Astronomy 111 **Fall 2017**

Homework Assignment #2

due in my TPL mailbox by 3 PM, Fri. 9/29

to be returned in class Tuesday, 10/3

(remember: no ragged edges; write on one side of page only to leave room for comments/corrections)

1. The B-V color of a star refers to its apparent magnitudes in the B and V filters (i.e., m_B-m_V). How does a star's *absolute* B-V (i.e., M_B-M_V) relate to its apparent B-V? Comment on why this is useful in situations where you might not know a star's distance.

2. To demonstrate the relative strength of the electrical and gravitational forces of attraction between the electron and the proton in the Bohr atom, imagine that the hydrogen atom is held together solely by the gravitational force instead of the electromagnetic force. **Determine the radius (in meters) and energy (in eV) of the ground state orbit (n=1), and compare with the values we calculated in class for the real Bohr hydrogen atom.** For the relevant gravitation formula, see equation 5.13 on page 88 of the textbook (instead of r_1+r_2 in the denominator, use R=separation between the proton and electron). In addition, you may wish to know that the expression for gravitational potential energy is: $-Gm_1m_2/r$. Use SI units: For the gravitational constant, G, use: 6.62×10^{-11} m^3-kg^{-1}-s^{-2}; for the mass of the electron, use 9.1×10^{-31} kg, and for the mass of the proton use 1.67×10^{-27} kg. Check on the web for the distance to the most distant galaxy yet observed (include the reference), and compare this with your answer. (*Based on a problem from Carroll & Ostlie*).

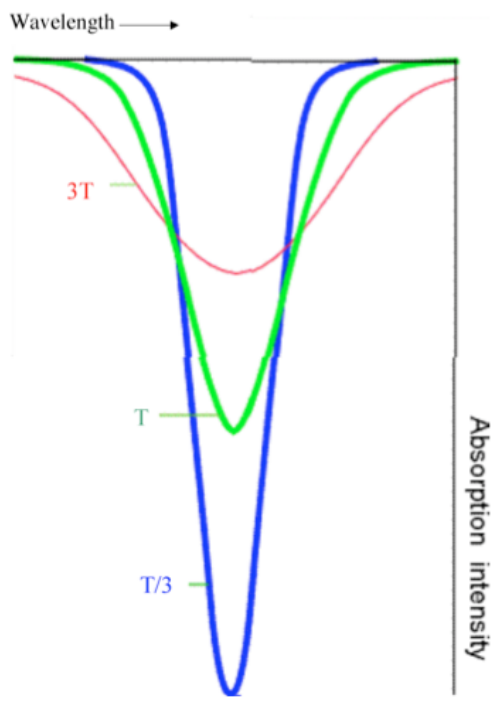
3. Calculate the wavelengths of the following transitions in hydrogen (all of which have been observed in various astronomical objects), expressing them in Ångstroms for a-c; meters for d, and indicating in what part of the electromagnetic spectrum they fall:

a) Lyman γ (n=4 to n=1) **b)** Balmer δ (= Hδ) (n=6 to n=2)

c) Paschen β (n=5 to n=3) **d)** H109α (n=110 to n=109)

4. Imagine you are cruising along a highway at the speed limit of 65 miles per hour. A traffic signal appears out of nowhere, and you find yourself having sailed right through the red light. As the inevitable police car pulls you over, you remember Astro111 and the Doppler Effect. Thinking quickly, you explain to the trooper that the light appeared green to you because of the Doppler shift. The trooper gives you a choice: you can either accept a $100 fine for running the red light, or pay $1 for each mile per hour by which you must have exceeded the speed limit in your approach to the light so that red became green. Which choice should you accept, and why? Show all calculations. Assume that green light has λ=5000 Å, and red light has λ=6000 Å.

5. A standard way of defining the width of an emission line is to use the full-width at half-maximum (FWHM). (See image below; the concept is the same whether it's an emission or absorption line.) For a gas consisting of atoms moving with a thermal energy distribution, the spectral line has a "Doppler profile," and the FWHM can also be called the "Doppler width." The FWHM, $\Delta\lambda$, of a spectral line emitted by such a gas is related to $v_{average}$, the average speed of the atoms producing it, by: $\Delta\lambda/\lambda center = 2v_{average}/c$. The higher the temperature of the gas, the broader the FWHM.



We saw in class how the temperature is related to the average kinetic energy of the particles in the gas (strictly, $\langle mv^2/2 \rangle = 3kT/2$) and that equipartition of energy mandates that all species of particles have the same average kinetic energy.

a) At a temperature of 10,000 K, what is the average velocity of the electrons in a star's outer layers, in km/sec?

b) What is the average velocity of a hydrogen ion (a proton)? Comment on the ratio between this and the electron's velocity; it will become important when we discuss electron degeneracy pressure.

c) What is the Doppler-width FWHM of the Hα absorption line (λ_{rest}=6562.8 Å) in a B star (T=15,000 K)? What about a G star (T=6000 K)?

Plus Kutner:

Chapter 2: Question 16; Problems 1, 3, 23, 26
Ch. 3: Questions 9, 12; Problems 10*, 19

* • To save you some calculation for Ch. 2 problem 10, the energy difference between the first two levels in hydrogen is 10.2 eV.
• Also, the problem incorrectly states the value for g_2; it is 8, not 6. For hydrogen, the value of g for any level n = $2n^2$.