

Astron 299/L&S 295 Problem Set 8

Given: Nov 16. Due: Wednesday, Nov 30 at the beginning of class

Homework Policy: You can consult class notes and books. Always try to solve the problems yourself; if you cannot make progress after some effort, you can discuss with your classmates or ask the instructor. However, you cannot copy other's work: what you turn in must be your own. Make sure you are clear about the process you use to solve the problems: partial credit will be awarded.

Reading: Kutner Chapter 17, 18, 19

Problem 1 Kutner 18.2

Problem 2 Kutner 18.4

Problem 3 Creation of the Magellanic Stream

The Small Magellanic Cloud is 60 kpc away and has one-tenth the mass of the LMC. The SMC has an angular diameter of $150'$, and its angular separation from the LMC is 21° .

- a. What is the distance between the LMC and the SMC?
- b. Ignoring the influence of the Milky Way, estimate the present tidal radii of both the LMC and the SMC due to the other.
- c. The Magellanic Clouds are in eccentric orbits around one another, and during the last few hundred million years they have been moving apart with an average speed of about 110 km s^{-1} . How recently did the LMC extend beyond its tidal radius? Assuming that the Magellanic Stream was formed by tidal stripping when the LMC and SMC were close to each other, when would you estimate that the Magellanic Stream was formed? (Note: Following this mutual tidal stripping, the gas was pulled from the LMC/SMC system by our Galaxy.)

Assume $2 \times 10^{10} M_\odot$, 51 kpc, and $460'$ for the mass, distance and angular diameter of the LMC. For the tidal radii, the approximate formula for the distance from the Lagrange point L_1 to M_1 and M_2 , called l_1 and l_2 respectively is:

$$l_1 = a \left[0.500 - 0.227 \log \left(\frac{M_2}{M_1} \right) \right] \quad (1)$$

$$l_2 = a \left[0.500 + 0.227 \log \left(\frac{M_2}{M_1} \right) \right], \quad (2)$$

where a is the distance between M_1 and M_2 .

Problem 4 The Magellanic Stream and the Mass of the Milky Way

The Magellanic Stream orbits the Milky Way and extends from 50 kpc to 100 kpc from the Galactic center.

- Consider a clump of gas in the stream in a circular orbit about the Galactic center. Take the radius of the orbit to be 75 kpc and the orbital speed to be 244 km s^{-1} . Treating the Galaxy and the mass clump as point masses, estimate the mass of the Milky Way. What is the corresponding mass-to-light ratio?
- Suppose a clump of gas at the tip of the stream starts with zero radial velocity at a distance of 100 kpc and reaches a radial velocity of -220 km s^{-1} after falling down to 50 kpc from the Galactic center. Assuming that the transverse (orbital) velocity of the clump has not changed, use conservation of energy to estimate the mass of the Milky Way. Find the corresponding mass-to-light ratio. As before, treat the Galaxy and the clump of gas as point masses.

Problem 5 Timescales in Galaxies and Clusters

- How long does it take the Sun to orbit the center of the Galaxy? Assume that we are moving at 220 km s^{-1} , and are 8 kpc from the Galactic center.
- How many times would the Sun have completed an orbit during the age of the universe? Assume 13.7 Gyr for the age of the universe.
- As an observational aside, how long would we have to wait to observe a star in Andromeda move through an angle of 1 arcsecond, i.e. to directly detect its rotation? Assume a rotation speed of 250 km s^{-1} and a distance to Andromeda of 750 kpc. You can neglect the inclination of the galaxy. Will you live this long?
1 arcsecond would be easily measurable with ground-based telescopes, but the Hubble Space Telescope could measure a change of 0.1 arcsecond. Will you live long enough to see an 0.1 arcsecond change?
- Now consider a cluster of galaxies. The Coma cluster has a velocity dispersion of roughly $\sigma = 1000 \text{ km s}^{-1}$, a core radius of 0.3 Mpc, and a total radius of about 3 Mpc. How long would it take a galaxy to completely cross the Coma cluster, if it were moving at the typical velocity dispersion?

Problem 6 Kutner 19.13

Problem 7 Kutner 19.14