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Tidal Debris from M33: Stellar Streams of M33 Proposal

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1. INTRODUCTION

Our Milky Way (MW) is located in a small group of galaxies called the Local Group. The three most massive galaxies in LG are all spirals: MW, Andromeda Galaxy (M31), and Triangular Galaxy (M33). These three galaxies account for most of the mass of the local group, their mass ratio is about 10: 10: 1 (Guo et al. (2010)). Besides, the distances between M33 and M31 from the Milky Way are almost the same, with a difference of only 0.8 Mpc.

The orbits and interactions of the MW, M31, and M33 have been examined in several previous studies. van der Marel et al. (2012) indicates that MW and M31 will merge at t = 5.87 Gyr. The most likely result is that MW and M31 merge first, and M33 sinks onto the orbits around them, and then may merge gradually. Before M31 reaches MW or collides with MW, M33 has a 9% probability of directly hitting MW at its first center point. In addition, the probability of M33 popping out of the local group temporarily or permanently is 7%.

In van der Marel et al. (2012)'s Monte Carlo simulation, at t = 10 Gyr, MW and M31 have been merged, and M33 has lost 23.5% of its star into a tidal stream. These streams do not lie along with the location of the orbit (Figure 1).

Before losing stars, more massive satellites sink deeper into the host's gravitational potential, so they contribute to the smaller radius inside the host. Conversely, low-quality satellites have a longer survival time, but dynamic friction cannot drag them into the innermost area, and there is a significant separation (Amorisco (2016)). In the Monte Carlo simulation of the MW-M31-M33 merger, we can observe the existence of this process, and the tidal debris of M33 contributes to the separated part (Figure 1). In addition, he claims that the material deposited by low-quality satellites maintains a large number of ordered rotations and that the radial velocity dispersion is also high due to the extension of the orbit. Angular momentum, in turn, is consumed and diluted in a larger number of accretion events, resulting in a contribution of almost no rotation and a strong radial deviation.

In the process of galaxy merger, the escaped ejecta in the leading (trailing) tail continues to be decelerated (accelerated) by the satellite 's gravity leading to large offsets of the ejecta orbits from the satellite 's original orbit (Choi et al. (2007)). And they proved that this is related to the Hill-Jacobi theory (broadly known as dark matter halo), which is suitable for satellites in circular orbits. In particular, the impact of the satellite's self-gravity on the tail will only decrease slightly as the satellite's mass decreases. For satellites of limited mass, the morphology of the tail and tail will be different due to the gradient of the potential halo throughout the satellite. Finally, the pop-up acceleration of large satellites during the escape process will disperse the velocity distribution. The diffusion of the velocity distribution is consistent with Amorisco's conclusion (Amorisco (2016)).

The study of tidal debris from M33 in the merger of MW-M31-M33 allows us to understand how relatively small mass galaxies affect the merger of massive galaxies and can be an example to help us understand the formation of similar structures in other galaxies. In addition, this study can also help us understand the evolution of substructures in the Milky Way, such as the formation of the leading and training arms of the Sagittarius Stream.

In this process, we can also understand the influence of the distribution of dark matter on the tidal debris distribution of M33, how the dark matter of M33 is incorporated into the MW-M31 system, and it affects the merger of MW and M31.

2. PROPOSAL

2.1. *Proposal Idea*

The purpose of this proposal is to study the tidal debris of M33 during and after the MW-M31 merger. This requires finding the stars that make up the M33 stream during the merger of MW and M31. So I need to write a program to record M33 stars that are outside the Jacobi Radius at any given point in time. By marking these stars, one can

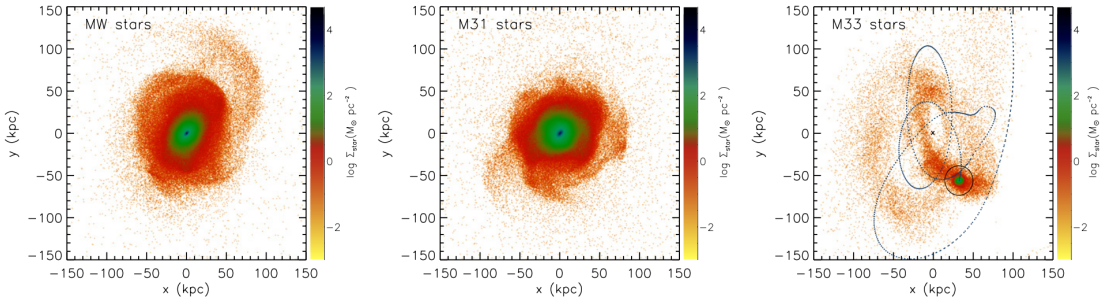

Figure 1. van der Marel et al. (2012)'s distribution of luminous particles at the end of the N-body simulation (t = 10 Gyr) for the canonical model with, from left to right, particles originating in the MW, M31, and M33. The color scale indicates the surface mass density. The MW and M31 have formed a merged remnant. However, the remnant is not yet fully relaxed, since particles originating from the two different galaxies still have a somewhat different spatial distribution. M33 maintains its own identity, but has lost 23.5% of its stars into tidal streams.

study the structure and distribution of M33 stellar debris at any time during the merger, and when they merged into the halo of MW and M31. Also, we can record the Jacobi radius and their changes at different times, so that we can analyze the adverse effect of the merger of MW and M31 on M33.

2.2. *Coding Step*

- Write function to calculate Jacobi Radius.
- Record Jacobi Radius for each time period M33, and plot it. The x-axis is time and the y-axis is Jacobi Radius.
- Mark the star of each time period M33 outside the Jacobi Radius. And make a video, mark the stars of M33 and the stars of the M33 star stream with different colors.
- Add the components of MW and M31 to the video, mark the stars of MW, M31, M33, and M33 streams with different colors and observe their interaction.
- Select some important moments in the evolution process, draw the spatial distribution maps of the star currents of MW, M31, M33, and M33, and calculate their COM separately, and draw the COM trajectory.

2.3. *Hypothesis Result*

I think Jacobi Radius of M33 will become smaller and smaller, and the number of member stars that make up M33 stream will increase. Because with the merger of MW and M31, their gravitational potential will tear M33 faster, which will draw M33 stream faster.

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