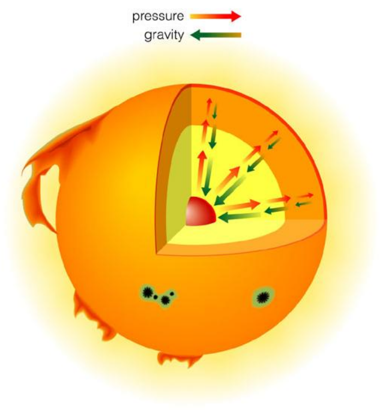
Star's life: Protracted battle with gravity



ALWAYS

To support weight:

⇒ need high pressure

MOSTLY

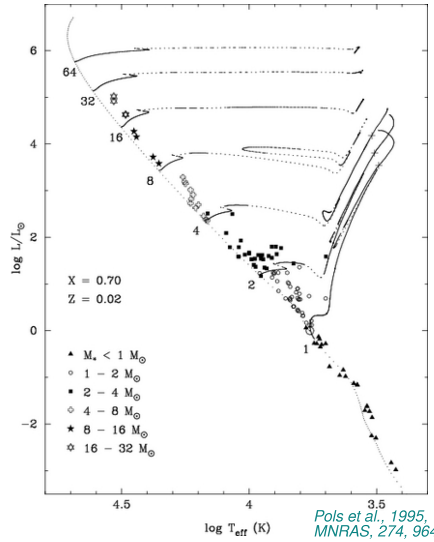
⇒ need high temperature

⇒ will loose energy

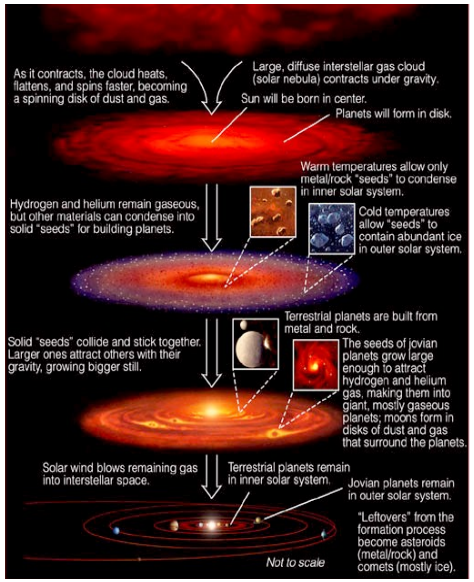
⇒ need energy source:
- Gravitational contraction
- Nuclear fusion

Ultimately,
Can something else than thermal pressure balance gravity?

Evolutionary tracks:
what happens depends on mass



Pols et al., 1995, MNRAS, 274, 964



Open issues

have to form planets in ~ few Myrs

1) how did the gas disk disperse?

2) how are planetesimals made? Are dust grains sufficiently sticky?

3) what makes chrondrules?

4) How do planetesimals survive collisions?

5) What is Jupiter's role in the fate of other planets?

6) Do giant planets only form outside frost lines? If so, how to explain the extra-solar hot Jupiters?

7)....

Distance	$d\,[pc] = 1/\pi\,[arcsec]$
magnitudes	$m = C - 2.5 \log f$; $m_1 - m_2 = -2.5 \log(f_1/f_2)$; $M - m = 5 - 5 \log d$
Doppler shift	$\frac{\Delta\lambda}{\lambda} = \frac{v_{rad}}{c}$
Gravity & tides	$a = \frac{GM}{r^2}$; $a_{tide} \approx \frac{GM}{r^2}\frac{2R}{r}$
Kepler	$GM = \Omega^2 a^3 = \left(\frac{2\pi}{P}\right)^2 a^3$; $\frac{a_1}{a} = \frac{v_1}{v} = \frac{m_2}{M}$; for circular orbit, $v = \sqrt{\frac{GM}{a}}$
Virial Theorem	$E_{kin} = -\frac{1}{2}E_{pot}$; $E_{tot} = E_{kin} + E_{pot} = \frac{1}{2}E_{pot}$ [where $E_{pot,bin} = -\frac{GM_1 M_2}{a}$ and $E_{pot,star} \approx -\frac{GM^2}{R}$]
Ideal gas	$P = nkT = \frac{\rho}{\mu m_H}kT$; typical kin. en. per particle $\langle e \rangle = \frac{3}{2}kT$; en. density $e = \frac{3}{2}nkT = \frac{2}{3}P$
Degenerate gas	$\Delta x \Delta p \sim \hbar$; $E_F = \frac{1}{2}\frac{p_F^2}{m_e} \propto n_e^{2/3}$; $P \propto n_e E_F \propto n_e^{5/3} \propto (\rho/\mu)^{5/3} \rightarrow R \propto M^{-1/3}$
Photon propagation	$l_{mfp} = 1/\sigma n = 1/\kappa\rho$; $t_{random} = \frac{R}{l_{mfp}}\frac{R}{c}$
Black body	$L = 4\pi R^2 \sigma T_{eff}^4$; $\lambda_{peak} \propto 1/T$
Hydrostatic eq.	$\frac{dP}{dr} = -\rho\frac{GM}{r^2}$; $\rightarrow$ $P \propto M^2/R^4$
Radiative transfer	$\frac{dT}{dr} = \frac{3\kappa\rho}{16\sigma T^3}\frac{L_r}{4\pi r^2}$; $\rightarrow$ $L \propto T_c^4 R^2 \frac{l_{mfp}}{R}$
Timescales	$\tau_{ff} \sim \sqrt{\frac{r^3}{GM}} \sim \sqrt{\frac{1}{G\rho}}$: $\tau_{KH} \sim \frac{GM^2/R}{L}$
Hydrogen fusion	$E = mc^2$; p-p start with $p + p \rightarrow D + e^+ + \nu_e$; CNO catalyst, start with ${}^{12}C + p \rightarrow {}^{13}N + \gamma$
Hydrogen atom	$E_n = -13.6\,eV/n^2$