UNIVERSITY OF OSLO

AST 4210 Radiation I
Second mid-term (take-home) exam
Deadline: Tuesday 23/11/2004 at 10.15

Problem 1

a) How do you define the resonnace line for a given atom? What is a meta-stable state?

The resonnance line of Na I consists of two individual lines with wavelengths 5890 Å and 5896 Å. In the Solar spectrum these lines are known as the Fraunhofer D–(absorption)lines.

b) Describe the spectral terms and the spectral levels involved in the formation of these lines. Why is the number of individual lines of the resonnance line equal to 2 for Na I?

c) What is the thermal Doppler width that you expect for these lines in the Solar spectrum?

d) Which factors determine the strength (intensity) of the D-lines in the Solar spectrum? Give the formal expression and explain the factors involved. [*Hint*: You are not expected to carry through a calculation of the actual numerical value, only to explain which physical quantities and what mathematical operations will be involved.]

A (slowly) varying, weak magnetic field is present at the Solar surface. The presence of this field will give rise to a splitting of the two D-lines.

e) Describe the splitting of the energy levels involved in the formation of the two D-lines induced by the presence of the magnetic field. Then describe the corresponding splitting of the two D-lines (number of lines and polarization).

f) For a location near the center of the Solar disk where the magnetic field is .1 T, what is the width of the two splitted D-lines? How does these widths compare with the corresponding thermal Doppler widths? Do you expect to be able to determine the given magnetic field from observations of this kind? If not, can you suggest a better observational strategy?

g) For the sake of the argument, let us now assume that the thermal Doppler width can be disregarded. What changes in the relative strengths of the individual splitted D-lines do you expect as the observational spot is shifted from a location where the magnetic field is .1 T horizontal to .1 T vertical, both locations near the center of the Solar disk? Explain.

In the Solar atmosphere Na is a minority specie. This means that ionized Na contributes negligibly to the total free electron density in the atmosphere. For the following discussion let $n_e = 10^{17}$ m^{-3} be a typical value for the electron density in the Chromosphere, increasing by one order of magnitude toward the temperature minimum $T \approx 4500$ K near the Photosphere interface.

h) Estimate the ratios of the densities of singly ionized and neutral Na, $n_{\mathrm{Na\,II}}/n_{\mathrm{Na\,I}}$, under these conditions for temperatures $T = 5040$ K and $T = 10080$ K. From your results, are you able to predict an approximate temperature range in the Solar atmosphere where the Fraunhofer D-lines are produced?