Bimodal Formation Redshift Distribution of Accreted Subhalos

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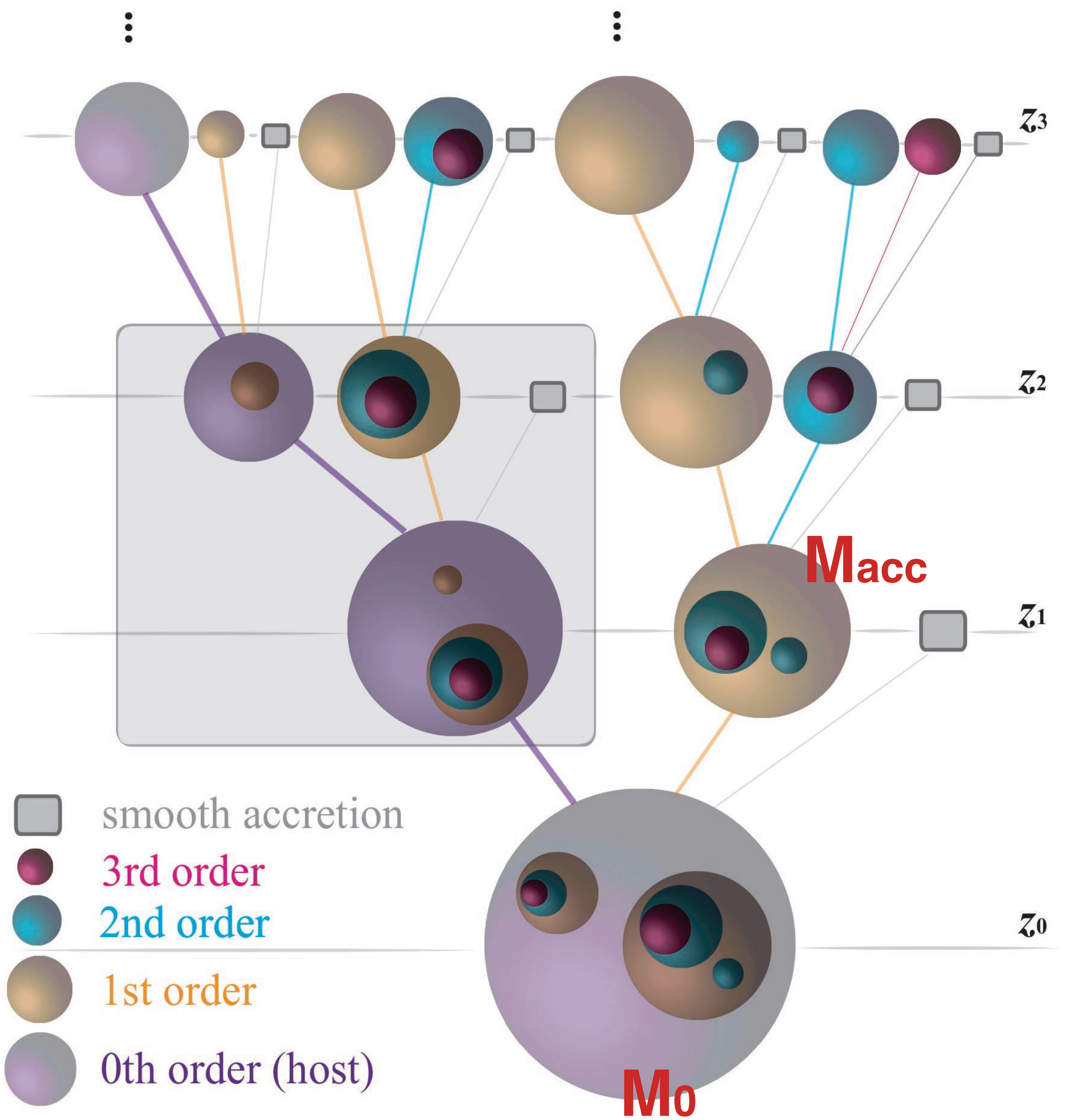
Simulations and Merger Tree

- Simulations: 200Mpc/h, 2048^3 particles, with 7.29*10^7 Msun/h

- Merger Tree: FOF + SubFind

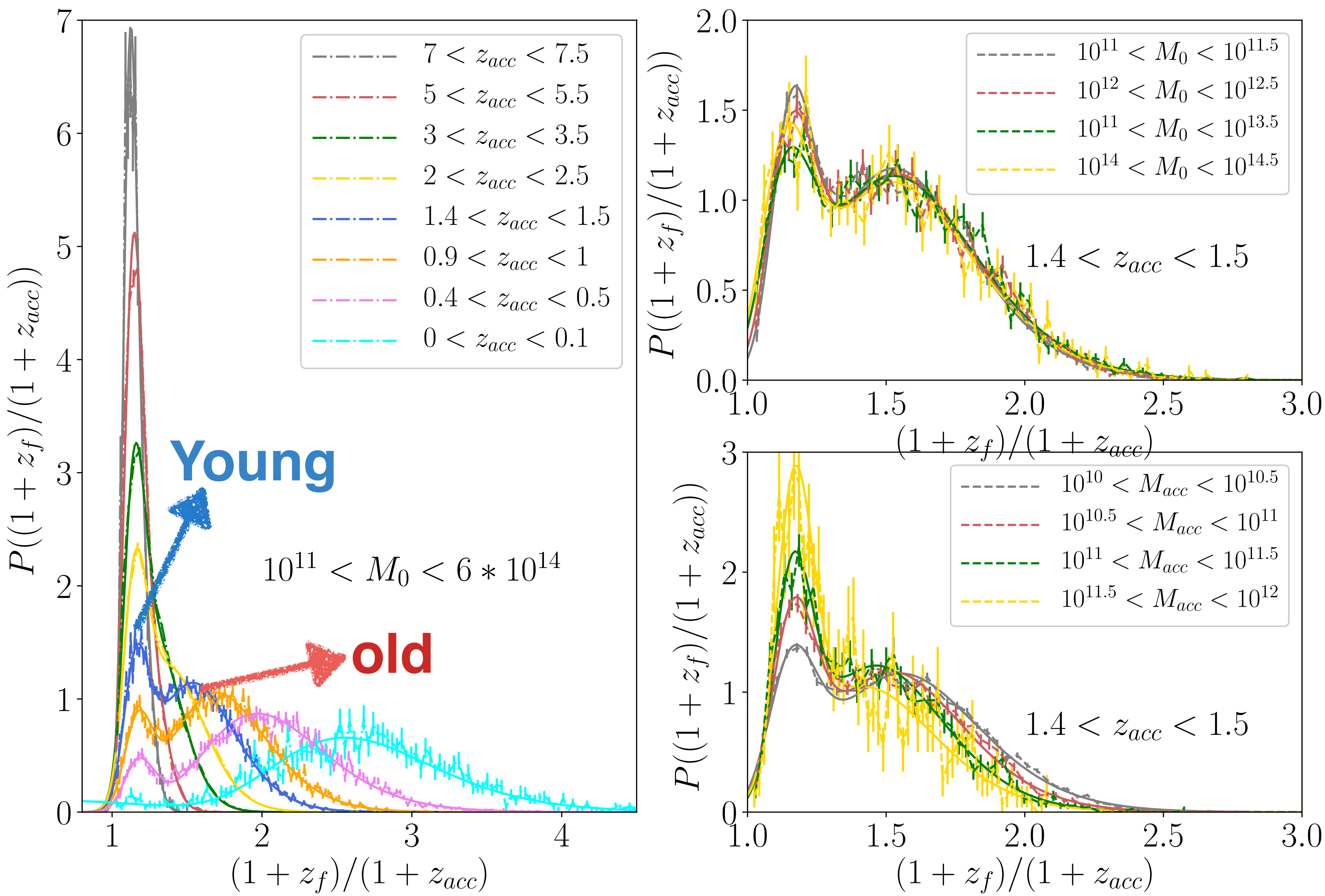
- Accreted Subhalo:

