Subhalo abundance matching and assembly bias

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THE EAGLE PROJECT

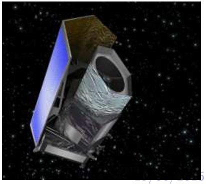
Motivation: Wide-field galaxy surveys (I)

Ongoing surveys:

- BOSS.
- WiggleZ.
- DES.

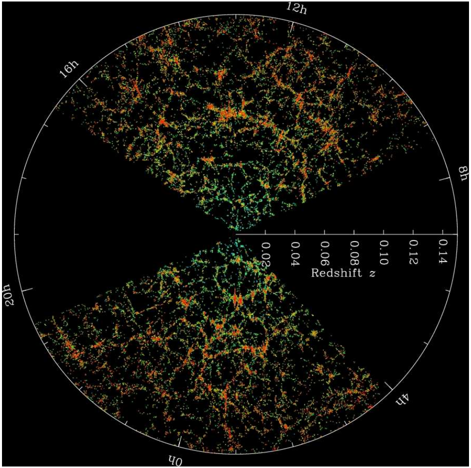
Future surveys:

- DESI
- J-PAS.
- LSST.
- Euclid.



Motivation: Wide-field galaxy surveys (II)

Cosmological information encoded on the clustering of galaxies.



Credit: M. Blanton and the Sloan Digital Sky Survey

N-body simulations

Hydrodynamical simulations:

- Fully treatment of the baryonic physics.
- Time expensive.
- Smaller volumes (non-linear scales).

Dark matter only simulations:

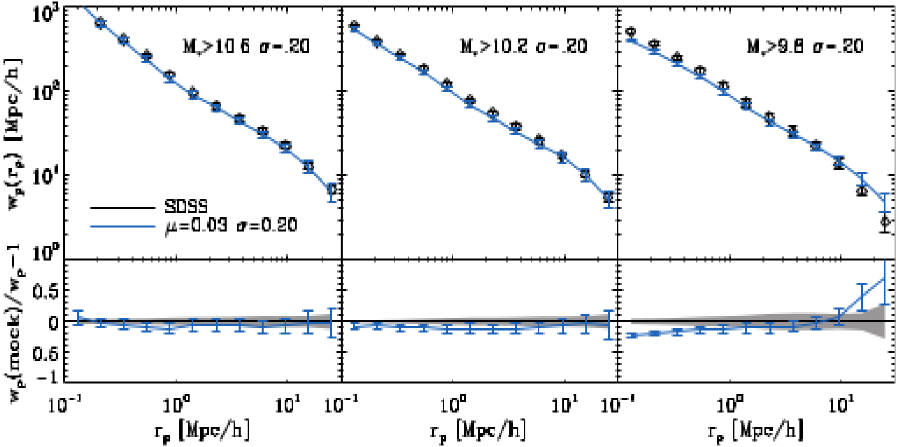
- Just dark matter.
- Need less time.
- Larger volumes (linear scales).

Different ways to introduce galaxies in DM-only simulations:

- Semi-Analytical models.
- Halo Occupation Distribution (HOD).
- <u>Sub-Halo Abundance Matching (SHAM)</u>.

SHAM: Previous results

SHAM predicts the clustering correctly (using free parameters).



Reddick et al. 2013

EAGLE (Schaye et al. 2015; Crain et al. 2015)

EAGLE, hydrodynamical state-of-the-art simulation:

- 1504^3 gas particles and the same number of DM particles.
- Periodic box of 100 Mpc on a side.
- Metal-dependent radiative cooling and photo-heating.
- Chemodynamics.
- Gas accretion onto SMBHs.
- Stellar and AGN feedback.

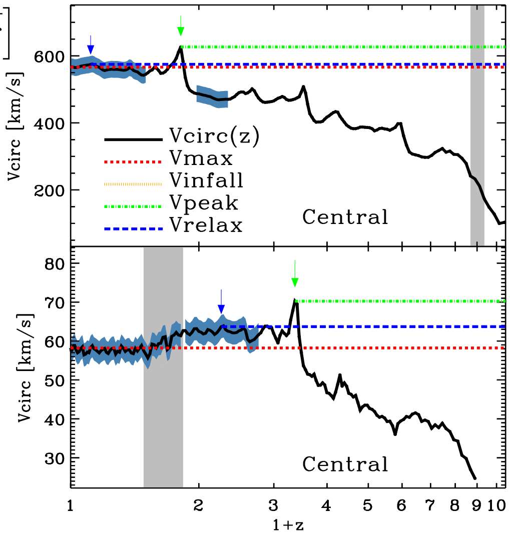
Dark matter only version of EAGLE (DMO):

- 1504^3 DM particles.
- Same volume, initial conditions, and cosmology.
- More than the 95% of the haloes can be linked between EAGLE and DMO.

