Astro 305: Problem Set 1
Due Monday October 4

1 AGN jets

Suppose that there is emission from a beam of relativistic particles from an active galactic nuclei at a cosmological redshift z with a Lorentz factor γ and a velocity v pointed at an angle θ from the line of sight. Given RL 4.11 for the relativisitic Doppler shift how does the surface brightness scale with γ, v and θ? If there are two identical jets, one pointed towards us at angle θ and the other away from us in the opposite direction, what is their surface brightness ratio as $v \to c$.

2 Multiple Opacities

Consider radiation propagating through a medium of pure hydrogen. Three important cross sections for interaction are from Thomson scattering off of free electrons [RL 7.1c]

$$\sigma_T = 6.65 \times 10^{-25} \mathrm{cm}^2, \tag{1}$$

free-free absorption ions (mediated by free electrons) [RL 5.19b]

$$\sigma_{\mathrm{ff}} = 1.7 \times 10^{-29} (h\nu/1\mathrm{eV})^{-2} (n_e/1\mathrm{cm}^{-3}) (T/1\mathrm{K})^{-3/2} \mathrm{cm}^2\,, \tag{2}$$

where n_e is the free electron density, and absorption by bound electrons [RL 10.56]

$$\sigma_{\mathrm{bf}} = 2 \times 10^{-14} (h\nu/1\mathrm{eV})^{-3} \mathrm{cm}^2 \tag{3}$$

Consider the medium to have a mass density of 1.4 g cm^{-3} and a temperature of 3×10^6K

Given that a fraction x_e of the medium is ionized, write down the mean free path to interaction. Which process dominates as $x_e \to 0$. Which dominates as $x_e \to 1$ at low energies? at high energies? In the latter limit, how long does it take a photon to traverse $R = 7 \times 10^{10}$ cm, the radius of the sun.

3 R&L

Problems 1.3, 1.4, 1.8