accretion redshift: z_acc
formation redshift: z_f



Jiang & Van Den Bosch 2014

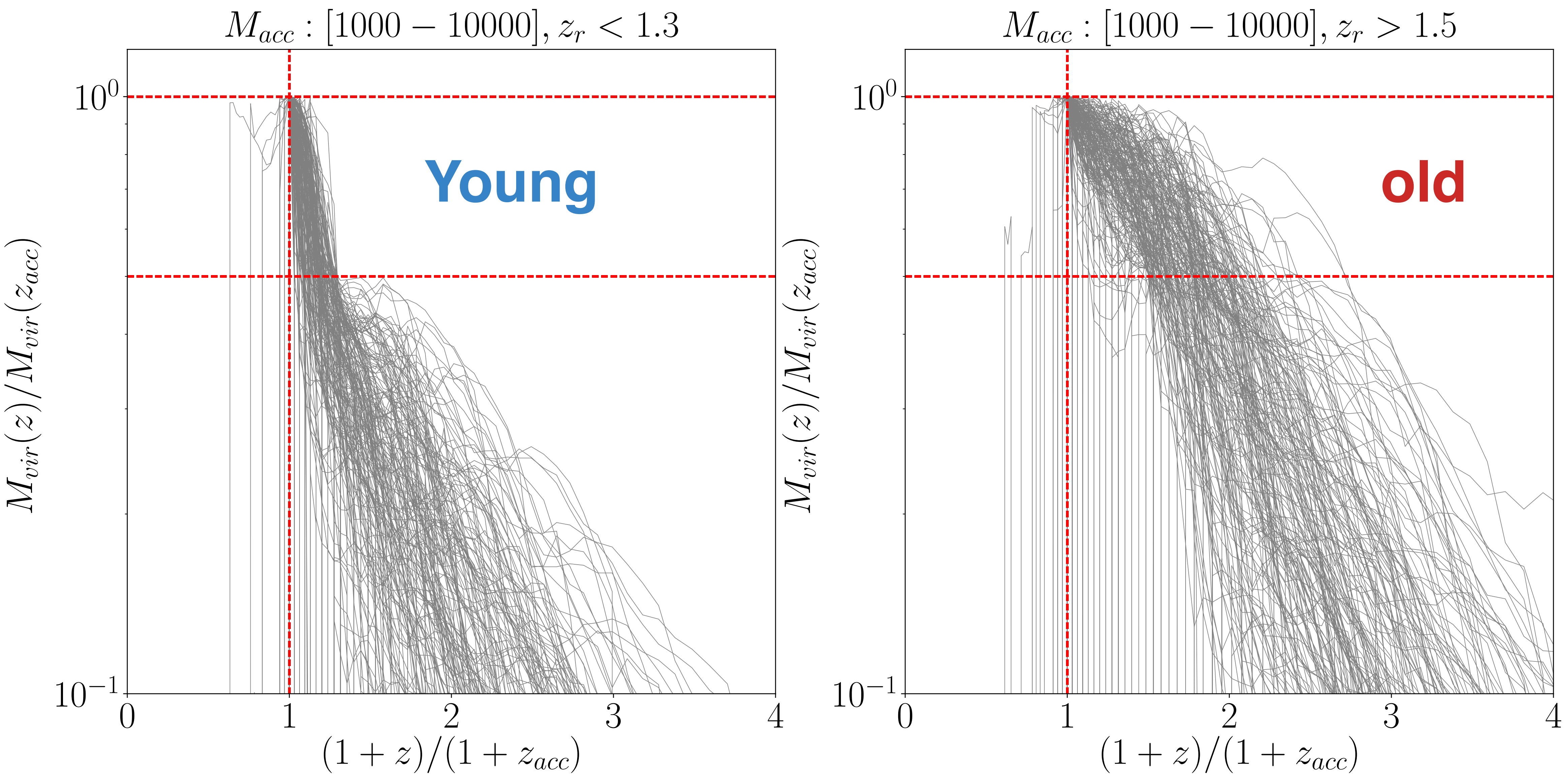
A Bimodal Feature



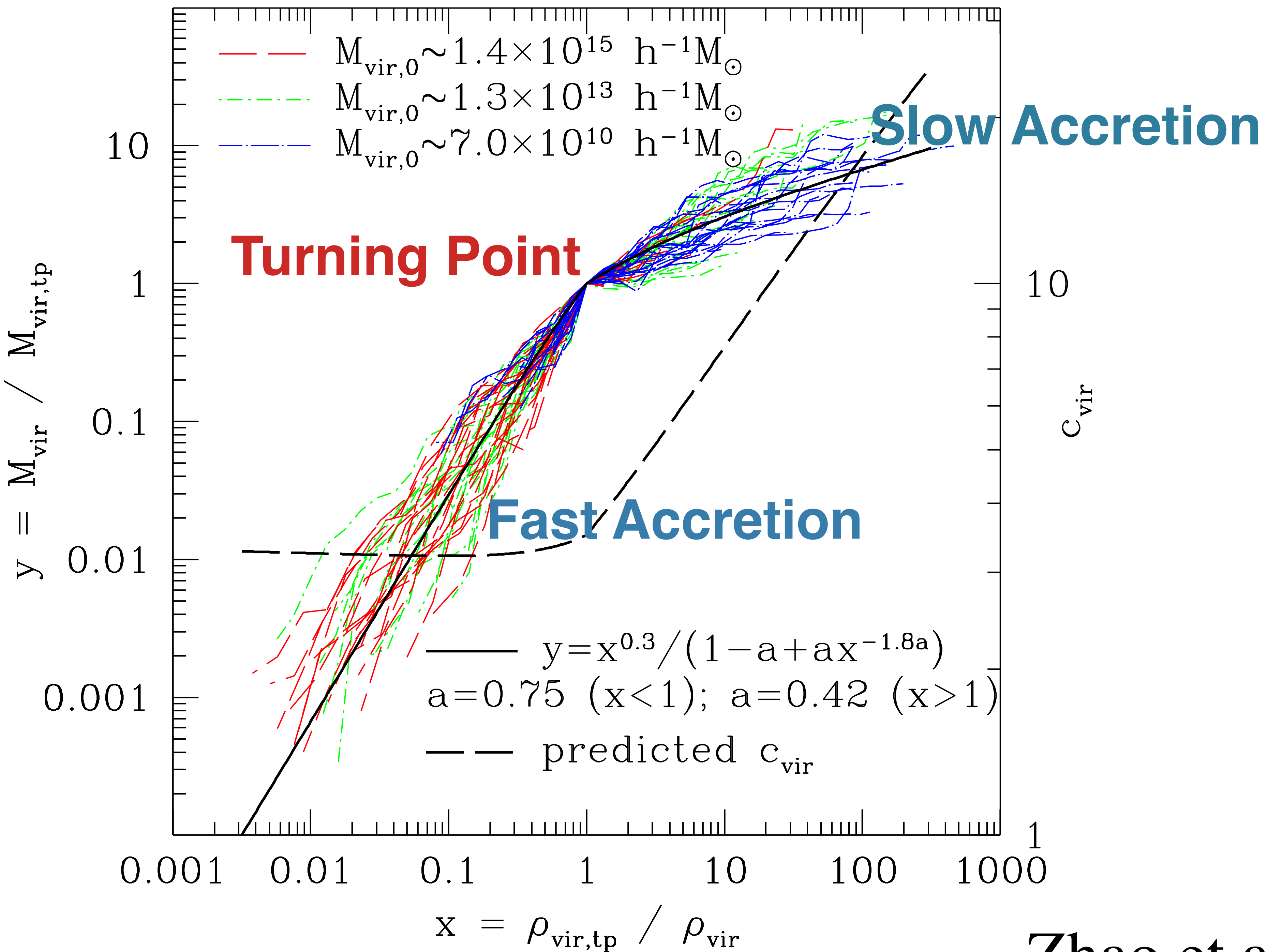
Numerical Effects?

- Resolution: Larger box and Re-simulation for single halo
- Varying definition of z_acc: V_{peak} instead of M_{peak}
- Rockstar