Subhalo proxies for stellar mass (I)

$$V_{\rm circ}(z) = \max\left[\sqrt{\rm GM(z, < r)/r}\right]$$

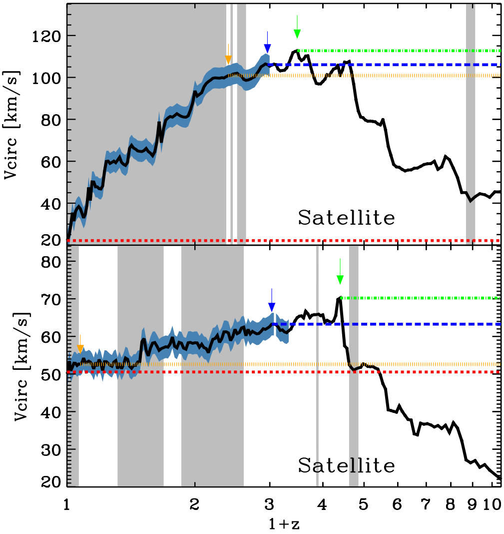
- $V_{\rm max}$: maximum circular velocity at the present time.
- $V_{\rm infall}$: maximum circular velocity at the last time a subhalo was a central.
- $V_{\rm peak}$: the maximum circular velocity that a subhalo has reached.



Subhalo proxies for stellar mass (II)

Some issues:

- V_{max}: tidal heating.
- V_{infall}: tidal heating before infall for satellites.
- V_{peak}: spurious values due to mergers.



New proxy: $V_{\rm relax}$

Vrelax: the maximum circular velocity that a subhalo has reached during the periods in which it satisfied a relaxation criterion.

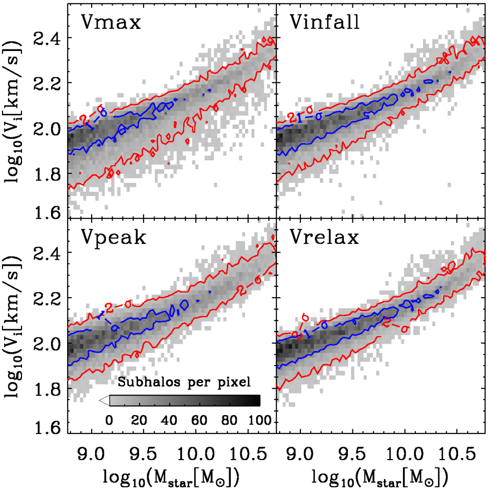
Relaxation criterion at $z_{\rm i}$: $t_{\rm form} > t_{\rm cross}$, where

$$t_{\rm cross} = \frac{2\,R_{200}}{V_{200}} \text{ and}$$

$$t_{\rm form} = t_{\rm int}(z_{0.75}) - t_{\rm int}(z_{\rm i}).$$

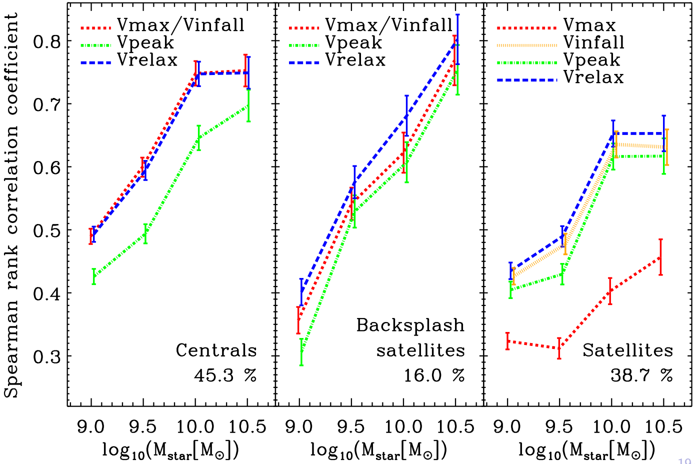
Predicting $M_{\rm star}$ (I)

Relation between $M_{\rm star}$ of EAGLE galaxies and SHAM parameters for the corresponding DMO subhaloes.

