Simulated thin Planes of Satellites in ΛCDM

are not kinematically coherent

Buck et al. (2015) and Buck et al. (MNRAS submitted)

Tobias Buck

13th Potsdam Thinkshop "Near Field Cosmology"

Andrea V. Macciò[1,2], Aaron A. Dutton[2]

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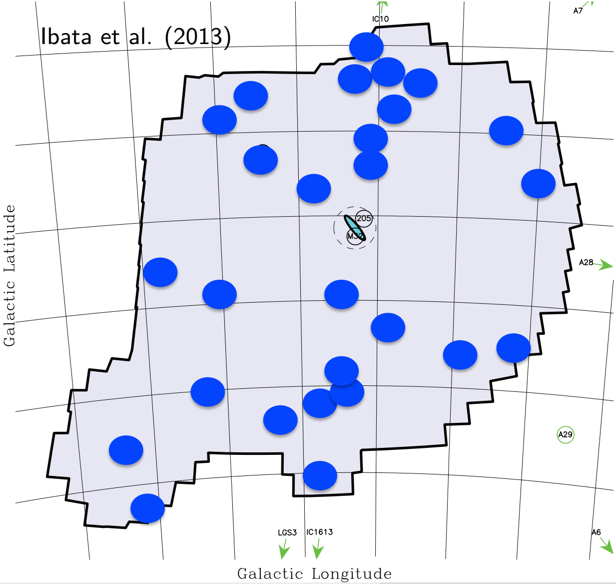
[2] New York University Abu Dhabi

Plane of Satellites around Andromeda

In PAndAS footprint:

- $N_{\mathrm{tot}} = 27$



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In PAndAS footprint:

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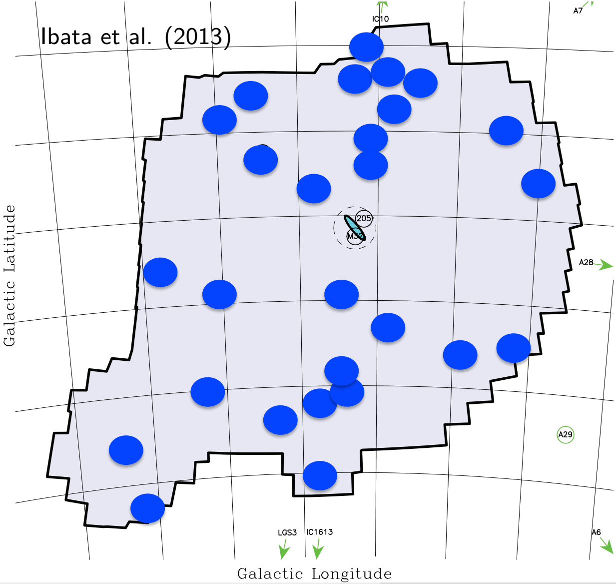

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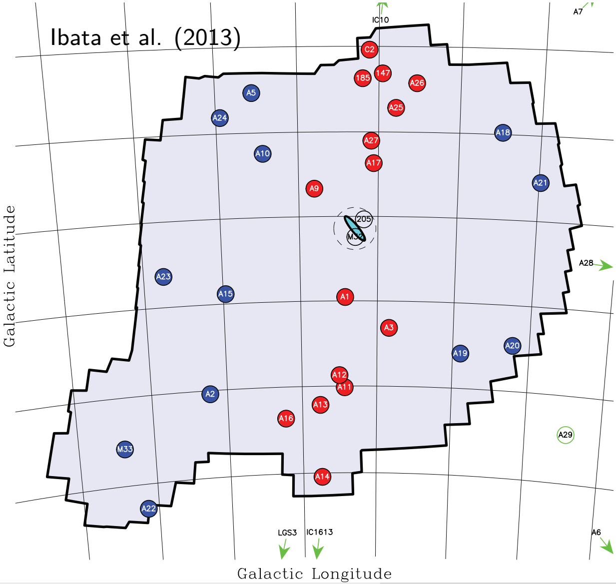

plane of satellites around MW: N_{in}=11, $\Delta_\perp = 19.6$kpc

Metz et al. (2008); Pawlowski et al. (2013)

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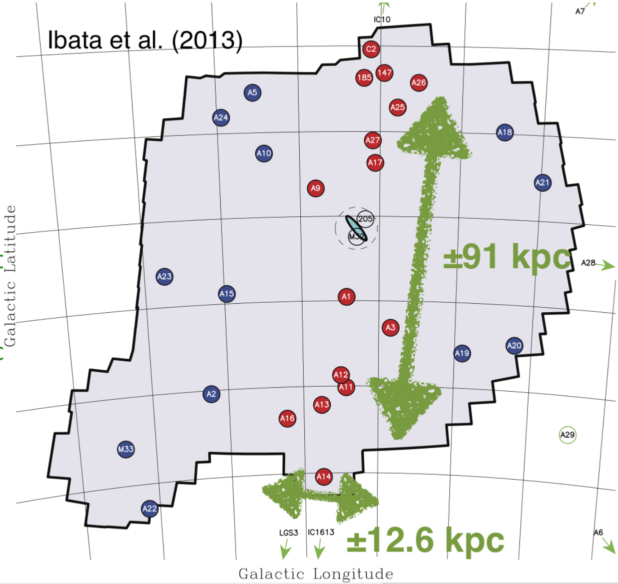

