

Astronomy 128: Galaxies and Galactic Structure

Week 7, Thursday, March 2

Topic: Spiral Galaxies II: Spiral structure and groups of galaxies

This week, we finish off spiral galaxies by examining the features that makes them stand out the most: disks, spiral arms, and bars. These structures can't simply be fixed collections of stars that orbit around the center: differential rotation would "wind them up" too quickly. Rather, they are due to a periodic "bunching up" of stars, like a traffic jam: the stars move in and out of the arms, just like cars move into a jam and then move out of a jam on the highway. The jam itself persists, but contains different cars (or stars) over time. This galactic traffic jam travels like a wave through the disk and this is why we call them spiral density waves. We'll look at the observational features of spirals and think about how they are generated. We'll then look at the influence of bars and bulges and evidence for the existence of black holes at the centers. To finish off, we'll look at galaxy groups and close encounters.

Break: Tara

Reading:

Read the rest Chapter 5 of Sparke & Gallagher, Section 5.4 to the end. You may also want to have a look (qualitatively) at Section 3.3. We didn't talk about epicyclic orbits (covered in that section), but in this chapter we're using the idea. Basically, the idea is that orbits of stars are *almost* circular, and we can describe their orbits well by treating them as moving on small epicycles (a small circle whose center travels along the main circular orbit). (To picture the overall idea, think about the Moon's orbit around the Earth, while the Earth travels around the Sun. This idea is analogous, but without the Earth, i.e. without any body at the center of the epicycle.) After thinking about it for a bit, you should be able to convince yourself that different frequencies of motion around the epicycle (relative to the frequency of the main orbit) can give you different shapes of the total orbit, including ellipses, off-center circles, and orbits that don't close at all. The main quantitative result we'll use from that section is the definition of the epicyclic frequency κ , in Eq. 3.69.

Problems:

1. Come to class with at least one *written* question on the reading.
2. SG 5.12.
3. On page 208, SG say that you need to know which side of the galaxy is closer to you so that you can determine whether or not the spirals are *trailing* or *leading*. Explain why.
4. Draw a spider diagram similar to the one in Figure 5.19 in the book using a light color (e.g., in pencil); you can just reproduce the one from last week if you like. Use an inclination of $i = 30^\circ$. Now make a rough sketch of a galaxy with two spiral arms (remember, the whole galaxy is inclined, so your arms should reflect this). Qualitatively, how will the spiral arms affect the velocities of stars on the concave and convex sides of the arms? How will this change the lines in the spider diagram? Modify the lines you drew with another color. Clearly indicate whether your spiral is trailing or leading.
5. SG 5.13. For this, it's important to note something that SG don't explain all that clearly. On p. 210, SG say that the pattern speed should vary with radius. However, the discussion starting on the next page (density-wave theory) is based on the assumption that the pattern speed does *not* vary with radius, i.e. that the whole spiral has a single pattern speed. They say this in passing, but it's easy to miss.
6. Let R_{cor} be the corotation radius (i.e., where the circular velocity of the stars is equal to the circular velocity of the spiral arms). Let R_{OLR} be the outer Lindblad radius and R_{ILR} be the inner Lindblad radius.
 - (a) Assuming a flat rotation curve, find R_{OLR}/R_{cor} and R_{ILR}/R_{cor} for a 2-arm spiral. (You can use the results of SG 5.13 here.)
 - (b) The dust lanes in a spiral galaxy are observed to switch from the concave side to convex side of the spiral arms at $R = 0.6R_{25}$. Where are the ILR and OLR?
7. SG 5.15.
8. Read the paper “A star in a 15.2-year orbit around the supermassive black hole at the centre of the Milky Way” Schödel et al., *Nature* 419:694 (October 17, 2002). Tara will present a 5–10 minute summary of this short paper, but everyone should read it and be ready to discuss and ask questions about the paper.

9. Use the orbit of the star discussed in that paper to calculate the mass of the Milky Way's central black hole. The orbit is shown in Figure 2 of the paper; use only the information shown in the Figure, and the distance to the Galactic Center, to calculate the mass. Clearly state any assumptions you make. You will likely get a mass that is a factor of a few smaller than the $3.7 \times 10^6 M_{\odot}$ quoted in the paper. If so, explain what assumptions you've made that have biased your mass estimate in that direction.
10. SG 5.16.