

Homework 6 Astr 400B

Kush Aggarwal

February 2023

Question 1: How many close encounters will the MW and M31 experience in the future?

Solution: As there are 2 minimas, so there are 2 close encounters. At third close encounter , they merge.

Question 2: How is the time evolution of the separation and relative velocity related?

Solution: They are inversely proportional. Maxima of separation, corresponds to minima of relative velocity. This is a consequence of energy conservation, at maxima of separation(ie when they are on their apocenters) , they have maximum potential energy , and they have zero radial velocity, and also the minimum tangential velocity hence, they have minimum kinetic energy.

Question 3: When do M31 and the MW merge? (you might need to zoom in on the plot - try a log y axis). What happens to M33's orbit when they merge?

Solution: The merge at 6.43 Gyr. Orbit of M33 remains unaffected. We see a giggle at this time, in M33vs M31 separation as well as velocity plots. This is because, earlier M33 was orbiting M31, but now its orbiting the M31+MW remnant. Hence, the potential energy has increased. So, there is an adjustment in the total energy, which corresponds to the abrupt giggle. Now, the increased central potential provides greater centripetal acceleration, hence the radial velocity needs to be adjusted. This, explains the giggle in the velocity curve for M33-M31.

Question 4: BONUS: what is roughly the decay rate of M33's orbit after 6 Gyr (ratio of the difference between two successive apocenters and the orbital period; you don't need to be precise). 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?

Solution: Basically, the situation now is that, M33 was earlier orbiting M31, and its orbit was decaying into M31 due to wake produced by M31 dark matter halo. But, before it could have merged with M31, M31 itself merged with MW, and so now, M33 is orbiting the MW+M31 combined remnant. Again, there is a backward pull by wake produced by dark matter halo accumulated on the back of M33 orbit and it will eventually merge with remnant. For the decay rate: We can calculate the distance between two adjacent maxima's and divide it by time, and repeat this for each pair of adjacent maxima after 6 Gyr, and we can average the decay rates to get an estimation. I would do this by just eyeballing the graph . So, the first pair gives $\frac{115-95}{9-7.5} = 13.33 \text{ Kpc/Gyr}$. Second, pair gives $\frac{95-80}{10-9} = 15 \text{ kpc/Gyr}$. So, average decay rate is approx : $\frac{15+13.34}{2} = 14.17 \text{ kpc/Gyr}$. So, to merge with M31+MW remnant 75 kpc away it would take approx : $75/14.17 = 5.3 \text{ Gyr}$. So, approximately it will take 5.3 Gyr.