Ay 10 - Problem Set #9
Due: November 15, 11am

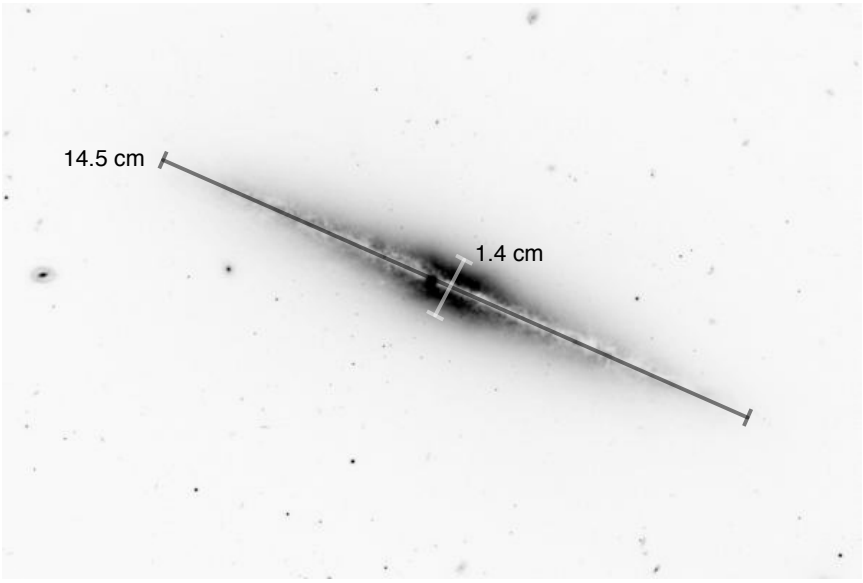
Please write your full name, section number, and GSI's name at the top of your homework. Also, be sure to put your homework in the correct box in the basement of Campbell Hall. There is a 20% penalty per day for the late submission of assignments, however you do get one "freebie" (see course syllabus for more info).

Remember to always show your work; no credit will be given for just a final answer. However, if you get most of the question right but get the final answer wrong, you will get most of the points. Use a calculator where necessary and dont forget units if the answer requires them.

If you use any resource besides the textbook, lecture, or section (*e.g.* a web site), be sure to include proper attribution for the reference. Feel free to work with other students in the class, but remember that all work turned in must be your own (*i.e.* don't just copy the work of another student).

1. **(5 points)** Galaxies are (relatively) Thin

   Take a look at the edge-on spiral galaxy NGC 4013 (note the colors in the image are inverted to prevent printer ink waste!):



   (a) The aspect ratio of a galaxy is the ratio of its diameter to its thickness at the center. Using a ruler, determine the aspect ratio of NGC 4013. (Your answer should be greater than one).

   (b) The angle that NGC 4013's disk subtends on the sky, from tip to tip, is 2.2 arcminutes. We also know that NGC 4013 is 55 million light years away. What is NGC 4013's diameter in light years?

   (c) Using your answers to (a) and (b), what is the thickness of NGC 4013's disk in light years?

2. **(5 points)** Spaghettification!

   (a) Calculate the **tidal acceleration** on a 2 meter tall human falling feet-first into a 1 solar mass black hole; that is, compute the difference in the accelerations (force per mass) on their head and their feet just as the feet cross the event horizon.

   (b) Repeat the calculation for a 10^6 solar mass black hole and for a 10^9 solar mass black hole.

   (c) Compare these three accelerations with the acceleration due to gravity on Earth ($g = 9.8m/s^2$).

3. **(4 points)** Triplets Take Time to Age

   One day you get a strange email that says you have two long lost identical siblings (i.e. youre a triplet), but youve never met either of them because one has lived in the Himalaya Mountains since birth and the other has lived in a SeaLab at the bottom of the sea since birth.

   You decide to invite your siblings to your place in Berkeley to meet each other for the very first time.

   (a) When you all finally get together, who will be the oldest?

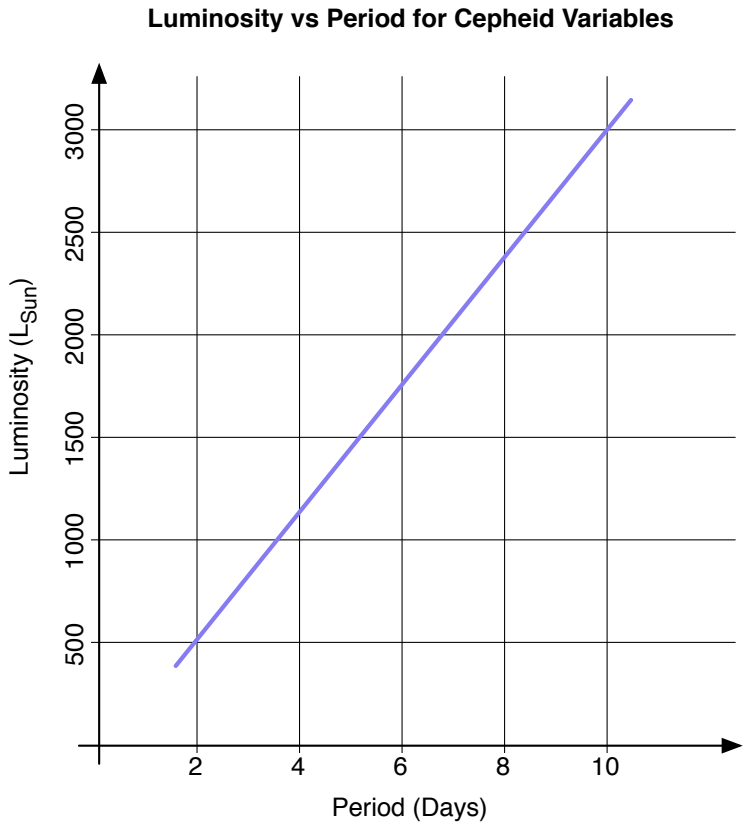
   (b) Who will be the youngest?

   (c) Will there be a readily noticeable difference in your ages?

4. **(16 points) Mapping the Galaxy**

Using your trusty telescope you managed to put together a wonderful set of data. You've located 6 Cepheid variables on the sky, and have successfully measured their periods and fluxes (apparent brightness). Your data is in the table at the bottom of this page.

The following Luminosity vs Period plot allows you to look up the luminosity of each of the Cepheid variables in your data set. This information, combined with the measured fluxes will allow you to calculate the distances to the Cepheid variables.



The sheet of graph paper attached to this problem set gives you the directions in which the Cepheid variables were observed. Once you know how far away the Cepheid variables are, you can construct a plot of the distribution of the Cepheid variables in space. Your plot should be to scale (note that 2 cm on the graph paper correspond to 1 kiloparsec in space). Fill out the following table, then plot the location of each Cepheid on the graph paper.

Cepheid	Period (Days)	Flux $\left(\frac{\text{Watts}}{m^2}\right)$	Luminosity (Watts)	Distance (meters)	Distance (kpc)	Distance on Graph Paper (cm)
A	2 days	2.31×10^{-13}				
B	8 days	1.82×10^{-12}				
C	10 days	1.00×10^{-12}				
D	4 days	1.01×10^{-12}				
E	10 days	9.83×10^{-13}				
F	2 days	3.26×10^{-13}				

You should hand in:

(a) The table.

(b) The graph paper with the positions of the Cepheid variables.

And answer the following question:

(c) Assuming the Cepheid variables orbit around the galactic center mark the approximate position of the galactic center on the graph paper. How far away from the Earth is this in kiloparsecs?