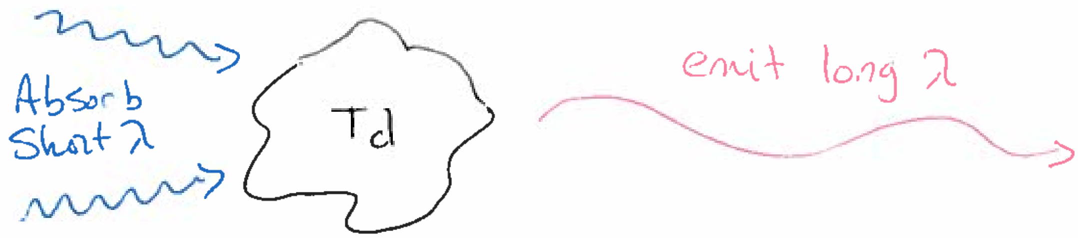
Dust Emission

ASTR 300B



Consider Pure Emission (and ignore any background):

$$I_\nu = \cancel{I_\nu(0)} e^{-\tau_\nu} + S_\nu (1 - e^{-\tau_\nu})$$

IGNORE

Thermal emission from dust $\Rightarrow$ $S_\nu = B_\nu(T_d) = \dfrac{j_\nu}{\alpha_\nu}$

$$j_\nu = B_\nu(T_d)\,\alpha_\nu$$

<u>If</u> emission is in optically thin limit:

$$I_\nu = B_\nu(T_d)\,\tau_\nu$$

$$\tau_\nu = \int_0^L \alpha_\nu\, ds = \int_0^L \underbrace{n_d}_{cm^{-3}} \underbrace{\sigma_\nu^{dust}}_{cm^2}\, ds = \int_0^L \underbrace{\rho_d}_{\frac{g}{cm^3}} \underbrace{\kappa_\nu^{dust}}_{\frac{cm^2}{g\ \text{of dust}}}\, ds = \int_0^L \underbrace{\rho_{gas}}_{\frac{g}{cm^3}} \underbrace{\kappa_\nu^{gas}}_{\frac{cm^2}{g\ \text{of gas}}}\, ds$$

Remember $\dfrac{\rho_{gas}}{\rho_{dust}} = \left\langle \dfrac{\text{mass in gas}}{\text{mass in dust}} \right\rangle \sim 100 \Rightarrow$ We can relate τ_ν to how much <u>GAS</u> along line of sight!

$$\kappa_\nu^{dust} \sim \kappa_\nu^{gas} \cdot 100$$

$$\frac{cm^2}{g\ \text{of dust}} \qquad \frac{cm^2}{g\ \text{of gas}} \times \frac{100\ g\ \text{of gas}}{1\ g\ \text{of dust}}$$

Putting this all together:

$$I_\nu = B_\nu(T_d) \cdot \int_0^L \rho_{gas} \cdot \kappa_\nu^{per\ gas} \, ds$$

$$= B_\nu(T_d) \cdot \int_0^L \mu m_H n_{gas} \cdot \frac{\kappa_\nu^{dust}}{100} \, ds$$

$$= B_\nu(T_d) \, \mu m_H \frac{\kappa_\nu^{dust}}{100} \int_0^L n_{gas} \, ds$$

If we measure n_{gas} in terms of H_2 molecules then:

$$I_\nu = B_\nu(T_d) \mu_{H_2} m_H \frac{\kappa_\nu^{dust}}{100} N_{H_2} \leftarrow \text{Column Density of } H_2$$

cm^{-2}

$I_\nu^{dust\ emission} \sim N_{H_2}$

optically thin limit

NOTE: We have assumed $T_d = \text{const}$ along line of sight and that $\kappa_\nu^{dust} = \text{const}$ along line of sight

If T_d, κ_ν vary – have to go back and solve radiative transfer equation:

$$\frac{dI_\nu}{ds} = j_\nu = \alpha_\nu B_\nu(T_{d(s)}) = \frac{\mu m_H}{100} n(s) \kappa_\nu^{dust}(s) B_\nu(T_{d(s)})$$

AND INTEGRATE ... $I_\nu = \frac{\mu m_H}{100} \int_0^L n(s) \kappa_\nu^{dust}(s) B_\nu(T_{d(s)}) \, ds$

We can relate ρ_{gas} to n_{gas} through the mean molecular weight:
g/cm^3 cm^{-3}

There are different definitions depending on whether you are calculating per H_2 molecule or per "particle":

$$\mu_{H_2} m_H N(H_2) = M$$

Number of H_2 molecules (or column Density)

Typical Abundance Ratios in ISM:

$$M = M(H) + M(He) + M(Z)$$

$$\frac{M(H)}{M} \sim 0.71 \quad \frac{M(He)}{M} \sim 0.27$$

$$\frac{M(Z)}{M} \sim 0.02 \quad \frac{N(H)}{N(He)} \sim 10$$

$$\mu_{H_2} = \frac{M}{m_H N(H_2)} = \frac{2M}{m_H N(H)} = \frac{2M}{M(H)} \simeq 2.8$$

Per free particle:

$$\mu_p \simeq \frac{M}{m_H \left[N(H_2) + N(He) + N(Z) \right]}$$

$$= \frac{M}{m_H \left[\frac{N(H)}{2} + \frac{N(H)}{10} + \overset{\approx}{\text{negligible}} \right]}$$

$$= \frac{M}{\frac{M(H)}{2} + \frac{M(H)}{10}} = \frac{M}{M(H)} \cdot \frac{5}{3} \simeq 2.34$$