AY 5, Summer Session I, 2008: Quiz #3

Draft: July 11, 2008

Instructions: *Choose one of the three problems.* Please ask for clarification as you need it. The more work you show the more credit you may receive. Remember to record units and to explicitly state to what the answer is equal. **It benefits you to consider whether your answers make sense based on physics.** Writing down whether your answers make sense and why (or why not) can only help.

1. Hubble's Law (**20 pt total**)

   (a) Draw a straight line that best fits the data in Figure 1. The line must go through the origin at (0,0). Label this best-fit line. (Note: you will be unable to draw a straight line through all the points.) (**3 pt**)

   (b) The slope of the best-fit line is your measure of the Hubble constant H. What do you measure H to be? (Hint: if you are unclear what "slope" is, look at the units of H_0 given in the "Useful constants and common symbols" section below.) (**2 pt**)

   (c) The "expansion age" of the Universe is $t = \frac{1}{H}$ What do you measure t to be in years? (**1 pt**)

   (d) Measure and record the central wavelengths of the Ca H+K absorption lines in the galaxy spectrum given in Figure 2. The central wavelengths will correspond to the point where the flux is lowest. (**3 pt**)

   (e) What is the (cosmological) redshift z of this galaxy given that the rest wavelength of Ca H is 3968.5 Å and Ca K is 3933.7 Å? (Record your two values of z as well as the average of your two measurements.) (**4 pt**)

   (f) Given your measurement of H and z, what is the predicted distance to this galaxy? (**2 pt**)

   (g) The apparent magnitude m of this galaxy is 3.4 mag. The absolute magnitude M is -21.1 mag. What is the measured distance to the galaxy? (**2 pt**)

   (h) Plot and label the galaxy on Figure 1 using your measured values of distance and velocity. (**3 pt**)