Mass Accretion History

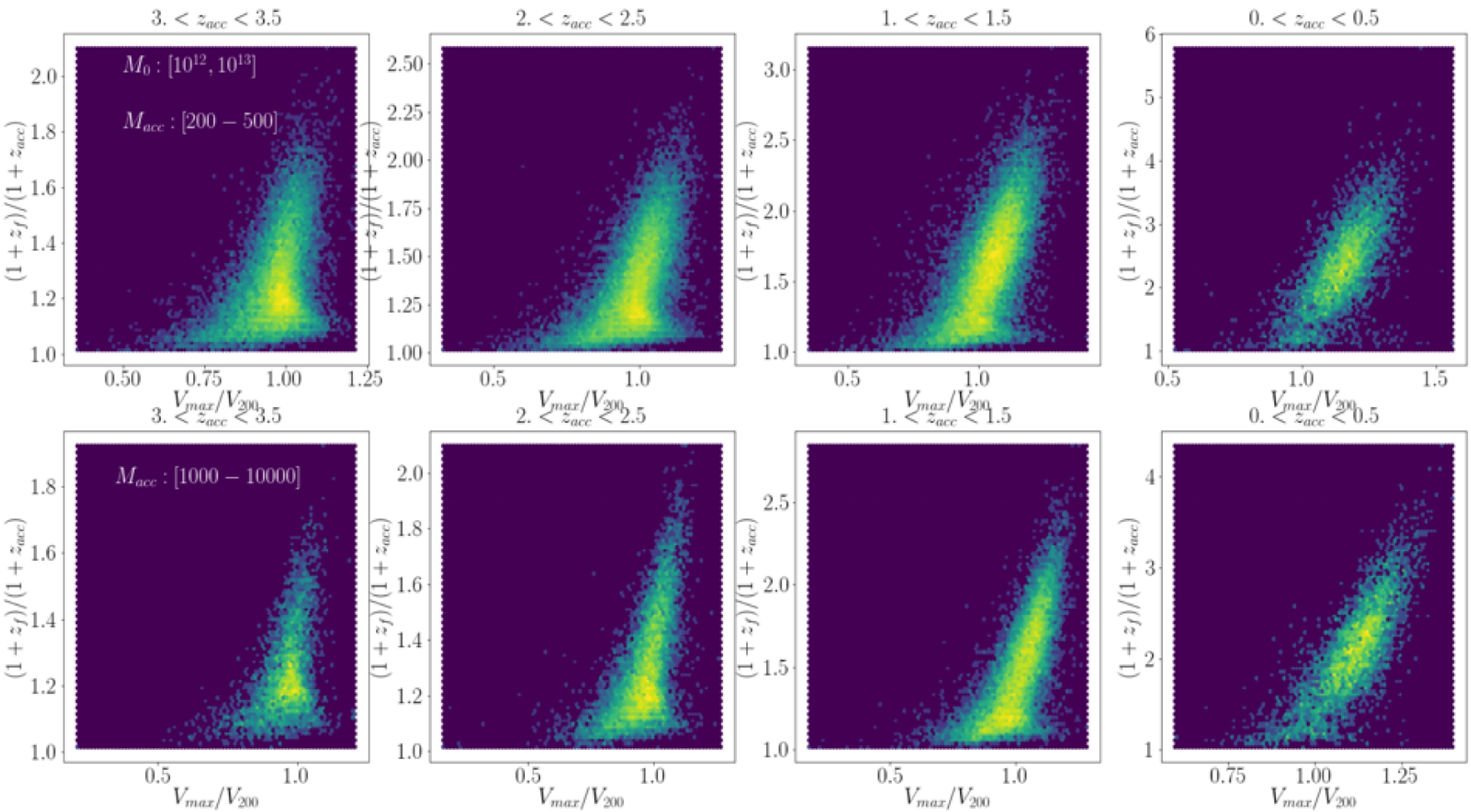


Connection with Two-Phase accretion

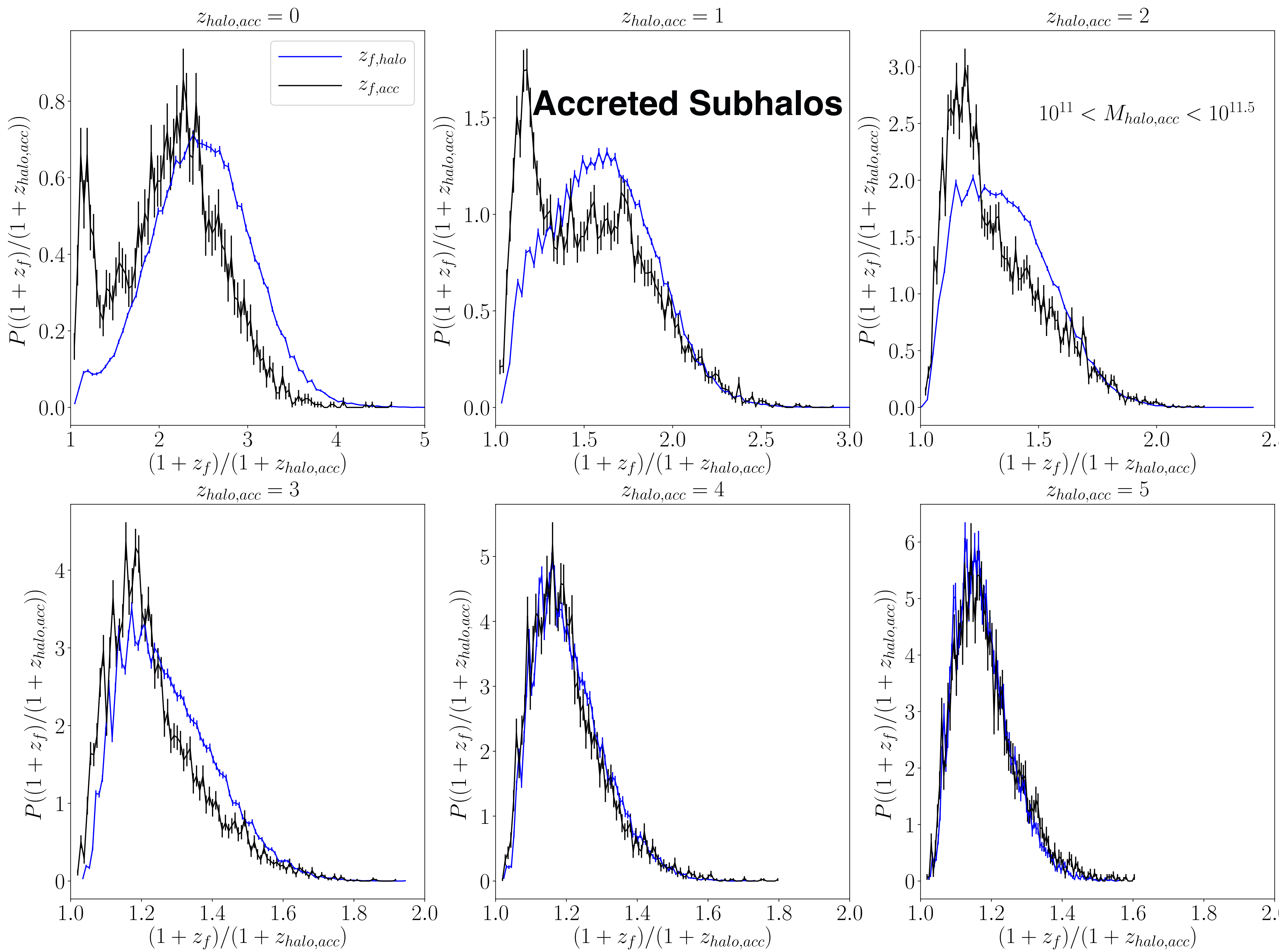


Zhao et al 2003

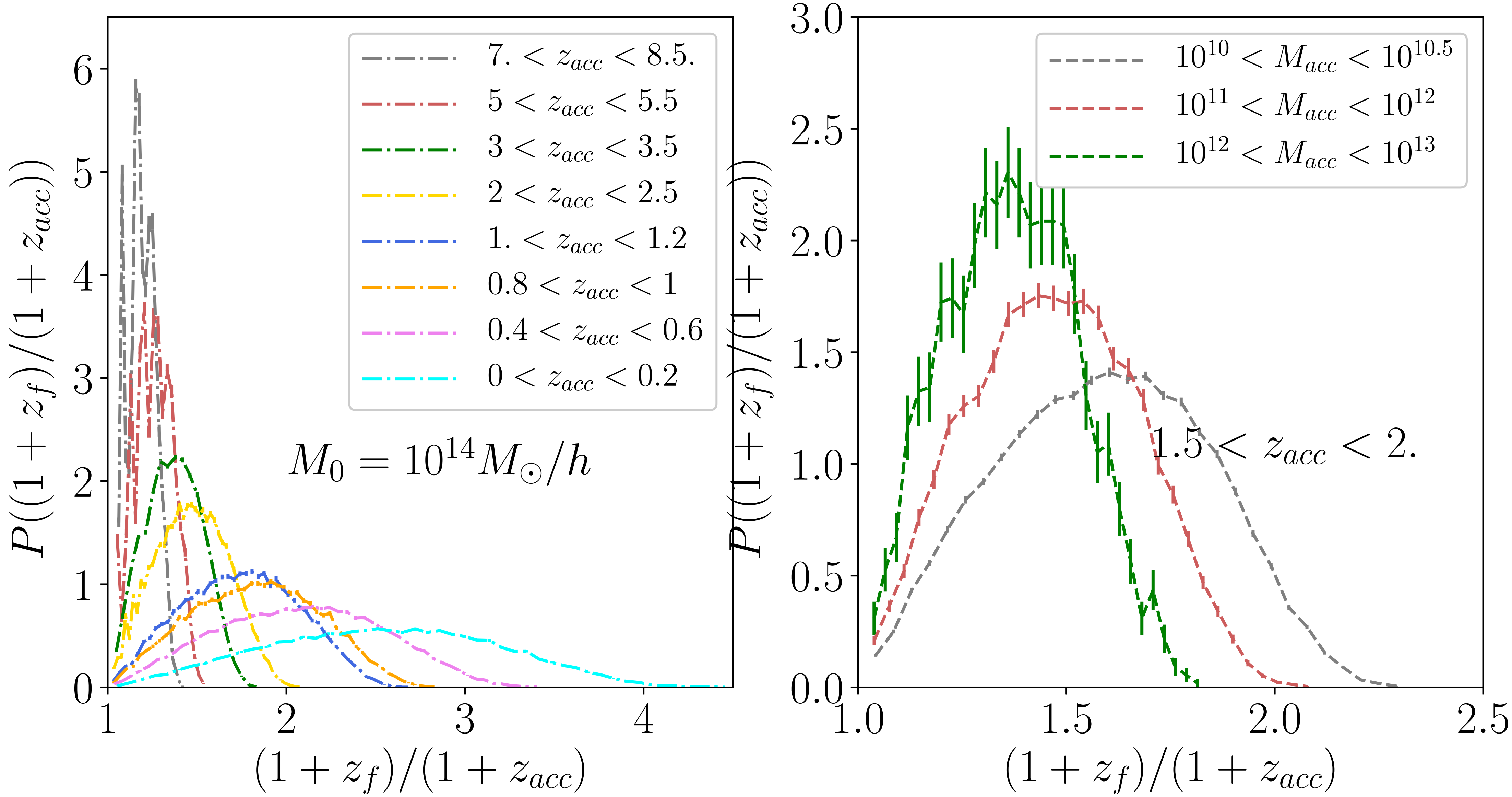
Connection with Two-Phase accretion



Comparison with distinct halos



How about EPS merger trees?



- Merger Tree generated using the code from Parkinson et al 2007

Discussion

- Environmental Dependence?
- understanding satellites and central galaxies: SFR, color, etc?
- Age Matching

Dependence of Halo Bias on Mass and Environment

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Abstract

The simplest analyses of halo bias assume that halo mass alone determines halo clustering. However, if the large scale environment is fixed, then halo clustering is almost entirely determined by environment, and is almost completely independent of halo mass. We give a careful calculation for this dependence in both Lagrangian and Eulerian space. And we further show how this is related to Assembly Bias.

Bias of Constrained Region

Consider the initial density field, smoothed with several scales R_h, R_e and R_0 which correspond to the scale associated with halo formation, the scale on which the environment is defined, and the scale on which the bias factor is measured. Note $R_h < R_e < R_0$.

