Astro 102, Fall 2006 — Review Problems #2

Useful Data

$$1\,\text{year} = 3.156 \times 10^7\,\text{seconds}$$
$$1\,\text{AU} = 1.496 \times 10^{11}\,\text{m}$$
$$1\,\text{pc} = 206,265\,\text{AU}$$

$$c = 3.00 \times 10^8\,\text{m}\,\text{s}^{-1}$$
$$\sigma = 5.67 \times 10^{-8}\,\text{W}\,\text{m}^{-2}\,\text{K}^{-4}$$

$$1\,\text{rad} = 206,265''$$
$$180^\circ = \pi\,\text{rad}$$

$$M_\odot = 1.99 \times 10^{30}\,\text{kg}$$
$$R_\odot = 6.97 \times 10^8\,\text{m}$$
$$L_\odot = 3.8 \times 10^{26}\,\text{J}\,\text{s}^{-1}$$
$$T_\odot = 5,800\,\text{K}$$

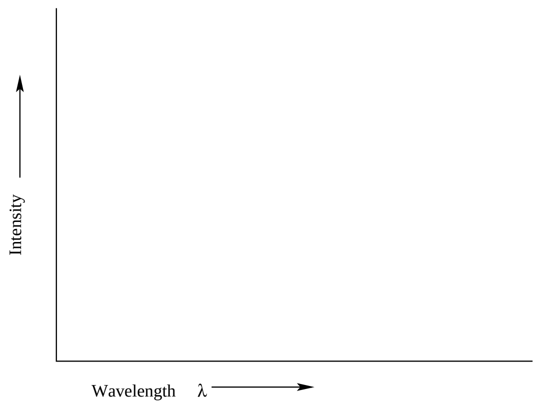
$$B = \frac{L}{4\pi\,d^2}$$
$$L = (4\pi\,R^2)\,(\sigma T^4)$$

$$d = \frac{1}{p} \qquad A = \frac{h}{d}$$

1. You observe a binary system. Because these stars are orbiting around each other, the distance between them is very small compared to the distance from us to the binary system.

Star 1 is a bright main sequence B-star with a surface temperature of 15,000 K. It is an unusual star whose spectrum shows emission lines as well as a blackbody. Star 2 is a red giant, a K-star with a surface temperature of 4,000 K, and has a more usual absorption line spectrum. Both stars appear equally bright.

On the axes below, sketch two spectra, one for Star 1, one for Star 2. Clearly label your plot. Don't worry about the exact wavelengths of specific features, but make sure that the overall spectra are plotted relatively right.



2. Betelgeuse is a reddish star in on the shoulder of Orion. Although it is a very bright star as stars go, it is only 1.4×10^{-10} as bright as the Sun. (That's why it's day when the Sun is up!) We have measured Betelgeuse to be about 130 pc away.

(a) What is the luminosity of Betelgeuse in units of Solar Luminosity ($L_\odot$)?

(b) Betelgeuse has a surface temperature of about 3,000 K, which makes it much cooler than the Sun. What is the size of Betelgeuse? (Give its radius in km.)

(c) How does the radius of Betelgeuse compare to the radius of Earth's orbit around the Sun?

3. When an object is moving away from you, not only are the wavelengths of any emission or absorption lines shifted to the red, but the total energy flux you observe from the object is lower than what you would have observed it the object were not moving relative to you (but at the same distance). (This effect is very small for objects moving with modest velocities.) Give at least one reason why this might be so, given what we've discussed in class to date.

4. Atomic emission "lines" as described in class always happen at exactly one wavelength: the wavelength where photons have the same energy as a specific atomic transition. In fact, atronomers usually observe "broadened" lines from astrophysical sources, where a line at a given wavelength is spread into nearby wavelengths. One very common mechanism for this broadening is called "Doppler broadenin": if a gas cloud is turbulent, with atoms moving about randomly, some of the atoms in the cloud will be moving towards you, some away from you. There will be a blueshift or a redshift of the light emitted by atmos moving towards or away from you, and as the light from all of the atoms is added together you get a smeared out (or broadened) line. Consider the $6563\AA$ line of Hydrogen. Suppose from a nebula it is observed to be spread from 6560–$6566\AA$. What range of speeds towards/away from you would you conclude the atoms in this nebula are moving, if you interpret this broadening as a Doppler broadening? (Give your answer in km/s.)

5. An electron and a positron (a particle of antimatter with the same mass as the electron) come together, annihilate each other, and produce two photons of identical energy. The mass of the electron is $m_e = 9.109 \times 10^{-31}$ kg.

(a) What is the energy of each one of these photons?

(b) What is the wavelength of each one of these photons?

(c) How many blue photons (wavelength 4500Å) would it take to equal the energy of one of these photons?

(d) You construct a device in which 1 nanogram ($1\,\mathrm{ng} = 10^{-9}\,\mathrm{g} = 10^{-12}\,\mathrm{kg}$) of electrons and 1 nanogram of positrons annihilate each other every second. You take the photons that result from the annihilation and (somehow) convert them into the same energy in blue photons. What is the blue-light luminosity (in Watts) of your device? Compare this to the luminosity of a typical light bulb.