Stellar Atmospheres, Ht 2002
Problem Set 2

Due date: Tuesday, 24 September 2002

1. Sources of continuous extinction

(a) How is the quantity κ in chapter 8 of Gray's book related to the κ_ν in chapter 5? In the case of Thomson scattering, how is Gray's κ related to the Thomson cross-section σ_T?

(b) Go through chapter 8 of Gray's book. List and comment on the various contributions to the continuous extinction coefficient in a stellar atmosphere. Be sure to note which absorbers or processes are important in which types of stars, and in which regions of the spectrum!

2. Calculation of continuous extinction

Estimate the various contributions to the total continuous extinction coefficient at different wavelengths for a point in the atmosphere where the temperature is 6500 K and the hydrogen and electron densities are 10^{17} and 10^{14} cm^{-3}, respectively.

Such repetitive calculations are best done with a computer. Write a program and try to produce plots similar to those on pages 140 and 141 in the book. (Alternatively, do the calculations for 3000, 5000 and 8000 Å.)

3. Line extinction coefficients

(a) Derive the expression

$$\alpha_\nu{}^{\text{line}} = \frac{h\nu}{4\pi} n_\ell B_{\ell u}\, \varphi(\nu - \nu_0) \left[1 - \frac{n_u\, g_\ell\, \chi(\nu - \nu_0)}{n_\ell\, g_u\, \varphi(\nu - \nu_0)} \right] \qquad (1)$$

What is the meaning of the factor in the square brackets?

(b) Explain the origin of the oscillator strength f and derive its relation to the Einstein coefficient $A_{u\ell}$.

4. The 21-cm line

The so-called 21-cm line has $A_{ul} = 2.9 \times 10^{-15}$ s^{-1} (per second and particle, but *not* per steradian). The relevant quantum numbers are $F = 0$ for the lower level and $F = 1$ for the upper level.

(a) What atomic process produces the 21-cm line, and why is this line so important in observational astronomy?

(b) What is the mean lifetime of the upper state (under which conditions)?

(c) What is the oscillator strength of the 21-cm line?

(d) Explain the concept of column density and calculate how many hydrogen atoms are needed to reach $\tau_\nu = 1$ in this line.