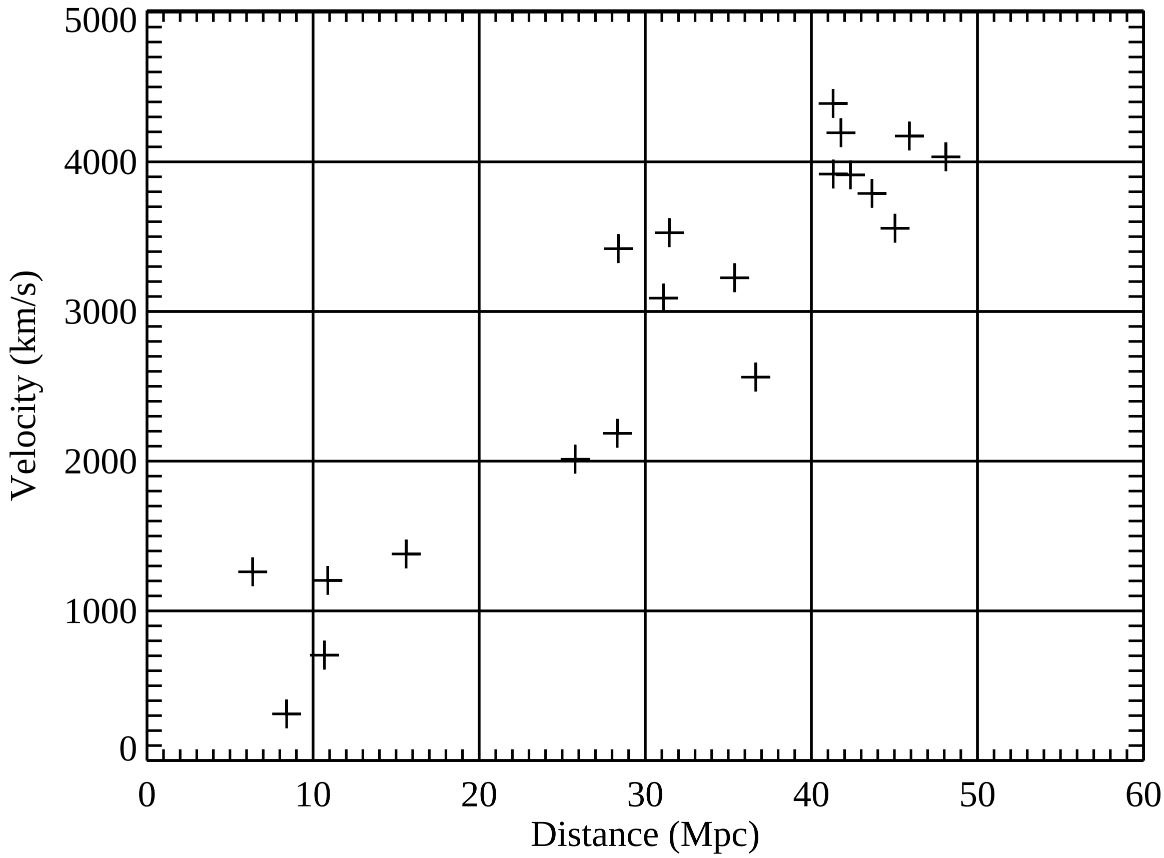

Figure 1: Hubble's Law diagram

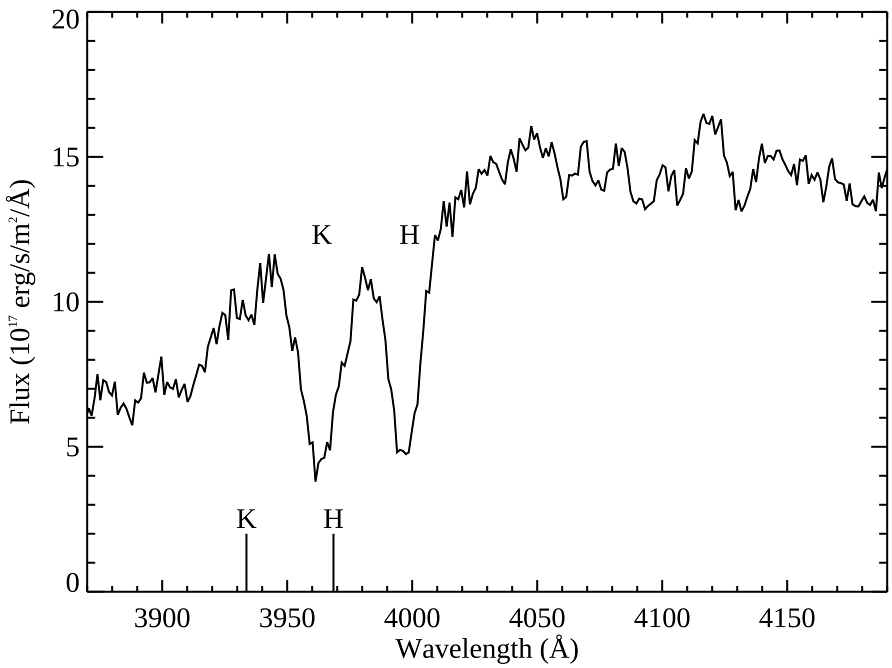

Figure 2: Galaxy spectrum around Ca H+K absorption lines

2. Blackbody radiation (**20 pt total**)

   (a) Measure and record the temperature of the blackbody from its spectrum shown in Figure 3. (**3 pt**)

   (b) How much energy is crossing the surface of this blackbody per second? (**2 pt**)

   (c) If the blackbody has a radius $R = 1\,R_{SUN}$, what is the luminosity of the blackbody in units of solar luminosity L_{SUN}? (**3 pt**)

   (d) What is wavelength at which a $T = 3000\,\mathrm{K}$ blackbody peaks in its emission? (**1 pt**)

   (e) Sketch and label a $T = 3000\,\mathrm{K}$ blackbody curve on Figure 3. (**3 pt**)

   (f) In which *wavelength* band of the electromagnetic spectrum (Figure 4) is each blackbody emitting most of its energy? (**3 pt**)

   (g) The two blackbody spectra (now) on Figure 3 are two observations of the *same object*. One observed spectrum is from today. The other spectrum is from an observation made a long, long time ago. Which observation, defined by T, is the observation from today? (**3 pt**)

   (h) What is the (cosmological) redshift of the older observation? (**2 pt**)

