Astr 423, Spring 2019

Homework 2: Introduction to stellar spectra

1 Boltzmann equation

Using the information given in the book by LeBlanc, calculate the ratio n_2/n_1 of populations of the first excited versus ground level of H for the following temperatures:

3000 K
5000 K
8000 K
10,000 K

You can do this with a pocket calculator, but you will get a bonus point if you write a short computer program that will calculate the ratios and print the results.

2 Saha equation

Assume a star made of pure H. At some point near the photosphere, the mass density is $\rho = 3.5 \times 10^{-7}$ g cm^{-3}. Calculate the number density n_H of H atoms, assuming that most of the H is neutral. Using the Saha equation, calculate the number of protons in the gas at the following temperatures:

3000 K
5000 K
8000 K

Repeat the calculations for a density $\rho = 3.5 \times 10^{-8}$ g cm^{-3}. You can do all this with a pocket calculator, but you will get a bonus point if you write a short computer program that will calculate the required quantities and print the results.

What conclusion can you extract from a comparison of the two sets of calculations?

3 Working with a stellar spectrum

File 1753905in.s is the wavelength-calibrated spectrum of a star, obtained with the high-resolution echelle spectrograph Espadons, which is a bench-mounted instrument, fiber-fed from a Cassegrain unit at the Canada-France-Hawaii Telescope (CFHT) on Maunakea, Hawaii. The spectral resolution of this spectrograph is

$$R = \lambda/\Delta\lambda = 68000$$

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The spectrum has been normalized, so that the intensity of the continuum is equal to 1. The heliocentric radial velocity correction has been applied, to compensate for the motion of the Earth around the Sun. Therefore, measurements of wavelengths of any features in this spectrum can be directly transformed into heliocentric radial velocities.

3.1 Plot the full spectrum

Write a computer program that will read all the data and plot the spectrum between 4200 and 6700 Angstroms. What are the strongest absorptions? Can you identify them?

3.2 Plot some selected spectral lines

Adapt your program so that you can plot the following features:

Mg II 4481.228
Fe II 4508.27
N V 4603.73
O V 5114.07
C IV 5801.33
C IV 5811.98

The wavelength range for each plot should be 4 Angstroms.

3.3 Instrumental profile

Select the Mg II absorption. Overplot a Gaussian

$$I(x) = \exp\Big(- \frac{x^2}{2\sigma^2} \Big)$$

with a full width at half-maximum (FWHM) equal to λ/R. Comment. Do you think there are other sources of broadening in addition to the instrumental broadening? What would you expect the most probable sources of extra broadening to be?

3.4 Measure radial velocities

Measure the center wavelength of each spectral feature and calculate the corresponding heliocentric radial velocities in km/s, using $V = c\Delta\lambda/\lambda$. Describe your results and offer an interpretation.