

Analyzing the Density Profile Evolution of the Dark Matter Halo Remnant of the MW-M31 System

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1. INTRODUCTION

It is predicted that in approximately 5.86 Gyrs, our galaxy, the Milky Way (MW), will collide with the Andromeda Galaxy (M31) in a major merger (van der Marel et al. 2012). While the dark matter halos of each galaxy are not directly visible, they are vital to our current understanding of cosmological formation since they are the cradle for all visible galaxy formation in the universe. Dark matter halos interact gravitationally with visible matter, and thereby completely envelope visible matter. Mergers such as the MW-M31 merger can have a major effect on the structure of the dark matter halo, specifically its shape and concentration, and provide a unique opportunity to examine these galactic cradles in their evolution as they combine (Drakos et al. 2019a). The concentration of the dark matter halo is defined as defined as R_{200}/R_{scale} where R_{200} is the radius where the dark matter halo density is 200 times the critical density to close the universe $\rho_{crit} = 1.62 * 10^{11} \text{ Msun Mpc}^{-3}$, and R_{scale} is the scale length of the Hernquist Halo Profile. The Hernquist Profile is an analytical expression for dark matter mass distribution in galaxies, the dark matter mass at a given radius r is given by $M(r) = M_{halo} * r^2 / (R_{scale} + r)^2$ where M_{halo} is the total dark matter halo mass and R_{scale} is the scale length (Hernquist 1990). The objective of this project is to better understand the evolution of the dark matter halo remnant of the MW-M31 system in terms of the density profile through simulation. These findings could help shed light upon the structure of dark matter and the formation and evolution of dark matter halos through hierarchical processes like galaxy mergers.

Dark matter is an unknown substance, proposed to only interact gravitationally by Cold Dark Matter (CDM) Theories, which is meant to account for the absence of enough visible matter to provide ample gravitational force to bind galaxies together. On large scales, dark matter tends to cluster into filaments, and it is the intersection of these filaments (where the density is higher) that are known as 'halos'. These halos are the exclusive site of galaxy, group, and cluster formation. In order to understand galactic formation and cosmology, an understanding of dark matter halo structure and evolution is essential (Drakos et al. 2019b).

While some information of dark matter halos can be observationally determined, through means of galaxy kinematics, satellite kinematics, and gravitational lensing, numerical simulation accounts for most of the detailed knowledge of dark matter halos (Drakos et al. 2019a). Halos form in a hierarchical manner, small structures, and also form "inside out", with a bound core collapse with small bits of material becoming loosely bound over time. Frenk & White (2012)

2. THIS PROJECT

In this project we will explore the evolution of the dark matter halos of the MW and M31 in terms of their density profile and shape as they approach each other and eventually merge. The density profile will be analyzed at three different times during the galaxy merger: when the two galaxies are far apart (present day), when the two galaxies are significantly close (about 3.87 Gyr), and when the galaxies finally merge (in roughly 5.86 Gyr) (van der Marel et al. 2012).

Along with the evolution of the dark matter halo, this project is concerned with studying the final density profile of the MW-M31 system. The final density profile will be compared to a Hernquist profile. If the final density profile does not match a Hernquist profile well, other snapshots will be examined to see when the system might best fit the

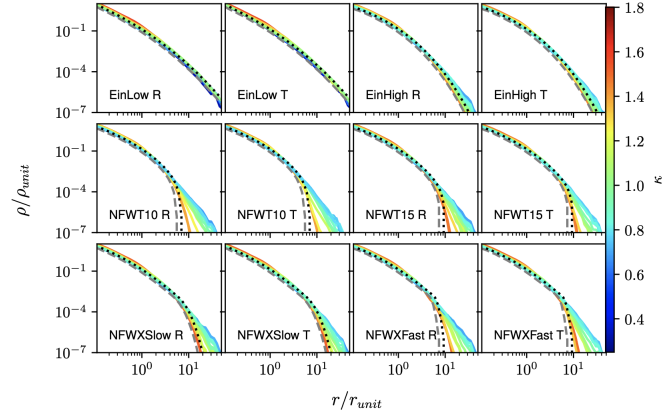


Figure 1. Density profiles of halo remnants for specific initial conditions (Drakos et al. 2019a).

Hernquist profile (Hernquist 1990). The distribution of dark matter particles from the MW and M31 will be analyzed and compared and the three periods in the galaxy merger.

3. METHODOLOGY

In order to properly compare the density profiles of the galaxies at different points in their evolution towards a merger, we must set a definite axis for which to align the angular momentum vector of the dark matter halos.

3.1. Figures

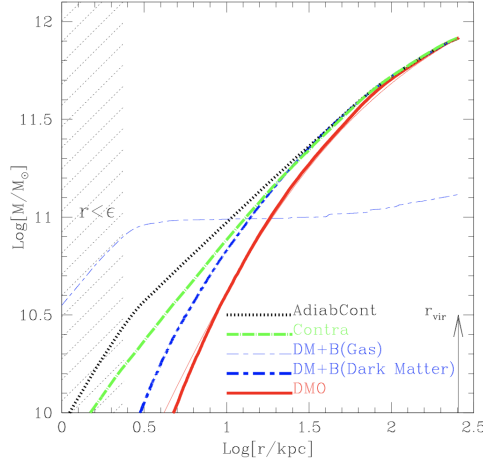


Figure 2. The enclosed mass profile of a certain dark matter halo for specific formulas (Abadi et al. 2010).

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