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The Stellar Disk Particle Distribution of the Merger Remnant of MW+M31

Justin Ugaitafa

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1. INTRODUCTION

Stellar merger remnants are an important stage of galaxy evolution. Their properties, such as the stellar disk particle distribution/morphology, will contribute much to our understanding of these processes. One way of analyzing the merger is to compare the distributions of the stellar particles of the merging galaxies so as to gain a better idea of how many stars the system has. This will give a good estimate of how much mass there is. Since the amount of light we see will change dramatically during and after the merger, we'll need to compare the final result to several Sersic profiles and see if one can accurately fit the data. This will tell us if the predictions for elliptical galaxies are accurate, or if we need to gather new information.

Galaxies are currently defined as massive, gravitationally bound systems that have stars and dust, where stars are born and dying in multiple stages and can be explained by baryons and Newton's laws of gravity. (Willman & Strader 2012) Most importantly, the key characteristic that defines a galaxy is that it must have dark matter. Galaxy evolution occurs when the stars age and become redder, along with the accretion and expulsion of gas by a central black hole. Collisions with other galaxies can also happen, which will dramatically effect the evolution process, whether by merging two galaxies into one or simply passing by one another. Understanding these galaxy mergers, as well as galaxy evolution as a whole will help us better understand how the universe became what we see today, and can even gives us some insight as to what the early universe (just after the Big Bang) might have looked like. Sersic profiles, which are the measure of a galaxy's light intensity with respect to the distance from the center of that galaxy, are one of our best tools in seeing if our theories actually match our observations. If they do match, then that means that the predictions that we make about the future stages of galaxy evolution are accurate and can be trusted, and knowing the stellar distribution gives an idea of what the star formation rate is.

Figure 1. On the right is the optical image of the prototypical merger NGC 7252 taken by ESO. On the left, is a HI map superimposed onto it by NRAO/VLA. From paper written by Duc+2013

Major mergers occur when two giant galaxies of roughly equal mass merge into a single body and create tidal structures known as 'tails' and 'bridges'. These structures are created due to the interacting tidal forces between the two disk galaxies. (Barnes & Hernquist 1992) This is important because so much material can be ejected into these 'tail' structures that in can become bound structures and form smaller dwarf galaxies. This in turn, will greatly affect the morphology and particle distribution of the final remnant. The number of tails depends entirely on how much mass there is between the colliding galaxies. When is comes to major mergers, such as the one in our simulation, the tails will be extremely long, curved, and binary, (Duc 2013) so we should expect to see such structures within our merger remnant. It should look something similar to Figure 1. We're also sure that the final remnant will be an elliptical, considering that the current theory is that elliptical galaxies mostly form through mergers.

Despite our current knowledge, there are still unanswered questions we have regarding stellar disc distribution/morphology. According to Querejeta et al,there are intermediate mergers that are not present in their database. This is important because studies show that intermediate encounters and multiple minor mergers may have been as relevant for the evolution of some galaxies, such as S0 galaxies. (Querejeta et al. 2015) This begs the question: What would our models and simulations look like if we were to include these intermediates? What parameters would have to be adjusted in order to accurately create them? However, a better question to work with is, can massive elliptical galaxies form from the major merger of two disk galaxies? This is an important question because as far as we can tell, early elliptical galaxies were small in comparison to what we see today, and although we have some good ideas about how they grew, we still don't know for sure.

2. THIS PROJECT

What we're specifically focusing on in this paper is the final stellar disk particle distribution and morphology for the combined system of the Milky Way (MW) and Andromeda (M31). The questions this paper aims to answer about this topic are: (1) What is the final stellar density profile for the combined system? (2) Is it well fit by a Sersic profile? This project will be able to answer these questions via the data used in the simulation.

The open question we'll be addressing is whether or not this merger is a valid method for forming a massive elliptical galaxy. This is because the most likely way for large ellipticals to form is through merging. As we observe today, a galaxy can gradually grow in size by accumulating the surrounding gas and stars in its local environment. However, there wasn't much material to accumulate in the early universe, so the only way to grow to the large masses we see today is through dry mergers, which occur when the merging galaxies have little or no gas left for star formation.

