1. Perspective acceleration (3 points). A nearby star has proper motion $\mu$ (arcsec/yr), parallax $\pi$ (arcsec) and radial velocity $v_r$ (km/sec, with $v_r > 0$ for stars travelling away from the Sun). If the star travels with constant velocity relative to the Sun, show that its proper motion slowly changes with time and derive a formula for the rate of change of proper motion (“perspective acceleration”) $\dot{\mu}$ (arcsec/yr$^2$). The star with the largest proper motion is Barnard’s star. Using the Hipparcos proper motion and parallax for Barnard’s star (available from the Hipparcos website) and its heliocentric radial velocity $v_r = -106.8$ km/sec, evaluate the perspective acceleration.

2. Final parsec problem (3 points). One of the short research projects I am considering for this semester involves trying to solve the “final parsec problem” (hint: this is related to supermassive black holes in centers of galaxies). In a couple of paragraphs (~ 10 sentences), explain what the problem is and briefly explain what, if any, solutions have been proposed to solve this problem. Your answer should include ~ 4 references to refereed papers. While discussion is usually encouraged in solving homework assignments, I would prefer if everybody did this problem individually because I am interested to see the full range of references you dig up.

3. Distance to the Galactic Center (6 points).
A catalog of Galactic globular clusters compiled by W.E.Harris is available at http://physwww.mcmaster.ca/~harris/mwgv.dat.

(a) Using column (8) of the catalog and your favorite plotting software (IDL, Python, SM), show the distribution of Galacto-centric distances of globular clusters (a histogram of the numbers of clusters per $R_{gc}$ as a function of $R_{gc}$). What would this distribution look like if the clusters were distributed homogeneously in space? Is your histogram in agreement with this hypothesis?

(b) Using only the values of X (column 9) in the catalog, estimate the distance $R_0$ from the Sun to the Galactic center and the associated uncertainty, using:

- The mean, with the uncertainty estimated using the standard deviation for a Gaussian distribution;
- The mean, with the uncertainty estimated using bootstrap;
- The median, with the uncertainty estimated using bootstrap. Comment on the differences between these estimators. (If necessary, the programs for computing these values are described in ”Numerical Recipes” by Press et al. and many other places.)

(c) Are your measurements in agreement with the best modern determinations of $R_0$? Provide references. Can you think of any reason the distance determined using globular clusters would be a biased measurement?

4. Galaxy classification (4 points).
A set of galaxy images is available in the directory within the webpage, SPR2013/galimages. Classify each galaxy according to the Hubble classification scheme (bonus for any name recognition).

Short problems (1-2 points).

5. The central surface brightness of a globular cluster is 17 mag/arcsec$^2$. What is the covering fraction of stars (i.e., the probability that a randomly selected straight line will intersect a star)? You may assume that most of the light comes from stars similar to the Sun.

6. If two disk galaxies similar to the Milky Way collide face-on at a relative speed of 1000 km/sec, roughly how many stars will collide?

7. What is the difference between “bootstrap” and “jack-knife”?