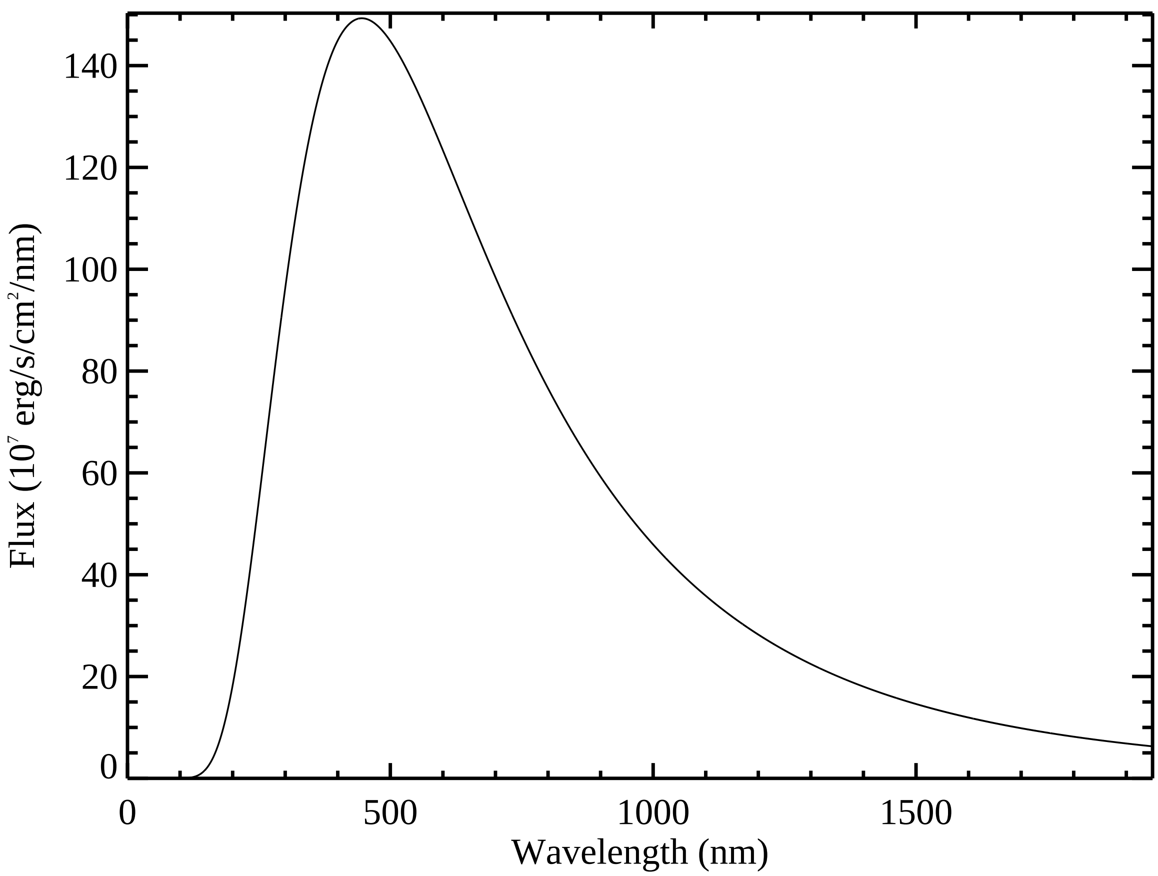

Figure 3: Blackbody curve

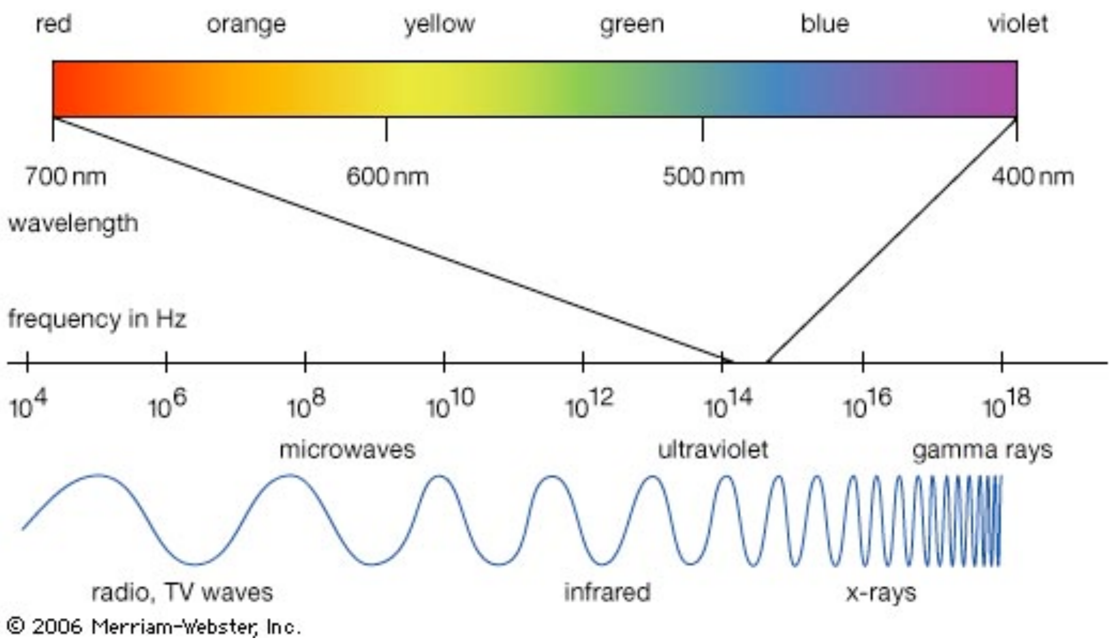

Figure 4: Electromagnetic spectrum

3. Mass-Energy Equivalence (**20 pt total**)

(a) How much energy is there contained in the mass of a ^{4}He nucleus? (**1 pt**)

(b) How much energy is released when four H nuclei are fused into one ^{4}He nucleus? Remember: a H nucleus is just a proton. (**3 pt**)

(c) What is the conversion factor between kg and MeV/c^2? (Hint: 1 kg is worth 9×10^{16} J.) (**2 pt**)

(d) The Sun is 73% H by mass. What is the total mass of H in the Sun in units of MeV/c^2? (**2 pt**)

(e) How many H nuclei are there in the Sun? (**2 pt**)

(f) If the Sun were to fuse all of its H into ^{4}He, how many reactions would it take? (In other words, how many times would four H nuclei have to fuse into one ^{4}He nucleus to deplete all the Sun's H?) (**2 pt**)

(g) How much energy would be released by the above number of reactions? (**2 pt**)

(h) If the Sun could fuse all of its H into ^{4}He, how long would it take in years? Assume a constant luminosity of $1\,L_{SUN}$. (**3 pt**)

(i) Three ^{4}He nuclei fuse to make one ^{12}C nucleus. This reaction releases 4.1409 MeV of energy. What is the *mass* of the ^{12}C nucleus? (**3 pt**)