DEPARTMENT OF PHYSICS AND ASTRONOMY

PHY305 Stellar Atmospheres

Problem Sheet No.2

Deadline: Monday 14th December 2015 (F10, 4pm)

1. Rigel (β Ori) has an effective temperature of $T_{\rm eff}$=12,000K, a measured surface gravity of $\log g = 1.75$ (cgs) and absolute visual magnitude $M_{\rm V}$=-7.7 mag.

   (a) Calculate the stellar mass and luminosity of Rigel in units of $M_\odot$ and $L_\odot$. (Note: you may assume an identical Bolometric Correction for Rigel to that of a B8 dwarf from your notes). [10]

   (b) Assuming a pure hydrogen atmosphere, calculate N(H^+)/N(H) in the atmosphere of Rigel given P_e = 400 dyn/cm^2, and hence determine q (the number of free electrons per atomic mass unit). [10]

   (c) Calculate the Eddington parameter Γ_e for Rigel. Might you expect this star to possess a powerful stellar wind? Justify your answer. [5]

   (d) A Si II line at 412.8 nm (atomic mass 28) and Hβ line are observed an optical spectrum of Rigel. Calculate their Doppler broadening FWHM (in km/s). [10]

   (e) If the rotational velocity of Rigel is $v_{\rm rot}$ = 35 km/s, which of the following broadening mechanisms – natural, linear Stark, rotational – would you expect to make a significant contribution to the observed line width of the Si II line, i.e. **quantify** their respective contributions. Would your answer be the same for the Hβ line? [15]

2. In the Solar photosphere (T =6000K, P_e=20 dyn/cm^2 at τ=2/3), the Mg I line at λ=4571Å is observed to have an equivalent width of W_λ=92 milli-angstrom. This is a transition between the ground state, $3s^2\ {}^1{\rm S}_0$, and a level within the first excited term, namely 3s3p $^3{\rm P}^\circ_1$, with a measured Einstein A coefficient of A_{ij}=430 s^{-1} from the NIST database.

   (a) What are the statistical weights of the two levels. Hence calculate the oscillator strength, f_{ij} for this line. Is it a permitted, semi-forbidden or forbidden transition? [10]

   (b) Use the 'generalized curve of growth' for the Sun to estimate the total number of ground state absorbing neutral Magnesium atoms (per cm^2), [15]

   (c) Use the Boltzmann and Saha equations to calculate the *total* number of Magnesium atoms above each square centimetre of the Sun's photosphere. The excitation energy of the first excited term is χ=2.7 eV and the ionization limit of Mg is 7.64 eV. [15]

   (d) Calculate an estimate of the column density of Mg atoms in the Solar photosphere (in g cm^{-2}). Estimate the number ratio of Mg to H in the format, log(N(Mg)/N(H))+12, if the corresponding column density of hydrogen is 1.1 g cm^{-2},
   Note: Magnesium has an atomic mass of 24, whilst the mass of a H atom is 1.67$\times 10^{-24}$ *g).* [10]