Correlations of DM halo properties:
Building the Hyades Suite

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In collaboration with
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Zoom-in simulations of galaxy halos spanning $M_{\text{vir}} = 0.05 - 5 \times 10^{12}M_\odot$

Identical initial conditions (MUSIC, Hahn & Abel 2011) with multiple codes: ENZO, GADGET, GASOLINE

Ultimate goal: How robust are halo (and galaxy) properties from code to code?

First step: Obtain a reliable and representative sample of halos
Hyades Simulations Suite

2 halos

same mass @ z=0

$2r_{\text{vir}}$

$z = 0$

Volume @ $z_{\text{ini}} = 250$

The initial high redshift volume can be defined by the convex hull (minimal polyhedron that englobes all particles).

Q: How big of a volume do we need to use to get no contamination?

Q: Can we pick small volumes without bias?
Hyades Simulations Suite

2 halos
same mass
@ z=0

\[ z = 0 \]

Volume @ \( z_{ini} = 250 \)

Red one would be much quicker run

Q: How big of a volume do we need to use to get no contamination?

Q: Can we pick small volumes without bias?

\[ 2r_{vir} \]

\[ 5r_{vir} \]
Use $L_{\text{box}} = 50 \text{Mpc}/h$, $N_p = 512^3$, $\epsilon = 1 \text{kpc}/h$ sim to explore how halo properties depend on the $\text{vol}_{hz}$.

**Dark Matter Halo Properties**

$M_{\text{vir}}$, $V_{\text{max}}$, $R_{\text{max}}$, shape, $\lambda$, $N_{\text{neig}}$, $a_{\text{form}}^{50}$, $N_{\text{mergers}}$, subhalo, $\text{vol}_{hz} (1 \times r_{\text{vir}})$,...

**Cosmology:** $\Lambda CDM$ WMAP7

**Sample:** Halos with $N_{\text{part}} > 500$

- Which halo properties contain more information? (Skibba & Maccio 2011, Jeeson-Daniel et al. 2011)
- How can we build a reliable sample with the lowest number of halos?
- How selective can we be with $\text{vol}_{hz}$?
Selecting a Milky Way Halo: How selective can we be?

MW Mass bin: 
$[1 - 3] \times 10^{12} \ M_\odot$
No subhalos

- How is correlated $vol_{hz}$ for a fixed mass?
- For some specific halo properties can we choose a low $vol_{hz}$?
Selecting a Milky Way Halo: How selective can we be?

**MW Mass bin:**

\([1 - 3] \times 10^{12} \, M_\odot\)

No subhalos

- How is correlated \(vol_{hz}\) for a fixed mass?
- For some specific halo properties can we choose a low \(vol_{hz}\)?

![Log \(M_{vir}\) vs Log \(vol_{hz}\): 0.326](image_url)
Selecting a Milky Way Halo: How selective can we be?

Color map and black points: full MW sample
White points: small initial volume

$\log a_{50}$ vs $\log c/a$: $-0.402$

$\log \lambda$ vs $\log V_{\text{max}}/V_{\text{vir}}$: $-0.434$

No bias with $vol_{hz}$
Testing reliability in Zoom-in simulations

- Using MUSIC (Hahn & Abel 2011)
- Set of dark matter zoom-in simulations.
  \[ m_p = 6.88 \times 10^7 - 1.67 \times 10^4 \, M_{\odot}/h \]

Comparison between Dark-Matter full box and zoom-in runs

- Initial high-res volume: no contamination and stability of halo parameters.
- Mass and spatial resolution tests.
- Lower resolution levels sizes and resolution.
- Code differences.

Katz & White 1993, Klypin et al. 2001
Testing reliability in Zoom-in simulations

\[ Vol_{hz} / Vol_{box} \text{ vs } M_{hr} / M_{tot} (\leq r_{vir}) \]

Contamination:
Any low res particles inside \( r_{vir} \)?

Log (Volume computed at high resolution)
Testing reliability in Zoom-in simulations

\[ \frac{Vol_{hz}}{Vol_{box}} \text{ vs } \frac{V_{max}}{V_{max}^{\text{box}}} \]

Only runs with no contamination

\[ V_{max} \text{ and most halo properties are very stable from run to run and as a function of initial volume.} \]

Some problems with ENZO because the halo moves within grid…
Testing reliability in Zoom-in simulations

$V_{ol_{hz}} / V_{ol_{box}}$ vs $\lambda / \lambda_{box}$

- **gadget**
- **enzo**

- $\sim 5 \times 10^{12} M_\odot$
- $\sim 1 \times 10^{12} M_\odot$
- $\sim 5 \times 10^{11} M_\odot$

Only runs with no contamination

Spin parameter less stable

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Correlations of DM halo properties: the Hyades Suite
Conclusions: Preliminary results

- For a fixed halo mass, there is no strong bias with the initial volume (good news for zoom simulations).
- Zoom volume need to be at least $\sim 2 \times r_{\text{vir}}$ for no contamination within $r_{\text{vir}}$.
- Halo properties are stable for non-contaminated zooms, except for spin parameter.
- Enzo approach needs higher initial volume and more detailed information on halo history.
Thank you!

**Hyades**: Daughters of Atlas, nurses of Dionysus. A sisterhood of nymphs that bring rain

Would you like to try any **Hyades** nymph with your code? Please contact us!!!

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Some Important Parameters

**WMAP 7 Cosmology.**
Model: $\text{lcdm} + \text{sz} + \text{lens}$

- $\Omega_\Lambda = 0.734$, $\Omega_m = 0.266$
- $\Omega_b = 0.0449$, $h = 0.71$
- $\sigma_8 = 0.801$, $n_s = 0.963$

**Full Box Parameters**

- $L_{\text{box}} = 50 \text{ Mpc}/h$, $\epsilon = 1 \text{ kpc}/h$
- $N_{\text{part}} = 512^3$, $z_{\text{ini}} = 250$
- $m_{\text{dm}} = 6.88 \times 10^7 \text{ M}_{\odot}/h$

**Full Box Halo Sample**

- $N_{\text{part}} > 500 \rightarrow M > 3.4 \times 10^{10} \text{ M}_{\odot}/h$

**"MW" Mass Bin Halo Sample**

- $1 \times 10^{12} \text{ M}_{\odot} < M_{\text{halo}} < 3 \times 10^{12} \text{ M}_{\odot}$
- No subhalos
Other Figures: Full Sample

log $M_{\text{vir}}$ vs log $v_h$: 0.552

log $M_{\text{vir}}$ vs log $v_h$: 0.552

log $v_h$ vs log $V_{\text{vir}}$: 0.026

log $v_h$ vs log $V_{\text{max}}$: 0.590

log $M_{\text{vir}}$ vs log $v_h$: 0.552

log $M_{\text{vir}}$ vs log $v_h$: 0.552

log $v_h$ vs log $\lambda$: 0.003

log $v_h$ vs log $V_{\text{max}}$: 0.590
Other Figures: MW bin

- $\log v_{\text{halo}}$ vs $\log c/a$: 0.142
- $\log v_{\text{halo}}$ vs $\log \lambda$: 0.062
- $\log v_{\text{halo}}$ vs $\log V_{\text{max}}/V_{\text{vir}}$: −0.003
- $\log v_{\text{halo}}$ vs $\log a_{50}$: −0.160
- $\log M_{\text{vir}}$ vs $N_{\text{neigh}}$: −0.308
- $\log V_{\text{max}}/V_{\text{vir}}$: −0.642