Universidad Nacional de Río Negro
Int Partículas, Astrofísica & Cosmología - 2020

- **Unidad** 02-Astrofísica, estrellas y planetas
- **Clase** U02 C03 - 7/16
- **Fecha** 16 Sep 2020
- **Cont** Fusión Estelar 2 y Evolución Estelar
- **Cátedra** Asorey
- **Web** https://gitlab.com/asoreyh/unrn-ipac/

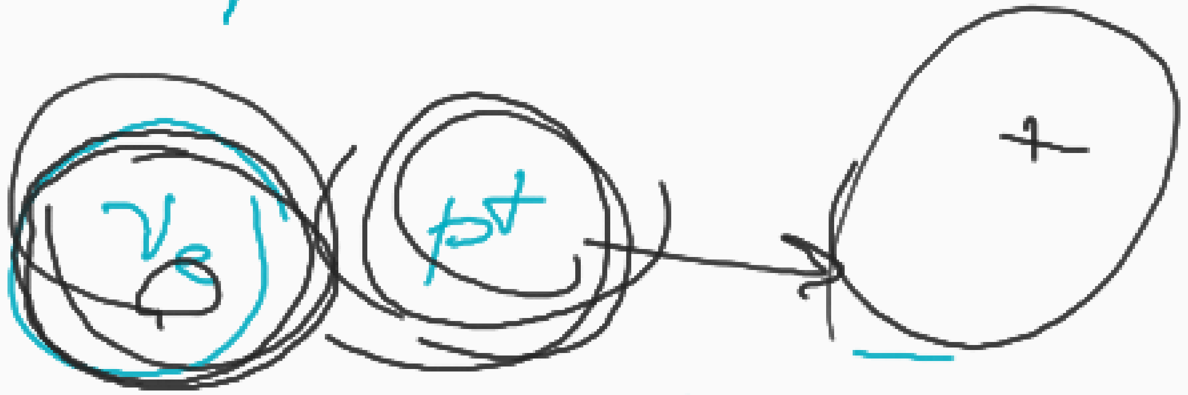
$\pi^+ \to \mu^+ \nu_\mu$ 99,8 %

$\hookrightarrow e^+ \nu_e$ 0,018 %

$\pi^- \to \mu^- \bar{\nu}_\mu$ 99,18 %

0,018 %

W^+ W^- // Z^0



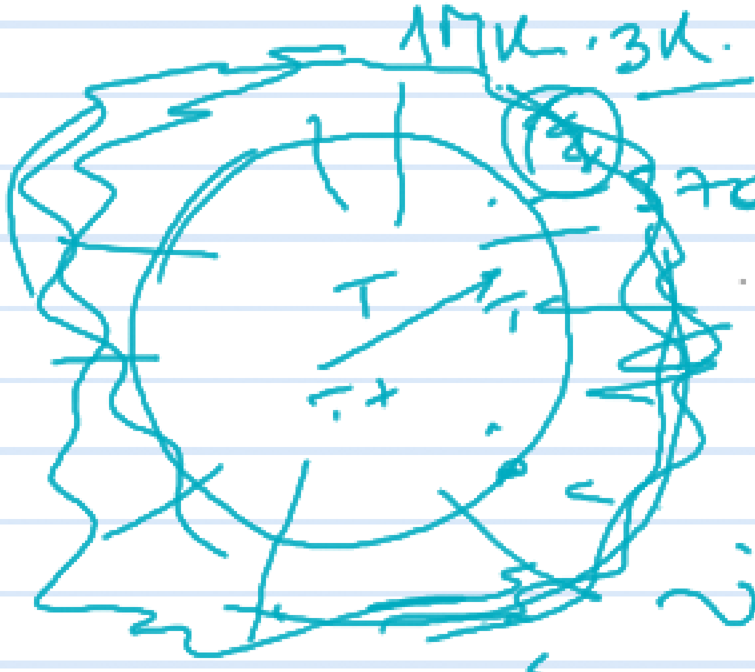
e^-

$n \to p + e^- + \bar{\nu}_e$

$p^+ \longrightarrow e^+ + n^0 + \nu_e$ β^+

938,3 MeV   0,511 MeV   939,6 MeV

$\bar{\nu}_e \, p^+ \longrightarrow e^+ n^0$.



1MK. 3K.

