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The kinematics of the stellar disk particles in the MW/M31 galaxy major merger remnant

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1. INTRODUCTION

As is well known throughout the astronomy community, The Milky Way (MW) and Andromeda (M31) are set on a course to collide in 4 billion years. Luckily, we can determine what this collision will look like and how the aftermath will behave dynamically through simulations. This project will be focusing on using simulation data to determine the kinematics of disk stars in the remnant of the MW and M31 major merger event. I plan to address how the motions of the disk stars from both galaxies contribute to the motion of the remnant as a whole. For example, I plan to determine whether or not the remnant is rotating. The stellar kinematics to be analyzed will be the velocity of particles, the dispersion of velocities, and its angular momentum as function of radius from the center of the remnant.

Analyzing the stellar kinematics of a major merger remnant is incredibly important to galaxy evolution because it can help us understand why the kinematics of a certain type of galaxy look the way they do in the present. In terms of galaxy evolution, studying the motions of a merger remnant allows us to take into account that galaxies can interact with each other which certainly affects how they evolve as opposed to if they evolved without any interactions. They also allow us to visualize how galaxies with similar mass that are on a collision course with each other will behave in the future.

The theory that motivates projects like this is referred to as "merger hypothesis", which states that the merging of two equal-mass, gas rich spiral galaxies forms an elliptical galaxy (Toomre & Toomre 1972). This is supported by Cox et al. (2006) who used numerical simulations to study the kinematics of major merger events between gas-rich and gas-poor mergers (referred to as dissipational and dissipationless respectively in the paper). As shown in Figure 1, they found that the simulations of gas-rich remnants successfully replicated the observed kinematic properties elliptical galaxies, while gas-poor remnants did not.

Many of the open questions in this field have to do with the accuracy of the "merger hypothesis" predicting the correct formation of ellipticals. For example, one thing it does not account for is the apparent lack of a dark matter halo observed in ellipticals (Romanowsky et al. 2003). *Where does the dark matter go after the spirals merge?*. For this project, some major open questions I hope to help answer are: *What will the Milky Way and M31 remnant look like?* and *How will the merger remnant behave kinematically?*

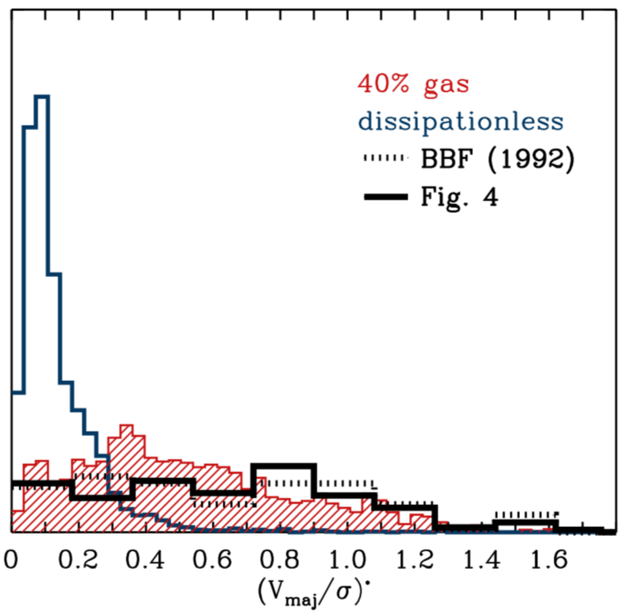

Figure 1. Histogram of (V/σ) for both gas-poor (blue) and gas-rich (red) remnant simulations overplotted with data from observed ellipticals and spheroids (Cox et al. 2006).

2. PROPOSAL

2.1. *What specific question(s) will you be addressing?*

I will be focusing on some specific aspects of the stellar kinematics of the MW/M31 merger remnant. I plan to address the following: whether the merged remnant is rotating, and whether it is a fast or slow rotator if it is. I will also be comparing the contribution of the Milky Way vs. M31 to the kinematics seen in the remnant, determining its velocity dispersion as a function of radius, and making an angular momentum comparison between the stellar component and the dark matter component of the remnant.

