Homework 1 – AS.171.627 – Zakamska

1. Perspective acceleration (3 ponts). A nearby star has proper motion μ (arcsec/yr), parallax π (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). One of the largest stellar proper motions is that of Barnard's star. What are the proper motion, the parallax and the heliocentric radial velocity of Barnard star? Use these values to evaluate its perspective acceleration.

2. Gaia (3 points). In a couple of paragraphs ($\sim$ 10 sentences) describe some of the key science topics that Gaia is supposed to make major contributions to. In other words, what awesome science was proposed to convince the European governments to spend hundreds of millions of dollars on the mission? Your answer should include $\sim$ 5 references. In open-ended questions, refereed articles are always preferable; however, in this particular case you may find so-called "white" papers (high-level analogs of observing proposals) even more helpful. 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. **Please type up the solution to this problem and email it to me separately from the rest of the homework.**

3. Photometric parallax (2+3 points). Here is a screen shot of my browsing a Hubble Space Telescope (HST) image and mousing over a star in this image: `http://zakamska.johnshopkins.edu/SPR2018/image_of_star.png`. My cursor was at the position of the red cross when the screenshot was taken. While all the information necessary to solve the problem is contained in the screenshot, you are welcome to download DS9 and use it to browse the image by yourself, though be aware that it is 400 MB: `http://zakamska.johnshopkins.edu/SPR2018/hst_9905_04_acs_wfc_f550m_drz.fits`.

(a - 2 points). If this is an image of a star, why does it look like this? Why are there four spikes? Why are there concentric shells?

(b - 3 points). What stellar type is this star? Can you estimate its mass? Can you estimate its distance? (Hint: use the coordinates of the star in the image, use the SDSS Navigate tool, figure out the colors and the magnitude of the star, and use photometric parallax method.)

4. 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/mwgc.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?

5. Galaxy classification (4 points).

A set of galaxy images is available at `http://zakamska.johnshopkins.edu/SPR2018/galimages/`. Classify each galaxy according to the Hubble classification scheme (bonus for any name recognition). Pictures are labeled by letters in the upper left corner.

Short problems (2,2 and 1 points).

6. 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.

7. 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?

8. What is the difference between "bootstrap" and "jack-knife"?