Astronomy 253, Spring 2004
Problem Set 1

Due Monday, February 2

Those problems marked "**[solo]**" you must do on your own, without talking to anybody else other than the instructor. On all other problems, you may discuss the problems with anybody, though of course the final solution you present must be your own.

1. **[solo]** The European Space Agency satellite Hipparcos has provided us with the best parallax (and hence distance) measurements of stars in our galaxy. It measured the trigonometric parallax of stars down to a magnitude of ~ 11 with a precision of $\sim 0.001''$.

   (a) What is the greatest distance to a star that may be measured with this precision in trigonometric parallax? (As $0.001''$ is the precision of the measurement, in practice reliable measurements will not be available all the way to this limit; for purposes of this problem, ignore this annoying experimental detail.) Compare this result to the distance to some of the Milky Way's globular clusters (*S&G* Table 2.3).

   (b) At this distance, what is the spectral type of the dimmest/smallest/coolest main sequence star which would be visible down to a magnitude limit of $m_V = 11$?

   (c) As an Earth satellite, Hipparcos used the same baseline as any other Earth-based observer. Suppose a similar instrument which could measure star positions to the same precision of $0.001''$ were placed in orbit around Jupiter; what would be the greatest distance to a star that this new spacecraft could measure? (Jupiter is about 5.2AU away from the Sun.) How does this new distance limit compare to the distance to some of the Milky Way's globular clusters?

   (d) At what distance from the Sun would the same instrument (now in orbit around the Sun) need to be in order to measure the distance to a star in the Andromeda galaxy (distance=780 kpc) using trigonometric parallax methods? Compare this to the orbit of Neptune (30AU). Note that Neptune takes about 165 years to make a complete orbit around the Sun.

2. **[solo]** Use Table 1.1 to determine the amount of time that the Sun will be on the main sequence, and the amount of time it will be a red giant. Assume that it has a constant luminosity (its current luminosity) while it is on the main sequence, and that it has an average luminosity equal to that of a "red clump" star while it is a red giant. (Use the Figure 2.2 to estimate this luminosity.)

   How does the total amount of energy that will be radiated by the Sun while it is a red giant compare to the total amount of energy that it will radiate while it is a main sequence star? (Give the ratio for your answer.) Comment.

3. *Sparke & Gallagher*, problem 1.8 (page 29).

4. *Sparke & Gallagher*, problem 2.2 (page 54).

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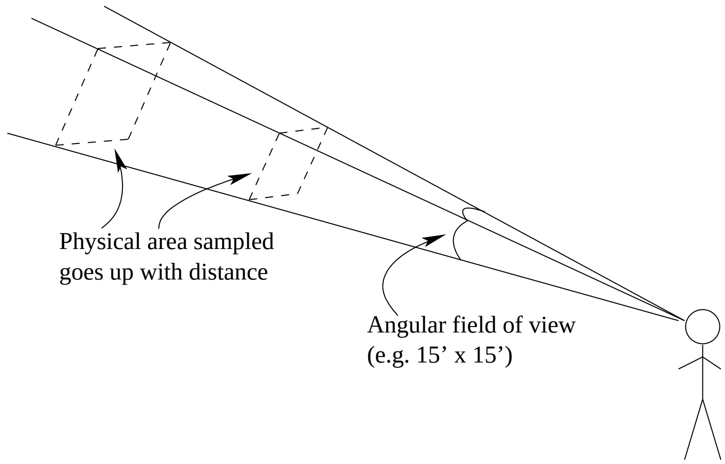
5. We measure distances on the sky using angles. Similarly, when we measure the area covered by an image (either a photograph or a digital CCD image), we measure it in units of “square arcminutes” or “square degrees”. (One degree is 60 arcminutes, so one square degree is 3,600 square arcminutes.) The actual volume of space you are sampling in a given picture depends on how far away you are looking.



William Herschel was one of the first people to attempt to make a map of the Galaxy (at the time thought to be the whole Universe). He did it by star gauging. He assumed that all stars had the same absolute magnitude (an assumption we now know to be incorrect), and counted how many stars of what magnitudes he could see in various directions to come up with a map of the Galaxy.

Suppose you are William Herschel and are looking at a visual (V-band) CCD image (which was transported back through time via a freak hyperspatial wormhole). This CCD image has a field of view of 15 arcminutes by 15 arcminutes. Suppose also that you live in the Universe that Herschel thought he lived in: all stars have the same absolute magnitude as the Sun (4.8), and the density of stars is uniform (assume one star per 25 pc^3). Finally, suppose that this CCD image has an exposure time such that it is able to see stars of magnitude 20 and brighter.

(a) How far away is the most distant star you see?

(b) How many stars with magnitude between 19 and 20 do you expect to see in your image?

(c) How many stars with magnitude between 12 and 13 do you expect to see in your image?

(d) What is the brightest star you might expect to see in this frame?

(e) Make a plot of $\Phi(m)$ vs m, so that $\Phi(m)$ shows the number of stars in the frame with magnitude between m and $m + 1$. Do this in bins of 1 magnitude, from magnitude 8 to 20.

(f) Suggest an explanation why William Herschel thought we were at the center of our Galaxy, whereas really we’re well off to the side of the center of the stellar distribution? Assume he was a good astronomer who took careful data and had a sister and collaborator who took extremely careful records.