{cases}$$



disque rotationnellement instable si
$E_{pot} + E_{rot} \geq 0$, soit:

$$R \leq \frac{H^2}{GM^3}$$

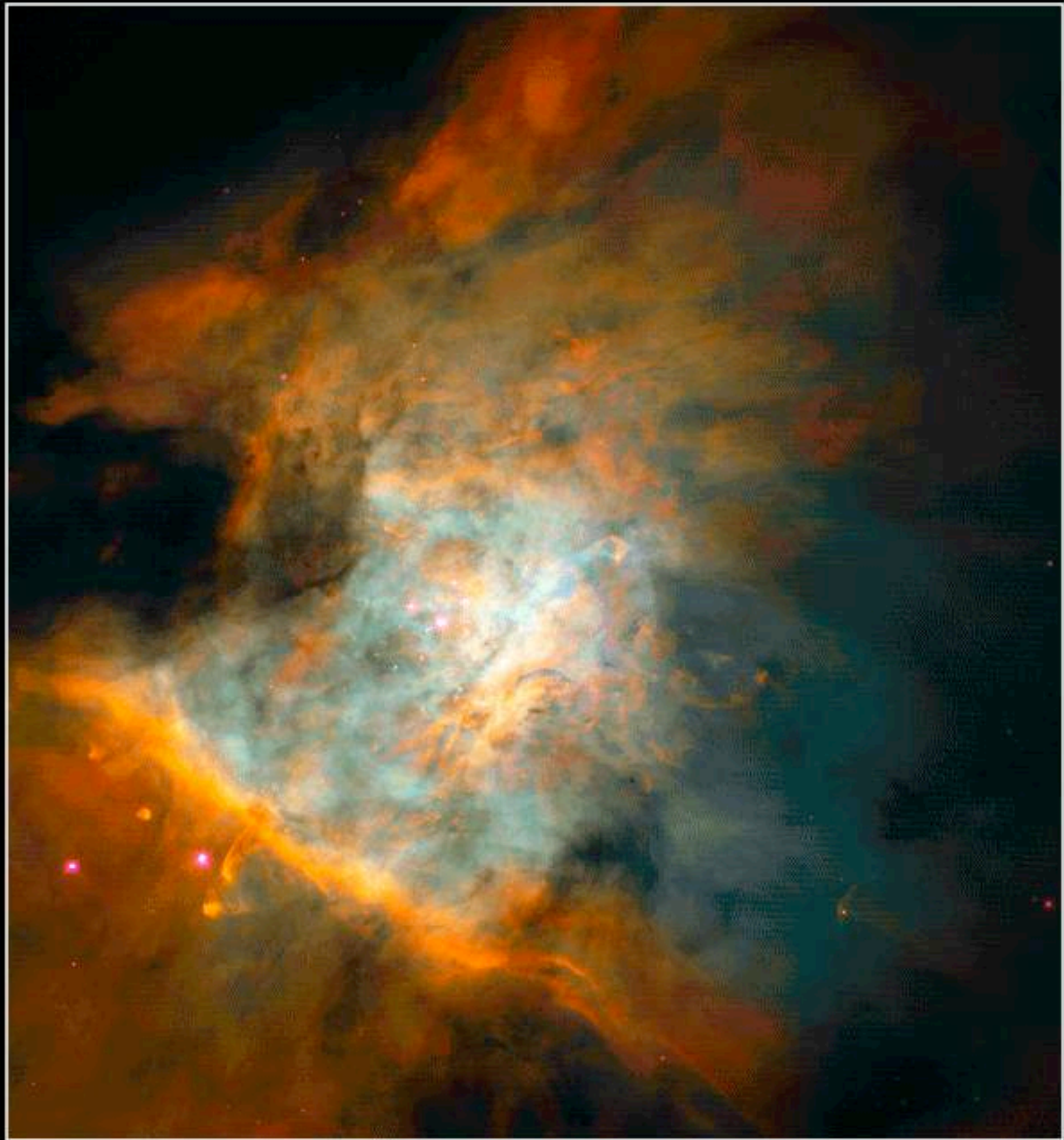
AN:

$M_0 \sim 1 M_\odot$

$R_0 \sim 0.1\ AL$ $\Rightarrow R < 2\ UA$

$T_0 \sim 3 x 10^7$ années

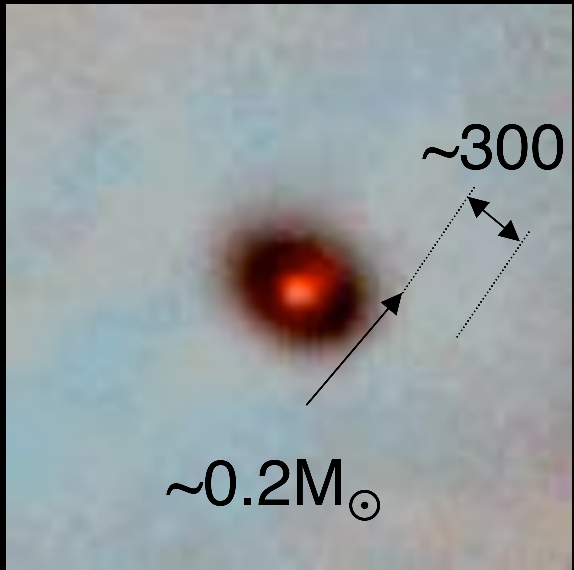
rotation attendue du Soleil: 10 mn!