7000K

Mm

ionizado.

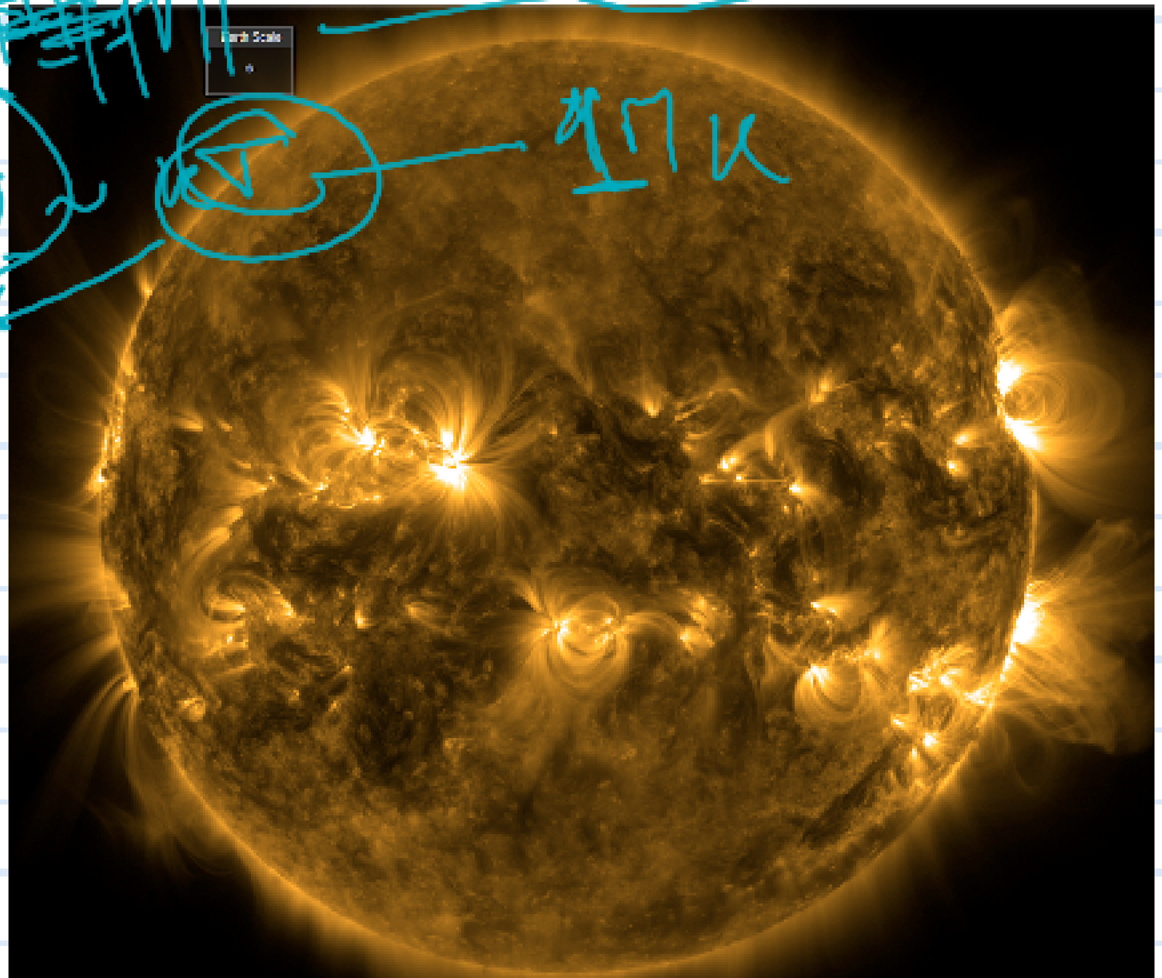
Corona?

Fe 23 ionizado.

Corona Solar.