2.2. *How will you approach the problem using the simulation data?*

The simulation data to be used was generated by van der Marel et al. (2012).

To find whether the merged remnant is rotating, I will create a phase diagram of velocity vs. radius for a snapshot of the system (after the two galaxies have fully merged around 6.5 Gyr) by making use of the MassProfile class we created for Homework 5 and making use of the CircularVelocity functions. I will determine whether it is a slow or fast rotator by calculating the (V/σ) ratio for the remnant through using the CircularVelocity functions and calculating the velocity dispersion using numpy and using the classification that if (V/σ) ratio is ¡ 0.6, then it is a slow rotator.

To determine the contribution of the MW vs. M31 to the kinematics of the remnant, I will create velocity profiles for the stellar component of each galaxy before they merged (curve for the Milky Way shown in Figure 2) and compare them to the stellar velocity profile of the remnant to see which one is the most similar. Therefore, I will be able to see which galaxy's kinematics contributed the most.

To determine the velocity dispersion of the remnant as a function of radius, I will calculate the mean velocity at each radius and determine its spread using numpy, then store the dispersions in an array and plot them as a function of radius using matplotlib.

To determine the specific angular momentum of the stellar component of the remnant I will calculate the angular momentum of the disk particles as a function of radius using the MassEnclosed and CircularVelocity functions. I will then do the same thing but for the dark matter halo particles and compare the results to those obtained for the stellar component.

2.3. *Figure that demonstrates methodology*

See Figure 2 to the right because it apparently does not want to be here. I will be creating a rotation curve for M31 before the merger as well, then create another rotation curve for the remnant to compare with the MW and M31 curves.

2.4. *What is your hypothesis of what you will find? Why do you think this will occur?*

I believe that the MW/M31 remnant will be rotating since both the MW and M31 have their own angular momentum, then there is no possible way it will be devoid of angular momentum. I also believe that both the MW and M31 will contribute about the same amount to the kinematics of the remnant because they have very similar dark matter and disk star masses as well as similar rotation curves.

For the velocity dispersion of the remnant as a function of radius, I believe that it will decrease at further radii as seen in Romanowsky et al. (2003). Following "merger hypothesis", the merging of two gas-rich spiral galaxies should form an elliptical as a remnant. Even though this remnant will not be the result of a gas-rich major merger, I believe that the observed dearth of the dark matter in ellipticals will still apply because dark matter does not interact with baryonic matter, so the lack of gas should not have much to do with the seeming disappearance of dark matter when the two galaxies merge.

Following the hypothesis that there will be a lack of dark matter in the remnant, I believe that the specific angular momentum of the stellar remnant will be larger than the angular momentum of the dark matter halo remnant.

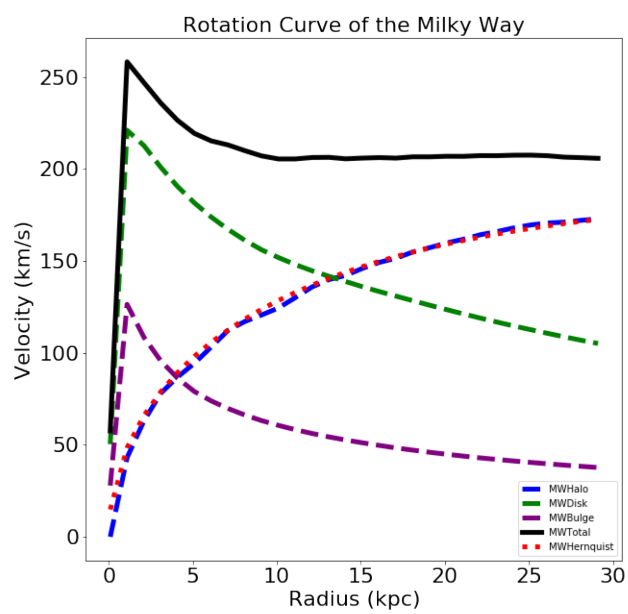

Figure 2. Rotation curve for the Milky Way before it merges with Andromeda including all components of the galaxy.

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