

Beyond Assembly Bias

Exploring Secondary Halo Biases for Cluster-size Halos

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5/17/2017 “Quantifying and Understanding the Galaxy-Halo Connection” @ KITP

Two takeaways

(in its strict definition)

($M_{\text{vir}} > 10^{14} M_{\odot}/h$)

1. Halo assembly biasTM does NOT exist for cluster-size halos; however, there exist other secondary halo biases.

(concentration, spin, subhalo occupation, average subhalo distance, etc)

2. Correlation between two properties has basically NOTHING to do with whether these two properties exhibit similar secondary bias (and vice versa).

Important implication for studying galaxy assembly bias / secondary halo bias

Presentation will continue after this ad...

What I do: [learn more at yymao.github.io]

- secondary halo bias / galaxy assembly bias
- cosmological/zoom-in N -body simulations
- empirical models of the galaxy-halo connection (e.g., flexible SHAM)
- mock catalogs for surveys (e.g., DESCQA)
- dwarf satellite galaxies (e.g., SAGA, MagLiteS)
- dark substructures / nature of dark matter

This talk is mostly about:

- [[1705.03888](#)] “Beyond Assembly Bias”, with Zentner & Wechsler

Other relevant works/talks:

- [[1705.04327](#)] “The Immitigable Nature of Assembly Bias”
by Villarreal, Zentner, YYM et al.
- [[1611.09787](#)] “Large-scale assembly bias of dark matter halos”
by T. Lazeyras, M. Musso and F. Schmidt. (cf. Titouan’s talk, Friday morning)
- Simon’s talk, Friday morning

What is “assembly bias,” anyway?

Halo bias: halo clustering depends on halo mass

I will use **assembly bias™** to refer to its strict definition

Secondary halo bias (commonly known as halo assembly bias):

At a fixed halo mass, halo clustering depends on a halo property other than mass

Dependence on halo mass definition? See Villarreal+2017

Galaxy assembly bias:

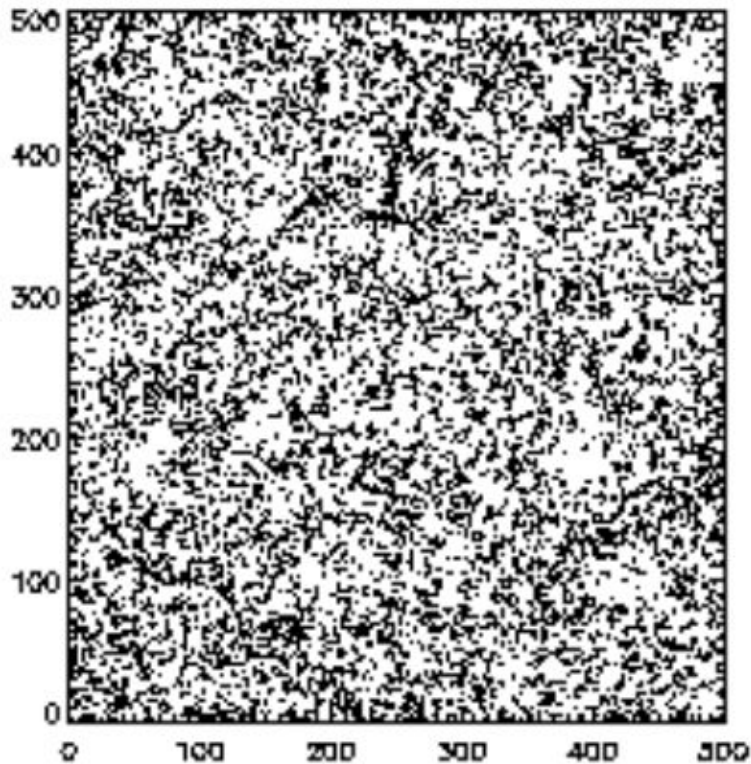
1. Galaxy clustering depends on galaxy property at a fixed halo mass
2. Galaxy clustering depends on galaxy property at a fixed stellar mass
3. Galaxy property (incl. M^*) depends on any halo properties other than halo mass
4. Galaxy property depends on a halo property that exhibits secondary halo bias
5. Galaxy property depends on properties of nearby galaxies (conformity)
6. And more....

