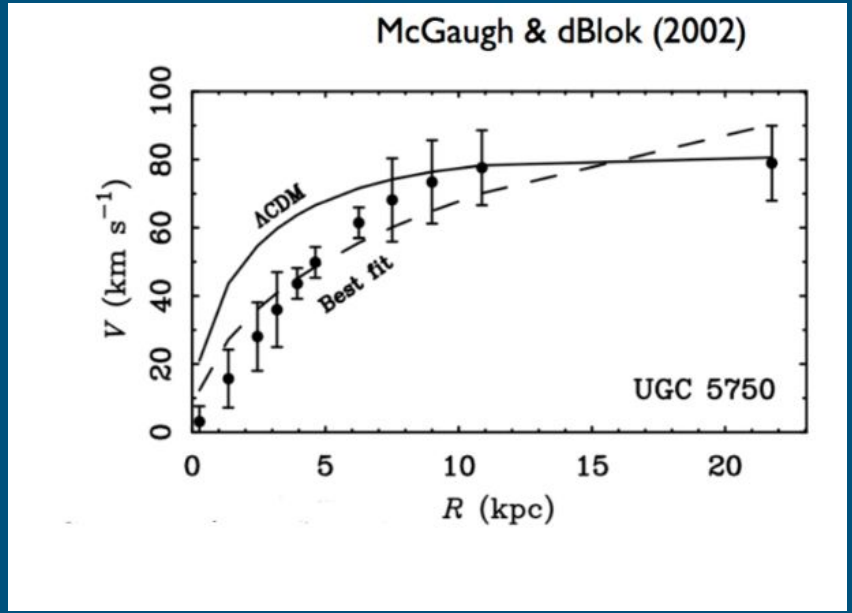
# Dark Matter Halo Evolution of the MW/M31 Major Merger Remnant

## Kinematic Evolution

By Aidan Gibbs

# Lambda CDM Model and Halos

- Cold dark matter consists of initially slow moving, massive particles which only interact via gravity.
- Galaxy clustering strongly disfavors HDM models, while favoring CDM
- May have problems at small scales, such as the cuspy halo problem and overpopulation of dwarf galaxies



# Halo Growth and Formation

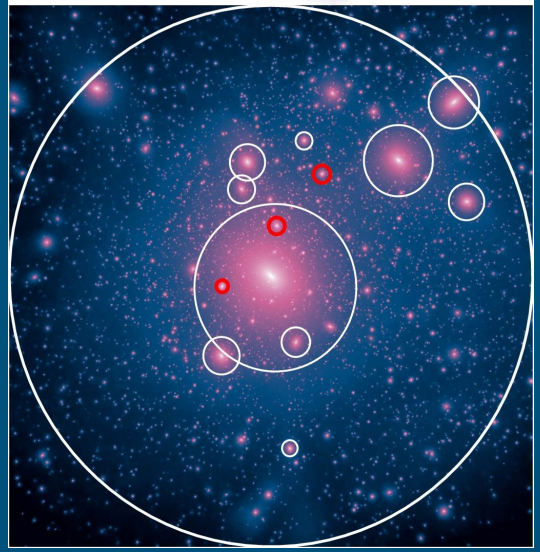
- Hierarchical growth. Low-mass structures form first then cluster together
- Inside out, core forms first. Only major mergers result in strong mixing.
- Majority of halo growth is from minor mergers and accretion of diffuse matter. Major mergers are subdominant.
- Halos can also lose mass due to mergers, known as ‘relaxation’.

# Halo Structure and NFW Profile

- NFW Profile (accurate to ~10-20% for most halos):

$$\rho(r) = \frac{\rho_s}{(r/r_s)(1+(r/r_s))^2},$$

- Mass conventionally taken at $r_{200}$
- Triaxial shapes with weak preference for near-prolate shapes
- Subhalos exist within halo, generally in outer regions

# Halo Kinematics - Dispersion Dominated

- Shapes are supported by anisotropic velocity dispersion, not rotation
- Rotate slowly, gaining angular momentum via tidal torques
- Spin parameter, J is angular momentum:

$$\lambda = \frac{J|E|^{1/2}}{GM^{5/2}},$$

Pure rotational support $\lambda \sim 0.4$
Most halos $\lambda \sim 0.04$, correlated to halo shape and radius