Let $S_e \equiv \langle\Delta_e^2\rangle$. The probability of being centered on a region(smoothed with R_e) with overdensity Δ_e is $p(\Delta_e) = \exp(-\Delta_e^2/2S_e)/(\sqrt{2\pi S_e})$. **Thus the constrained bias can be defined as**

$$\langle\Delta_0|\Delta_e\rangle \equiv b_e\,\langle\Delta_0\Delta_e\rangle \qquad \text{where} \quad b_e \equiv \Delta_e/S_e. \tag{1}$$

Take additional constraints on small scale overdensity:

$$\langle\Delta_0|\Delta_e,\Delta_h\rangle = \langle\Delta_0|\Delta_e\rangle + \langle\Delta_0|\Delta_{h|e}\rangle \tag{2}$$

when $R_0 \gg R_e$ and $R_e \gg R_h$, then $\langle\Delta_0\Delta_h\rangle \ll \langle\Delta_0\Delta_e\rangle$. **In this limit, $\langle\Delta_0|\Delta_e,\Delta_h\rangle \to \langle\Delta_0|\Delta_e\rangle$: the constraint on Δ_h is irrelevant. This happens especially when sharp-k filter is adopted.**

Take additional constraints of small scale overdensity plus its derivatives:

In more general case(not with sharp-k filter), following Musso & Sheth (2014), the derivatives of Δ_h also matter.

$$\langle\Delta_0|\Delta_e,\Delta_h,\Delta_h'\rangle = \langle\Delta_0|\Delta_e\rangle + \langle\Delta_0|\Delta_{h|e}\rangle + \langle\Delta_0|\Delta_{h'|he}\rangle \tag{3}$$

We show in the work that the first term on the right hand side dominates especially when $R_h \ll R_e \ll R_0$.

