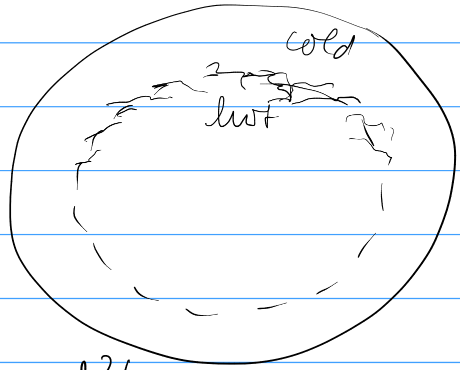
Shock is radiation dominated

& mediated

$aT^4 \gg \frac{\rho}{\mu m_H} kT$

compton scattering



photons diffuse across some thickness d

$$\frac{d}{c}\frac{d}{l_{mfp}} = \frac{d^2 \kappa \rho}{c}$$

$$\frac{d}{l_{mfp}} \equiv \tau$$

$$t_{diff} = \frac{d}{c}\tau$$

Must be equal to the shock crossing time

$\frac{d}{v_{sh}}$ $\Rightarrow$ optical depth over shock region $\tau = c/v_{shock}$

Given $\tau = c/v$ & $\kappa = \kappa_{es} \approx 0.34\ g/cm^2$

$$d \simeq \tau l_{mfp} = \frac{\tau}{\kappa\rho}$$

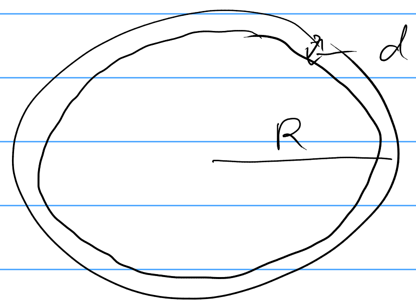
$$\Delta M = 4\pi R_*^2 d \rho = \frac{4\pi R_*^2 \tau}{\kappa}$$

$$E_0 \simeq \Delta M v_{sh}^2$$

$$L = \frac{E_0}{t_{diff,0} = d/v_s} \simeq 4\pi R_*^2 \rho v_{sh}^3$$

speed at which shock generates energy

Light curve



dyn. time scale $\frac{d_0}{v_{sh}} \equiv t_0$

At any time, see rad from $\tau(t) = \frac{c}{v}$

Planar case where volume $R^2 d \approx R_*^2 d(t)$

$$v_{sh} t < R_*$$

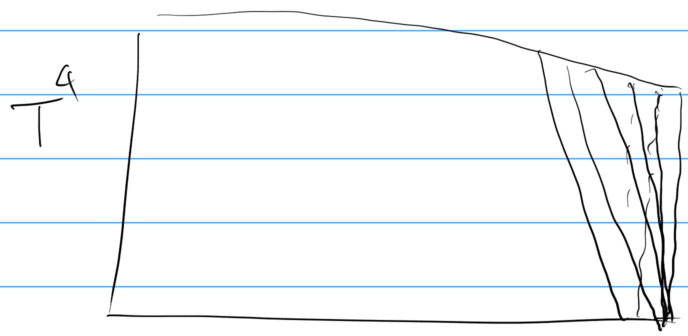
$$\tau = d/l_{mfp} = d\kappa\underbrace{\rho}_{\propto \frac{1}{d} \propto \frac{1}{t}} = \text{const.}$$

→ see only outermost layer

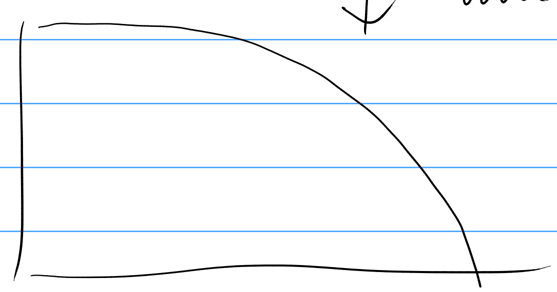
$$E = E_0 \left(\frac{d_0}{d}\right)^{1/3} = E_0 \left(\frac{t}{t_0}\right)^{-1/3}$$

$$L = \frac{E}{t_{dif.}} = \frac{E_0}{t_{diff,0}} \left(\frac{t}{t_0}\right)^{-4/3}$$

$$t_{diff} = \frac{d}{c}\frac{d}{l_{mfp}} = \frac{\overbrace{d}^{\propto t}}{c}\tau = t_{diff,0}\left(\frac{t}{t_0}\right)$$



↓ much



Spherical phase

$\tau \downarrow \Rightarrow$ see deeper layers

$\rho \propto d_i^{\,n}$ ← polytropic index

$P = \frac{\rho}{\mu m_H} kT$

Polytropic equation of state $P = K\rho^{1+1/n}$

$P = K\rho^{\gamma}$

$\frac{4}{3} \le \gamma \lesssim \frac{5}{3}$

rad ideal gas

$3 \ge n \ge 1.5$

Near R_* at some depth d $\quad \frac{dP}{dd} = g\rho$

$g = \frac{GM}{R_*^2} \simeq$ const $\quad K \frac{d\rho^{1+\frac{1}{n}}}{dd} = g\rho$

$(n+1)\, d\rho^{1/n} = \frac{g}{K}\, dd$

$\Rightarrow \rho \propto d^n$

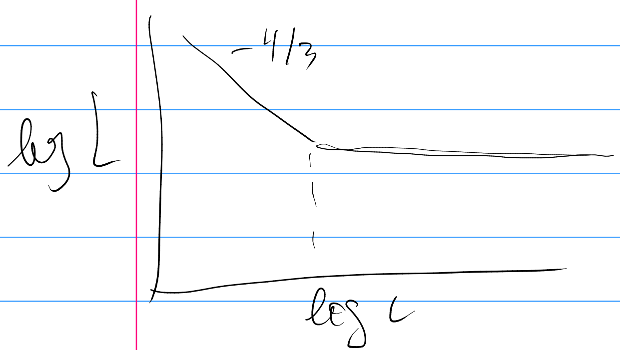
← comes from sim.

$v \propto \rho^{-0.19} \propto d^{-0.19n}$

$m \propto d\rho \propto d^{n+1}$

$$\tau(t) = \underset{\propto t}{d}\, k \underset{\propto t^{-3}}{\rho} \propto d^{n+1} t^{-2} = \frac{c}{v} \propto d^{+0.19n}$$

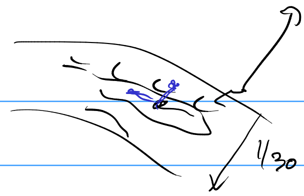
$\Rightarrow d \propto t^{2/(1.19n+1)}$



$\frac{E(t)}{t} = L \propto \left(\frac{t}{t_s}\right)^{-\frac{(2.28n-2)}{3(1.19n-1)}}$

quite shallow

Spectrum



Always see photons from some depth $\tau = \frac{c}{v}$ which have scattered their way out

$\Rightarrow$ if nothing intervenes, typical photon en. set by deeper depth ($\hat{T}$)

If $\tau_{abs} \tau = 1 \Rightarrow$ can thermalize