Radiative Processes in Astrophysics
Problem Set 1

Due date: Wednesday, 26 March 2003

1. Radiation quantities

(a) Define the following monochromatic quantities in terms of dE_ν, $d\nu$, dt, direction of the beam $\hat{\ell}$, $d\Omega$, and area $d\vec{A} = \hat{n}dA$. Explain what the various quantities are (include diagrams).
- intensity I_ν
- mean intensity J_ν
- flux $\mathcal{F}_\nu$

(b) Why is it generally more useful to know I_ν than $\mathcal{F}_\nu$?

(c) For which kind of astronomical objects is it possible to measure I_ν directly?

(d) Does $\mathcal{F}_\nu = 0$ mean that there is no radiation?

2. Flux and Intensity

(a) Assume two detectors are standing at the same distance from a point source of radiation. What is the ratio $\mathcal{F}_2/\mathcal{F}_1$ of the measured fluxes if the detector areas are $A_1 = 10\,\mathrm{cm}^2$ and $A_2 = 30\,\mathrm{cm}^2$?

(b) Now assume there is a third detector which is twice as far away from the point source and has an area of $A_3 = 10\,\mathrm{cm}^2$. What is the ratio $\mathcal{F}_3/\mathcal{F}_1$?

3. Conversions

(a) Show that $d\nu/\nu = -d\lambda/\lambda$.

(b) Are I_ν and I_λ equal for a given beam? (E.g., show that $\nu I_\nu = \lambda I_\lambda$.)

(c) Derive the expression for $B_\lambda(T)$ from

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\,\frac{1}{\exp(h\nu/kT) - 1}$$

4. Radiation pressure

Use the equation for radiation pressure, together with the Stefan-Boltzmann law, to show that

$$P_{rad} = \frac{1}{3}aT^4$$

where $a = 4\sigma/c$. Write down the assumption(s) it was necessary to make along the way!