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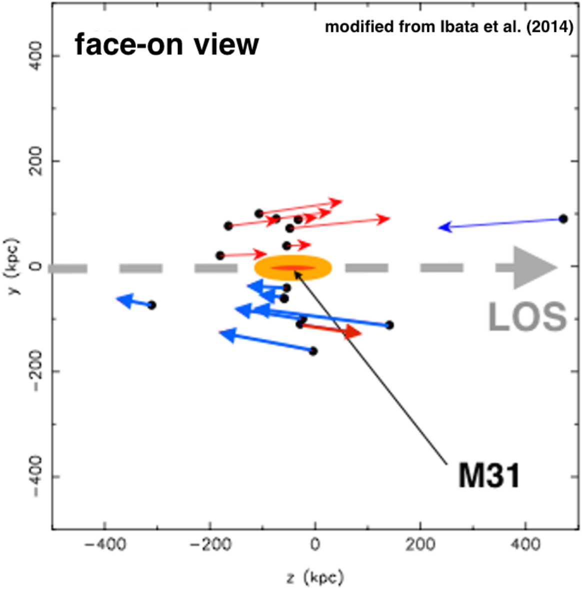

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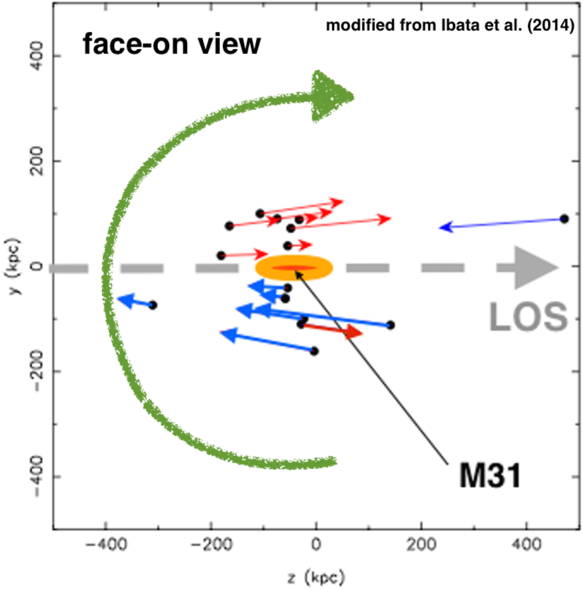

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Previous work on thin planes of satellites

Millenium II Simulation

Thin planes in simulations:

- 0.04% of all galaxies host thin planes
  Ibata et al. (2014), Pawlowski et al. (2014)
- 10% of all galaxies host thin planes
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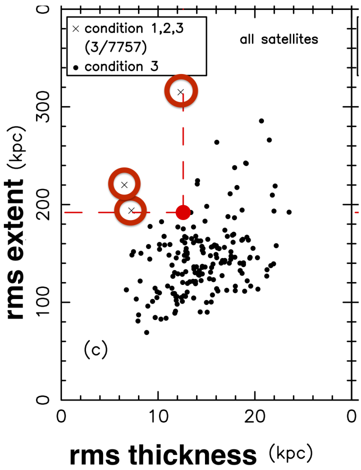
see also: Gillet et al. (2015) for hydro simulation



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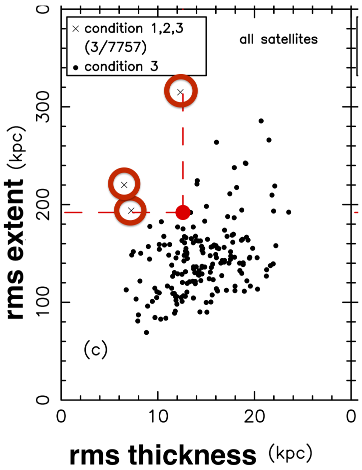
→challenge for ΛCDM



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Previous work on thin planes of satellites

Formation of thin planes:

- thin plane produced by merger
  Hammer et al. (2013), Smith et al. (2016)
- anisotropic accretion of satellites
  Aubert et al. (2004), Libeskind et al. (2005,2009,2011), Lovell et al. (2011)

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Does M31 reside in a typical halo?

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Early forming haloes

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- anisotropic accretion of satellites
- high concentration haloes

no observable difference between on and off plane satellites

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$z = 3$, boxsize = 3000 ckpc

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Late forming haloes

- accrete their substructure less anisotropically

  see also: Libeskind et al. (2014)
- low concentration haloes

$z = 3$, boxsize = 3000 ckpc

This work - Main halo selection

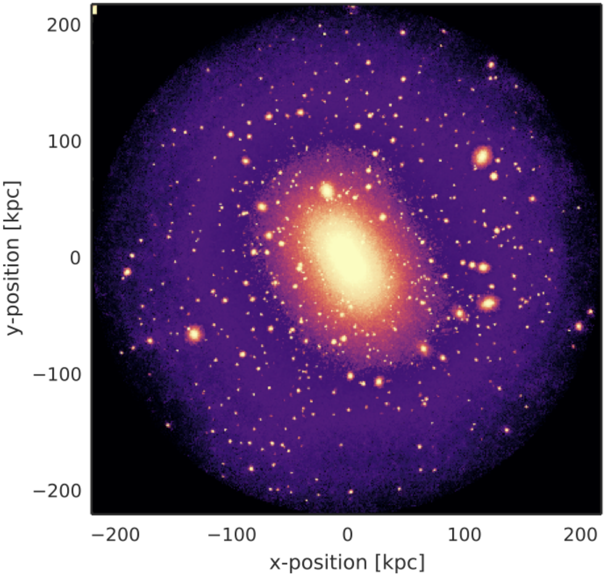
Zoom-in Dark Matter only simulations

- PKDGRAV2, Planck Cosmology
- 100 higher resolution than Millennium II
- 21 high res. simulations

- selection criteria:
  - main halo selection via formation time
  - mass range: 0.5 - 1.5 $\times 10^{12}$ M_{sun}