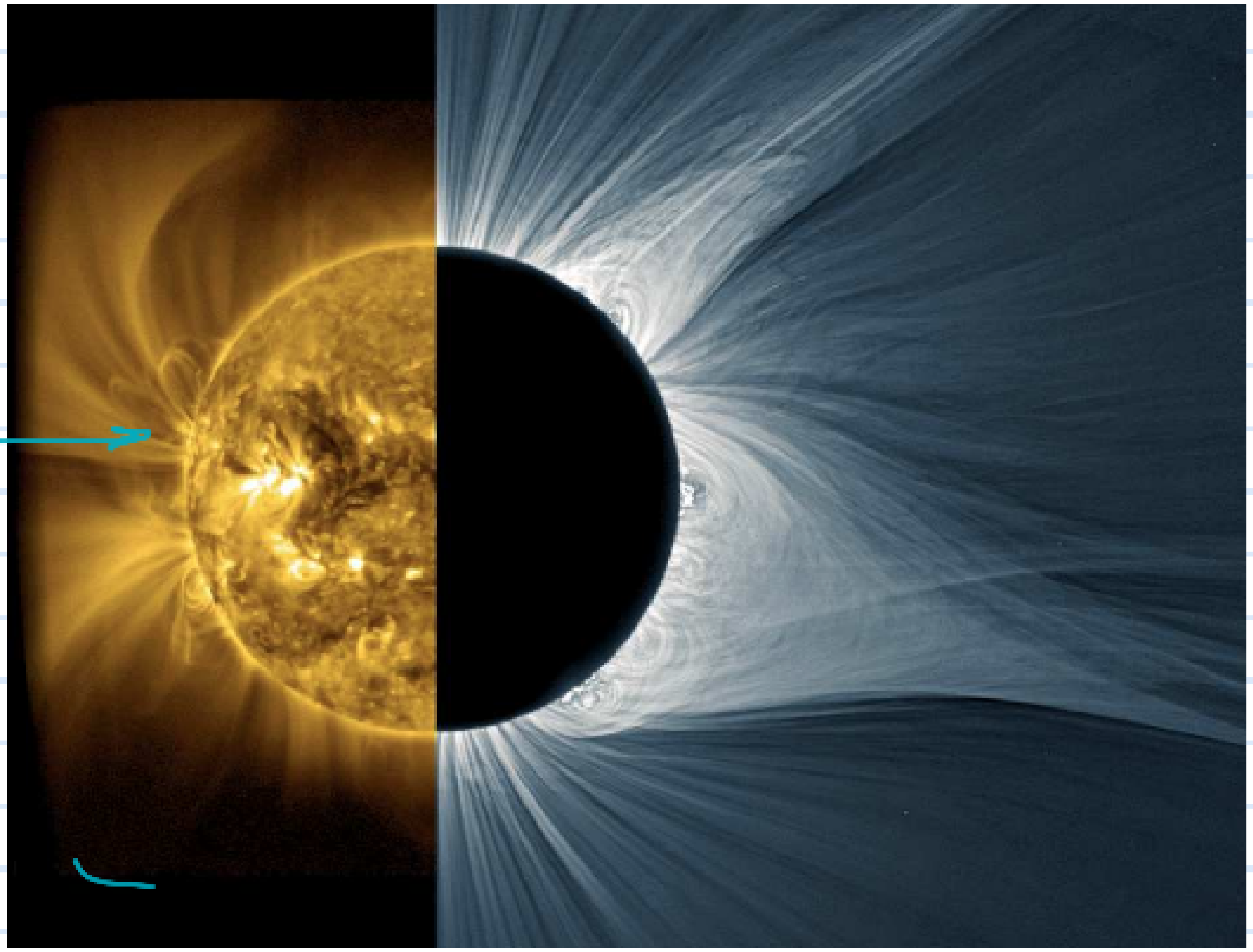
$E\gamma$ keV

$h\nu$ kT 1MK



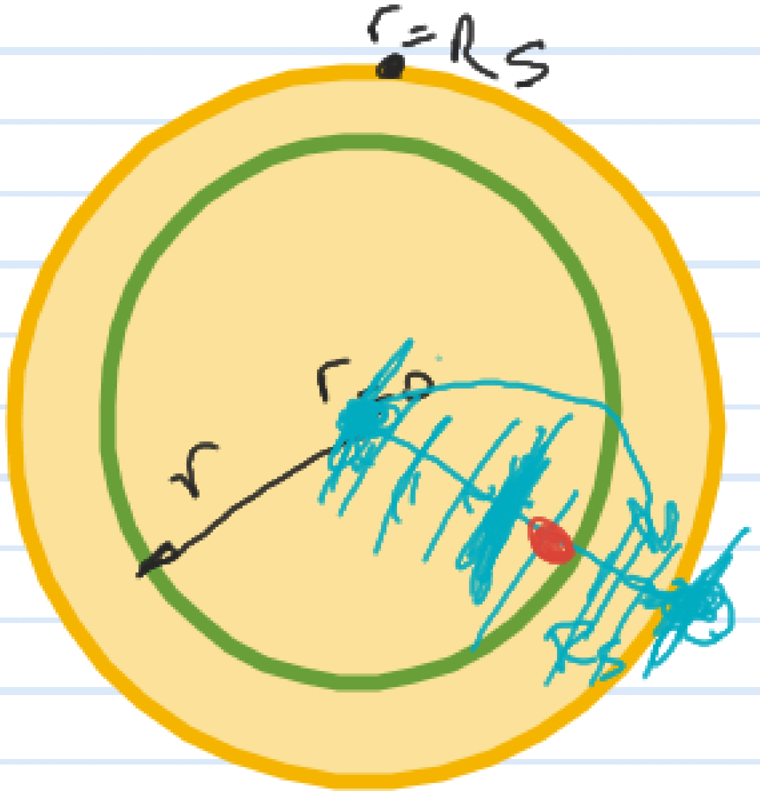
2014

Hierro ionizado.



$$\Delta\nu \propto \frac{\partial\phi}{dt}$$

$$\bar{\phi} = A\cos$$



$M_0 = 0 \qquad M_{R_S} = M_S$

$l_0 = 0 \qquad l_{R_S} = L_S$

$P_0 = P_c \qquad P_{R_S} = 0$

$T_0 = T_c \qquad T_{R_S} = T_S \simeq 0$

$\rho_0 = \rho_c \qquad \rho_{R_S} = 0$

$\epsilon_0 = \epsilon_c \qquad \epsilon_0 = 0$

$K = cte \qquad K = cte$

Condiciones de borde propuestas.

$d \longrightarrow \Delta$

tamaño de la malla (mesh)

r, $r + dr$, dr

$\Delta r \simeq 1\,mm$

$R \sim 100000\,km$

$$dM \rightarrow \Delta M = M_{R_S} - M_0 = M_S - 0 = M_S$$

$$\rho_r = \frac{\rho_{R_S} + \rho_0}{2} = \frac{0 + \rho_0}{2} = \rho_0/2$$

$$r \rightarrow r = \frac{R_S + 0}{2} \Rightarrow r = R_S/2 \qquad r^2 \rightarrow r^2 = R_S^2/4$$