Dynamical Evolution with Excursion Set Approach

We aim to justify the above discussion in Lagrangian space survives non-linear evolution, and we want to derive the Eulerian bias given the environment.

Analytic Results

The gist of the argument is that Eulerian statistics on scale V are related to Lagrangian statistics on scale M(Sheth, 1998), the mapping between the Eulerian density δ_V on scale V and the Lagrangian density Δ_M on scale M is

$$\frac{\Delta_{\rm M}}{\delta_c} = 1 - (1+\delta_{\rm V})^{-1/\delta_c}. \tag{4}$$

Since m and δ_e constraints correspond to simple constraints in Lagrangian space, the mean Eulerian density δ_0(on scale V_0) given that the Eulerian cell is centered on a region with δ_e (on scale V_e) which itself is centered on a halo of mass m can be given once $\langle\delta_0|\Delta_e,m\rangle$ is known, i.e.

$$\langle\delta_0|\delta_e,m\rangle \Leftrightarrow \langle\delta_0|\Delta_e,m\rangle. \tag{5}$$

On large Eulerian scales V_0 we expect $\delta_0 \ll 1$, and hence $\Delta_0 \approx \delta_0$. In this limit, we expect

$$\langle\delta_0|\delta_e,m\rangle \approx \langle\Delta_0|\Delta_e\rangle + \langle\Delta_0|\Delta_{h|e}\rangle \tag{6}$$

where $\langle\Delta_0|\Delta_e\rangle = \Delta_e\,\langle\Delta_0\Delta_e\rangle/\langle\Delta_e^2\rangle$ dominates. This would make

$$b_{\rm e}^{\rm E} = \frac{\Delta_e}{\langle\Delta_e^2\rangle} = \frac{\delta_c[1-(1+\delta_e)^{-1/\delta_c}]}{S[\bar\rho V_e(1+\delta_e)]}, \tag{7}$$

which is the expression in Abbas & Sheth (2007). **Comparison with equation (1) shows explicitly that, in this limit, the Eulerian bias is like the Lagrangian one provided that one correctly re-scales the density *and* volume.**

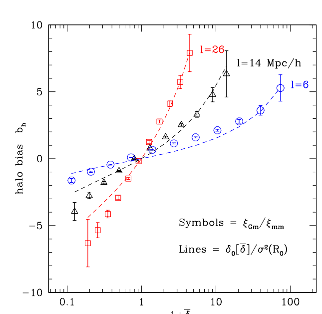


Figure 1: halo bias as a function of environment measured from N-body Simulations. Dashed lines are equation 7. Credit: Pujol et al. (2017)

Reference

Abbas U., Sheth R. K., 2007, MNRAS, 378, 641

Musso M., Sheth R. K., 2014, MNRAS, 443, 1601

Pujol A., Hoffmann K., Jiménez N., Gaztañaga E., 2017, A&A, 598, A103

Sheth R. K., 1998, MNRAS, 300, 1057

Dynamical Evolution with Excursion Set Approach

Monte-Carlo Realization

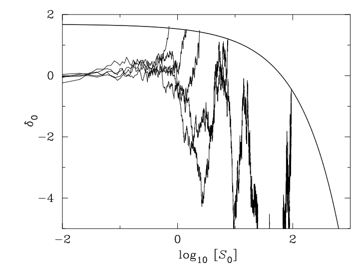


Figure 2: Illustrative Lagrangian trajectories, in the space of overdensity δ_0 versus smoothing scale S_0, that are absorbed by the barrier which represents the mapping from Lagrangian to Eulerian space (c.f. equation 4). Credit: Sheth (1998)

Monte-Carlo Results

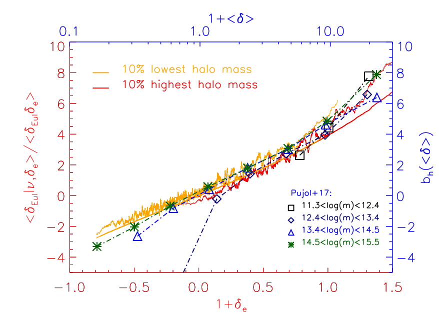


Figure 3: Bias for fixed mass as a function of environment:
The Eulerian bias of halos surrounded by large overdensities is larger; however, at fixed overdensity, bias is the same for all except the most massive halos. Thick smooth curve shows $b_e^{\rm E}$ of equation (7). Data points are measurements in simulations taken from Pujol et al. (2017).

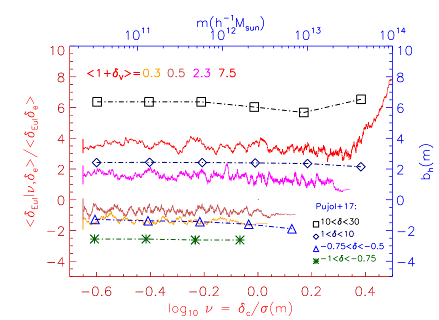


Figure 4: Bias for fixed environment as a function of halo mass:
Denser Eulerian cells are more biased, but this bias is independent of the mass of the halo. The mismatch of the amplitudes between Pujol et al. (2017) and the Monte-Carlo realization are mainly due to the different P(k) and mismatching environmental thresholds adopted. **The bias is determined by the environment, and not by halo mass. And our Monte-Carlo realization has captured the essence of the effect.**