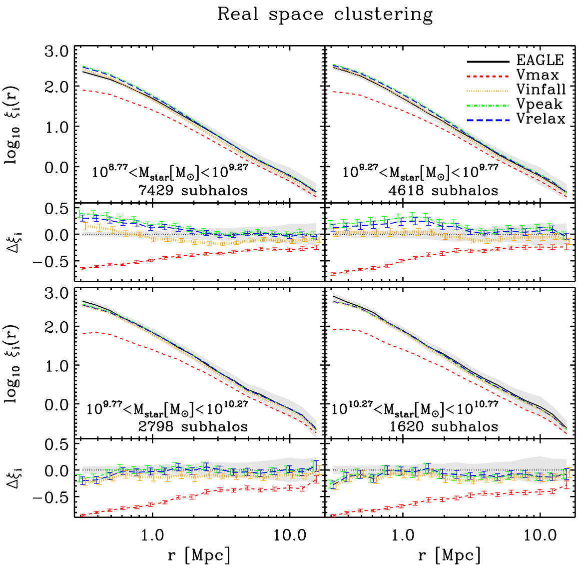


Predicting $M_{\rm star}$ (II)

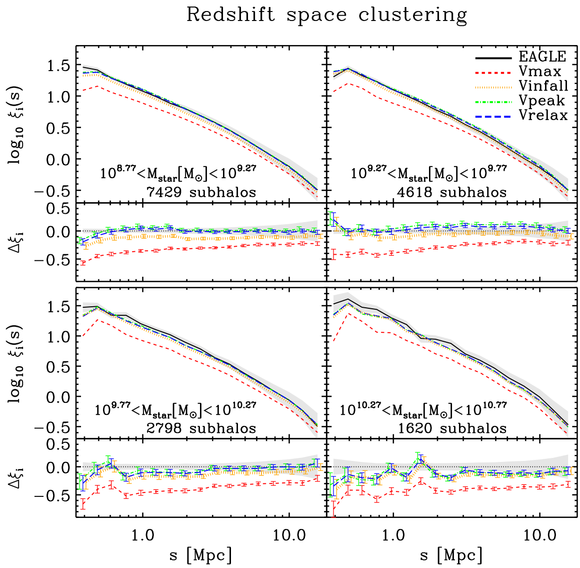
The Spearman rank correlation coefficient between the $M_{\rm star}$ of EAGLE galaxies and SHAM parameters for the corresponding DMO subhaloes.



