Research Assignment Proposal
ASTR 400B Spring 2020

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1 Introduction

We would like to examine the effect of the Milky Way-Andromeda major merger on the stellar disk of M33 (Triangulum galaxy). M33 is a smaller ($5 \times 10^{10} M_{\odot}$ halo) spiral galaxy and satellite of the Andromeda galaxy (M31). Unlike M31, M33 is not on a collision trajectory with the Milky Way, and will become a satellite galaxy of the major merger remnant.

It is well known that gravitational tidal interactions can alter the morphology and structure of galaxies. For example, strong tidal interactions between host and satellite galaxies typically evolve dIrr satellites to dSphs and dEs (Mayer et al. 2001). While M33 is not a dwarf galaxy, it will be dwarfed by the massive galaxy that will be created from the Milky Way-M31 merger. It is possible that given this huge mass ratio, a similar process will change M33 from a spiral to a spheroidal or elliptical galaxy. It is also thought that the morphology of M33 was altered in its recent tidal interaction with M31. The last tidal interaction between between the two galaxies is thought to have produced M33s two spiral arm structure (Łokas et al. 2015).

It is not obvious what M33 will look like in the future, nor how fast it will evolve. This is a complicated, many body system with many factors that will affect the tidal evolution of M33. For example, the direction of rotation could dramatically alter this evolution. It has been shown in simulations that the tidal evolution of disky satellites is stronger when their internal angular momentum lines up with the orbital angular momentum. This orientation is also strongly correlated with the formation of a central stellar bar structure (Semczuk et al. 2018).

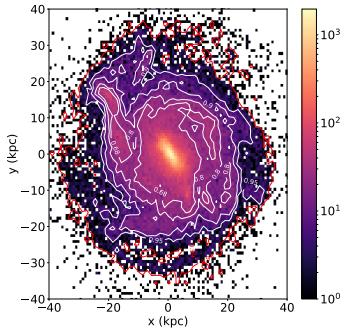

Figure 1: Density contour plot of M31, face-on. Made in ASTR400B in class lab 7.

2 Proposal

2.1 Research Questions

1. What will the morphological evolution of M33's disk look like?
2. Will M33 become more like a spheroidal?
3. Will M33 have spiral arms or a bar structure in the future?

2.2 Methods

All of these questions could be answered by analyzing 2D histograms with density contour plots, showing the stellar mass distribution in M33. For proper examining of the morphology, we would have to make 2D histograms from an edge on perspective (see fig 2) and a face on perspective (see fig 1). To properly depict the evolution of M33, we should make plots for the very first and last snaps in the simulation. Optionally, we could also look at these plots directly before and after major tidal interactions to see their effect.

2.3 Hypotheses

I predict that M33 will evolve into a spheroidal galaxy. After the major merger of the Milky Way and M31, the mass distribution of the Local Group will be very compact, and the tidal field of the merger remnant should be intense. I predict a dramatic change in the morphology and structure of M33 as it orbits this massive new galaxy. Alternatively, one could argue that M33 should

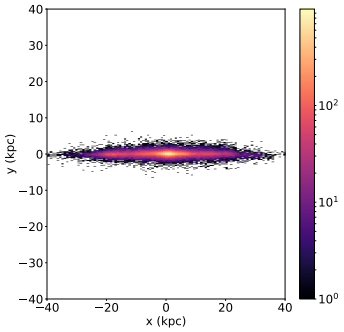

Figure 2: Density contour plot of M31, edge-on. Made in ASTR400B in class lab 7.

accrete much material ejected from the major merger, a process known to rejuvenate spiral arms and disk structures. However, even if this does happen at some point, I predict that these structures would not be long lived due to rapid tidal evolution.

References

[Łok+15] Ewa L. Łokas et al. "The Resonant Nature of Tidal Stirring of Disky Dwarf Galaxies Orbiting the Milky Way". In: *The Astrophysical Journal* 810.2, 100 (Sept. 2015), p. 100. DOI: 10.1088/0004-637X/810/2/100. arXiv: 1505.00951 [astro-ph.GA].

[May+01] Lucio Mayer et al. "The Metamorphosis of Tidally Stirred Dwarf Galaxies". In: *The Astrophysical Journal* 559.2 (Oct. 2001), pp. 754–784. DOI: 10.1086/322356. arXiv: astro-ph/0103430 [astro-ph].

[Sem+18] Marcin Semczuk et al. "Tidally Induced Morphology of M33 in Hydrodynamical Simulations of Its Recent Interaction with M31". In: *The Astrophysical Journal* 864.1, 34 (Sept. 2018), p. 34. DOI: 10.3847/1538-4357/aad4ae. arXiv: 1804.04536 [astro-ph.GA].