Discussion

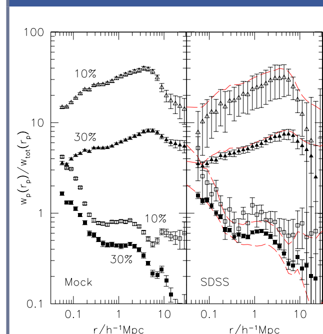
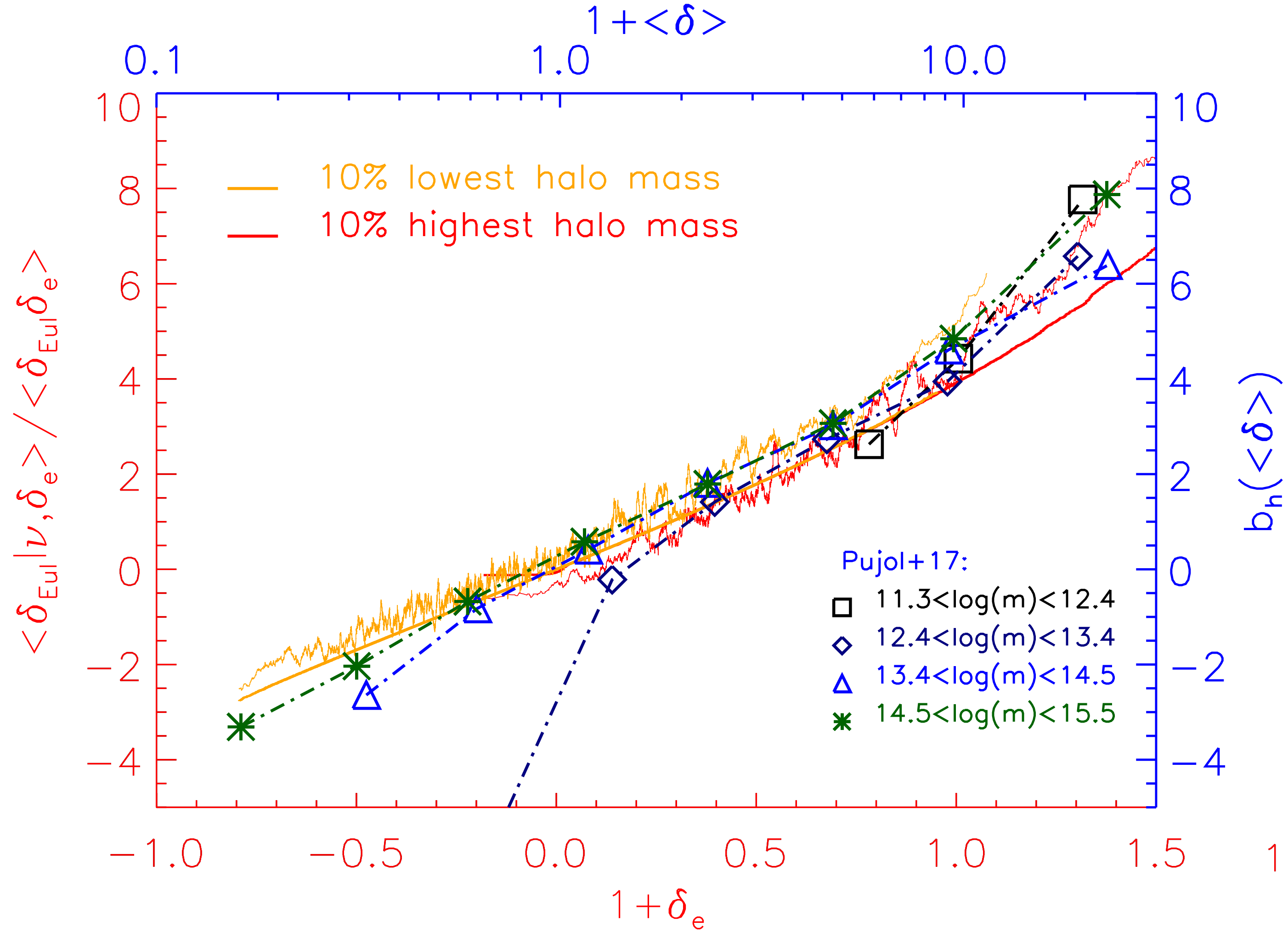


Figure 5: Galaxy clustering in varying environments. Open and filled triangles are objects in the 10% and 30% densest regions, filled and open squares show similar measurements but in the least dense regions. Left panel is the for the mock catalog built with