Astronomy 253 — Group Problems 3

Friday, February 6

Do the problems on separate sheets of paper. Each group will turn in only one set of solutions. Make sure your solutions are clear enough that I can understand what you were doing and what you were thinking! You probably won't get through all of these problems in an hour; that is OK. Do all problems in order.

1. Many of you correctly stated that the stars in the disk are bluer on average than the stars in the halo. This is because blue stars are more massive main sequence stars, and they don't live very long. As such, the stars in the halo, which are all old, don't have any of the bluest stars left, whereas the disk is still making stars and has some very hot, very luminous blue main sequence stars.

   However, many of you were then disturbed by Figure 2.15, which showed that looking at stars between magnitude 19 and 20 at Galactic lattiude 90°, the disk stars you see are actually **redder** than the halo stars you see!

   (A few of you noted that the disk would be reddened by dust inside the disk. This is true, and insightful. However, if you look perpendicular to the Galactic plane, you're looking through so little dust that this doesn't make much difference.)

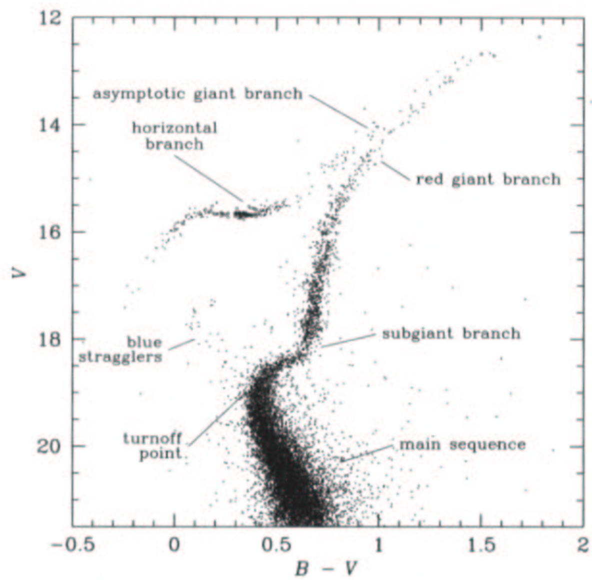
   (a) Draw a picture of the edge-on galaxy, indicating where we are and the direction in which we are looking.

   (b) Assume that the thin disk is about 2kpc thick, and we're right in the middle of it. What is the absolute magnitude of a star at the edge of the thin disk which we would observe with apparent magnitude 19?

   (c) Refer to Table 1.3; what sort of main sequence star would have this absolute magnitude? What is the B-V color of this sort of star? What will be the apparent magnitude stars at the edge of the thin disk (i.e. as far away as they exist in the disk) that are *bluer* than this star?

   (d) Halo stars are spread over big distances. Pretend that the HR diagram of the globular cluster M3 (on the next page) is also the HR diagram of the halo. (Not strictly true, but what the heck.) What will be the B-V color of the most common bright stars in the halo? How far away will they be?

   (e) Compare the colors you got in (c) and (d) to what you see in Figure 2.15. Do things make sense now? Use two or three sentences to explain why you see the colors you do in figure 2.15.



HR diagram of Globular Cluster M3

2. When astronomers measure the magnitude of a star, they talk about the flux, or brightness of the star. This is well and good for a compact object like a star. However, galaxies and star clusters are extended objects, with a brightness that varies across the face of the object. In objects like this, it's often useful to talk about *surface brightness*.

   Surface brightness is defined as the amount of light detected from some standard square area of an object. It often comes in units such as "Magnitudes per Square Arcsecond". That is, if you add up all the light from one square arcsecond of that object, you will get enough light so that the numerical magnitude will match the surface brightness (in mag/$''$) of the object.

   (a) Suppose you observe a very unusual astronomical object which has a total magnitude of 10, and which is shaped like a perfect square which you measure to be $4''$ on a side. What is the surface brightness of this object in magnitudes per square arcsecond?

   (b) Take this same object and move it so that it is twice as far away as it had been initially. What magnitude would you observe for this object now?

   (c) How big would the object appear after it is moved? (Hint: draw a picture including you (the observer), the object at the two different distances, and indicate what you really mean by the $4''$ size that you measured for the object in (a).)

   (d) What is the surface brightnes (in magnitudes/$''$) after it is moved?

3. It is very natural to confuse "surface brightness" with "brightness at the surface of an object". The are *not* the same thing at all. Consider the Sun.

   (a) Asssuming the Sun to be a perfect blackbody of $T = 5800\,\mathrm{K}$, what flux (in $\mathrm{W/m^2}$) would you measure coming from the Sun if you were right at the surface of the Sun? This is the "brightness at the surface" of the Sun. (Some numbers that may or may not be useful: the Steffan-Boltzmann constant is $\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$; the radius of the Sun is $7.0 \times 10^7\,\mathrm{m}$.)

   (b) We are $1\,\mathrm{AU}{=}1.5{\times}10^{11}\,\mathrm{m}$ away from the Sun. The Sun appears to us as a disk on the sky which is about $1/2^\circ$ in diameter. The Luminosity of the Sun is $3.86 \times 10^{26}\,\mathrm{W}$. What is the flux ($\mathrm{W/m^2}$) that we measure coming from each square arcsecond of the Sun's disk on the sky? (This is the "surface brightness" of the Sun in Watts per meter per square arcsecond.)

   (c) The magnitude of the Sun as observed from Earth is about -26.7. The Sun appears on the sky to be a disk of diameter $1/2^\circ$. Given just this information, calculate the surface brightness (in magnitudes per square arcsecond) of the Sun. (Hint: be very careful with your logs!)

4. For some objects, to determine their "surface brightness", you have to consider the full three-dimensional structure of the object. This points out that the "surface" we're talking about is *not* the surface of the object, but the "surface of the sky" (or, more prosaically, the surface of our photograph/image).

   Rather than getting all complicated with an actual globular cluster, consider a distribution of stars that has a *constant* density. The density of stars is 10 stars per cubic parsec, and each star is a red giant in a red clump. These stars are small enough compared to how far away they are from each other than you can ignore eclipsing; i.e., you can see through the "forest", and no star will end up in front of another star.

   What is the surface brightness of this cluster (both in Watts per square meter per square arcsecond and in magnitudes per square arcsecond)?

   (If you think you need to know the distance to this cluster to answer this question, review your answers to problem 2.)

5. Consider an "optically thin" gas (i.e. you can see through it) which is emitting light. Because it is optically thin, any light emitted anywhere within the gas will escape from the gas. (This does describe many nebulae seen in astronomy.)

   Suppose that there is a spherical shell of this tenuous glowing gas with an inner radius of $0.01\,\mathrm{pc}$ and an outer radius of $0.02\,\mathrm{pc}$. Sketch what you would see if you took a picture of this object.