Draft version April 16, 2020
Typeset using LaTeX **twocolumn** style in AASTeX62

DM Halo Merger Remnant: Density Profile/Shape (Pre vs Post Merger)

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Keywords: Major Merger, Spiral Galaxy, Dark Matter Halo, Galaxy Merger, Merger Remnant

1. INTRODUCTION

Our galaxy, the Milky Way (MW), is on track to eventually collide with M31, the Andromeda Galaxy, located at about 2.5 million light years from us. The collision between two galaxies is known as a galaxy merger. Throughout this process, each galaxy's dark matter halo will merge too. This is one of the key aspects of halo formation and evolution. Halos form in hierarchical order where small structures merge with other halos forming denser and more massive structures.

Dark matter makes up five sixths of all matter and it is scattered throughout the universe forming a network of filaments. A dark matter halo (DMH) is defined as the point where these filaments intersect and form higher density structures. These gravitationally bound halos are where we find galaxy groups and clusters (Drakos et al. 2019a). Therefore, the understanding of the evolution and assembly of dark matter halos is key to understand galaxy formation and evolution and vice versa. After all, our understanding of this relationship is so poor that a galaxy has been defined as "a gravitationally bound collection of stars whose properties cannot be explained by a combination of baryons and Newton's laws of gravity" (Willman & Strader 2012), leaving dark matter out of the definition for now. The study of this relationship is also of great importance to develop a better understanding of our current cold dark matter theory.

There has been many studies to understand the structure of cold dark matter halos. Observationally, halos tend to have a triaxial mass distribution, that is, different distribution and length in each axis (Knebe & Wießner 2006). N-body simulations like those used in Abadi et al. (2010), have shown that the assembly of the central galaxy affects the three dimensional shape of the halo as it tends to be more axisymmetrical, almost oblate in the presence of a central galaxy. In the simulations where baryonic matter was ignored, the halo tends to be more prolate so the question of why in observations halos are triaxial remains unanswered (Abadi et al. 2010).

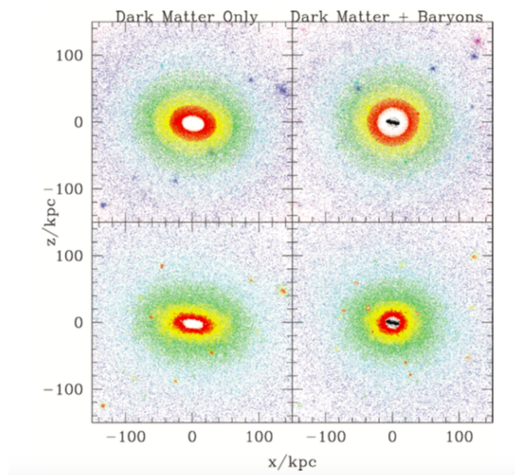

Figure 1: Abadi et al. (2010) The left panel shows dark matter particles from two different simulations. We can see that even though they are not triaxial, once a stellar disk is present (right panel), the halo becomes more spherical.

Another question that remains unanswered is the effect that mergers have on halo structure. Simulations that have been done to study major mergers between dark matter halos, e.g. Drakos et al. (2019a), have shown that that the remnant tends to be larger and more elongated along the merger axis resulting in a prolate or oblate structure. The density profile of the remnant also seems to increase as a function of radius without having a significant change in the central density compared to the individual halos. These results seem to be similar in simulations where baryonic matter is accounted for. However, other results have reported a decrease in the central density and there is no explanation yet for that. These simulations have only used isolated and equal mass halos; how halo assembly occurs between different mass mergers and other surrounding halos is still an open question for investigation. (Drakos et al. 2019b)

2. THIS PROJECT

The attempt of this project is to understand the process of galaxy mergers and the effect that has on the structure and the mass distribution of the halo remnant.

We will look at each individual dark matter halo from the Milky Way and Andromeda and look at their density profiles and shapes before they merge. We will then look at the halo remnant after the galaxies have merged and study again the density profile and final shape of the DMH. The goal is to answer whether the 3D dark matter distribution is prolate (two short axes), oblate (two long axes) or triaxial. Is the remnant more spherical after the merger compared to the individual halos? As mentioned before, previous simulations have shown major merger halos to be almost spherical with some elongation along the merger axis (Drakos et al. 2019a). We will compare with our results.

3. METHODOLOGY

Using the data from the N-body simulation (a simulation of a dynamical system of particles influenced by laws of physics) used in van der Marel et al. (2012), we will look at each galaxy's DMHs before and after merger and discuss the density profile and shape of the merger's halo.

To approach these questions we will plot the isodensity contours from each galaxy (like those in Figure2) at time=0 and then plot these contours again after the galaxies have merged. To do this, we will rotate the halo so that the angular momentum vector is aligned with the z-axis. The next step is to plot the density projections. In order to visualize the structure of the remnant, the ratio of densities have to be calculated in the three axes. We expect these figures to be very similar to those of Figure2, shown below, with density profile increasing as a function of radius and a prolate or oblate structure rather than a triaxial distribution. The reason we expect a prolate or oblate structure is because in previous simulations like those in Abadi et al. (2010) have shown more axisymmetrical halos. Those simulations were done with and without baryonic matter. However, when accounting for baryonic matter, star formation and feedback were ignored. These results where consistent with the simulations done by Drakos et al. (2019b), were they used identical halos for the mergers. In the case of the MW and M31, both have almost an identical mass so we should expect similar results.

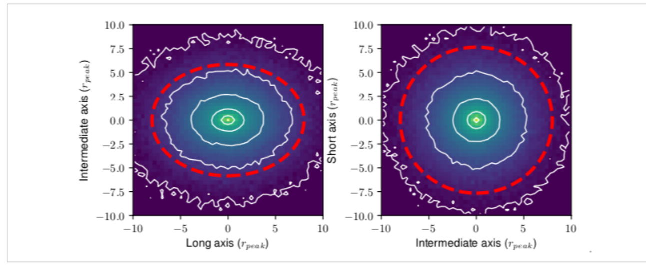

Figure 2: Drakos et al. (2019a) Isodensity contours of the halo remnant are shown in white and the projected fit of the axial ratios is shown in red. We can also appreciate the shape of the halo with the left panel being more elongated and the right panel almost circular.

The code created for this project computes the center of mass of each dark matter particle of the simulation. It then rotates the angular momentum vector and aligns it with the positive z direction. This is done to create a plot where we can visualize the density contours and over-plot a fitting ellipse for the shape of the halo. To find the best fit we need to try different axial ratios for an ellipse which will tell us what type of distribution the halo has.

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