ASTR 400B Research Assignment 1

Due: Feb 25th 2025 5 PM

Here is a link to an article, images, and videos about the simulation you are to use as the basis of your research project. https://hubblesite.org/contents/news-releases/2012/news-2012-20.html

In this class you will explore a particular research topic and answer specific questions using the provided simulation of the future fate of the MW-M31-M33 system.

For Research Assignment 1, you must create a PDF using LaTeX that lists:

1. The Research Project Topic Heading (1-6), or propose your own
2. The specific research question(s) you will study (from the bulleted list within the topic heading), or propose your own.

Upload the PDF to your github repository by the deadline.

The easiest way to generate LaTeX documents is using online editors like overleaf.com

Possible Topics (or make up your own !!) :

1. Stellar Streams of M33 (during or after the MW-M31 merger)
    - M33's Stream Dynamics - velocity gradients, velocity dispersion within the stream. How do the kinematics evolve throughout the merger or about the merged remnant.
    - M33's Stream Structure - density gradients along the stream, spatial plots. How well do M33's streams trace the orbit of M33 and how does this behavior evolve and why does this happen? How and when do M33's streams form?
2. Tidal Transformation of Satellites (M33):
    - Stellar Structure: Evolution of the internal stellar structure of M33 (disk thickness, profile), Mass loss rates (tidal radius evolution).
    - Stellar Kinematics: How does the disk kinematics evolve? e.g. Evolution of "observed" or mass-derived rotation curve, vertical velocity dispersion.
    - Dark Matter Structure: Evolution of M33's dark matter halo - mass loss rates, tidal radius evolution, changes to the internal dark matter profile, changes to the shape of the dark matter distribution.

- Dark Matter Kinematics: Evolution of the velocity dispersion profile and angular momentum of dark matter particles in M33's (bound/unbound) halo.

3. MW/M31 Galaxy Major Merger Remnant: Stellar remnant and formation of elliptical galaxies

   - Kinematics of the Merged Bulges and Disks: evolution of the rotation curve ("observed" and mass-derived), dispersion profile, angular momentum. How well is the remnant described as a classical elliptical galaxy based on kinematics? Is there any rotation?
   - Stellar Density Profile of the Merged Bulges and Disks - How well is the remnant described as a classical elliptical galaxy based on its surface density profile? What is the best fit sersic profile?
   - Shape of the Stellar Remnant: Is the remnant a spheroid or does it have some elongation/triaxiality? How does this vary as a function of radius? Is there substructure in the remnant - i.e. tidal tails?
   - Properties of Bulge Particles vs. Disk Particles within the remnant: What is the contribution of the bulge vs. disk to density profile/velocity dispersion/angular momentum of the remnant? What component is rotating (if any)?

4. MW/M31 Dark Matter Halo Major Merger Remnant

   - Kinematic Properties of the Merged Dark Matter Halos: is there any rotation/what is the evolution of the angular momentum? What is the velocity dispersion profile of the remnant and how does this compare to the original profile of each galaxy?
   - Density Profile of the Merged Dark Matter Remnant. What is the density profile of the combined MW + M31 halo? How does this compare to the original profile of each galaxy halo? How does this compare to a Hernquist profile or other dark matter profile (e.g. NFW, Isothermal Sphere)?
   - What is the Shape of the Dark Matter Distribution of the remnant? Is it Triaxial? Oblate? Prolate?
   - What is the contribution of the MW vs. M31 halo particles to the density profile/shape/or kinematics of the merged remnant? Does the contribution from each galaxy have the same spatial orientation/angular momentum direction?

5. Galaxy Merger Sequence of MW and/or M31: stellar evolution through close encounters

   - how does the "observed" and mass-derived rotation curve of each galaxy evolve (disk + bulge) ? ("observed" meaning plot the simulated disk particle line of sight velocity field edge on).
   - how does the velocity dispersion of each galaxy evolve (bulge/disk) throughout the interaction ?
   - how does the stellar (surface) density profile of each galaxy evolve (disk and/or bulge) ? i.e. Sersic profiles, disk warps, exponential density profiles?

- how do the bars within both galaxies evolve? What happens to those bars after the merger?
- what is the evolution of stellar debris in tidal tails and bridges throughout the merger?

6. Galaxy-Halo Connection

   - How does the net angular momentum vector of the merged remnant halo compare to that of the stellar remnant? Is it aligned? How does this evolve? How does the alignment depend on radius ?
   - Is the dark matter halo prograde or retrograde to the disk ? Does it depend on the radius ?
   - What fraction of the angular momentum is in the disk and halo prior and post merger ?
   - Is the net angular momentum (disk + halo) conserved prior and post merger ?
   - Does the merged remnant follow the Stellar Mass-Halo Mass relation?