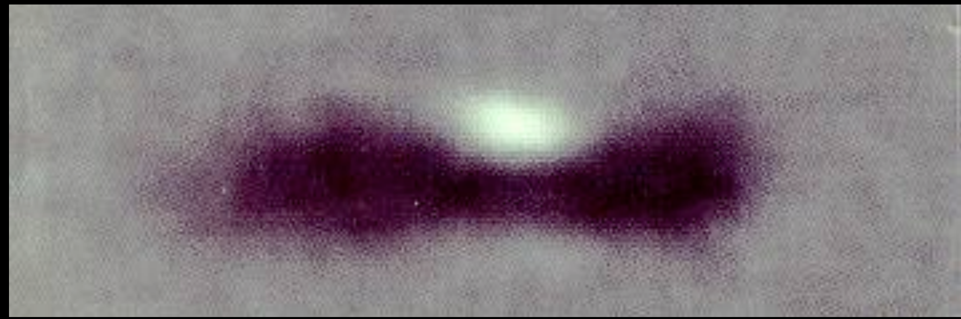


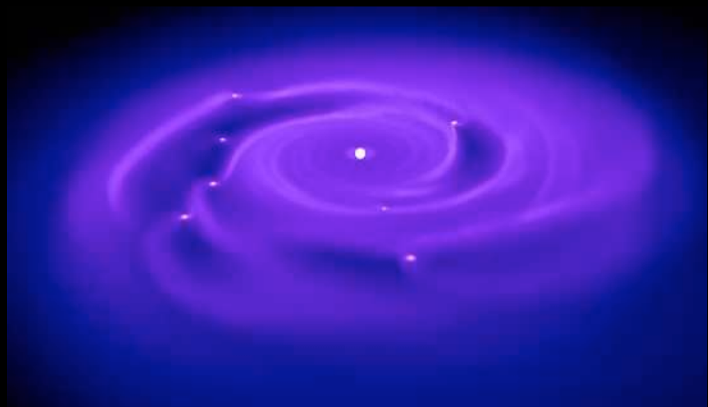
Orion Nebula Mosaic HST • WFPC2

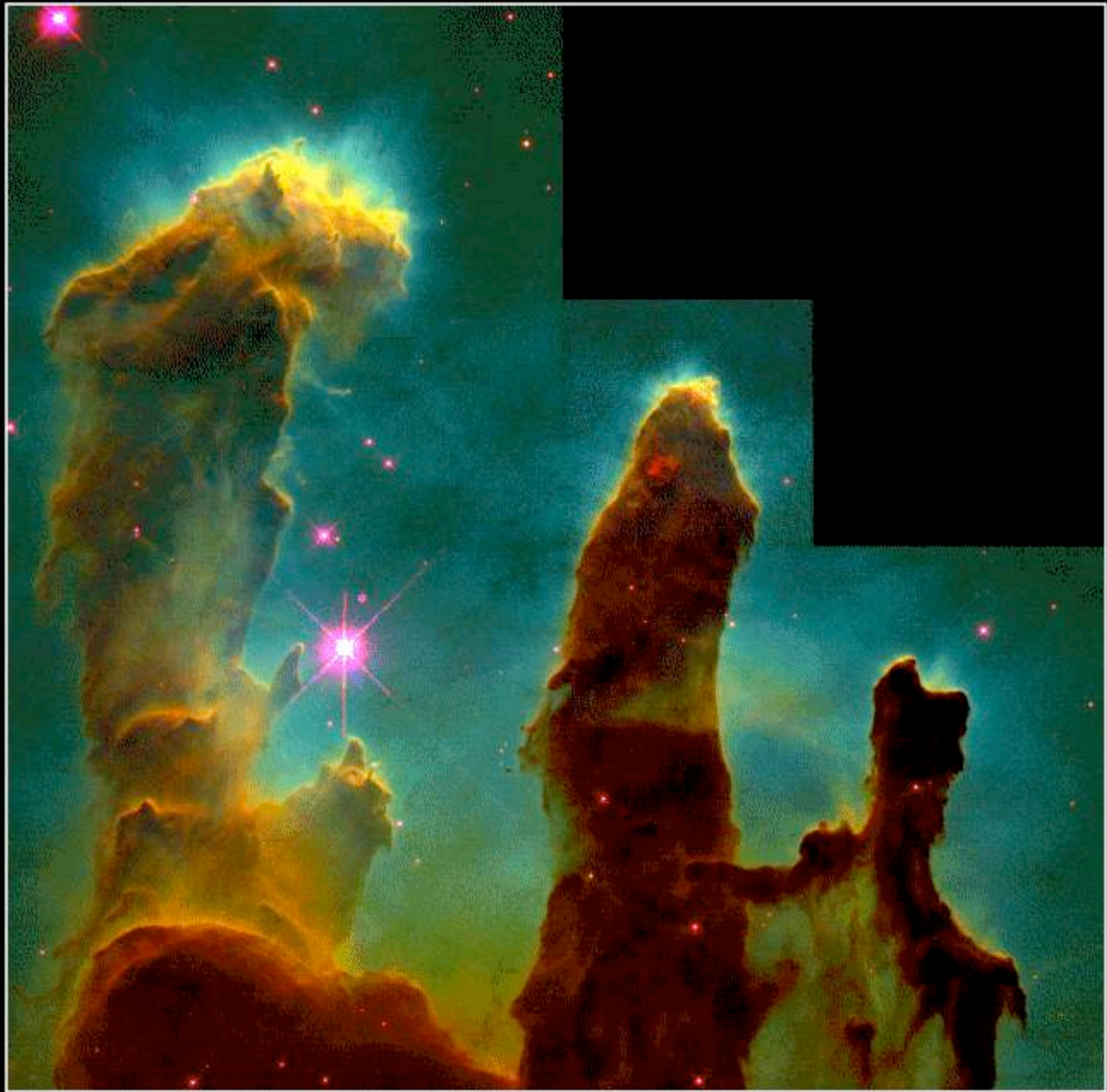
PRC95-45a • ST ScI OPO • November 20, 1995