$$\frac{dM_r}{dr} = 4\pi \rho_r r^2 \Rightarrow dM \to \frac{\Delta M}{\Delta r} = \frac{M_S}{R_S} = 4\pi \cdot \frac{\rho_0}{2} \cdot \frac{R_S^2}{\cancel{4}} \Rightarrow M_S = 4\pi \frac{\rho_0}{2} \cdot \frac{R_S^2}{\cancel{4}} \cdot R_S$$

$$\Delta r = R_S - 0 = R_S \Rightarrow \boxed{M_S = \frac{\pi}{2} \rho_0 R_S^3} \quad (1)$$

$$dP = \frac{GM_r \rho_r}{r^2} dr \xrightarrow{d \to \Delta} \Delta P = -\frac{GM_r \rho_r}{r^2} \cdot \Delta r \to (\cancel{P_{R_S}}^{0} - P_0) = -\frac{GM_r \rho_r}{r^2}(R_S - 0)$$

$$\cancel{+}P_0 = \cancel{+}G \frac{M_S}{\cancel{2}} \cdot \frac{\rho_0}{\cancel{2}} \frac{\cancel{R_S}}{R_S^{\cancel{2}}/\cancel{4}} \to \boxed{P_0 = \frac{GM_S \rho_0}{R_S}} \quad (2)$$

$$\frac{N}{m^2} = \frac{N \cancel{m^2}}{\cancel{kg^2}} \cdot \frac{\cancel{kg}}{\cancel{m^3}} \frac{\cancel{kg}}{m^{\cancel{3}2}} = \frac{N}{m^2}$$

$$dL = 4\pi \rho_r \epsilon_r r^2 dr \to \Delta L = 4\pi \rho_r \epsilon_r r^2 \Delta r \Rightarrow L_S = \cancel{4\pi} \frac{\rho_0}{2} \frac{\epsilon_0}{2} \frac{R_S^2}{\cancel{4}} R_S$$

