

## Homework # 5

Name \_\_\_\_\_

DUE: November 5 (at the start of class)

**NOTE: This homework is worth 30 points!**

Your homework grade depends not only upon your getting the correct answer but also grammar, spelling and punctuation, particularly in questions that require explanations. Obviously numerical answers to problems do not need to be written in complete sentences. You will also be graded on the use of significant figures, proper units of measure and proper scientific notation. Partial credit may be given for showing your work even if your result is incorrect. You may work with others in determining the answers to the questions, but what you write should be in your own words – any homework assignments that look too similar to that of other students will receive no credit. Unless otherwise noted, all questions are worth 1 point.

1. (12 points) **Mass of the Milky Way.** Believe it or not, it is fairly easy to calculate the mass of the Milky Way. You get to use Kepler's 3rd law to calculate the mass, so get ready for some fun math!!! First of all, the rotation curve for the galaxy is located at the course website. This shows how fast the different parts of the Milky Way move based upon how far they are from the center. You'll want to be careful if you print it out, since you may cut off the edges. You'll just need a few numbers from this graph.

a. For simplicity we'll assume that the Sun is 7.5 kpc from the center. What is the corresponding velocity of rotation for that distance from the center? (use the solid line drawn through the data points to get the velocity, not the individual dots)

b (2 points). At a distance of 7.5 kpc, the size of the Sun's orbit about the galaxy is a path that is  $1.46 \times 10^{18}$  km long – we're going to assume that it's a circular orbit. Using the velocity from the previous step, what is the period of one orbit? (time = distance/velocity)

c (2 points). Your answer from the previous step is in seconds. To use it in Kepler's third law you'll need to convert it into years.  $1 \text{ year} = 3.16 \times 10^7$  seconds. What is the orbital period in years?

d (2 points). The average size of the orbit is 7.5 kpc, which also equals  $1.55 \times 10^9$  A. U. Kepler's Third Law (as if you'd ever forget) is  $M = a^3/P^2$ , where  $a$  has to be in A. U. and  $P$  is in years. You now have those two values so you can plug it in and determine the mass of the galaxy out to the Sun's orbit (your answer will be in solar masses). Your answer should be more than a billion but less than a trillion.

e (3 point). Now let's do the same for a point located 16 kpc from the center. The orbital path around the galaxy at this position is  $3.11 \times 10^{18}$  km, while the size of the orbit ( $a$  in Kepler's formula) is  $3.30 \times 10^9$  A. U. Using the graph and the method that you used in steps a-d, determine the mass of the galaxy interior to this location. Make sure you show your math and the values you got in each step (in case you make a mistake and want partial credit).

f (2 points). Is there more mass located inside of the Sun's orbit about the galaxy (within a distance of 7.5 kpc) or outside of it (between 7.5 and 16 kpc)? Is this what you would expect?

2. (10 points) **Galaxy Classification.** At the website there are links to images of 20 galaxies. Follow these links and look at the galaxies. Determine their type. Your options are Spiral, Barred Spiral, Elliptical and Irregular. Put only one type down for each galaxy.

Galaxy 1

Galaxy 11

Galaxy 2

Galaxy 12

Galaxy 3

Galaxy 13

Galaxy 4

Galaxy 14

Galaxy 5

Galaxy 15

Galaxy 6

Galaxy 16

Galaxy 7

Galaxy 17

Galaxy 8

Galaxy 18

Galaxy 9

Galaxy 19

Galaxy 10

Galaxy 20

3. (8 points total) On March 19, 2008 a rather amazing thing happened. On that date the most powerful gamma ray burst occurred. This event was named GRB 080319B, and was actually visible to the naked eye for a short period of time. The object produced gamma-rays at a peak wavelength of  $1.90 \times 10^{-12}$  meters.

a. Using Wien's law, what sort of temperatures would correspond to the observed wavelength of GRB 080319B?

b. (2 points) It is thought that this object was some sort of ultra-powerful supernova in a distant galaxy. If that was the case we can estimate the energy produced by such an event. Using the temperature given above, we'll assume that the radius of the star's core was 100 times smaller than the Sun. Use the L-R-T relation to determine the luminosity of this object relative to the Sun (you'll have to divide the temperature you got in part "a" by 5800 before you plug it into the formula).

c. The value you just determined is how many times more luminous GRB 080319B is compared to the Sun. A typical galaxy is hundreds of billions of times brighter than the Sun. How does this object compare to a typical galaxy in terms of brightness?

d. The redshift of GRB 080319B had a value of 0.937, indicating that it was quite far away, but how far was it? Use the link at the website to determine how far away the object was based upon current values for the Hubble Constant (use a value of 70 km/s/Mpc), Matter Density (0.26), and the Cosmological Constant (0.74). This will tell us how far away this object is now. How far away is this object now?

e. You'll notice that the program you used also produces other values, in particular information about how long ago the outburst must have occurred before the light finally got to us, as well as the age of the Universe. How long ago did the outburst occur?

f. What happened first – the event that caused GRB 080319B or the formation of the Sun?

g. I mentioned previously the GRB 080319B could have been seen with the naked eye (if you knew exactly where to look and when). How is it possible for an object that gives off gamma-rays to also be visible to the human eye? (HINT: go back to the properties of black bodies and how they give off light)