# Astronomy 128: Galaxies and Galactic Structure

Week 3, Thursday, February 3

**Topic:** Location and motion of gas in the Milky Way

This week, we investigate galactic rotation and the evidence for dark matter in our own galaxy. The stars in the local neighborhood orbit on roughly circular orbits around the galactic center. But stars on the inside track will out-pace us and stars on the outside track will fall behind (unless the galaxy rotates as a rigid body). It appears from our point of view that there is a local shear and rotation to the stars' velocity field. Measuring them can tell us about how the orbital velocity varies with galactic radius (rotation curve). This in turn tells us about the mass profile of the galaxy. This leads us to believe there is dark matter out there. Micro-lensing is a technique we can use to find dark compact objects in the galactic halo.

**Break:** Michael

**Reading:**

Read the rest of Chapter 2 of Sparke & Gallagher (section 2.3 to the end), including the sections on micro-lensing. Read sections 6.1–6.5 of Elmegreen's *Galaxies and Galactic Structure*: it's a short read and has some useful information about the different gas phases in galaxies.

**Problems:**

1. Come to class with at least one *written* question on the reading. (Please also write down any of these questions on the written assignment you turn in, so that I can get a chance to see them before class. If you come up with extra questions after that, that's fine, but if you've come up with them already by Wednesday, please write them down.)
2. SG 2.14
3. SG 2.15
4. SG 2.16
5. SG 2.17

6. Now that you have working code to read in the Hipparcos catalog, we'll make use of those data (this time the proper motions) to find the apex of solar motion. Stars go around the galaxy at different rates, depending on their galactic radius and also their random deviations from perfect circular motion. Stars which are close-by should share the same rough motion as the sun. If we average their motion, the random velocities should cancel out and we are left with the local standard of rest (LSR), which is a hypothetical circular orbit at the sun's distance from galactic center. But the sun has its own random velocity with respect to the LSR and we're going to find its direction using Hipparcos. Have a look at the figure on the next page. If the sun is moving with respect to the LSR, then from our perspective, the average velocity of stars will systematically appear to drift in one direction in space. However, Hipparcos only measures proper motions ($v_t$). As you can see, when looking at stars in the direction of our motion (or away from it), the average proper motion should be zero. This is the location of the apex (or antapex) of the solar motion.

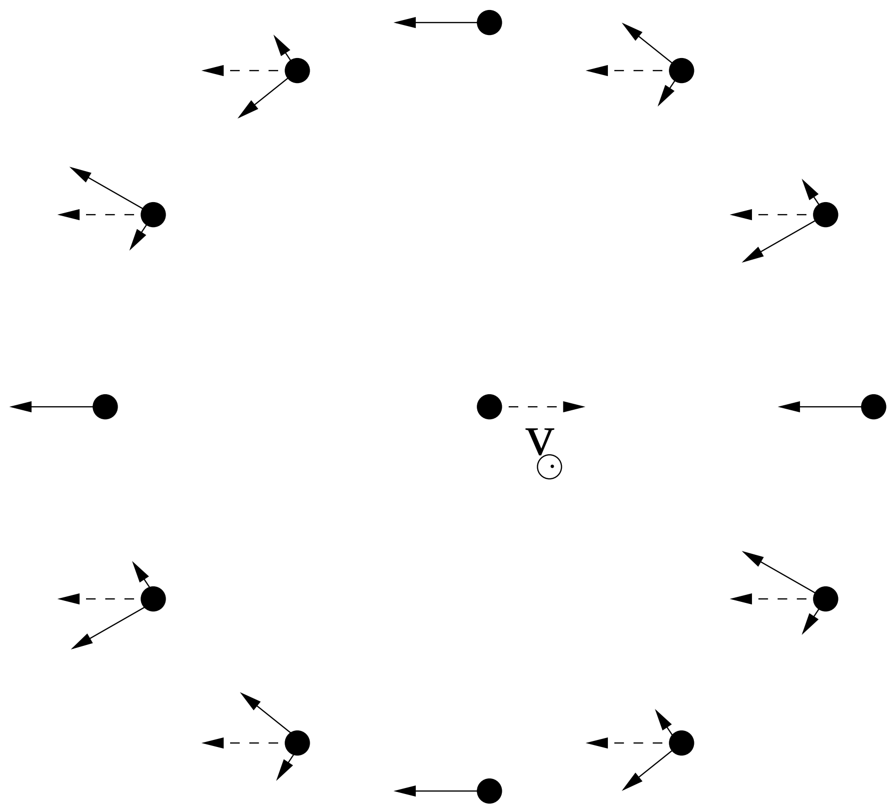
   (a) Use your pre-existing code to extract the coordinates and proper motions (RA, DEC, pmRA and pmDEC) for each star. Note: there are columns for RA and DEC in decimal degrees; you should use these instead of parsing the hh:mm:ss formatted columns. (Remember, in the FITS file, the RA and Dec are in radians and the proper motions are in rad/yr [though the errors are in mas/yr], so be sure to convert.)

   (b) Sort the data into bins of RA and DEC (say 20 bins in RA and 10 bins in DEC). For each bin, compute the average proper motions $< pmRA >$ and $< pmDEC >$. I suggest using IDL's `where()` function to pick out data that falls in each bin.

   (c) Using your zero DEC bins, plot $< pmRA >$ versus RA. Locate the approximate RA of the apex and of the antapex.

   (d) Now that you know the RA for the apex and the RA for the antapex, use these bins to plot $< pmDEC >$ versus DEC and hence find the approximate DEC of the apex.

   (e) Look up the real apex and compare with your results. In what constellation is the solar apex?




7. SG 2.20

8. SG 2.21

9. SG 2.22. For an Einstein ring, $\beta = 0$. What is the amplification in this case? How can you explain this obvious problem?

10. SG 2.23. Plot the amplification as a function of time and compare with the micro-lens candidate lightcurve at http://wwwmacho.mcmaster.ca/Results/LMC/LC.html

11. Take a look at the major paper on the MACHO project for looking at microlensing by halo objects, Alcock et al. ApJ 542, 281 (2000). Everyone should at least read the abstract and look through the figures; in addition, I'd like one volunteer to give a roughly 10-minute summary presentation on the paper. (We'll be doing this for other papers in subsequent weeks, so everyone will get a chance.) If you're up for doing this, e-mail the class and let us know; I'll let it be first-come, first-served.