$$\boxed{L_S = \frac{\pi}{4} \rho_0 \epsilon_0 R_S^3}$$

$$L_r = -\frac{16\pi\sigma}{K_r \rho_r} \cdot r^2 T_r^3 \frac{\Delta T}{\Delta r} \Rightarrow \frac{L_S}{2} = \frac{-16\pi\sigma}{\frac{K\rho_0}{2}} \cdot \frac{R_S^2}{4}\left(\frac{T_0}{2}\right)^3 \frac{(0 - T_S)}{(R_S - 0)}$$

$$\frac{L_S}{2} = \frac{\cancel{+}\cancel{16}\pi\sigma \cdot \cancel{2}}{K\rho_0} \cdot \frac{R_S^{\cancel{2}}}{\cancel{4}} \cdot \frac{T_0^3}{\cancel{8}} \cdot \frac{(\cancel{+}T_S)}{\cancel{R_S}} \Rightarrow \boxed{L_S = \frac{2\pi\sigma}{K\rho_0} \cdot R_S T_0^4} \quad (4)$$

$$P_r = \frac{k_B}{\langle m \rangle} T_r \rho_r \Rightarrow \frac{P_0}{\cancel{2}} = \frac{k_B}{\langle m \rangle} \cdot \frac{T_0}{\cancel{2}} \cdot \frac{\rho_0}{2} \Rightarrow \boxed{P_0 = \frac{\rho_0}{2\langle m \rangle} \cdot k_B T_0} \quad (5)$$

De (1) y (2):

$$\boxed{\rho_0 = \frac{2M_S}{\pi R_S^3}} \quad y \quad P_0 = \frac{R_S P_0}{G M_S} \Rightarrow \frac{2M_S}{\pi R_S^3} = \frac{R_S P_0}{G M_S} \Rightarrow \boxed{P_0 = \frac{2 G M_S^2}{\pi R_S^4}}$$

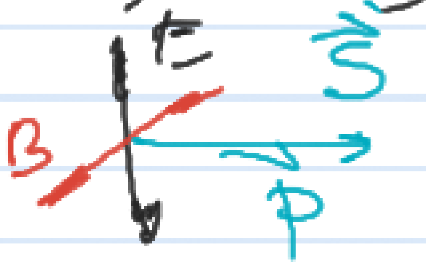
$$m \rightarrow E \quad \simeq E = mc^2 \qquad \frac{\Delta E}{\Delta T} = L \Rightarrow \Delta t = \frac{\Delta E}{L} \Rightarrow \Delta t = \frac{\Delta E}{M_S^x} \Rightarrow \tau \simeq \frac{M_S c^2}{M_S^x} \Rightarrow \tau = M_S^{1-x}$$

$$\text{Si } x = 3 \Rightarrow \tau \sim M_S^{-2} \quad // \quad \tau \sim M_S^{-3}$$

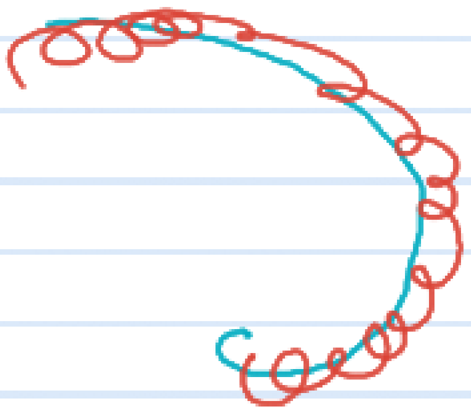
$E_r = ?$ Emisividad de Energía por unidad de masa y de tiempo.

$E^2 = p^2 + m^2$ $\quad \left(E^2 = p^2c^2 + \cancel{m^2c^4}\right) \Rightarrow E^2 = p^2c^2 \Rightarrow E = pc$ fotón $E = h\nu \Rightarrow$

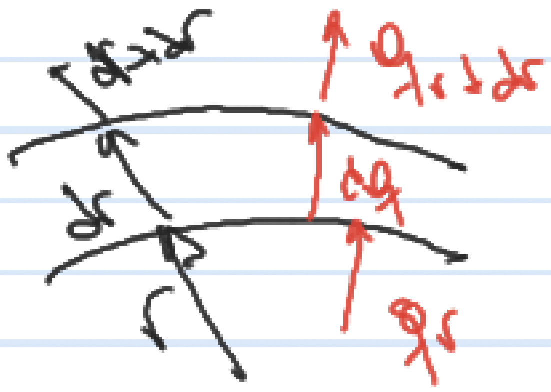
$h\nu = pc \Rightarrow \boxed{p = \frac{h\nu}{c}}$



Vector de Pointing.



