Assignment #12: due Thursday, Jan. 15

Theoretical Astrophysics

Winter 2008/2009

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1. **Eddington limit** 20 pt

   (a) Derive the conditions under which a star with luminosity L_* can disperse its surrounding, optically thin gas with mass M (result: $M/L < \kappa/(4\pi\, G\, c)$, where κ is the frequency independent mass absorption coefficient).

   (b) Calculate the terminal velocity of the gas in this case.

   (c) Calculate the Eddingtion luminosity, i.e the critical luminosity at which a central source starts to disperse its environment. Use the minimum value of κ which can be estimated from Thomson scattering of free electrons off fully ionised hydrogen. Express your result as a function of the solar mass $M_\odot$.

2. **Energy density in the radiation field** 10 pt

   Assume the radiation field in a galaxy is isotropic and has an energy density u. Calculate the energy density of this radiation field measured by an observer moving through the galaxy with speed $c\beta$ (and hence Lorentz factor $\gamma = 1/\sqrt{1-\beta^2}$).

   [Hint: Use the Lorentz invariance of the quantity I_ν/ν^3, where I_ν is the specific intensity of radiation and ν the frequency, and the Lorentz transformation of the frequency:

   $$\nu' \;=\; \gamma\nu(1-\beta\cos\theta) \qquad (1)$$

   where θ is the angle between the observer velocity and the direction of a photon of frequency ν, (both measured in the rest frame of the galaxy) and ν' is the frequency of the photon measured by the moving observer. Recall that the energy density u is the integral of I_ν over all angles and frequencies.]

3. **Inverse Compton scattering** 10 pt

   Electrons with an energy of 100 GeV are observed at the top of the Earth's atmosphere. Inverse Compton scattering on photons of the cosmic microwave background places a lower limit on the energy loss-rate of these particles. Estimate the maximum time that can have elapsed between their acceleration and their detection. [Hint: Assume that their initial energy was $\gg$ 100 GeV.] Approximately how many scattering events occur in this time?