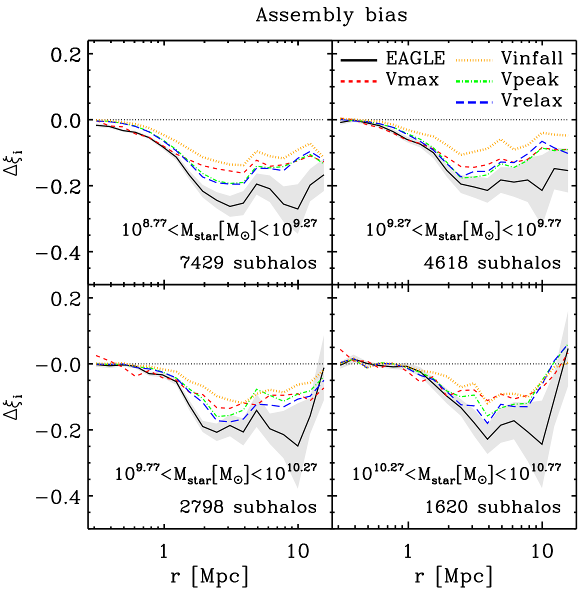
Real-space clustering



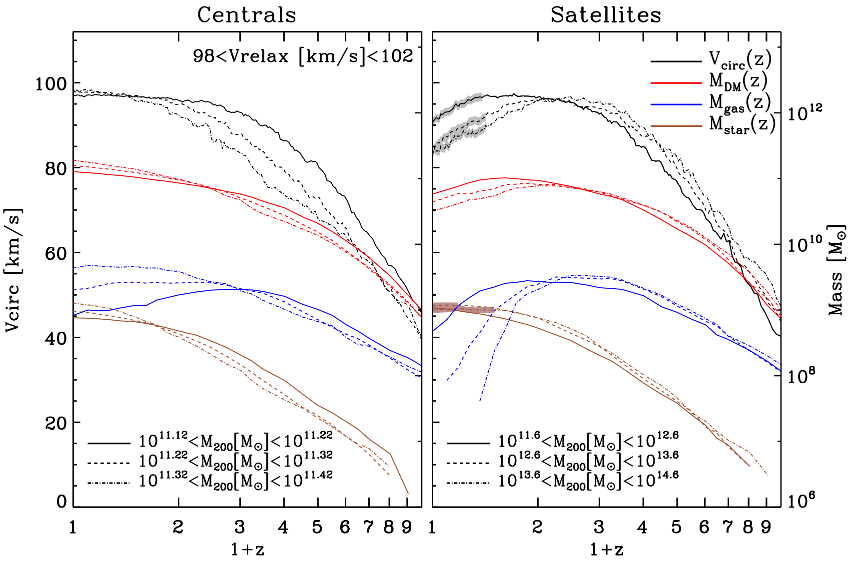
Redshift-space clustering



Assembly bias

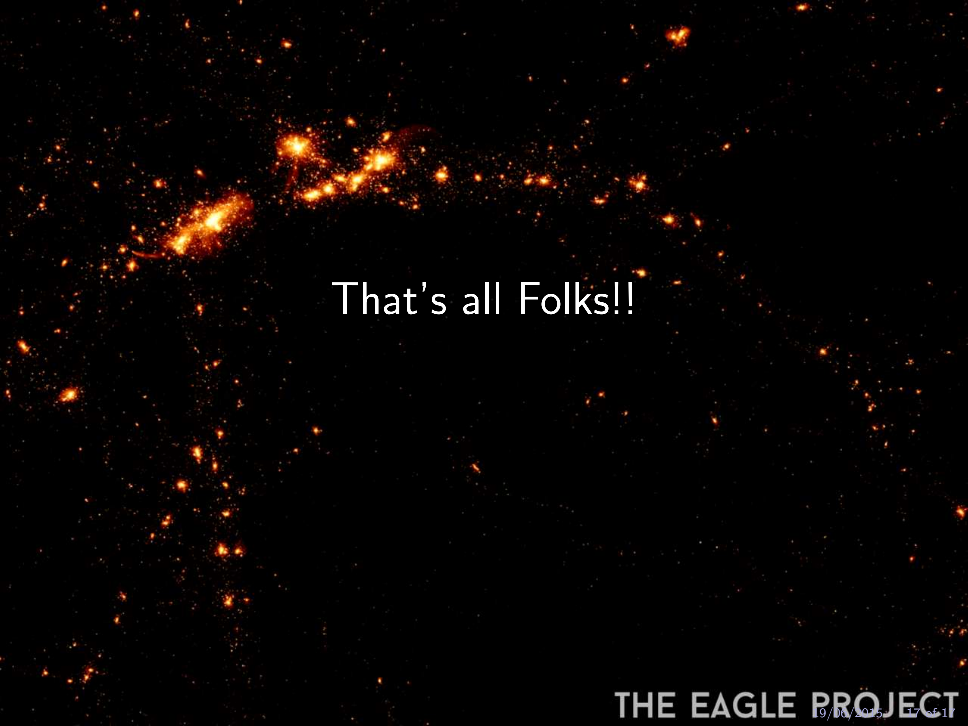


Why fails?


