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Tidal Evolution of M33's Dark Matter Halo—Mass loss of Dark Matter and changes to internal dark matter profile

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1. INTRODUCTION

The spiral galaxy M33, which is located in the constellation Triangulum, is the third largest member of our Local Group of galaxies. Also, M33 and M31 are the closest massive galaxies to the Milky Way, and all of these galaxies(MW,M31,M33) are spiral galaxy. Thus, these galaxies are expected to be dark matter dominated, particularly in the outskirts of their disks, as indicated by optical measurement of the rotation of spiral galaxies (Blok 2010). According to the orbital analysis an velocity measurments presented in van der Marel 2012, M31 and the MW will merge at t = 5.86 Gyr (Marel et al. 2012). The process of merging will result in strong gravitational interactions between the MW, M31 and M33, resulting in tidal fields that will change the morphology and kinematics of the inner and outer structures of all galaxies. In addition, During the merging process, the tidal field of a massive galaxy can cause the bound mass of a smaller satellite galaxy (like M33) to decrease over time (Boylan-Kolchin et al. 2011). Therefore, the proposed topic of the project is to study and analyze the tidal evolution of M33's dark matter halo, and put emphasis on two points: 1.mass loss of dark matter, 2.change of internal dark matter profile.

'Dark matter' is always the controversial and hot topic in the area of science. The majority of mass in the universe is in the form of dark matter, which, in cold dark matter theory, can only interact with baryons via gravity. Because the mass budget of a galaxy is dominated by dark matter, this dark matter also controls the depth of the potential well. This in turn controls whether a galaxy can retain its baryons or even accrete more gas. Thus the depth of the potential well controls the evolution of the galaxy. If a galaxy loses dark matter because of tides, it will be harder for it to hold on to baryons or capture more gas. So understanding the mass loss of the dark matter halo is important to understanding the evolution of satellite galaxies, which are subject to strong tides. Therefore this topic is quite important to understanding of galaxy evolution, whatever in the future or nowadays.

After t = 10 Gyr, the MW and M31 have formed a merged remnant, and M33 would lose 23.5percent of its that stars will be stripped from M33 (see the third graph of figure1) (Marel et al. 2012). This result indicate that the mass of M33 will lose, due to the tidal evolution beside MW and M31 merger process. Otherwise, in Boylan Kolchin et al.(2012)'s research, the M33 dark matter distribution will become part of the merged remnant. Boylan-Kolcin was saying that when the dark matter density is highest, say in the center of a satellite, you can potentially see the signal of dark matter annihilation (Boylan-Kolchin et al. 2011). If the central dark matter density of a satellite were decreased (e.g. by tides), then the expected annihilation signal would be lower.How the internal density profile of a satellite galaxy evolves is indeed very important to indirect dark matter detection experiments that are trying to find the signal of dark matter annihilation. Then, the questions comes to M33.

After reading of Boylan Kolchin et al.(2012), I got some inspirations.Is the central dark matter density profile of M33 sufficiently high enough to produce a dark matter annihilation signal. And will that density profile change in the future. Everything related to dark matter is still a open question, in this field. However in this project, the mainly focus is studying and understanding the tidal evolution of M33's dark matter halo through mass loss of dark Matter and changes to internal dark matter profile based on the limited evidence we have.

2. PROPOSAL

The specific question of this proposal is to prove that M33 will lose dark matter mass due to the tidal influence from M31 and M33.My program will compute Jacobi Radius and examine how much mass is outside this radius as function of time. Also, it is important to show, what happened to internal dark matter profile of M33, will it change. So according to the equation of mass profile, I will use the Jacobi mass via radius to make a estimation plot of internal

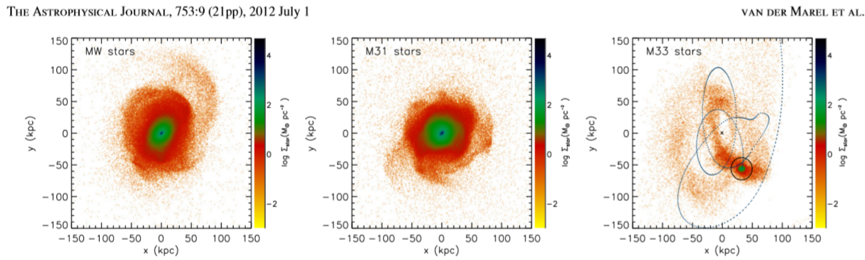

Figure 1. :illustrates the mass distribution of the MW, M31 and M33 in the final snapshot of the simulation, when the MW and M31 have coalesced. The third graph is the last snapshot of simulation M33, 23.5 percent stars of M33 that will be stripped from M33. Much mass per particle is outside the Jacobi radius of M33 Marel et al. (2012).

$$m(r) = \int_0^r 4\pi r^2 \rho(r) dr \qquad R_j = r\left(\frac{M_{sat}}{2M_{host}(<r)}\right)^{1/3}$$

Figure 2. :left is mass profile equation, right is Jacobi equation

mass profile of the M33(see the left equation on figure 2).

Outline the coding step:

1.First, reading the M31 and M33 simulation files. And write a for loop read 800 snapshots file one by one. After reading the first snapshot, calculate the center of mass position in x, y ,z axis. After that, calculate the magnitude distance between M31 and M33, through the x, y, z coordination.

2.Next, according to Jacobi Radius equation, I have to define two equations in the code. One is counting mass per particle, which is in the range between center of mass position of M33 and M31, as host mass from both M33 and M31 reading files. Another is counting mass per particle, which is in Jacobi radius of M33, as satellite mass.

3.Then, we have to initialize the Jacobi radius, because we do not know M33's Jacobi radius. I will regard the first satellite mass as the initial Jacobi mass, and use the first host mass to get initial Jacobi radius. After that, I would bring the initial Jacobi radius,as the index, to Jacobi mass equation, when it is reading the second snapshot. And we can see how much mass per particle still in the initial Jacobi radius, get new Jacobi mass. Through new Jacobi mass and second host mass, we would get new Jacobi radius. Since we get new Jacobi radius, we could bring it to the third snapshot, and repeat above steps, until calculated Jacobi radius of last snapshot.

4.Recording those data to text file. And taking out the Jacobi mass and Time values, we can plot those data. From the Jacobi mass vs time plot, we will see if M33 lose the dark matter mass. Finally, taking out the Jacobi radius and mass values, those can make internal mass density plot. We will figure out the change of M33 internal mass profile.

I think the total mass of M33 will become smaller, and the amount of dark matter will decrease in dark matter halo of M33, due to the tidal influence from MW and M31 .And the internal dark matter of M33 will also decrease, because stars of M33 went into tidal streams that the internal gravitational balance between dark matter and stars has broken. Thus, part of internal dark matter of M33, will toward out M33' disk.

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