This work - Sub-halo selection

- 30 most massive sub-haloes at infall time
- exclude innermost 34 kpc of main halo
- plane fitting via random planes
- selecting richest and thinnest plane



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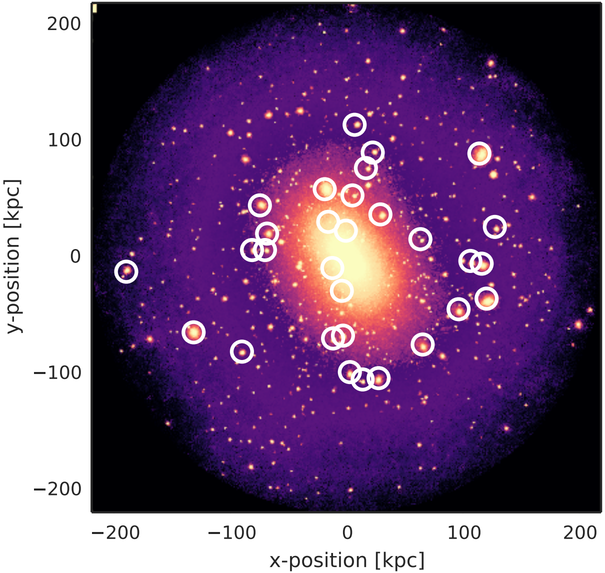

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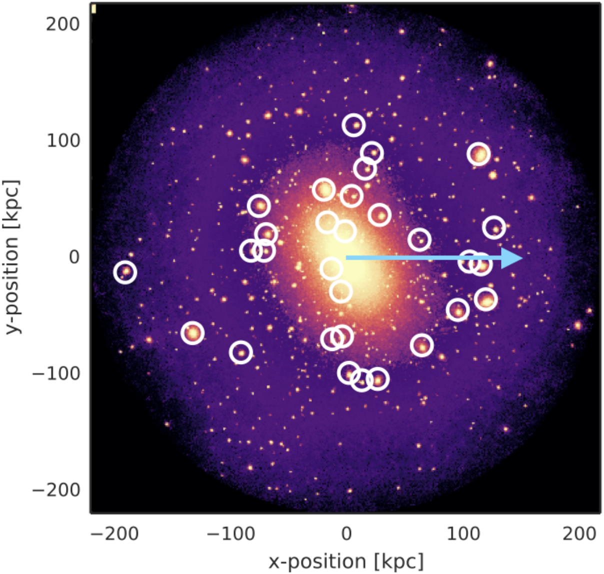

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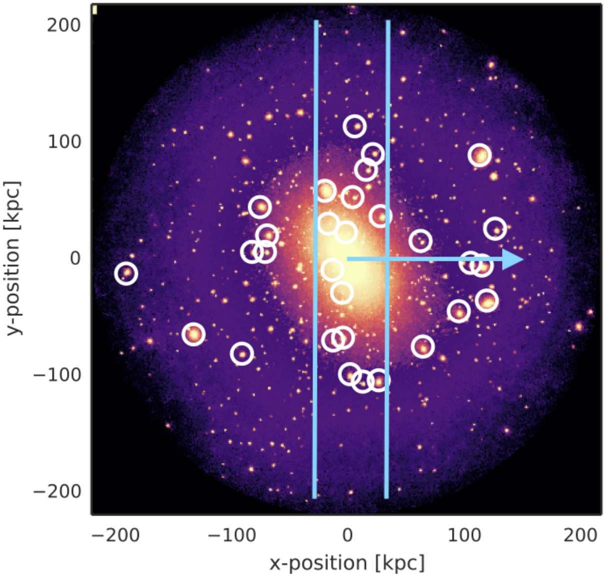

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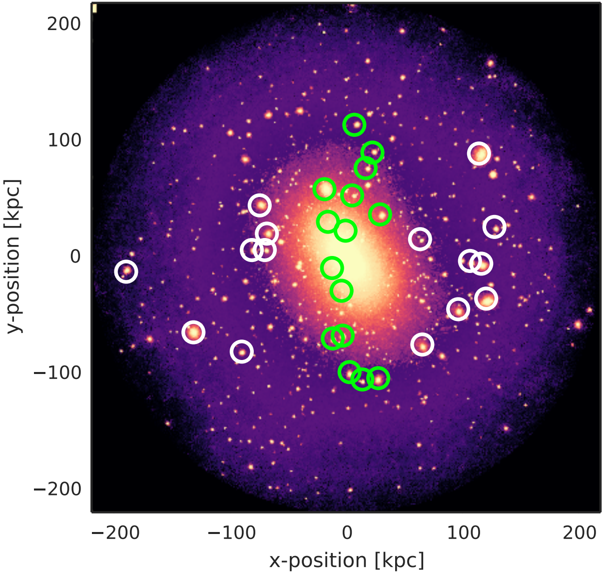
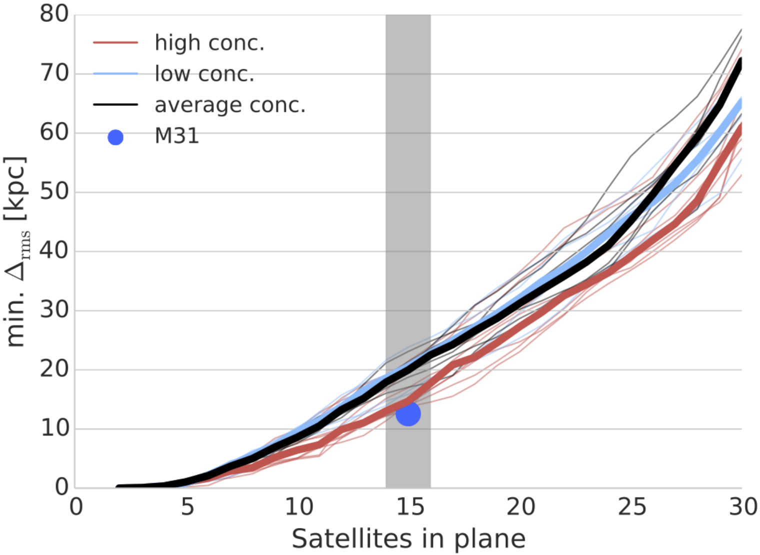