Simon and I will lead a discussion next Thursday (5/25), or maybe earlier? :)

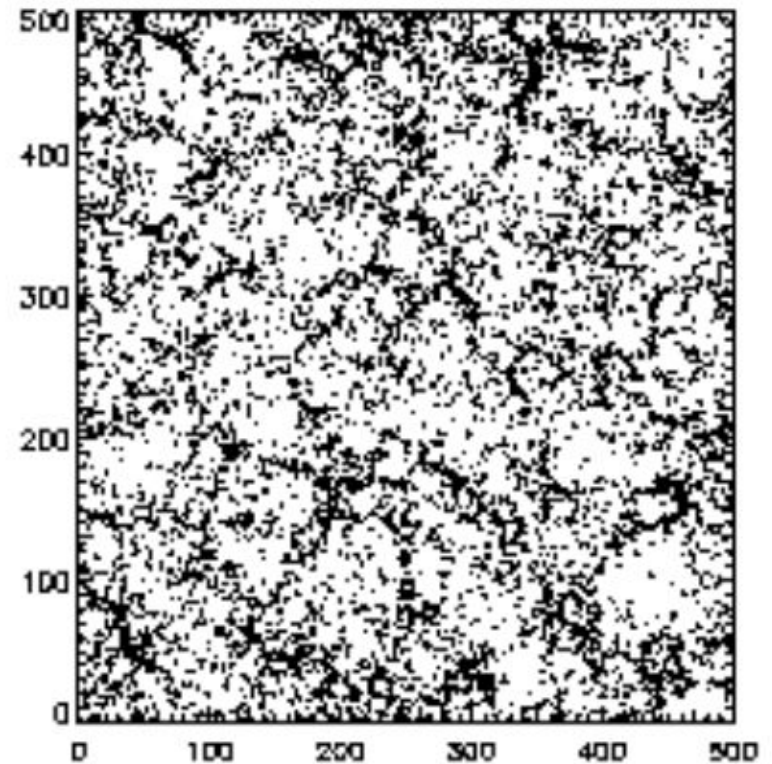
The *classic* halo assembly bias™ as we know it

Gao, Springel & White (2005) show assembly bias™ in Millennium simulation (500 Mpc/h)

