Astr 350 Homework Set #3 – Due: Thursday, October 11

1. The formal definition of the partition function diverges as you sum to infinity the excited levels, but the atoms become extremely large. In the case of hydrogen, the partition function at 6000 K is 2.0. What level, n, do you have to sum the definition of the partition function to before it differs from this value by more than 5%? What is the size of the atom in this case? What density does this correspond to? How does this compare to the typical density in a stellar photosphere?

2. Consider a gas cloud composed of hydrogen atoms (no H_2 molecules and no H^- ions). Relate the temperature at which one-half of the hydrogen atoms are ionized to the density in grams per cubic centimeter. In an interstellar gas cloud, the density may be 10^{-27} g/cm^3. How hot must that cloud be (if it is in thermal equilibrium) to be one-half ionized? In the outer layers of a star, the density may be of the order of 10^{-4}. How hot must that stellar atmosphere be in order that the hydrogen is 50% ionized? You will notice that the required temperature changes by slightly more than 1 order of magnitude when the density changes by 23 orders of magnitude.

3. For a grey atmosphere, estimate the maximum line depth for a spectral line at 3000 Å, at 6000 Å, and at 10000 Å. Use T_{eff} = 5800 K.

4. The center to limb variation of the solar radiation at 5010 Å has been measured to be

$$I_\theta / I_o = 0.2593 + 0.8724 \cos\theta - 0.1336 \cos^2\theta$$

   I_o = 4.05 X 10^{14} erg cm^{-2} s^{-1} per $\Delta\lambda$= 1 cm at 5010 Å. Calculate $S_\lambda(\tau_\lambda)$. Assume LTE and calculate $T(\tau_\lambda)$ where τ_λ is the optical depth at 5010 Å. What effective temperature do these measurements imply for the Sun?

5. In the case of the simple Zeeman effect, a spectral line that is magnetically sensitive will split into 3 components if there is a magnetic field in the region of the stellar atmosphere where the line forms. The amount (in wavelength or frequency) by which the 2 extra line components split to either side of the line is proportional to the strength of the magnetic field. Note, these components are always present, but if there is no field there is no splitting. Imagine such a line forming in an atmosphere where there is a magnetic field strong enough to split the 2 extra components by an amount equal to one half the FWHM of the line. First, draw a theoretical curve of growth for the line when there is no magnetic field present. Then, draw in a dashed line the theoretical curve of growth when the magnetic field is present at the strength described above. Justify any differences between the two curves.

6. Qualitatively, what happens to the Balmer jump in a G2V star if the metal abundance is increased by a factor of 10? Why?