$L \propto M^x \quad 3 < x < 4 \quad M = 50 M_0 \quad \frac{L}{L_0} = \left(\frac{M_s}{M_0}\right)^4 \Rightarrow L = \left(\frac{50 M_0}{M_0}\right)^4 = 6{,}25 \times 10^6 L_0 \sim 2 \times 10^{33} \frac{J}{s}$



$dq = -\kappa q_r \rho_r dr \qquad E_\gamma = h\nu \Rightarrow p_\gamma = h\nu / c \qquad dq = E_\gamma \frac{dN}{dt} = -\kappa q_r \rho_r dr$

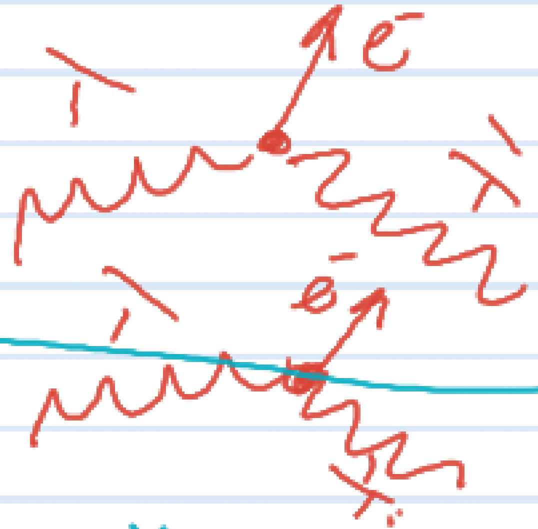
$\Rightarrow \frac{dN}{dt} = \frac{-\kappa_r \rho_r q_r dr}{E_\gamma} \frac{c}{c} \Rightarrow \frac{dN}{dt} = -\frac{\kappa_r q_r \rho_r}{p_\gamma \cdot c} dr \Rightarrow \frac{d(N p_\gamma)}{dt} = \boxed{-\frac{\kappa_r q_r \rho_r}{c} dr = F_\gamma}$

$F_G = -\frac{G M_r \rho_r}{r^2} dr \Rightarrow \cancel{-}\frac{\kappa_r q_r \cancel{\rho_r}}{c} \cancel{dr} = \cancel{-}\frac{G M_r \cancel{\rho_r}}{r^2} \cancel{dr} \Rightarrow \frac{\kappa q_r}{c} = \frac{G M_r}{r^2} \rightarrow r = R_s$

$r = R_s \Rightarrow \frac{G M_s}{R_s^2} = \frac{\kappa q_s}{c}$ q_s es el flujo de energía $\Rightarrow q = \frac{L}{A} = \frac{L}{4\pi R_s^2}$

$\Rightarrow \frac{G M}{\cancel{R^2}} = \frac{\kappa}{c} \frac{L}{4\pi \cancel{R^2}}$ Masa de Eddington $\Rightarrow$ $\boxed{M^* = \frac{\kappa}{4\pi c G} L}$ Límite de Eddington.

