Theoretical Astrophysics
Exercise Sheet 9

HS 17
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Exercise 1 [Radiative transport]
Consider two clouds on the line of sight with respect to an observer O. These clouds have different properties τ_i (the optical thickness) and $S_{\nu,i}$ (the source function), both assumed to be constant. Below, the index 1 shall refer to the background region and index 2 to the forground region. Let us ignore all radiation from behind the background system, i.e. $I_\nu(0) = 0$.

(a) Write down the radiative transport equation (neglecting scattering) and its formal solution.

(b) Compute the total intensity $I_\nu(\tau_1 + \tau_2)$ that reaches the observer O (still neglecting scattering).

(c) Consider the following asymptotic cases. Write down approximative expressions for the total intensity if

  (i) $\tau_1 \ll 1$ & $\tau_2 \ll 1$
  (ii) $\tau_1 \ll 1$ & $\tau_2 \gg 1$
  (iii) $\tau_1 \gg 1$ & $\tau_2 \ll 1$
  (iv) $\tau_1 \gg 1$ & $\tau_2 \gg 1$

Exercise 2 [Eddington luminosity]
The radiation emitted by a star (measured by the *luminosity* L) exerts an outward-directed force $\vec{F}$ on its gas particles. On the other hand, the particles tend to fall towards the center of the star due to gravity. The *Eddington luminosity* (or *Eddington limit*) L_{Edd} is the luminosity where these two forces exactly balance each other.

We assume that a star has an opacity corresponding to the Thomson scattering cross section σ_T , i.e. $\alpha_{abs} = n_e\sigma_T$, where α_{abs} is the absorption coefficient and n_e is the electron number density.

(a) Derive the expression for the force $F_{rad}(L)$ exerted by radiation on the gas particles depending on the luminosity. Compute the Eddington luminosity $L_{Edd}(M)$ as a function of the star mass M, the Thomson cross section σ_T, the proton mass m_p, the gravitional constant G and the speed of light c.

(b) Compute the Eddington luminosity $L_{Edd}(M_\odot)$ of the sun. Compare this value to the actual luminosity $L_\odot$ of the sun and interpret this result. Additionally, discuss what happens if the luminosity of a star exceeds the Eddington luminosity.