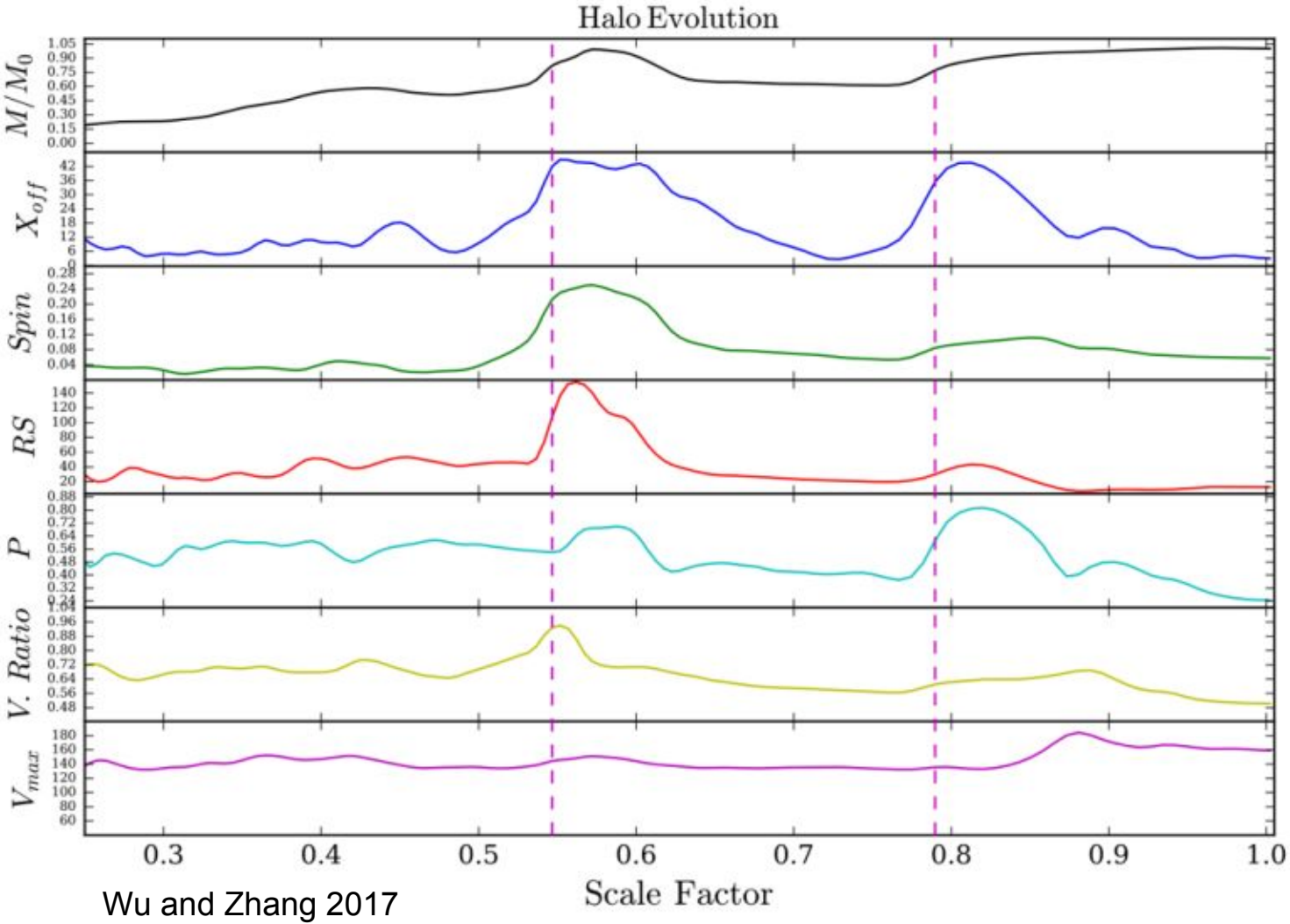
- Velocity anisotropy: $\beta(r) \equiv 1 - 0.5\sigma_t^2(r)/\sigma_r^2(r)$

□(r) = 1 is purely radial, -∞ is purely circular
0 is isotropic dispersion

# Halo Evolution during a Major Merger

- Major mergers can disrupt central regions of halo that are undisturbed otherwise
- Major shifts in the spin vector and magnitude
- Changes in density profile and shape of halo
- Ultimate relaxation of the halo

All of these can have implications for the baryonic structure of the embedded galaxies! Halos are most of the galaxy mass!




Wu and Zhang 2017

# Open Questions

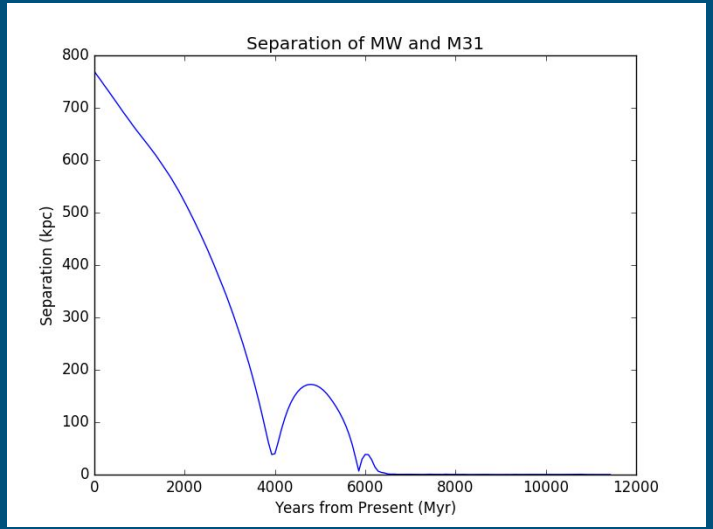
- How do halo kinematic properties fluctuate post merger?
- How much variability exists between different mergers?
- How can halos experience relaxation without a major merger?
- What properties of a galaxy does relaxation directly effect?
- Can problems with CDM halo predictions be resolved by a better understanding of halos?

# My Questions

1. How do the dispersion and rotational velocities of the MW and M31 evolve?
2. How do the halo spins evolve in the inner and outer regions of each galaxy?
3. How does halo velocity anisotropy evolve in the inner and outer regions of each galaxy?

# Method

- Pick 20 evenly spaced time slices throughout the major merger simulation for analysis
- Determine the $r_{200}$ radius for both galaxies at each time
- At each time, calculate rotational velocity, spin vector, and velocity anisotropy of halo particles within two radii ($0.25r_{200}$ and $r_{200}$) for both galaxies
- Calculate the change in spin vector angle between each time
- Plot these quantities to observe evolution



# Predictions

- $r_{200}$ expands as the merger progresses and halo is disturbed by other halo, but may contract after merger due to relaxation
- Spin magnitude jumps during major merger due to tidal forces
- Observable change in spin vector directions due to initial misalignment of MW and M31 initial spin vectors
- Velocity anisotropy increases as halo velocities become more radial
- Differences between inner and outer regions become smaller as the merger mixes the halo

# Questions