Early forming haloes have thinner planes



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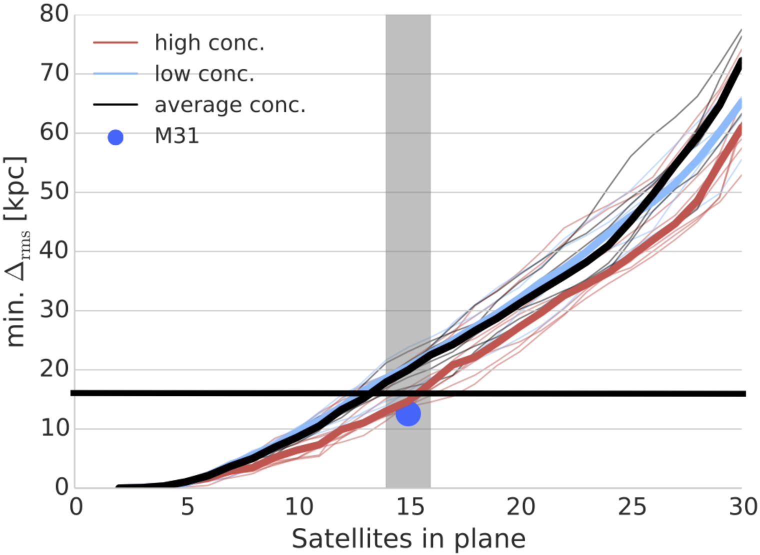
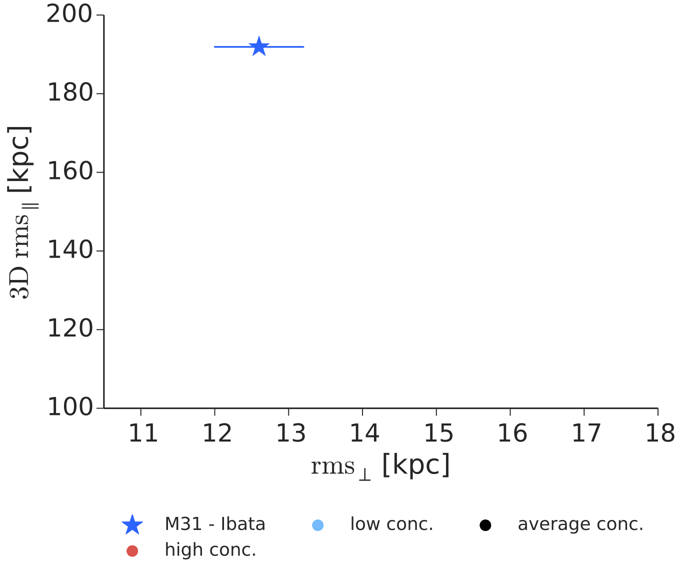


Thickness vs. extent of the planes



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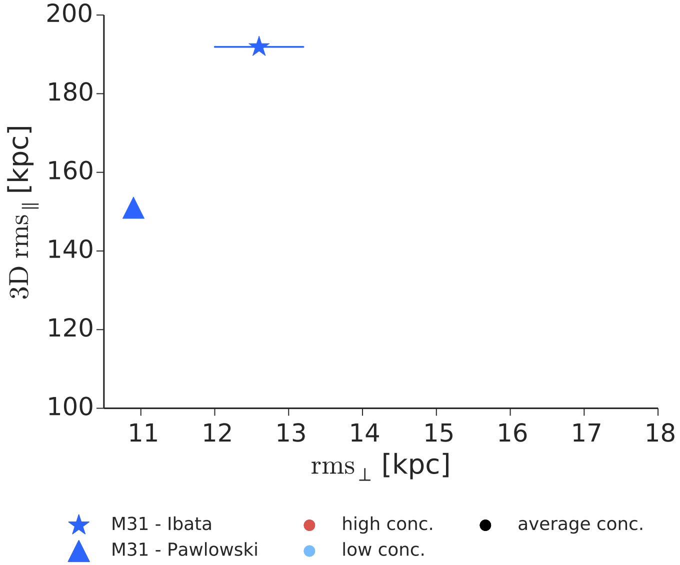

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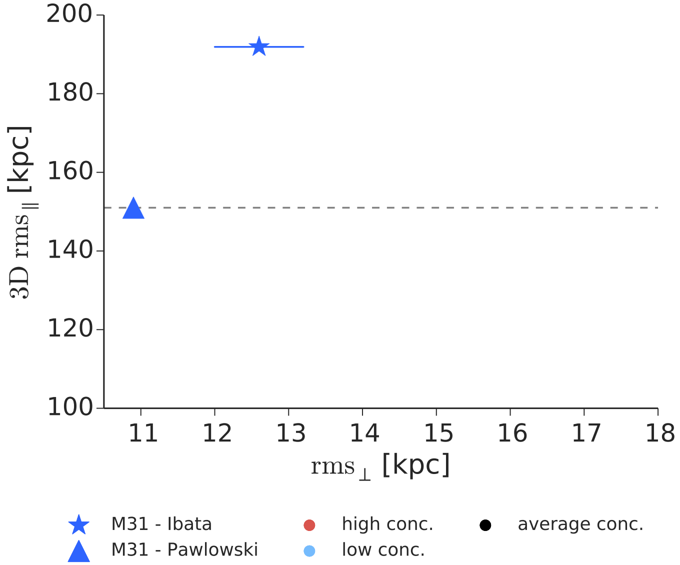

