Dust Extinction

Consider the extinction (= absorption & scattering) of light by dust grains:

$$d\tau_\nu = n_{dust}\, \sigma_\nu^{ext}\, ds$$

number density of dust grains cm^{-3}

extinction cross-section cm^2

$$\sigma_\nu^{ext} = \sigma_\nu^{abs} + \sigma_\nu^{sca}$$

$$\tau_\nu = \sigma_\nu^{ext} \int_0^L n_{dust}\, ds = \sigma_\nu^{ext} N_{dust}$$

Dust column density cm^{-2}

If we are at a λ where the dust does not emit (i.e. optical λ and cold dust), then we can ignore the source fctn. in the solution of the 1D radiative transfer equation:

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

We define the extinction A_λ at a wavelength λ:

$$A_\lambda \text{ mag} = 2.5 \log_{10} \frac{F_\nu(0)}{F_\nu^{obs}}$$

$$= 2.5 \log_{10} \frac{I_\nu(0)}{I_\nu^{obs}}$$

$$= 2.5 \log_{10} e^{+\tau_\nu}$$

NOTE $\tau_\nu = \tau_\lambda$

$$= \tau_\lambda \cdot (2.5 \log_{10} e)$$

$$A_\lambda \simeq 1.086\, \tau_\lambda$$

NOTICE: 1 mag of extinction $\simeq \tau \sim 1$ (within 8.6%)

Dust Opacity / Cross-section

There are 2 main ways that dust cross-sections and opacities are defined:

① CROSS-SECTIONS

$$\sigma_\nu^{abs} = \pi a^2 \cdot Q_{abs}$$

dust grain size

absorption efficiency

$$\sigma_\nu^{sca} = \pi a^2 \cdot Q_{sca}$$

scattering efficiency

cm^2

unitless

$$\sigma_\nu^{ext} = \sigma_\nu^{abs} + \sigma_\nu^{sca} \Rightarrow Q_{ext} = Q_{abs} + Q_{sca}$$

To calculate Q's – we need to determine how EM waves interact with dielectric material in the grain (COMPLICATED!)

② MASS OPACITY

$$\kappa_\nu \equiv \frac{\sigma_\nu^{ext}}{m_d} = \frac{\pi a^2 Q_{ext}}{m_d} \qquad \frac{cm^2}{\text{gram of dust}}$$

mass of dust grains

Q_{ext} is popular at short (UV – IR) wavelengths

κ_ν is popular at long (FAR IR – RADIO) wavelengths

In general Q_{ext} is a function of grain type and varies with grain size and wavelength. We must integrate over size distribution to get total Q_{ext} or κ_ν.