Draft version March 30, 2020
Typeset using LaTeX default style in AASTeX63

Tidal Debris from M33: Stellar Streams of M33

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1. INTRODUCTION

Our Milky Way Galaxy is in a merging course with its neighbor, the Andromeda galaxy (M31). These two galaxies, and their respective satellite galaxies form our Local Group. The term Local Group simply refers to the fact that our galaxies gravitational forces are significant enough to affect their evolution, and can't be ignored. With the new M31 proper motion measurement we can predict the timing of the collision between the MW and M31: $3.87^{+0.42}_{-0.32}$ Gyr (van der Marel et al. 2012).

The merging process will cause dynamical structures within the galaxy that tidally evolve over millions of years. The evolution of these structures can help us better understand galaxy mass distributions and the shapes of the black matter halos. Mergers simulations allow us to explore the evolution of said structures and study them. Choi et al. (2007) investigates satellite galaxy evolution by performing high-resolution N-body, and find an intrinsic mass dependence that provides additional leverage on both halo and progenitor satellite properties.

In (van der Marel et al. 2012), scientist presented an entirely deterministic Local Group evolution dataset as a result of recent Local Group phase-space measurements, and improvements thereof. The kinematic information of our own Local Group is essential to reproducing accurate evolution models of galaxies. This is not the case for farther galaxies since extracting such data is much harder to get. While Milky way like N-body simulations are effective at telling us about galaxy evolution, the realistic initial state of our Local Group can probe important information that we are missing.

In this paper we will focus on the M33 streams that survive the MW-M31 merger. Tidal streams act as past constraints on the progenitor orbits and allow us to probe the parent galaxy's gravity, and hence its dark matter halo. In Andromeda, we know of roughly 4 stellar streams such as the Giant stellar stream, Andromeda NE, Tidal Stream Northwest, and Tidal Stream Southwest streams (Guhathakurta et al. 2010; Grillmair & Dionatos 2006). Choi et al. (2007); Amorisco (2017) have explored the distribution of tidal streams to assess galaxy morphology, and phase-space distribution.

2. PROPOSAL

For my project I want to track M33 streams distribution that will be located in the MW-M31 merged halo. At the same time I want to assess how well the streams trace the orbital path of M33. I want to produce a qualitative timeline for the satellite galaxy disruption and stellar stream creation. Additionally, and potentially optionally, I want to assess the detection of dark matter subhalos.

2.1. *Tracking Streams*

A technique I can implement to track the stellar streams is to use the Jacobi radius, and label those stars outside of it. Jacobi (or tidal) radius is the distance from the center of the satellite galaxy at which the external gravitation of the host galaxy has more influence over the stars in the satellite than does the satellite itself. The initial M33 stars are already labeled, so I need to add a second layer to my pipeline in order to track those outside the tidal radius. The stellar streams orientation is also important, so once each stream is labelled separately, I can calculate the morphology using basic techniques such as moments.

Another interesting feature of streams is that they can potentially be used to indirectly detect dark matter clumps. When a dark matter subhalo clump grazes a stellar stream, it could disrupt the stream and produce gaps as indicated in Pearson (2018)[1]. However, as they discuss, I must track the effect of the galactic centers (MW/M31), as it also generates underdensities in streams. I think I should keep this part of the project as optional since it may require the

[1] It seems like there is no source for this paper, but I found a video of her presentation:https://youtu.be/HJJsIHrBBLQ

most time. I will need to spend some time in finding an optimal way to find the underdensities in the halo to find the subhalos. While Pearson (2018) explores this process by inserting artificial streams, I am interested in finding the impact from new realistic incoming streams from M33.

2.2. *Visualization*

I will use Blender software to produce a custom visualization of the streams. Blender is the free and open source 3D creation suite. There are other similar projects, but the advantage of using Blender is that it is open source, and as such there is a lot of documentation. It provides a Python interface for all of its features. This allows me to import the Python code we have generated in class and for assignments, create custom animations, run everything in a single pipeline.

The van der Marel et al. (2012) MW-M31-M33 merger system dataset has 800 snapshots that will produce a 24 frame rate animation of approximately 100 seconds assuming I can introduce three interpolated frames between each snapshot. Blender has a Python interface capable of performing said animation.

As of now, I have a working code that will render one frame at a time. The results are shown in Figure 1. While this work is awesome, I need to come up with a way to automate the procedure such that I don't have to process each snapshot manually. Here is an example of two frames. The Blender Cycles engine is capable of rendering all 42,500 particles from the low resolution dataset with no problem.

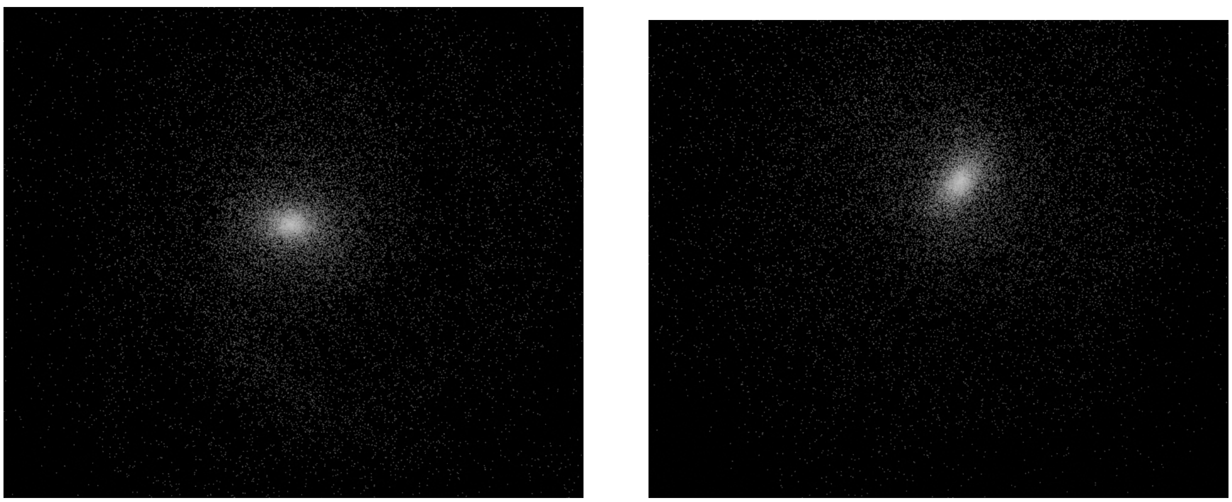

Figure 1. The lefthand picture shows the initial snapshot of the Milky Way, while the righthand picture shows the 50th snapshot of the simulation. Both pictures were taken from a Z-axis perspective from the initial arbitrary reference frame.

In order to proceed with this method of visualization I need to learn how to move the scene camera, the one that produces the images above, using the Python interface to follow the galaxy, or certain components of it. Blender also has a few features that should allow me to apply different colors to different particles; which will be useful for visualizing the streams. Another improvement is to attempt working with the full resolution dataset to improve my results accuracy, and push the limits of this method.

2.3. *Expected Results*

For my results I should expect, as Amorisco (2017); Choi et al. (2007) found, M33 being a relatively massive satellite galaxy won't produce efficient clues to its orbital path. This is the same for the tail orientation; it won't be a great indicator for path. However, M33's stellar debris is expected to fall deep into the potential, which means any incoming subhalo remnant should dissipate fast (Amorisco 2017). As for the stream hole-punching subhalo, I should expect the galactic centers to have a greater impact in stellar stream underdensities than any subhalo clump, especially for non-retrograde streams, and

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