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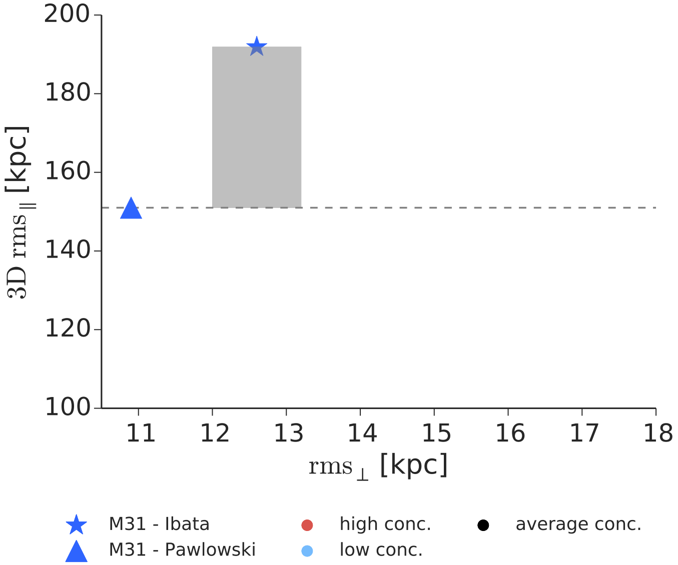

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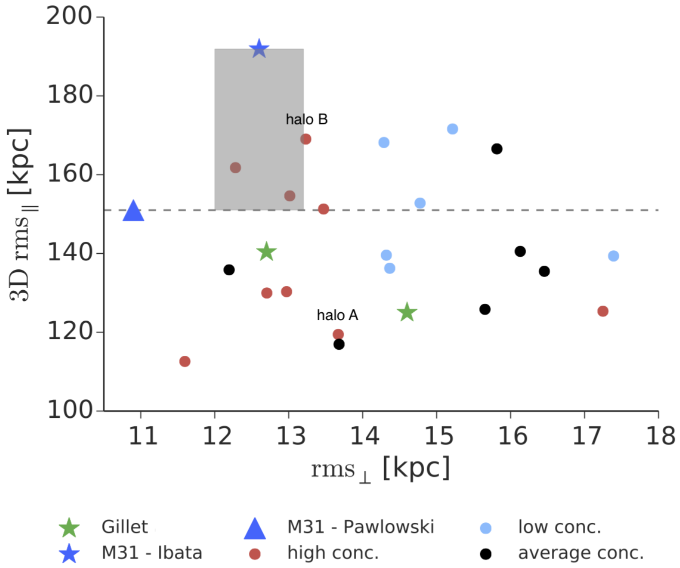
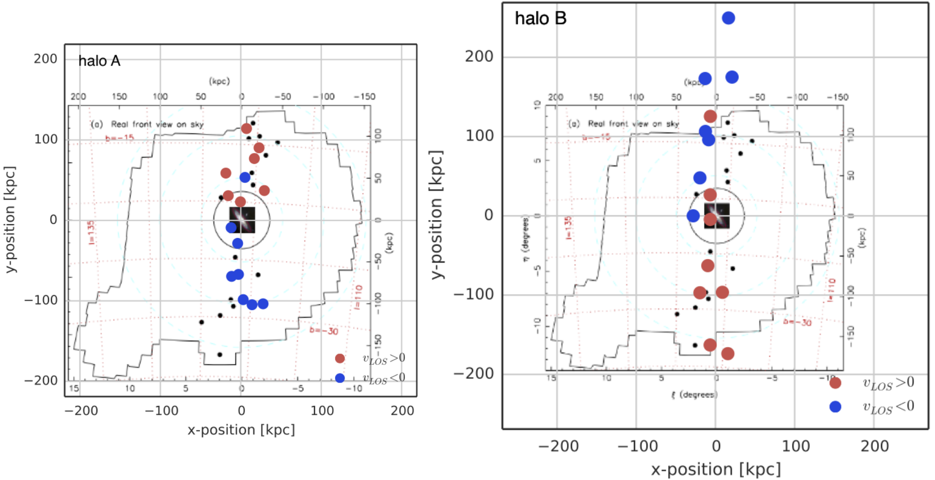
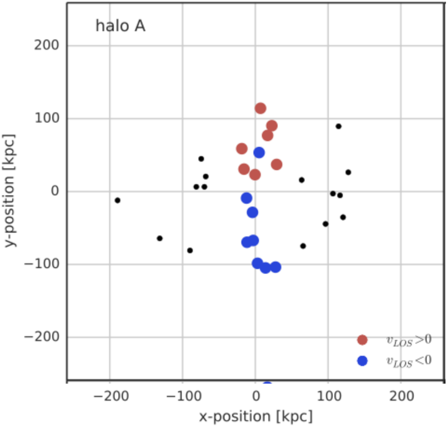
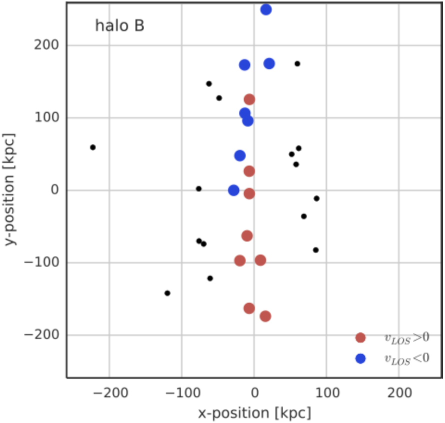


