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FATE OF STARS AT THE SUN'S LOCATION IN THE DISK OF ANDROMEDA

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ABSTRACT

Galaxy evolution is an active field of research, we study the interactions and orbital paths of merging systems, like the Milky Way and Andromeda, to make predictions of galaxy formation and evolution. This is still an active field of research, we don't fully understand galaxy evolution or how their interactions with each other will determine the final rearrangement of material. By using N-body simulations we study the fate of stars at r = 8.29kpc, where our own Sun lies in the MW, but in M31. By looking at M31, we can study how stars will be arranged in another similar system as it merges with another galaxy. Our results show that at the end of the merger the solar candidates will be distributed as far as 120kpc from the galactic center, and will have an increase of those candidates at 8.29kpc. This tells us some information about the MW-M31 merger, stars within 8.29k in M31 will be pushed as far 150kpc, the remnant will expand, and the solar particles will also accumulate within 8.29kpc once the two systems merge.

Keywords: galaxies:individual(M31) — galaxies:evolution and formation — galaxies:interactions(M31, MW, M33

1. INTRODUCTION

Galaxy interactions and evolution is an active field of study, we use N-body simulations to study their interactions and make predictions for their future orbital evolution. With multiple simulations, we can restrict kinematic parameters to help us evolve our simulations and with these new developed methods we can understand with more accuracy and better predict how other merger systems, like major mergers (two spiral galaxies with roughly the same size), may have interacted with each other at desired times of their evolution.

It's important to note that although we do have many observations of MW, M31, and M33; M31's transverse velocity adds uncertainty to our N-body orbital parameters. To account for this, observations of M31's satellite population (39 satellites) are modeled against each other. (J.-B. Salomon et al., 2015) uses cosmologically-motivated velocity dispersion and density profiles to obtain a value for the transverse velocity. This shows how important it is to study galaxy interactions and evolution, as we take more observations of M31 we hope to reduce this uncertainty and this improve our simulations to help us understand the complex evolution and rearrangement of material of galaxy mergers.

It has been predicted by observations that the Milky Way (MW) and Andromeda (M31) are heading for a collision at 120 km/s in 6.2 Gyrs (Cox and lebb 2008). We could be certain that the end result of this merger is an elliptical galaxy as stated in the paper (Van der Marel et al., 2012), and if this holds true, we can then compare our end result from our simulations to the observed distribution of material to present-day elliptical galaxies and maybe refine our model of galaxy evolution. One paper argues that there will be less stellar density in the center of the merger than what we observe on present-day elliptical galaxies, and therefore states that the merger of present-day spirals could not form the predicted elliptical we expected (Naab and Ostriker, 2007).

While it may be unclear whether or not the merger between the two spiral galaxies, MW and M31, will result in an elliptical galaxy, we can still use these simulations to study their interactions with each other. As we are uncertain with the result of this merger, we are uncertain with the evolution of stellar objects within MW and M31. The majority of the galaxys stellar mass lies in the disk; therefore, we can look at the disk particles separately and observe where they might lie, will they distribute evenly or with the mixing due to the merger of the galaxies will they be unevenly mixed. As the two merges, we are also uncertain of our own Suns fate within our own galaxy (MW), we will ask how stars at a certain position evolve over the course of collision.

2. THIS PROJECT

For this project, I will analyze the distribution of stars within 7-9kpc of M31s disk at each pericenter of the MW-M31 merger as well as long after the final collision. This ring of particles will eventually be disturbed each time as M31 passes through the MW. The disk mass of M31 is significantly larger than the MW, with more mass and a stronger gravitational potential this could mean a larger number of particles might lie within the initial radius of 8.29kpc.

Its important to understand this rearrangement of material for galaxy mergers to gain an understanding of how galaxies might evolve over time.

3. METHODS

3.1. *N-Body Simulation*

N-body simulations were used on the MW-M31-M33 system with gaseous components not included as its a small fraction of the total galaxy mass. The initial conditions discussed for this simulation are that the galaxies are in the Galactocentric frame, with MW starting at rest (t = 0 Gys) and at the origin. The bulge masses (with M33 having no bulge) are stated to be based on literature values, the disk values set up with exponential profiles and halo masses with the corresponding Hernquist profiles (Van der Marel et al).

3.2. *My Code*

For this paper, I developed a code that analyzes a ring of disk particles at a given snap shot. I also wrote this code to have M33 at the origin of the Galactocentric frame. I also have written a code that will obtain a value of radii from M33 and see how much disk particles from M31 will pass through that radii.

4. RESULTS

To see how this ring of particles change over time we look at snap shots during MW-M31 pericenters, including times before the merger and well after: 0, 3.87, 5.87, 6.2 and 10 Gyrs. [Figure 2 and 3]

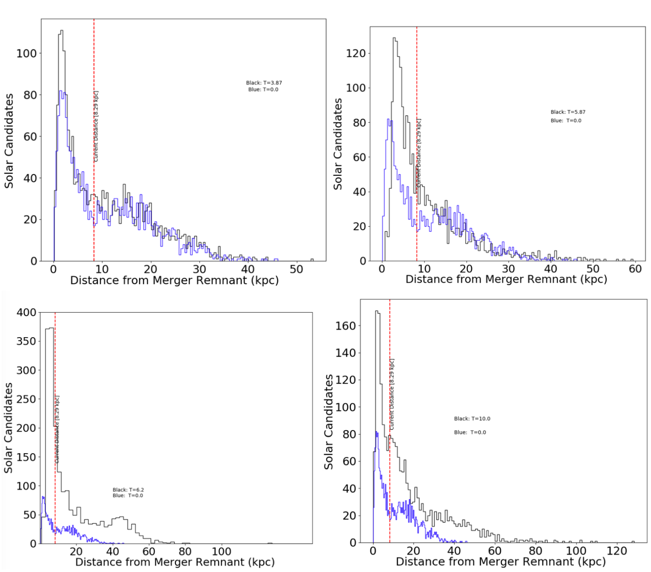

Figure 1. From these plots we can how the distribution of the solar particles evolves over time. The red dashed line is the radial distance of 8.29kpc and the blue histogram is the distribution of all the COM of the disk particles fixed at T=0 for comparison.At the end of the simulation, we can see how far out the solar particles have become, reaching as far as past 100kpc from the center of M31.

