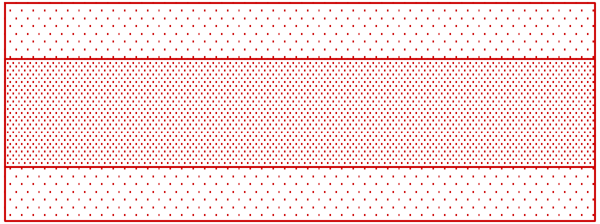
Transport by radiation

- Consider a plasma slab of thickness dr at position r inside an isotropic atmosphere
  - Radiation pressure on the upper and lower surfaces of the slab



- The net force/unit area exerted by radiation field on slab is

$$[P_{\text{rad}}(r) - P_{\text{rad}}(r + dr)] = -\frac{dP_{\text{rad}}(r)}{dr}dr$$

with the radiation pressure being $P_{\text{rad}}(r) \overset{*}{=} \frac{w_{ph}}{3} = \frac{4\sigma_S T^4(r)}{3c}$

- The change in radiative energy flux F_{rad} due to the opacity is $dF_{\text{rad}} = -\kappa\rho F_{\text{rad}}dr$ and therefore the net momentum transfer to the slab gas is $dP_{\text{rad}} = -\kappa\rho F_{\text{rad}}dr/c$

*For relativistic particles, e.g. photons (instead of $p = \frac{2}{3}w$ for classical particles)

Transport by radiation (cont.)

- Equate transferred momentum per unit time with the net force

$$-\kappa(r)\rho(r)F(r)/c = -\frac{dP_{\mathrm{rad}}(r)}{dr} = \frac{16\,\sigma_s T^3(r)}{3\,c}\frac{dT(r)}{dr}$$

$$\Rightarrow \qquad \frac{dT(r)}{dr} = -\frac{3\,\kappa(r)\rho(r)F(r)}{16\,\sigma_s T^3(r)}$$

- With $F(r) = L(r)/(4\pi r^2)$ we obtain the *radiative transport equation*

$$\frac{dT(r)}{dr} = -\frac{3\,\kappa(r)\rho(r)L(r)}{64\,\pi\sigma_s\,r^2\,T^3(r)}$$

- **Large temperature gradients** are favored by either a **low temperature** and a **high density** and **high opacity**
  - ➢ This happens in the outer 30% of the solar radius, where the opacity becomes far greater than in the inner region, while ρ/T^3 changes less