Visual comparison to observation

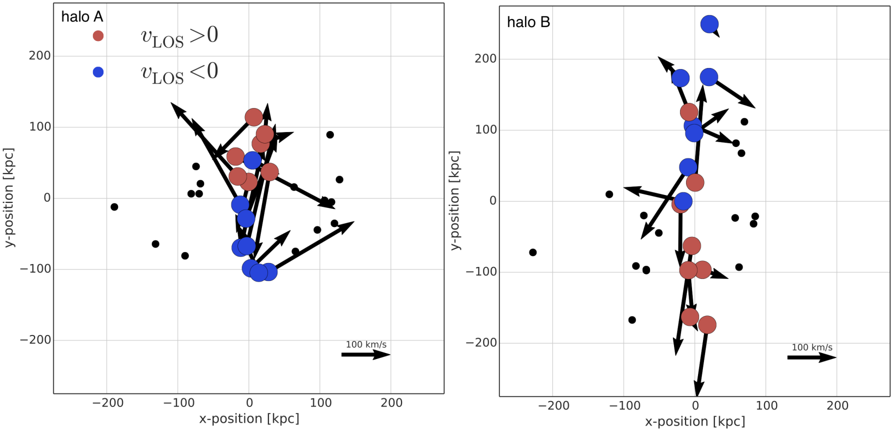


Line-of-sight co-rotation - 1D kinematics

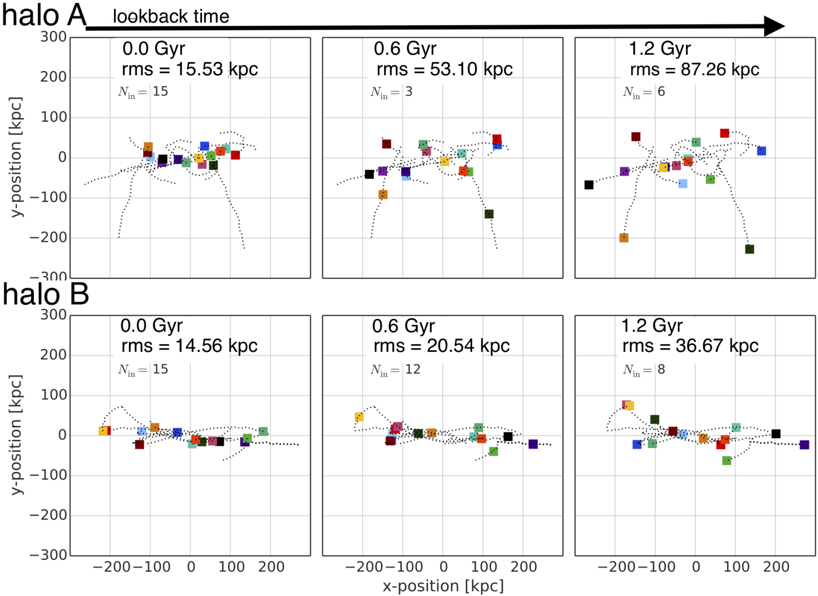




Full velocity information - 3D kinematics



Inclusion of the time - Plane evolution



Inclusion of the time - Plane evolution

Conclusion

1. thin planes of satellites are reproduceable within ΛCDM
2. solution to the problem of rareness: formation time of the host halo

Kinematics:

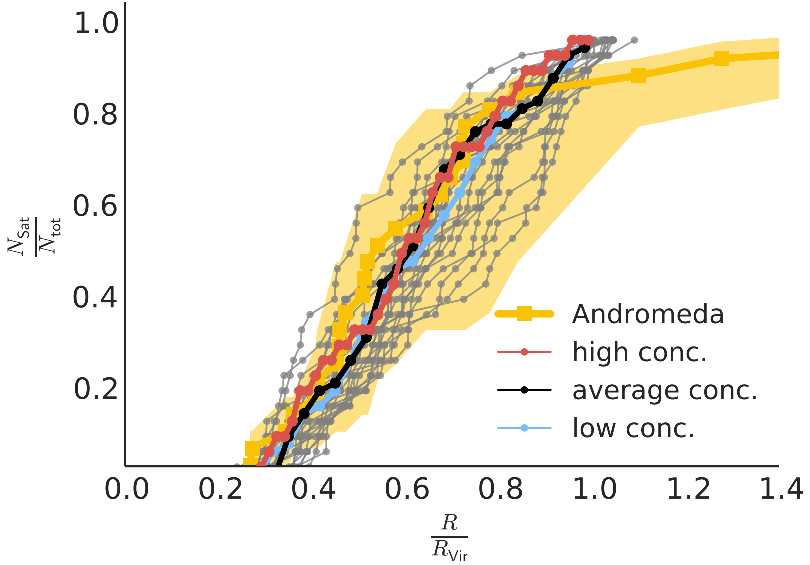
3. simulated planes include $\sim$30% of interlopers
4. prediction: high proper motions ($\sim$0.03 mas/yr) perpendicular to the plane for some of the satellites

5. flattened satellite configurations as a diagnostic for the formation scenario of halos