HOD. Right panel is for the SDSS catalog, with the results measured in the mock over-plotted using red dashed lines. Credit: Abbas & Sheth (2007)

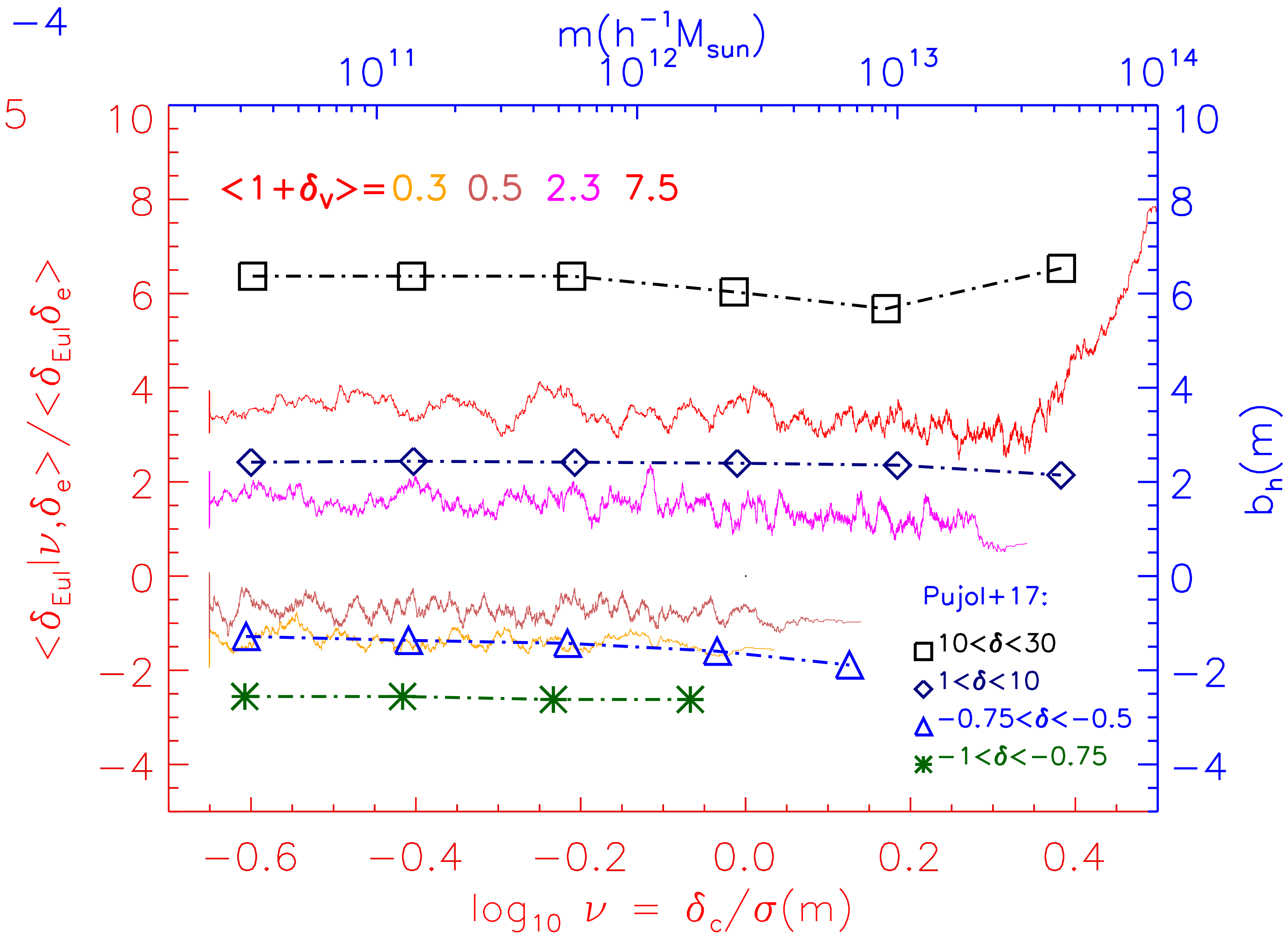
Studies of Abbas & Sheth (2007) show that bias(r) measured from Mock catalog matches well with the one in the data. **I. e. HOD depends only on mass, and not on environment.**

