Draft version March 16, 2023
Typeset using LaTeX **twocolumn** style in AASTeX631

ASTR 400B: Theoretical Astrophysics Final Project Proposal*

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ABSTRACT

This document defines and proposes Rianne Kooi's final project in ASTR400B: Theoretical Astrophysics for the Spring 2023 semester. She will be focusing on the dark matter halo remnant of the major merger of the Milky Way galaxy and the Andromeda galaxy, and how the density of dark matter looks following the galaxies colliding.

Keywords: Dark Matter (353) — Galaxy mergers(608) — Milky Way Galaxy (1054) — Andromeda Galaxy(39) — Galaxy dark matter halos(1880)

1. INTRODUCTION

1.1. *Defining*

The inevitable merge of the Milky Way (MW) galaxy and the Andromeda galaxy, or M31, lead to many questions that are begging to be answered. The basic premise of the collision, as seen in van der Marel et al. (2012) will motivate not only myself, but the rest of my classmates to embark on finding out what happens to the galaxy we call home once it and M31 collide. For myself, I am interested in what will be the product of these two galaxies once they merge? Specifically, the dark matter halo of the collided galaxies.

1.2. *Importance in Terms of Galaxy Evolution*

The dark matter halo is important to our understanding the evolution of our galaxy because dark matter represents a little over 90 percent of the mass in our galaxy. When we collide with M31, the overwhelming amount of dark matter of the two galaxies will be one of the focal points of how the final product of the merger will look. Understanding the the dark matter halo remnants of the collision is crucial to how our home will look, even if we can't see the mass that makes up most of our universe. It's also important to understand what the density looks like so that we can predict what will happen following this collision. What mergers will happen next? What will those collisions look like once they are complete? What does this tell us about the formation of MW and M31?

1.3. *Current Understanding*

Currently, there are several research pushes for dark matter halo density profiles following galaxy mergers. In Frenk & White (2012), Frenk and White lay out a timeline of the discovery, and key developments of dark matter. There are three main parts to this timeline following the pre-history in the 1970s. The "breakthrough years," which has the well-known measurement for elementary particle dark matter. In this time frame, scientists categorized initial conditions for particles into "Hot, Warm, and Cold Dark Matter (HDM, WDM, and CDM respectively)." Following that, we enter the era of establishing the standard model. In this era, many simulations were done as well as "the first detection experiments and first searches for dark matter annihilation radiation are set up."Frenk & White (2012) In addition, "WMAP convincingly measures the second acoustic peak also, excluding many alternatives to the standard model and giving precise estimates of the baryon and dark matter densities."

In addition to this timeline given in Frenk & White (2012), the dark matter halo evolution of galaxy mergers research as seen in Drakos et al. (2019a) set the ground work for my project as well. The researchers

* Released on March, 16th, 2023

utilized 6 different profiles in creating the simulations described here: "Two were NFW models truncated using an exponential cut-off (NFWX), and two were NFW models truncated by iteratively removing unbound particles outside a specified radius (NFWT). The last two models were Einasto profiles(Ein), one with a low shape parameter α_E= 0.15, and one with a high shape parameter α_E= 0.3," Drakos et al. (2019a). They found that "These mergers do not generally decrease the central density or the concentration parameter, and often cause remnants to become more concentrated," Drakos et al. (2019a). The plots of the 6 different profiles, which I took special interest in, are in Figure 1. I plan on utilizing these results to compare my results when utilizing a different profile.

In Drakos et al. (2019b), the researchers outline how the dark matter halo will behave in terms of the "size, shape, and spin." The physical attributes of the dark halo remnants will play a significant role in how the density is concentrated. How halos are structured are very closes related to the merger history, and how these halos are structured will impact the density of the dark matter in the final form after the collision. It's importatnt to note that in Drakos et al. (2019b), the researchers are assuming that the haloes are of the same form, and essentially identical, in my project, I will not be making this assumption.

1.4. *Current Questions*

Some of the main questions regarding dark matter in mergers I found come from Drakos et al. (2019a), where they state "given our results, if the central density in haloes does drop as they grow, the mechanism for this remains unclear." The researchers hypothesize that this could be due to the fact that they are only considering "the simplest model for major mergers; binary, equal-mass mergers of identical haloes that are spherical, non-rotating, and lack substructure," Drakos et al. (2019a). One of the other issues that the researchers found was how their results apply to more realistic mergers. They stated that "cosmo-logical conditions are different because equal-mass and/or isolated binary mergers are rare," Drakos et al. (2019a).

2. PROPOSAL

2.1. *Motivating Questions*

For my final project in ASTR 400B, I am specifically wanting to answer the question, "What does the final density profile of the dark matter halo following the Milky Way - Andromeda merger? look like?" I will be investigating if the final profile is similar to that of a Hernquist profile, and whether or not the dark matter halo is more or less concentrated than the Milky Way or Andromeda before the merge.

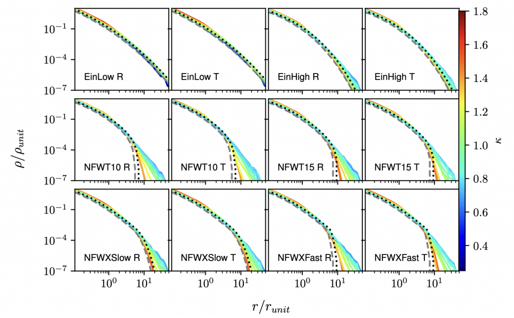

Figure 1. Figure from Drakos et al. (2019a), the density profiles of the halo remnants

2.2. *Approach*

In general, the approach I plan on taking is to explore the density of the dark matter of MW and M31 separately, and create time evolution plots of the two galaxies separately. In a similar fashion to Homework 5 in this class, I plan on utilizing the MassProfile class and the various important snapshots for MW and 31, see Figure 2 for example from homework. We have created many different code sets that will help me find the density of the dark matter halo, specifically the Hernquist profile. It is important however, to make clear that I have to isolate the dark matter from the total mass profile of the galaxies.

Upon creating diagrams that show each galaxy separately, I want to create plots of the two galaxies together and analyze them utilizing the Hernquist profile. I will rely heavily on the work fromDrakos et al. (2019a) as they did very similar work with different profiles.

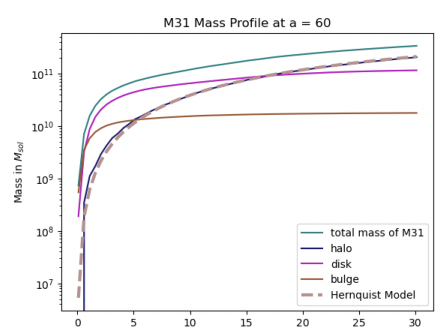

Figure 2. Figure from ASTR 400B: Homework 5 by Rianne Kooi, M31 Mass profile

2.3. *Hypothesis*

As seen in Drakos et al. (2019a), I anticipate that the dark matter halo remnants of the MW-M31 merger will become more concentrated than that of when they were separate, like they are currently. I also believe that I will be able to fit the Hernquist model to the density of the dark matter halo. I can anticipate that my major struggles will be simulating the collision within my code given the various snapshots in the data given to us.

3. ACKNOWLEDGEMENTS

I'd like to acknowledge the University of Arizona College of Science for giving the opportunity to undergraduates to perform research projects such as this one. Specifically, I'd like to thank the Department of Physics for supporting my undergraduate career since 2019. I'd also like to thank Dr. Gurtina Besla for teaching ASTR 400B: Theoretical Astrophysics for Spring 2023.

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