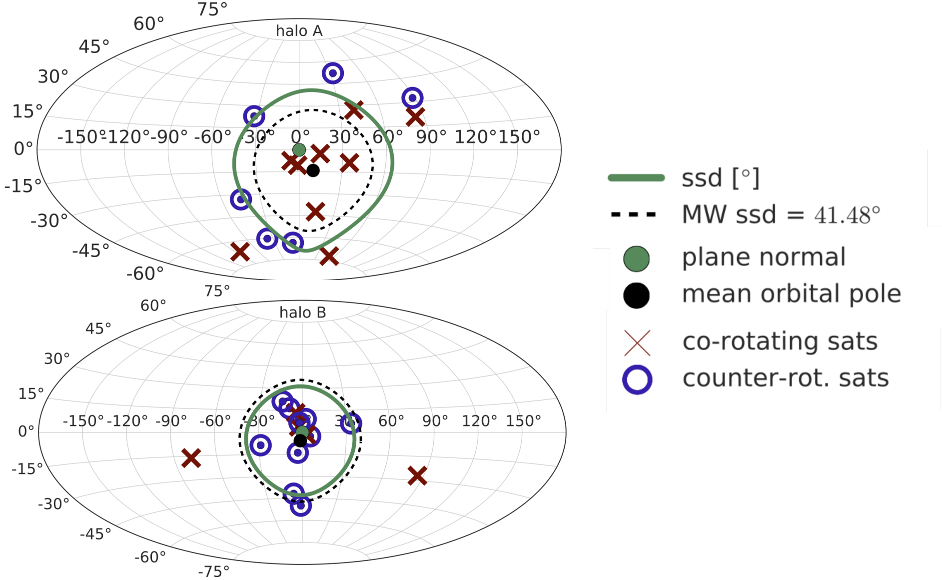
Thank you for your attention!

Questions!