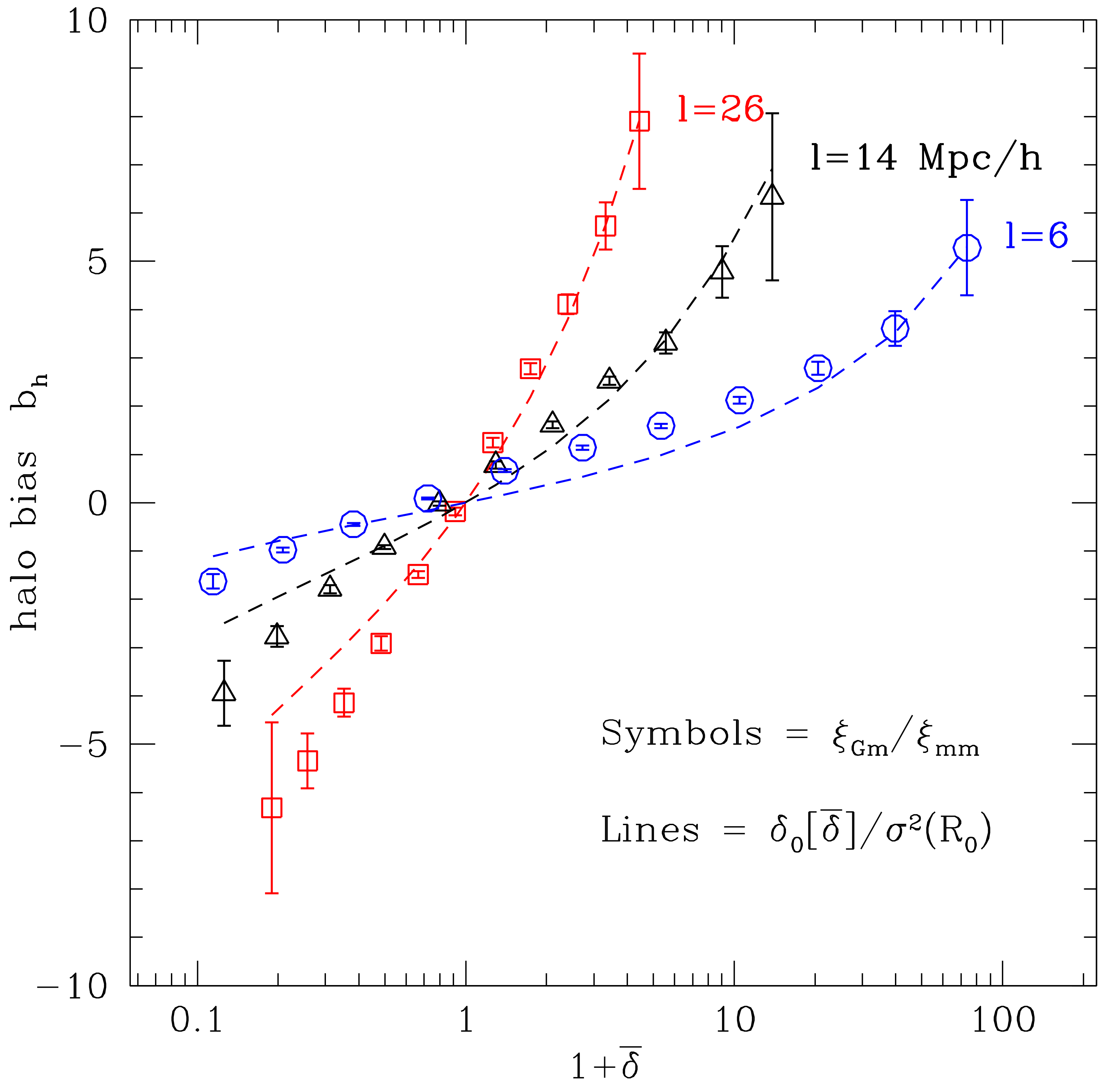
Dependence of halo bias on mass and environment



- For fixed halo mass, bias is totally determined by the environment

- For fixed environment, bias is almost independent of mass





Pujol et al 2017

Thanks!