This question is an important one to answer because there are plenty of galaxies that aren't 'quenched', meaning they still have plenty of gas for active star formation, and these galaxies are also merging. There can be mergers between two quenched galaxies, mergers between two gas-rich galaxies, and mergers between one of each. While it's easy to assume that two gas-rich will leave a gas-rich remnant, this isn't necessarily going to be the case every time. The goal of this project is to try and be able to accurately predict what the resulting merger of MW and M31 will, so that we may accurately predict what the remnant of all galaxy mergers will be.

3. METHODOLOGY

First and for most, I will need to find the mass profiles of each galaxy, then of the merger remnant using the code from Lab 5. Afterwards, I can use the code from Lab 6 to find the density profiles what should look like, and once I do I can go about finding a Sersic profile with a reasonable fit. Finally, I'll make a density contour map of both the MW and M31 in order to compare the distribution of stellar particles of the galaxies and see if they're different or not. Figure 2 below shows the surface brightness profile vs the distance to the mass centroid of two galaxies. I will want something that resembles the left side.

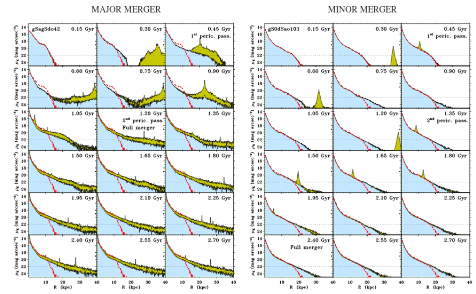

Figure 2. This figure shows the surface brightness of two merging galaxies before, during, and after the merger that will result in a S0-like remnant. Left panels show a major merger involving the galaxies Sag and Sdo42. Right panels show a minor merger involving the galaxies S0d and Sao103. From paper written by Querejeta et al.

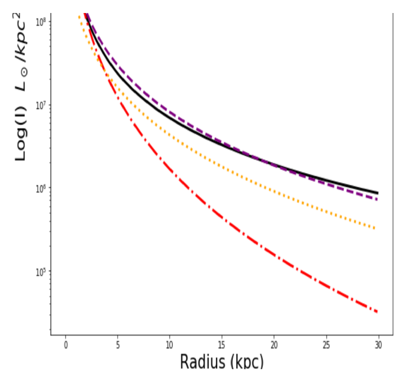

Figure 3. Bulge mass (solid black line) and different Sersic profiles (dotted lines) Figure from In Class Lab 6

The first thing my code will do is fin the Sersic profiles of each galaxy separately, and then the Sersic profile of a combination of the two. Tis profile is given by the equation:

$$I(r) = I_e exp^{-7.67/((r/R_e)^{1/n}-1)} \tag{1}$$

where r is the radius of the galaxy (kpc), Re is the half mass radius (kpc), and n is the Sersic index. Ie is defined by another equation:

$$L = 7.2 I_e \pi R_e^2 \tag{2}$$

where L is the luminosity of the galaxy and you just solve for Ie, then plug it into Eq.(1). Once this is done, we then use the mass profile of the galaxies to find the bulge mass, then find Re for that bulge mass. Once this is done, we graph the results. It should look something like this:

Because this collision will be between two galaxies with roughly the mass, I expect to see a distribution of stellar particles that show two main tails coming from the remnant. According to the paper written by Duc,

"...major mergers between spiral galaxies are long..., curved and binary. A main tail and a counter-tail are formed from each colliding galaxy. At the post-merger phase, the two counter-tails have already dis-appeared; remain the two main tails." (Duc 2013) And since I know what kind of shape the remnant will more or less have, I have a good idea of how much light should be at a given distance, so I can find a more accurate Sersic profile fit. This also tells me that the stellar distributions of the particles for the MW and M31 should be about the same, since they're about the same mass, and therefore should exhibit the same behavior.

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