Mock Galaxy Catalogs from the Horizon Run 4 Simulation with the Most Bound Particle – Galaxy Correspondence Method

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Horizon Run 3: 10,815 $h^{-1}$Mpc

Horizon Run 2: 7,200 $h^{-1}$Mpc ($z \sim 12$)

Horizon Run 1: 6,592 $h^{-1}$Mpc ($z \sim 8$)

Horizon Run 4: 3,150 $h^{-1}$Mpc ($z \sim 1.5$)

Millenium: 500 $h^{-1}$Mpc ($z \sim 0.17$) (Springel+2005)
Horizon Run 4 Simulation
(Kim, Park, L’Huillier & SEH, 2015)

- 6,300$^3$ DM particles in 3,150$\, h^{-1}$Mpc box
- WMAP5 $\Lambda$CDM cosmology
- Lowest halo mass: $2.7 \times 10^{11} \, h^{-1} M_\odot$
- Full-sky lightcone up to $z = 1.5$
How to Simulate Galaxies?

Hydrodynamic Simulations
(Illustris; Vogelsberger+2014)

Semi-Analytic Model
(MUPPI; Monaco+2004)
How to Simulate Galaxies?

Halo Occupation Distribution
(Takamitsu+2011)

One-to-one Correspondence
Traditional One-to-one Correspondence: Subhalo-Galaxy

Galaxy position/velocity = position/velocity of subhalo

Stellar mass of satellites: more related to infall mass than the current halo mass (e.g. Nagai & Kravtsov 2005)

May not detect satellites close to halo center or orphan galaxies
Subhalo $\rightarrow$ Most Bound Particle (MBP)

◊ MBP: gravitationally most bound member particle of a halo (widely adopted in SAMs)

◊ MBPs can represent galaxies well because galaxies are compact and likely to be near the halo’s potential well.

◊ Monitoring MBPs is easier than finding subhalos and linking them through merging tree.

◊ MBP could be found near the host center, even in simulations with a bit low resolution.
New One-to-one Correspondence: MBP-Galaxy

Galaxy position/velocity = position/velocity of MBP

Monitor the MBP even after the infall, by using infall mass as stellar mass proxy

Merger timescale is additionally calculated: close satellites could be resolved
Models on Merger Timescale

◊ Isothermal analytic model: **LC93** (Lacey & Cole 1993)

◊ Isolated galaxy/halo simulations:
  B08 (Boylan-Kolchin, Ma & Qataert 2008), V13 (Villalobos+2013)

◊ Cosmological simulations:
  J08 (Jiang+2008), M12 (McCavana+2012)
Galaxy Group Properties \( @ z = 0 \)

**Mass Function**

\[
\frac{d n}{d \log M_{\text{NFW}}} \left[ h^3 \text{Mpc}^{-3} \right] = \begin{cases} 
10^{-3} & 
10^{-4} \\
10^{-5} & 
10^{-6} 
\end{cases}
\]

\[
M_{\text{NFW}} \left[ h^{-1} M_\odot \right] = \begin{cases} 
10^{13} & 
10^{14} \\
10^{15} & 
10^{16} 
\end{cases}
\]

\[M_r - 5 \log h < -20\]

**Mass – # Member Galaxies**

Isothermal Model

Subhalo

FoF galaxy-group mass from velocity dispersion & projected radius
Galaxy Group Properties @ z = 0

Mass – Velocity Dispersion

$M_r - 5 \log h < -20$

FoF galaxy-group mass from velocity dispersion & projected radius
Two-Point Correlation Function @ z = 0

$\pi$ [h^{-1} Mpc] vs. $r_p$ [h^{-1} Mpc]

- $M_r - 5 \log h < -21$
- $M_r - 5 \log h < -20$

- LC93
- B08
- J08
- M12
- V13
- PSB
- SDSS
- (Zehavi+2011)
- Isothermal Model
- Subhalo
Two-Point Correlation Function @ z = 0

\[ \mathcal{M}_r - 5 \log h < -21 \]

\[ \mathcal{M}_r - 5 \log h < -20 \]

Isothermal Model Subhalo

\[ w_p(r_p) \]
What Leads the Disagreement in the Isothermal Analytic Merger Timescale Model?

- Short Merger Timescale
- More centrals in volume-limited sample
- Longer galaxy-galaxy distance
- Suppression of 2pCF
- Harder group detection
What Leads the Disagreement in the Subhalo-Galaxy Correspondence Model?

- Low spatial resolution
- Missing orphans
- More centrals in volume-limited sample
- Longer galaxy-galaxy distance
- Lack of Finger-of-God
- Suppression of 2pCF
- Harder group detection
Summary

✧ We applied one-to-one correspondence model by using the gravitationally most bound member particle

✧ Our new method can resolve satellites close to host center better than traditional subhalo-galaxy correspondence model, and hence reproduce better Finger-of-God effect.

✧ Galaxy-group properties and two-point correlation function @ z = 0 match well with SDSS observations.

Can be applied to other studies!!!