Radiative transfer

- how radiation interacts with matter

macroscopic ~~tot~~ level: emission and absorption coeficients

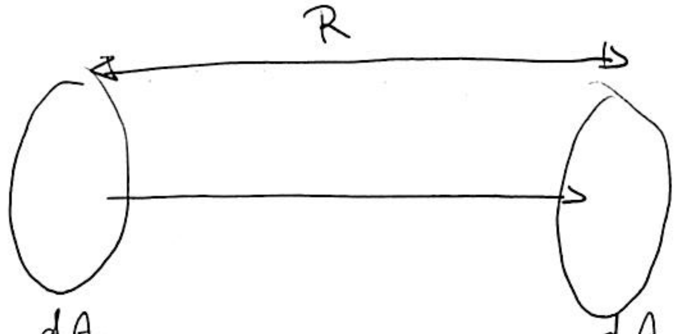
microscopic ~~tuo~~ range: what is the origin and what are the <u>emission and absorption coeficients</u>

Radiation field

simplest case: blackbody radiation - homogenious and isotropic inside a container

Radiative transport

frequency range ν $\nu + d\nu$



one of the dAs can be the solid angle Ω

I_{ν_1} ← specific intensity I_{ν_2}

$$I_{\nu 2} \, dA_2 \, dt \, d\Omega_2 \, d\nu = I_{\nu 1} \, dA_1 \, dt \, d\Omega_1 \, d\nu$$

with: $d\Omega_1 = \frac{dA_2}{R^2}$ $\quad d\Omega_2 = \frac{dA_1}{R^2}$

$$\Rightarrow I_{\nu_1} = I_{\nu_2}$$

→ in empty space the specific intensity does not change

if s is the distance measured along a ray's path than

$$\frac{dI_\nu}{ds} = 0$$

specific intensity is the intensity devided by the solid angle

→ if things are far and appear as unresolved point sources the source is smaller than the resolution element and the intensity „washes out" decreases

(2.) matter in the path :

if the matter is emitting → adding the emission coefficient j_ν
absorption is proportional to intensity, the absorption coef: α_ν

$$\frac{dI_\nu}{ds} = j_\nu - \alpha_\nu I_\nu$$

⇒ radiative transfer equation

if the matter only absorbes $j_\nu = 0$

$$\frac{dI_\nu}{ds} = -\alpha_\nu I_\nu$$

integrating this along $s_0 \to s$

$$I_\nu(s) = I_\nu(s_0)\exp\left[-\int_{s_0}^{s}\alpha_\nu(s')\,ds'\right]$$

optical depth: $d\tau_\nu = \alpha_\nu ds$

$$\tau_\nu = \int_{s_0}^{s}\alpha_\nu(s')\,ds'$$

$$I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu}$$

$\tau_\nu \gg 1$ optically thick
$\tau_\nu \ll$ optically thin

source function: $S_\nu = \frac{j_\nu}{\alpha_\nu}$

deviding the radiative transfer equ. by α_ν

$$\frac{dI_\nu}{d\tau_\nu} = -I_\nu + S_\nu$$

$$\frac{d}{d\tau_\nu}\left(I_\nu e^{\tau_\nu}\right) = S_\nu e^{\tau_\nu}$$

Integrating the optical path $\tau_0 \to \tau_\nu$

$$\boxed{I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu} + \int_0^{\tau_\nu} e^{-(\tau_\nu-\tau_\nu')}S_\nu(\tau_\nu')\,d\tau_\nu'}$$

general solution to the radiative trans. eq.

(3) if the matter has constant properties $\Rightarrow S_\nu$ is constant

$$\Rightarrow \quad I_\nu(\tau_\nu) = I_\nu(0)\, e^{-\tau_\nu} + S_\nu \left(1 - e^{-\tau_\nu}\right)$$

if there is no background source : $I_\nu(0) = 0$

$$I_\nu(\tau_\nu) = S_\nu \left(1 - e^{-\tau_\nu}\right)$$

if $\tau_\nu \ll 1$

$$I_\nu(\tau_\nu) = S_\nu \tau_\nu$$

$\tau_\nu = \alpha_\nu L$ where L is the total length of the ray

optically thin $\quad I_\nu = j_\nu L$

optically thick: neglect $e^{-\tau_\nu}$ compared to 1

$$I_\nu = S_\nu$$