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Tidal Debris from M33: Stellar Streams of M33

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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 the MW and M31 will merge at t = 5.87 Gyr. The most likely result is that MW and M31 merge first, and M33 evolves on a decaying orbit around the MW+M31 combined galaxy, and will eventually also merge. 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. Conversely, low-mass satellites have a longer survival time, but dynamical friction cannot drag them into the innermost area, and there is a significant separation (Amorisco (2017)). In the Monte Carlo simulation of the MW-M31-M33 merger, we can observe this process, and the tidal debris of M33 remains at large radii (Figure 1). In addition, he claims that the material deposited by low-mass satellites maintains a large number of low mass satellites continue to make multiple orbits about the host and that the radial velocity dispersion of tidal is also high due to the extension of the orbit.

Through tidal processing, 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 discuss this process that this is related to the Hill-Jacobi theory, 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 leading and tailing tails will be different due to gradient of the host's gravitational potential from one end of the satellite to the other.

The study of tidal debris from M33 in the merger of MW-M31-M33 allows us to understand how relatively small mass galaxies contribute to the stellar halo 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 (Law & Majewski (2010)).

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 final stellar halo merger of MW and M31.

2. THIS PROJECT

In this article, we want to study how M33 formed a star stream and influenced the merger process during the merger of M31 and MW. This includes how the Jacobi Radius of M33 changed during the merger of M31 and MW, and how

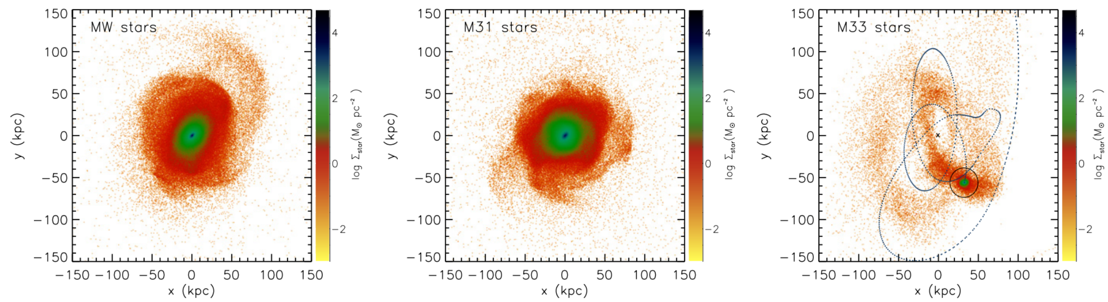

Figure 1. van der Marel et al. (2012)'s distribution of luminous particles at the end of the N-body simulation (t = 10 Gyr) for the canonical model with, from left to right, particles originating in the MW, M31, and M33. The color scale indicates the surface mass density. The MW and M31 have formed a 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.

many stars of M33 were torn apart, and how the mass-loss rate changed over time. In addition, we also want to study the merge the velocity dispersion profile of the M33 stars with respect to the merged remnant after the merger.

This project can help us understand how relatively small mass galaxies contribute to the stellar halo of massive galaxies and how substructures in galaxies have evolved.

If we know how the Jacobi Radius of M33 changes during the galaxy merger, this can better help us know the process of formation of the stellar stream. We can combine the loss of M33 mass with time to help us understand the history of galaxy halo formation. In addition, by comparing the M33 stars velocity dispersion profile and merged remnant, it helps us understand the dynamics of the substructure.

3. METHODOLOGY

An N-body simulation is a simulation of a dynamical system of particles, usually under the influence of physical forces, such as gravity. In this project, we treat each star as a particle and study the gravitational force received by each star in the MW-MW-M33 system and how it moves under the influence of force (van der Marel et al. (2012)).

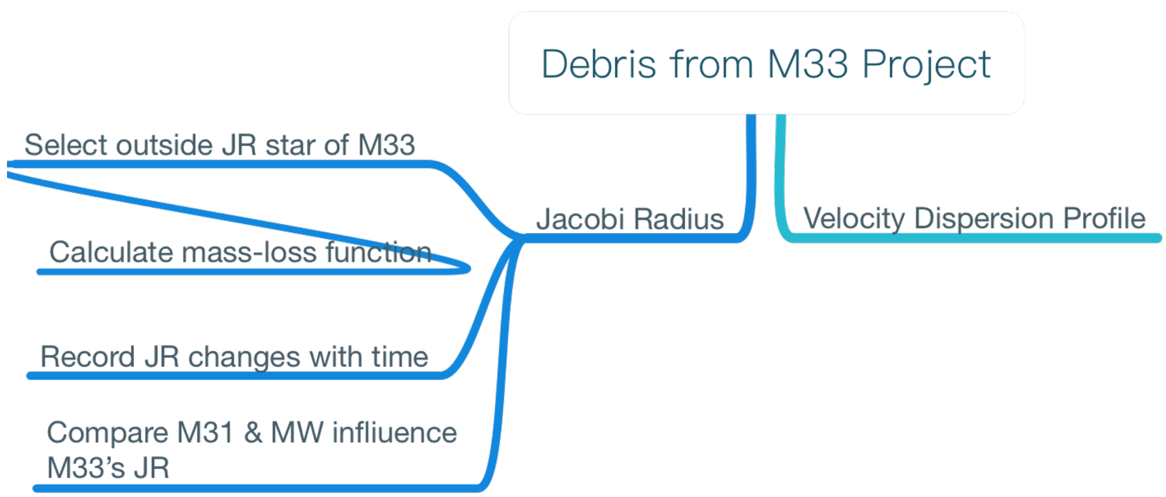

Figure 2. This picture describes the logic of the entire project, the most important thing is to calculate Jacobi Radius. Based on each time Jacobi Radius selects the stars that become streams' star and calculates the mass-loss rate function.

In this project, we need to calculate the Jacobi Radius of M33 under the influence of M33 and M31 at each time in N-body simulation, and then pick out the stars of M33 outside Jacobi Radius. These stars are the members of the star stream. On this basis, we can calculate the quality loss of a time M33, and finally make a figure of the mass loss with time. Finally, we calculated M33 the velocity dispersion profile of the M33 stars with respect to the merged remnant after the merger.

In this project, several pictures need to be made. The first one is the change chart of Jacobi Radius of M33, including M33 under the influence of M31, M33 under the influence of MW, and M33 under the influence of MW and M31. At the beginning of evolution we used Jacobi Radius of M33 under the influence of M31 because MW is too far away from M33. We can compare these three pictures and determine when to use Jacobi Radius under the influence of MW and M31 to define the whole process. On this basis, we can make the mass-loss of M33 every time, and then draw on a picture. Finally, pick out the remnants of M33 and the star stream formed by M33, and calculate their Velocity dispersion profile separately.

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