Astrophysics A

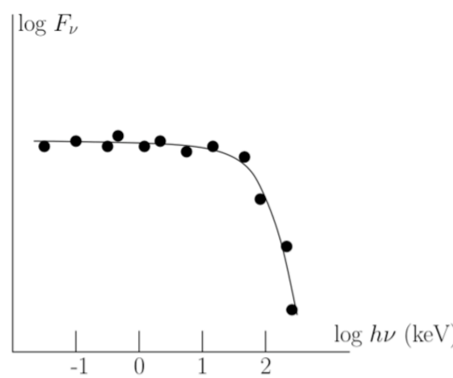
Problem Set 4

Due: 7th June 2007

1. a. Show that an observer moving with respect to a black body field of temperature T will see a blackbody radiation with a temperature that depends on angle according to:

$$T' = \frac{(1 - v^2/c^2)^{1/2}}{1 + (v/c)\cos\theta'}\, T$$

2. X-rays are received from a source of known distance $L = 10$ kpc with a flux $F = 10^{-8}$ erg s^{-1} cm^{-2}. The X-ray spectrum is shown in the figure here:



It is conjectured that these X-rays are due to bremsstrahlung from an optically thin, hot, plasma cloud, which is in hydrostatic equilibrium around a central mass M. Assume that the cloud thickness ΔR is roughly its radius R (i.e. $\Delta R \sim R$).

a. Estimate the temperature T of the hot plasma cloud.

b. Find the radius R of the cloud in terms of the conjectured central mass M, expressing the central mass in solar masses: $M/M_\odot$
Hint: because of the assumption that the gas is in hydrostatic equilibrium, you can use the virial theorem.

c. Find the density ρ of the cloud in terms of the conjectured central mass M, expressing the central mass in solar masses: $M/M_\odot$.

3. In astrophysics it is frequently argued that a source of radiation that undergoes a fluctuation of duration Δt must have a physical diameter of order $D \leq c\Delta t$. This argument is based on the fact that even if all portions of the source undergo a disturbance at the same instant and for an infinitesimal period of time, the resulting signal at the observer will be smeared out over a time interval $\Delta t_{min} \sim D/c$ because of the finite light travel time across the source.

Suppose, however, that the source is an optically thick spherical shell of radius $R(t)$ that is expanding with relativistic velocity $\beta \sim 1$, $\gamma \gg 1$ and energized by a stationary point at its centre.

By consideration of relativistic beaming effects show that if the observer sees a fluctuation from the shell of duration Δt at time t, the source may actually be of radius, $R < 2\gamma^2 c\Delta t$, rather than the much smaller limit given by the non-relativistic considerations. In the rest frame of the shell surface, each surface element may be treated as an isotropic emitter.

This last argument has been used to show that the active regions in quasars may be much larger than the $c\Delta t \sim 1$ light month across, and thus avoids much energy being crammed into so small a volume.