Expanding the Research Questions

Thursday, November 27, 2025 5:59 PM

Milky Way / M31 Halo Major Merger Remnant Structure

Major merger: A merger of two spiral galaxies that are approximately the same size.

Areas of investigation:-

1.) Density Profile of the Merged Dark Matter Remnant

Def: The density profile = how the mass of the halo is distributed as a function of radius from the halo center.

$$\rho(r) = \frac{\text{mass in the shell at radius } r}{\text{volume of shell}}$$

Possible strategy:-

→ documentation identifies these particles

a.) Identify all MW + M31 dark matter particles in the merged halo.

b.) Determine the center of the merged halo. → find center of mass.

c.) Compute radial distances of particles from the center.

d.) Bin particles by radius and compute mass density in each bin.

e.) Plot $\rho(r)$ vs r.

i) How does this compare to the original profile of each galaxy halo?

We will compare the merged halo profile to the original MW and M31 halos before the merger.

It'll show:-

a.) How the merger changed the density distribution?

b.) Whether the central density increased or decreased?

c.) How outer parts (halo outskirts) were affected?

detailed investigation of the different regions in the mergers remnant to detect changes

ii) How does this compare to a Hernquist profile or other dark matter profile (NFW, Isothermal sphere)

a.) A Hernquist or NFW profile is given by the following formulae:-

$$\text{Hernquist}: \rho(r) = \frac{M}{2\pi} \frac{a}{r(r+a)^3}$$

NFW : $\rho(r) = \dfrac{\rho_0}{(r/r_s)(1+r/r_s)^2}$

We can overlay / fit the simulation data with these models to check the following :-

- Does the merged halo correspond to a standard profile?
- Are there deviations caused by the merger?

• Basically, the goal is to quantify how the merger changes the halo structure.

2.) Shape of the dark matter halo (triaxial, prolate, oblate) and its evolution over time

Assuming a Cartesian coordinate

a.) Spherical - roughly equal axes in x, y and z.

b.) Oblate - flattened along one axis (like a disk or pancake)

c.) Prolate - elongated along one axis (like a cigar)

d.) Triaxial - all three axes have different lengths

Studying the shape of the halo tells us :-

a.) How the merger affects the dark matter distribution;

b.) Whether the halo is rotationally supported or isotropic.

Standard Methodology : Computation of the inertia tensor

i) The inertia tensor is defined as :-

$$I_{ij} = \sum_K m_K x_{K,i} x_{K,j}$$

, where, $x_{K,i}$ = i-th coordinate of the particle K relative to the halo center, & m_K is the particle mass.

ii) Diagonalize the tensor : eigenvalues give the squared axis lengths (a^2, b^2 & c^2).

iii) Determine the axis ratios :-

b/a, c/a, if :-

- $b/a \approx 1$ & $c/a \approx 1$, spherical.
- $b/a \approx 1$ & $c/a < 1$, oblate (flattened along z)
- $b/a < 1$ & $c/a \approx b/a$, prolate (elongated along one axis)

- $b/a < 1$ & $c/a \approx b/a$, prolate (elongated along one axis)
- $b/a \neq c/a \neq 1$, triaxial.

Given that our datasets have multiple snapshots, we can do this calculation for each of them and ask:-

i> Does it become more spherical over time?

ii> Does it retain triaxiality?

iii> How do mergers or accretions affect axis ratios?