Centrals
Satellites
98<Vrelax [km/s]<102
$V_{circ}(z)$
$M_{DM}(z)$
$M_{gas}(z)$
$M_{star}(z)$
Vcirc [km/s]
Mass $[M_\odot]$
1+z
1+z
$10^{11.12}<M_{200}[M_\odot]<10^{11.22}$
$10^{11.22}<M_{200}[M_\odot]<10^{11.32}$
$10^{11.32}<M_{200}[M_\odot]<10^{11.42}$
$10^{11.6}<M_{200}[M_\odot]<10^{12.6}$
$10^{12.6}<M_{200}[M_\odot]<10^{13.6}$
$10^{13.6}<M_{200}[M_\odot]<10^{14.6}$

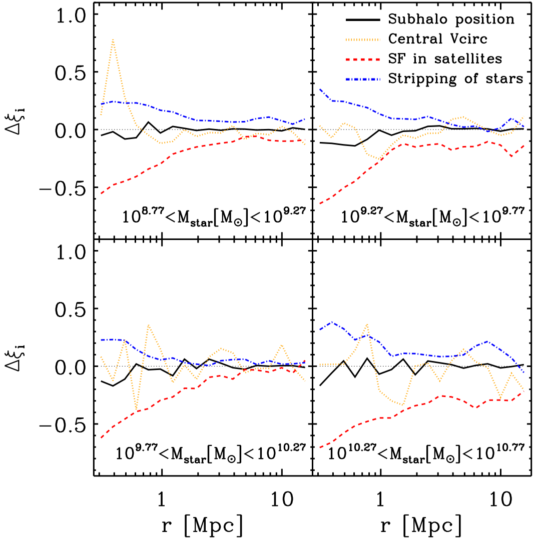
Summary

- Physical relation between the $M_{\rm star}$ and the SHAM parameters. $V_{\rm relax}$ exhibits the strongest correlation with $M_{\rm star}$.
- Using $V_{\rm relax}$ as SHAM parameter in DMO we recover the same clustering as in EAGLE on scales $2-17$ Mpc. The clustering is overpredicted $\sim 25\%$ on scales below 2 Mpc for low mass galaxies.
- Detection of assembly bias in EAGLE. It increases the clustering $\sim 25\%$ on scales $2-10$ Mpc. $V_{\rm relax}$ underpredicts its strength $\sim 15\%$.
- Dependence of galaxy properties with halo mass at a given $V_{\rm relax}$.

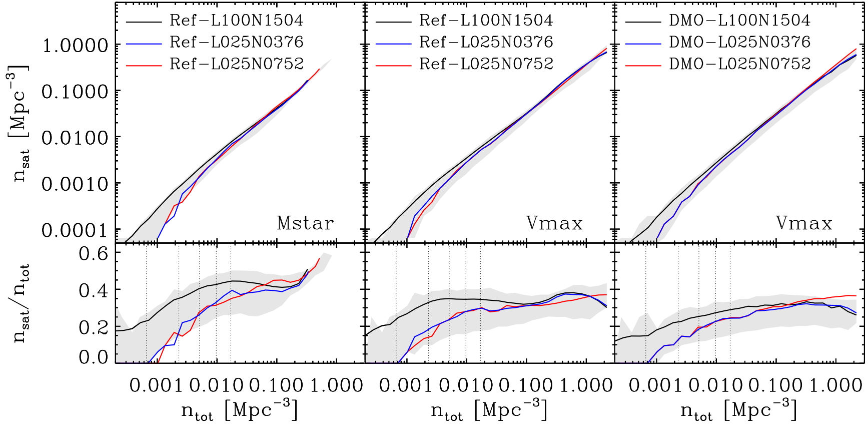


That’s all Folks!!

Why fails?


Subhalo position
Central Vcirc
SF in satellites
Stripping of stars
$\Delta\xi_i$
1.0
0.5
0.0
−0.5
$10^{8.77}<M_{star}[M_\odot]<10^{9.27}$
$10^{9.27}<M_{star}[M_\odot]<10^{9.77}$
$10^{9.77}<M_{star}[M_\odot]<10^{10.27}$
$10^{10.27}<M_{star}[M_\odot]<10^{10.77}$
1
10
r [Mpc]

Resolution



Ref−L100N1504
Ref−L025N0376
Ref−L025N0752
DMO−L100N1504
DMO−L025N0376
DMO−L025N0752
Mstar
Vmax
Vmax
1.0000
0.1000
0.0100
0.0010
0.0001
n_sat [Mpc^−3]
0.6
0.4
0.2
0.0
n_sat/n_tot
0.001 0.010 0.100 1.000
n_tot [Mpc^−3]