Final Assignment

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1 Introduction

The Milky Way resides in a small group of galaxies, called the Local Group. The Local Group is dominated by the three spiral galaxies: Milky Way (MW), Andromeda (M31) and the Triangulum galaxy (M33) with mass ratios $\approx 10 : 10 : 1$ [5]. It is well known within the astronomical community that this triad is on a collision course and a merger is expected in the next 10 billion years. For my project, I am going to concentrate on different orbital interaction scenarios of the triple galaxy system, based on different initial conditions.

1.1 Topic

The collision of Milky Way and Andromeda is heavily dependent on the initial conditions. Nevertheless, it is generally predicted by all models that the first close approach is expected to be in the next 3-5 Gyr and the collision is expected to occur in 10 Gyr [3]. However, the velocity constraints on M31 (the tangential velocity) are not well-defined and depending on what velocity one uses, the dynamics of the collision change. For my project in this class, I will concentrate on the following question:

What are the alternative orbital interaction scenarios of the MW+M31+M33 system, given the uncertainties in the initial conditions of the system?

1.2 Why does it matter?

Since MW, M31 and M33 are the three spiral galaxies that dominate our Local Group, their interaction is central to understanding the future evolution of the Local Group. It is also important for understanding the satellite galaxy dynamics and tidal streams [6]. Depending on the initial conditions that this triad is subjected to, the merger remnant is affected significantly.

1.3 Current understanding

All the previous work done (before 2012) in understanding the interaction of the three galaxies had treated the three dimensional motion between M31 and either of the two galaxies as a free parameter [5]. The proper motion of M31 remained elusive. However, in 2012, the first proper-motion measurements of M31 stars were reported with the Hubble Space Telescope [4]. Extracting the results from [4], [5] studied the future dynamical evolution of the MW+M31+M33 system using N-body simulations and semi-analytic orbit interaction.

Recently, a paper outlining the dynamics of M31 found out the tangential velocity of this system is $v_{tan} = 57^{+35}_{-31}$ km/s using the detection from Gaia and data from Data Release 2 (DR2) [6]. Alternatively, the tangential velocity of M31, inferred from indirect dynamical methods, was consistently found between 60-90 km/s with a method-dependent uncertainty. However, the indirect dynamical estimate adopted by [2], calculated the tangential velocity to be 162 ± 62 km/s. The discrepancies in the inferred velocities either suggest a head-on collision of MW and M31 or imply that the Local Group may not be in a bound system.

There is a lot of debate on the initial condition problem of these galaxies because this can not only affect the final product of the merger, but it can also affect the course of evolution of the Local Group.

1.4 Open questions

In the light of these developments, there are still a lot of open-ended questions. Some of them are:

1. How do the initial conditions affect the final product of the merger?
2. What affect does the merger have on the further evolution of the Local Group?
3. How will a head-on collision affect the further evolution of the merger remnant (and the Local Group) in contrast to an inspiral collision of the galaxies?

2 The Proposal

2.1 Questions to be addressed

To accomplish the goal of this project I will be concentrating on the following questions:

1. What are the current uncertainties in the observational properties of the three-body system? I am interested in varying the tangential velocity measurements of M31 and studying the various scenarios of the merger.
2. While working on this project, my main reference code will be the code developed in homework 6 (OrbitCOM). Also, I will be using the code developed in homework 4 (CenterOfMass).
3. The distance versus time and velocity versus time plots (as developed in homework 6) will be the plots I will be making to answer the thesis of my project.

2.2 Expectation

I am expecting that with the variation of the initial conditions of the system, the following properties of the system will be affected:

1. The shape of the decaying orbit of the MW-M31 system.
2. The collision time (the final merger) of the system will vary according to different initial conditions.
3. The final product: how will it be in the case of head-on collision versus how will it be in the case of material exchange? This will be highly dependent of the value of the tangential velocity of M31.

2.3 Approach to the problem

In order to generate the desired plots, my approach to the project is going to be pretty straight forward. I will be using the data set provided in class and also refer to the measured tangential velocity parameters provided in the papers. Then using the OrbitCOM code, I will try to generate the plots for different initial conditions.

A 2008 paper by Cox and Loeb [1] used an N-body hydrodynamic simulation to predict the future collision of MW and M31 and three figures listed in the paper will drive my research project in this class:

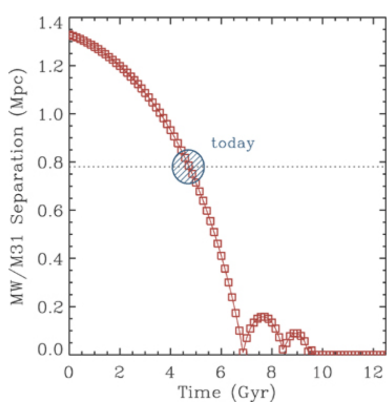

Figure 1: Separation of MW and M31v during their collision course. The current separation, at 780 kpc, is marked with a dotted horizontal line.

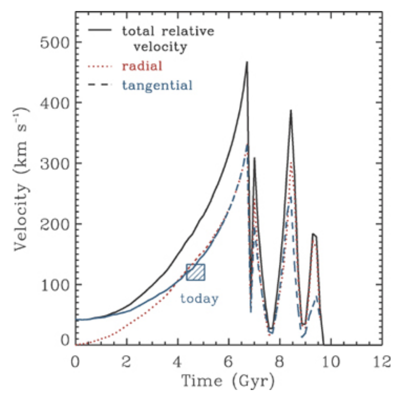

Figure 2: The relative velocities between the centers of MW and M31 during their collision course. The current velocities are marked at $\approx 4.7 Gyr$.

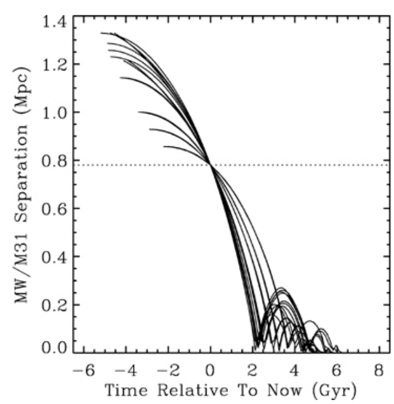

Figure 3: The separation between the centers of MW and M31 during the their collision course for a large ensemble of models.

References

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[4] Sangmo Tony Sohn, Jay Anderson, and Roeland P. van der Marel. THE m31 VELOCITY VECTOR. i.HUBBLE SPACE TELESCOPEPROPER-MOTION MEASUREMENTS. *The Astrophysical Journal*, 753(1):7, jun 2012.

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