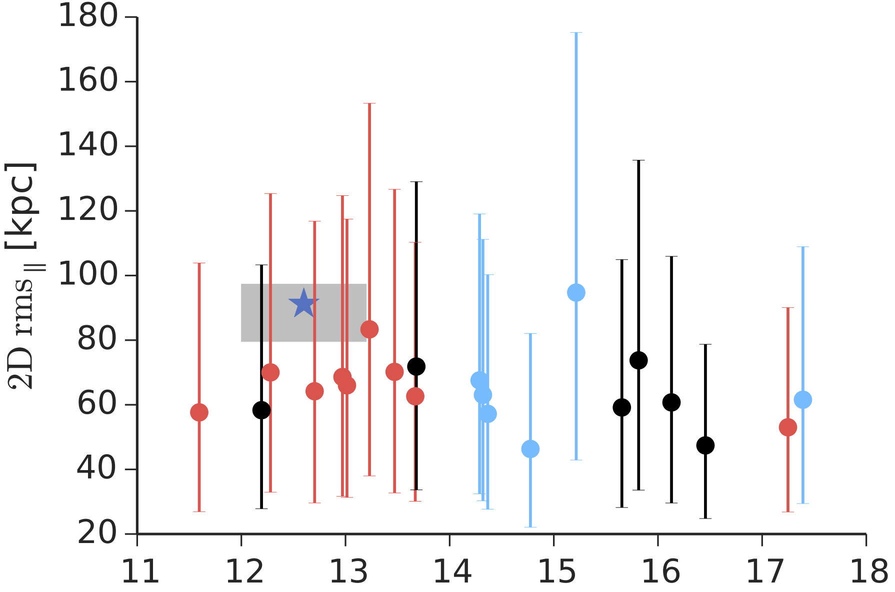
Radial distribution of satellites



Angular momentum and orbital poles

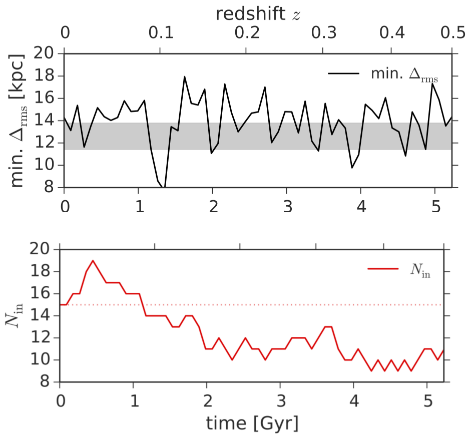


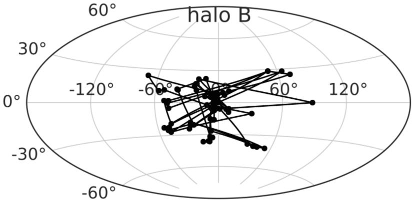
2D root-mean-square thickness



Plane evolution over time

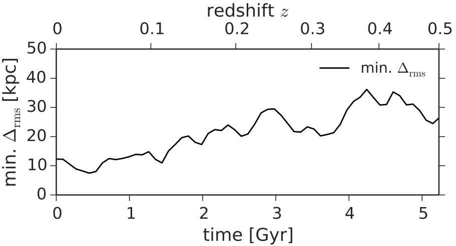
best plane fitted to all 30 satellites

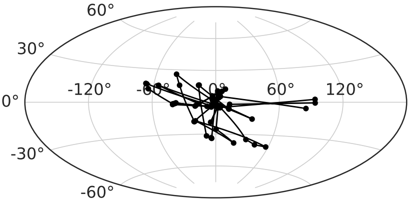




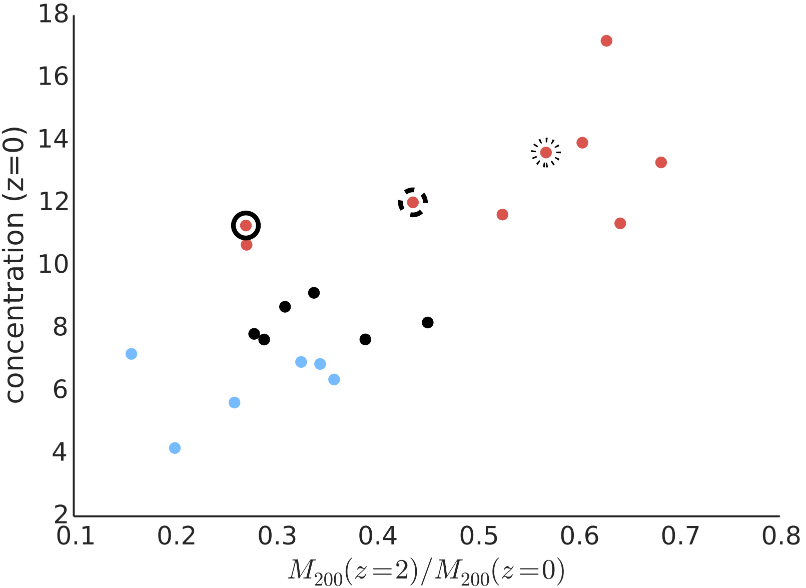
Plane evolution over time

best plane fitted to the 15 satellites in plane at $z = 0$

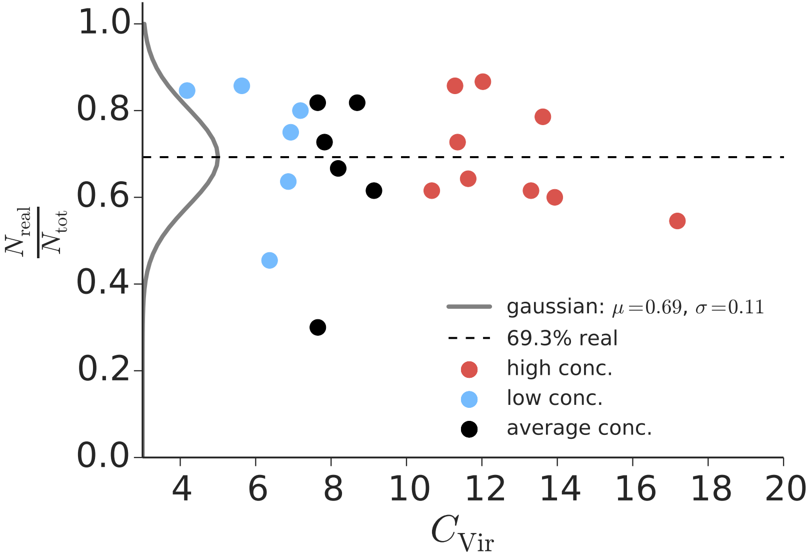




FORMATION TIME VS. CONCENTRATION



Interloper fraction



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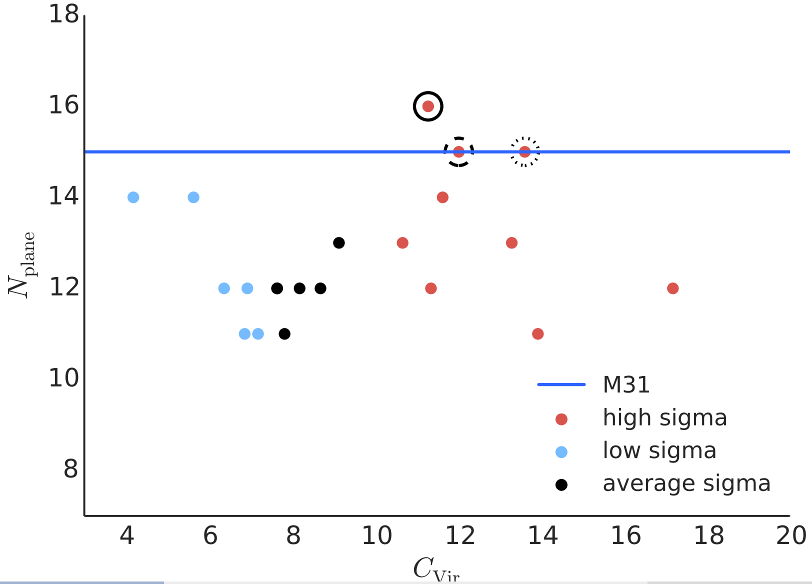

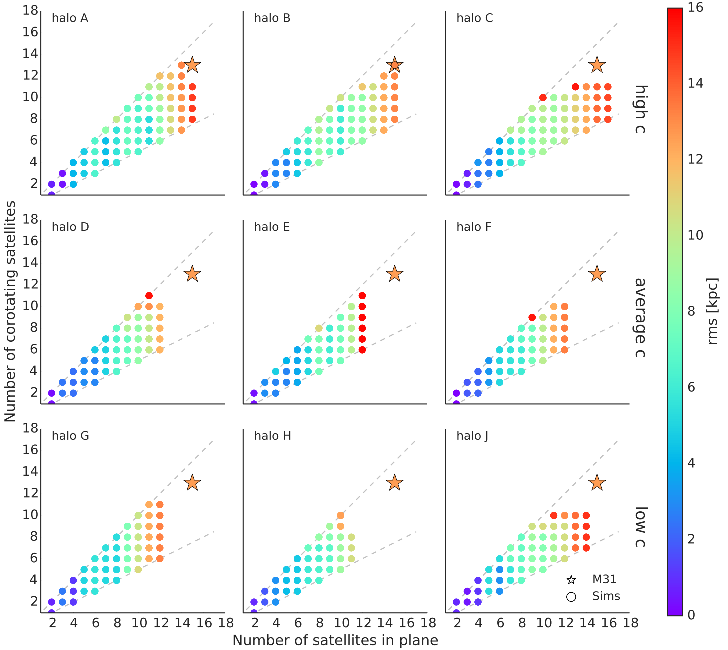
halo A
halo B
halo C
halo D
halo E
halo F
halo G
halo H
halo J
high c
average c
low c
Number of corotating satellites
Number of satellites in plane
rms [kpc]
M31
Sims
2 4 6 8 10 12 14 16 18
0 2 4 6 8 10 12 14 16