

# Questions for Homework 6

Mackenzie James

Due: March 6th, 2020

**1. How many close encounters will the MW and M31 experience in the future?**

You can identify the close encounters on the plot where the position between the Milky Way and M31 move quickly towards a smaller number (not quite reaching 0) before quickly moving away towards a larger separation again. This occurs twice for these galaxies, and on the third encounter the separation between the two trails off at 0.

**2. How is the time evolution of the separation and relative velocity related?**

The velocity is the derivative with respect to time of the position between the two galaxies. This relationship is highlighted in a few places in the plot. When the separation becomes closer, the relative velocity between the Milky Way and M33 becomes larger due to the fact that the two galaxies are moving directly towards each other. The velocity peaks when the position is at its lowest value-the galaxies are the closest. The velocity then starts to decrease as the galaxies move past each other, showing that they will slow down (lowest relative velocity to each other) until they are at a maximum value in position-the farthest separation- before they start to move closer together and one observes the velocity increasing again as the galaxies move towards one another after a flyby. You can see the galaxies are slowing down each time they pass due to the separation being smaller after each pass, and the velocity starting to decrease as well.

**3. When do M31 and the Milky Way merge? What happens to M33's orbit when they merge?**

You can see that the Milky Way and M31 have merged by the end of the position plot where the separation between the center of mass of the two galaxies flattens out to 0. Zooming in on this tail end of the graph, the full merger occurs about 6.5 Gyr in the future. This tail also occurs in the velocity plot, where aside from small fluctuations the relative velocity between the center of mass has gone to 0 as well. When you look at this same time point on the plots between M31 and M33, M33's behavior goes to one that is relatively periodic

in the position and the relative velocity. This is implying that it is orbiting as a satellite galaxy around where M31 is, which has now merged with the Milky Way by this point in time. However, looking at both position and velocity you can observe that the amplitude of the position plot is decreasing, showing that M33 is getting closer to the merge, and will probably eventually merge with M31 and the Milky Way

**4. BONUS: What is roughly the decay rate of M33's orbit after 6 Gyr. If this rate is constant, how long will it take M33 to merge with the combined MW + M31 remnant if it is at a distance of 75 kpc?**

Estimating one period of rotation at 1.5 Gyr, and with the separation between M33 and M31 decreasing at about 10 kpc in that period, the decay rate is about 6.67 kpc/Gyr. (amounts estimated from plot). Starting at a separation of 75 kpc, it would then take about 11.25 Gyr for M33 to merge with the MW + M31 remnant.