Since M31 is tilted, printing the x-y plane we're not able to plot those we have missed from indexing the scale height. However, as time passes we see the solar particles are no longer contained in a ring, but are already distributed throughout M31's disk due to the close encounters with MW (and M33). We also see visually the disk density of M31 as it evolves over time.

We then found the radial distribution of solar particles of the MW-M31 merger as well as for its pericenters [Figure 1]. We found that at the MW-M31 merger, the solar particles lied past its initial position of 8.29kpc, we also found the distribution at each snap shot past T=0 (present day 0 Gyrs). We can see from the histograms that there is still concentration of particles near the middle of M33, and we can see from the disk density plots, at snap shot 700 (T=10 Gyrs), the distribution of the solar particles are likely to concentrate within 50kpc, which our histogram plots also show.

As time moves on we see that the solar candidates start to move towards the right, passing the initial radial dis-

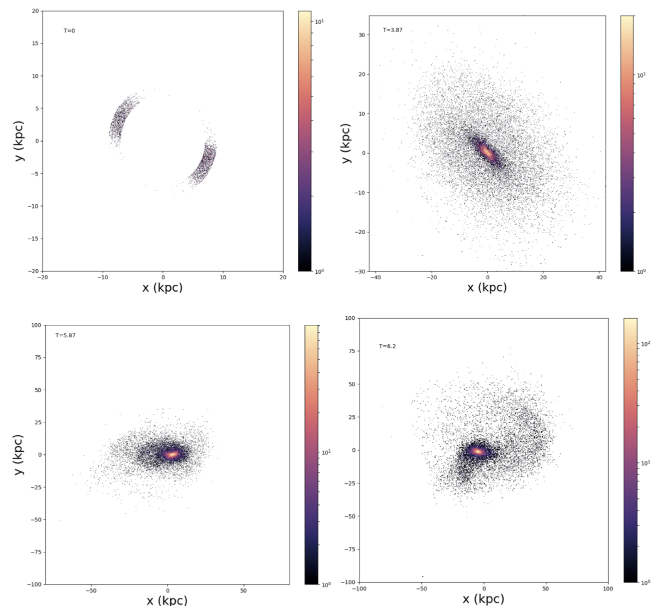

Figure 2. Here are several snap shots to show the evolution of M31's ring of disk particles. This is centered on M31's COM, only the solar disk particles are shown.

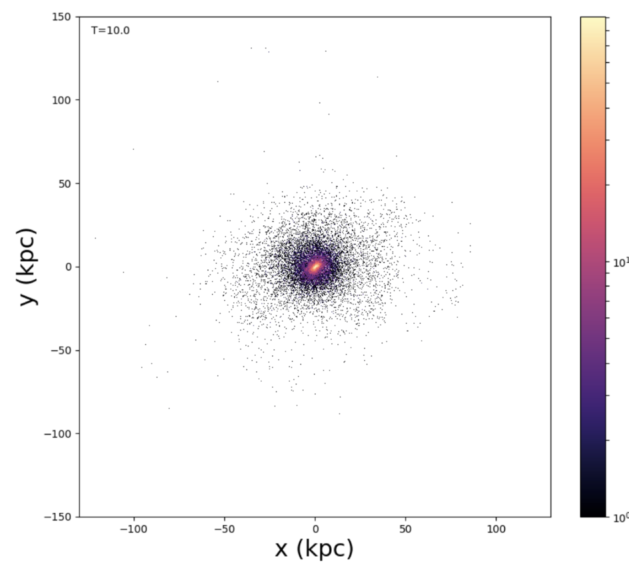

Figure 3. At the end of the simulation, we can see how far out the solar particles have become, reaching as far as past 100kpc from the center of M31.

tance of 8.29kpc. Similar to the result in the paper (Van der Marel et al.) the distribution of solar particles within the MW also migrates past the initial radial distance.

5. DISCUSSION

In our results we showed that the amount of solar particles moves towards the right, past the initial radial distance, and although M31 is more massive than MW, its disk particles seems to evolve in the same way, an interesting observation. Since both these galaxies share similar properties we can assume that, for stellar particles in the range of 7-9kpc, the merger of two spiral galaxies will have these particles migrate further out.

This might effect star formation for the merger, as in the paper by (N. Lahen et al., 2018) states, with the merger of the Antennane galaxies (spiral galaxies with gas rich morphology in the outer regions), gas pools into the center raising the chance for SFR (star formation regions) in those regions. This also increases the metallicity in the merger.

6. CONCLUSIONS

Galaxy evolution is still not fully understood, we ask questions such as, how does the material rearrange while the system is merging, and to help understand this visually, we use N-body simulations to observe the the evolution of the MW-M31-M33 system.

By comparing our results with (Van der Marel et al.) we can observe that solar particles will migrate outward as MW-M31 merges. Both are spiral galaxies and for both we focused on disk particles.

6.1. *Future Directions*

A further study of the MW-M31-M33 system, of the likely outcome of the solar particles, is needed to fully comprehend the outcomes. In the MW-M31 merger, their spiral arms will become heavily deformed by tidal forces, M31 has a larger disk mass, there must be a percentage of the solar particles we've chosen that will be ejected outward to MW tidal tail.

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