Wolf Rayet $\rightarrow$



$\lambda' > \lambda \Rightarrow E'_\gamma < E_\gamma$ Compton. σ_K

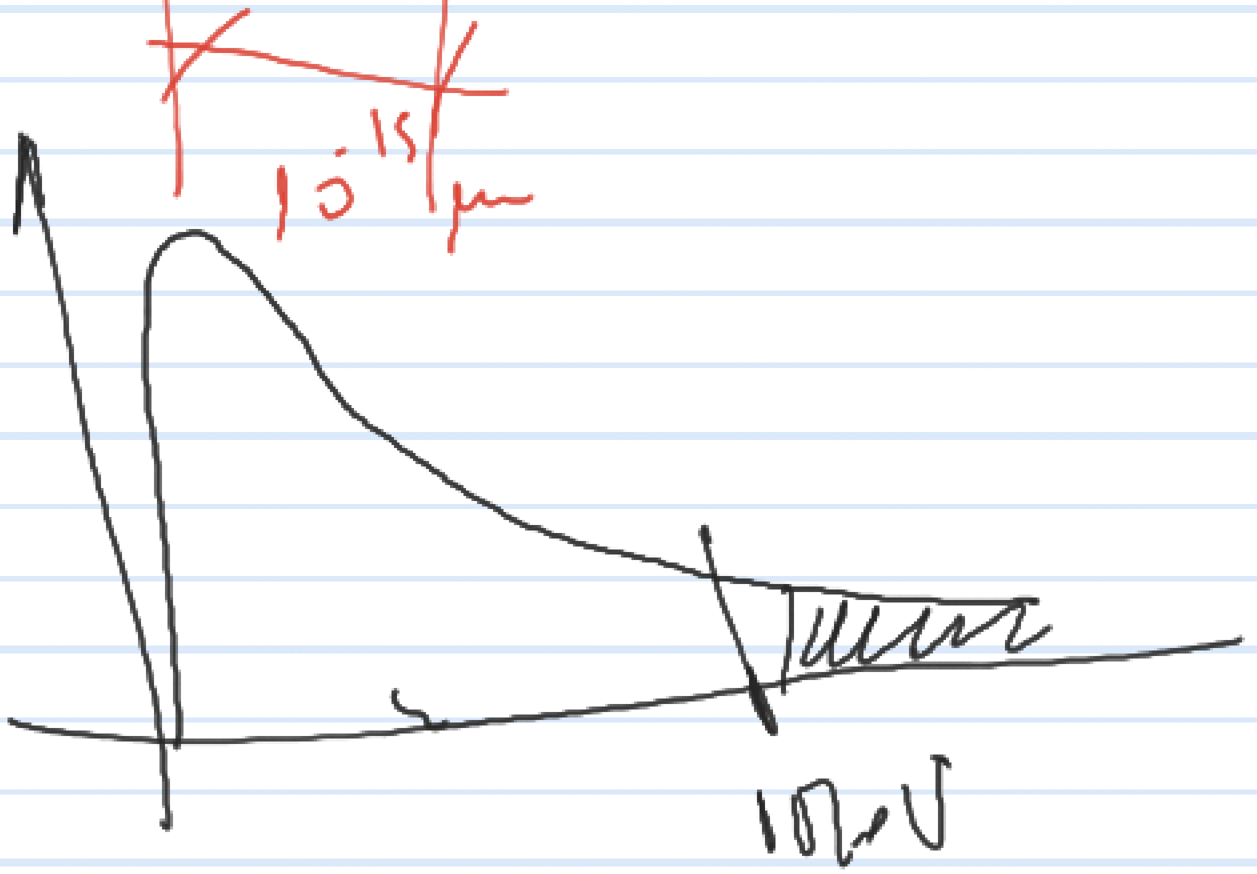
$\lambda' = \lambda$ $E'_\gamma = E_\gamma$ thomson. σ_T

$\frac{L}{L_0} = \left(\frac{M}{M_0}\right)^x \Rightarrow L = \frac{M^x}{M_0^x} \cdot L_0 \Rightarrow M^* = \frac{\kappa}{4\pi c G} \frac{M^{*x}}{M_0^x} \cdot L_0 \Rightarrow \frac{M}{M^x} = \frac{\kappa}{4\pi c G} \frac{L_0}{M_0 M_0^{x-1}}$

$\Rightarrow M^{*1-x} \cdot M_0^{x-1} = \frac{\kappa}{4\pi G c} \left(\frac{L_0}{M_0}\right) \Rightarrow \left(\frac{M^*}{M_0}\right)^{1-x} = \frac{\kappa}{4\pi G c} \cdot \frac{L_0}{M_0}$ $\boxed{\Rightarrow \left(\frac{M^*}{M_0}\right)^{x-1} = \frac{4\pi G c}{\kappa} \frac{M_0}{L_0}}$