C. R. O'Dell and S. K. Wong (Rice University), NASA


~300
~0.2M⊙



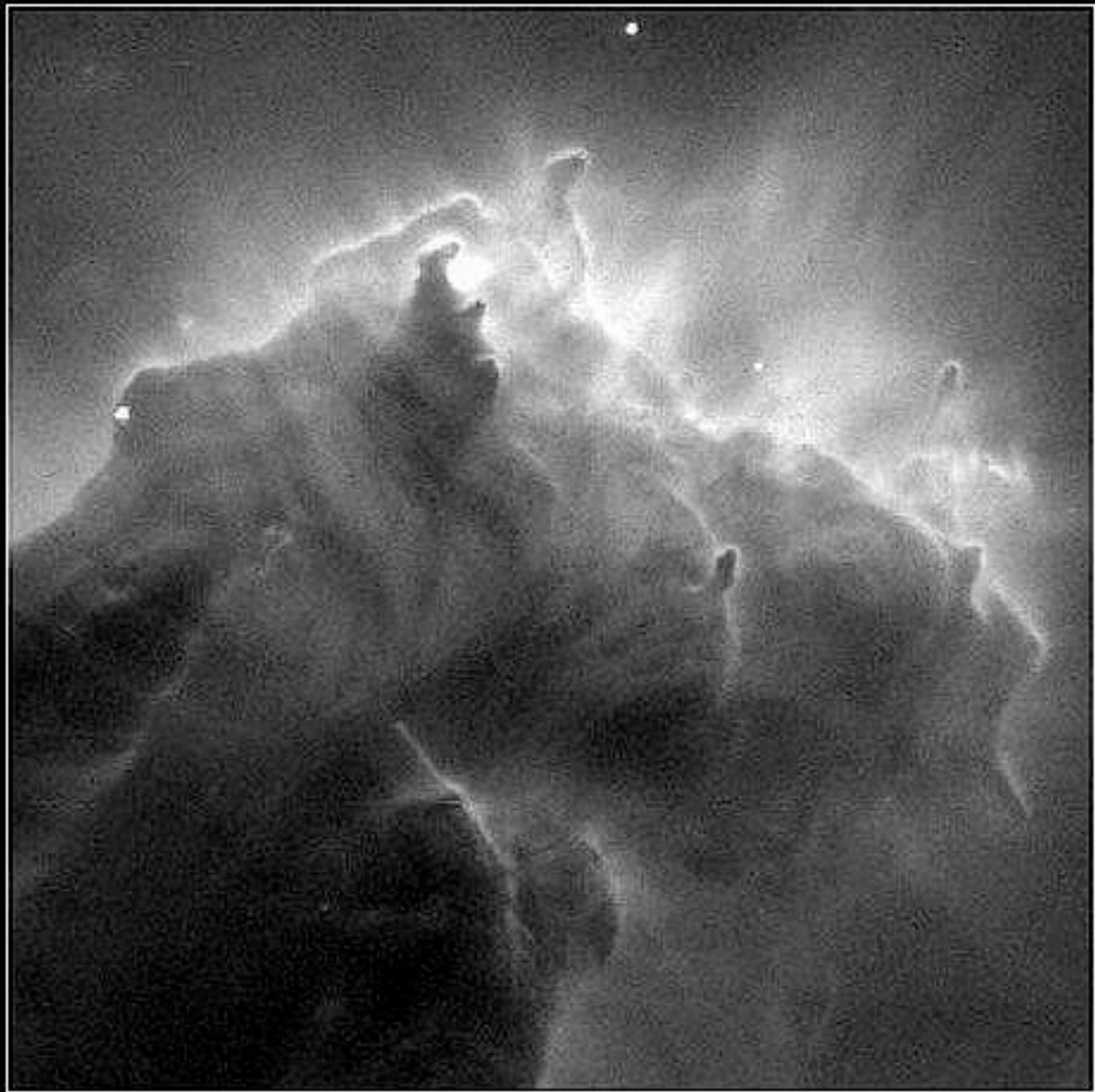




Gaseous Pillars · M16 HST · WFPC2

PRC95-44a · ST ScI OPO · November 2, 1995

J. Hester and P. Scowen (AZ State Univ.), NASA



Evaporating Globules • M16 HST • WFPC2

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