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Visualization of Local Group Merger from M31

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1. INTRODUCTION

We currently understand that the three largest galaxies in the local group will likely collide in the future (van der Marel et al. 2012, 2019, e.g.). The local group is the largest gravitationally bound system (a system in which the gravitational force is the dominant force) that includes us. Some publications document visualizations (Cox & Loeb 2008). However, I have not found a visualizations from the perspective of a planet in an M31 solar system that is in a sun-like position within M31 (8 kpc from the center of the galaxy). This is what I am hoping to create.

Galaxy visualizations provide a sense of visual intuition as well as give us a higher level of understanding of how internal dynamics of a galactic system are influenced by interaction. For clairity, a "galaxy" is a collection of gravitationally bound stars whose properties can not fully be described by combination of baryons and Newton's laws of gravity (Willman & Strader 2012).

Understanding the internal morphological change of stars within a galaxy is fundamental to our understanding of galaxies on a more foundational level and visualizations are critical to that understanding as a visually intuitive tool.

These visualizations usually manifest in a two-dimensional form which requires the utilization of some sort of mapping between a three-dimensional system to a two-dimensional one. There are several of these "map projections" and one choice is the Mollweide Projection. A root-mean-square logarithmic distance error (σ) is often used to quantify the errors in these projections and the Mollweide projection has $\sigma = 0.39$ (Gott et al. 2006). For reference, the Mercator projection has $\sigma = 0.444$ and one of the best projections, the Gott-Mugnolo azimuthal projection (Gott et al. 2006), has $\sigma = 0.341$. The aim of this project is to create an intuitive medium to visually understand the local group merger via a point within the merger, using a Mollweide projection.

2. THIS PROJECT

In this paper, we will document the process of visualization of the galaxy merger (the collision of galaxies) between three galaxies for which we have the most detailed and accurate initial conditions: The Milky Way (MW), The Andromeda Galaxy (M31), and The Large Magellanic Cloud (M31).

Taking a series of particles within the simulation that share a similar property, such as all being on circular orbits within their home galaxy, and visualizing their paths over the course of the galactic merger can be enlightening. For example, if those particles distribute themselves all over the system, the visualization would be showing the integral morphological change of originally stable circular orbits due to gravitational tides. Understanding these morphological changes is understanding galaxy evolution. Visualizations can help us get closer to fully understanding this evolution.

3. METHODOLOGY

The paper van der Marel et al. (2012) laid the groundwork for this visualization. They conducted an N-body simulation of the local group merger – a simulation of a dynamical system of N particles under the influence of physical laws. They created the data set to be visualized in this project. The procedure of creating the visualization starts with choosing a set of particles.

Select a few particles that could be considered "earth like" from within the stellar bulge (particles closely packed near the center of spiral galaxies) and stellar disk (stars within a galaxy not included in the stellar bulge) and map their paths over the entire data set (perhaps relative to the center of mass of the entire system). Then, select one (or a few) of these particles as the perspective point for the visualization. Create an image (frame) of the Mollweide projection from that point via a series of coordinate transformations, each frame corresponding to a specific snap number. Do this for a series of frames and incorporate these frames into a sin-

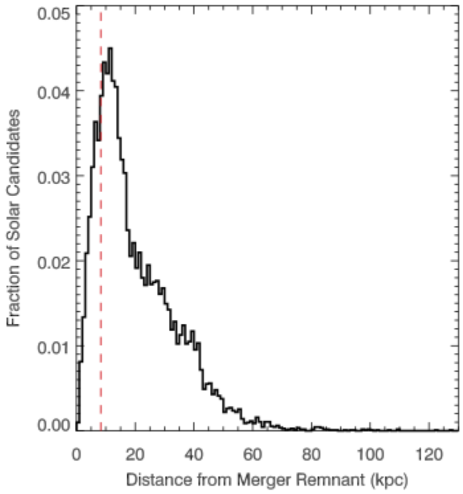

Figure 1. A figure from van der Marel et al. (2012). This plot shows the dispersion of sun-like stars' distance from the center of the galactic merger remnant (the collection of matter previously referred to as separate galaxies) the end of the simulation (10Gyr). The red dashed line indicates the current distance of the sun from the center of the Milky Way galaxy for reference. This parameter, the final distance from the center of mass of a set of stars, could be a very useful parameter to visualize.

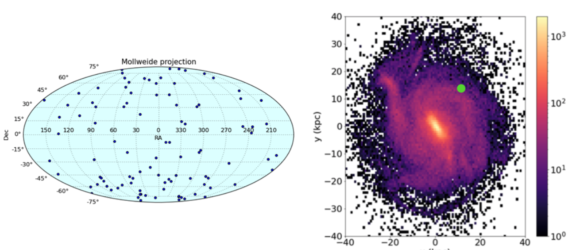

Figure 2. An example of multiple frames from varying perspectives used to provide context to the physical situation. The left image is an example image of the sky from the perspective of a particular particle. The right image is a example image of M31 where the particle in question could be highlighted. Over the course of the visualization, both of these would be animated and would provide useful information to the viewer.

gle movie. Another perspective could be created with the same procedure from a fixed point that showed the entire system. This would give context to the aforementioned particle-perspective visualization. See Figure 2 for an example. Many calculations must be done to make this visualization possible as well as useful. For each particle "in the sky" of the perspective-particle, the displacement vector must be calculated.

$$n_s = n_i - n_p$$

Where n represents one coordinate value in three dimensions (x,y, or z), i represents the corresponding coordinate value of the ith particle and p is the corresponding coordinate value of the perspective particle. From the displacement vector, we can perform a coordinate transformation to geographic coordinate system (latitude and longitude) via the following equations:

$$\Phi = arctan\left(\frac{z}{\sqrt{x^2 + y^2}}\right)$$

$$\lambda = arctan\left(\frac{y}{x}\right)$$

Where Φ is the latitude, λ is the longitude, and x, y, z are the corresponding values for the displacement vector. The value for the longitude will be adjusted to account for the four combinations positive and negative x and y coordinates to arrive at accurate values.

The latitude and longitude coordinates can be plotted easily in a Mollweide projection (See the left of Figure 2 for an example Mollweide projection). This would be done for all particles to be plotted. However, it is important to note that there may be too many total particles to make a useful frame. This could be solved a number of ways, one of which is filtering the displacement vector by magnitude (essentially defining a radius outside which other particles can not be "seen" by the perspective particle) The Mollweide projection plot is the primary plot for this paper. It is an equal-area, pseudocylindrical map projection that attempts to plot spherical coordinates as geographic coordinates. I expect to create a visualization the provides some sense of spacial intuition for the collision of the local group. Gaining some kind of intuition for the nature of the merger could shine light on the system as a whole and inspire those to approach the research of this incredible merger event from a more well-informed position.

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