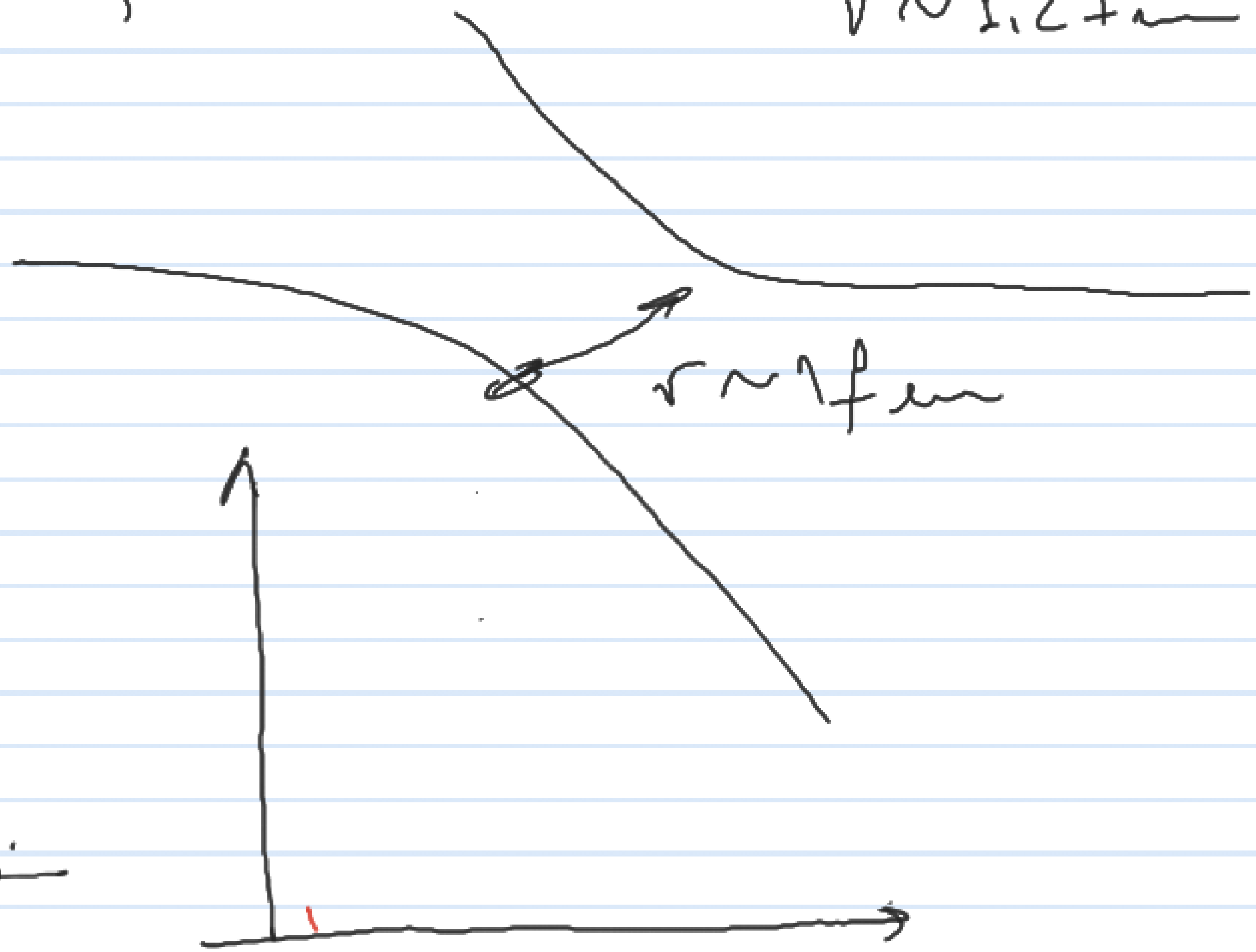
Si $x = 4 \Rightarrow M^* = \sqrt[3]{\frac{4\pi G c M_0}{\kappa L_0}}\, M_0 \Rightarrow$ $\boxed{M^* = 110\, M_\odot}$

$${}^{2}H + {}^{3}H \longrightarrow {}^{4}He_2 + n + Q$$



$$U(r) = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r} \Rightarrow U_{pp} = \frac{1}{4\pi\epsilon_0}\frac{e^2}{r}$$

$r \sim 1{,}2$ fm



$${}^{12}_{6}C_6 + {}^{4}_{2}He_2 \longrightarrow {}^{16}_{8}O_8 + Q.$$