10% youngest halos



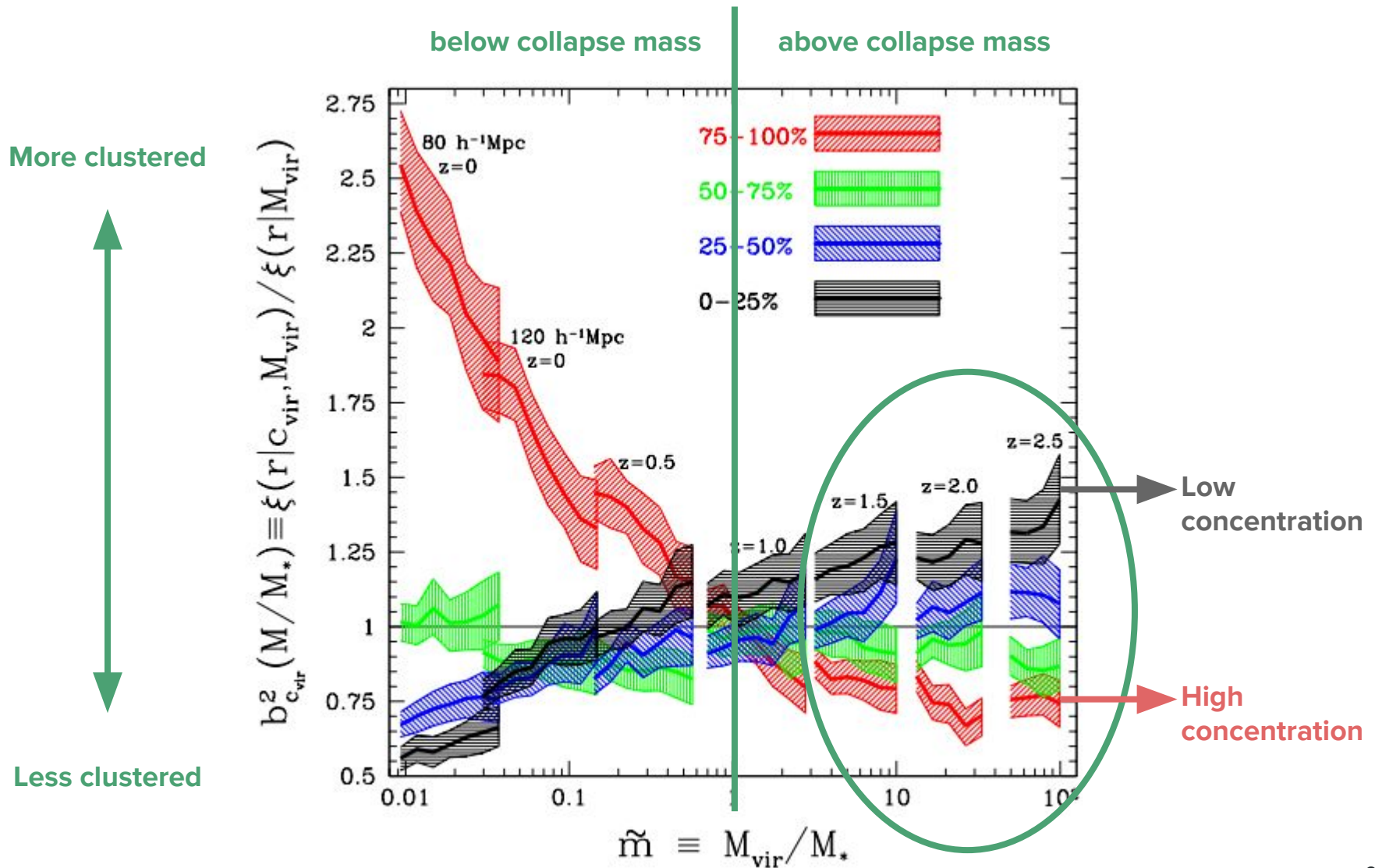
10% oldest halos



Theoretical explanation? See e.g. Sandvik+ 07; Zentner 07; Desjacques 08; Dalal+ 08; Wang+ 2009

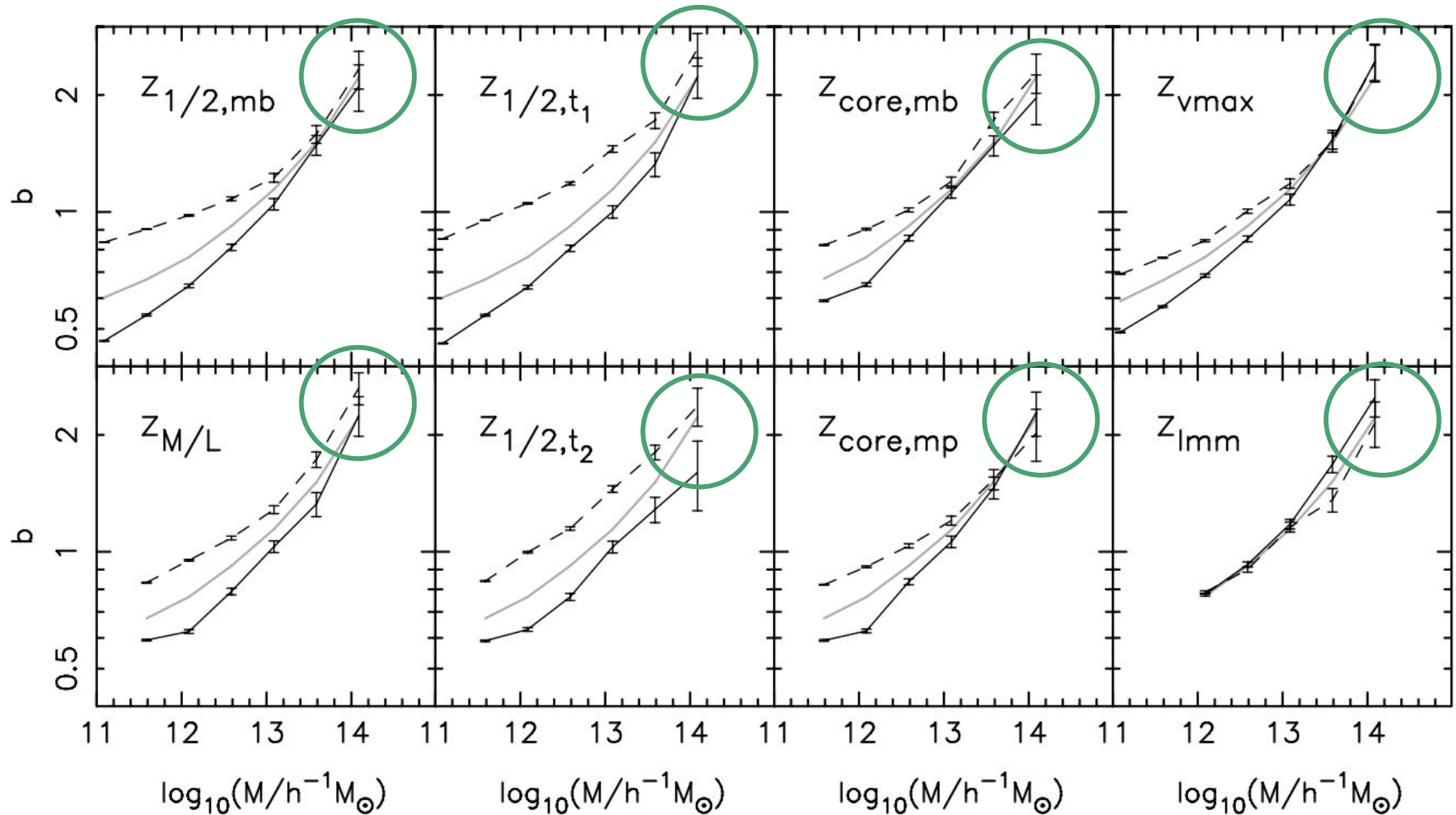
The *classic* halo “concentration” bias as we know it

Wechsler, Zentner et al. (2006) show concentration bias as function of halo mass



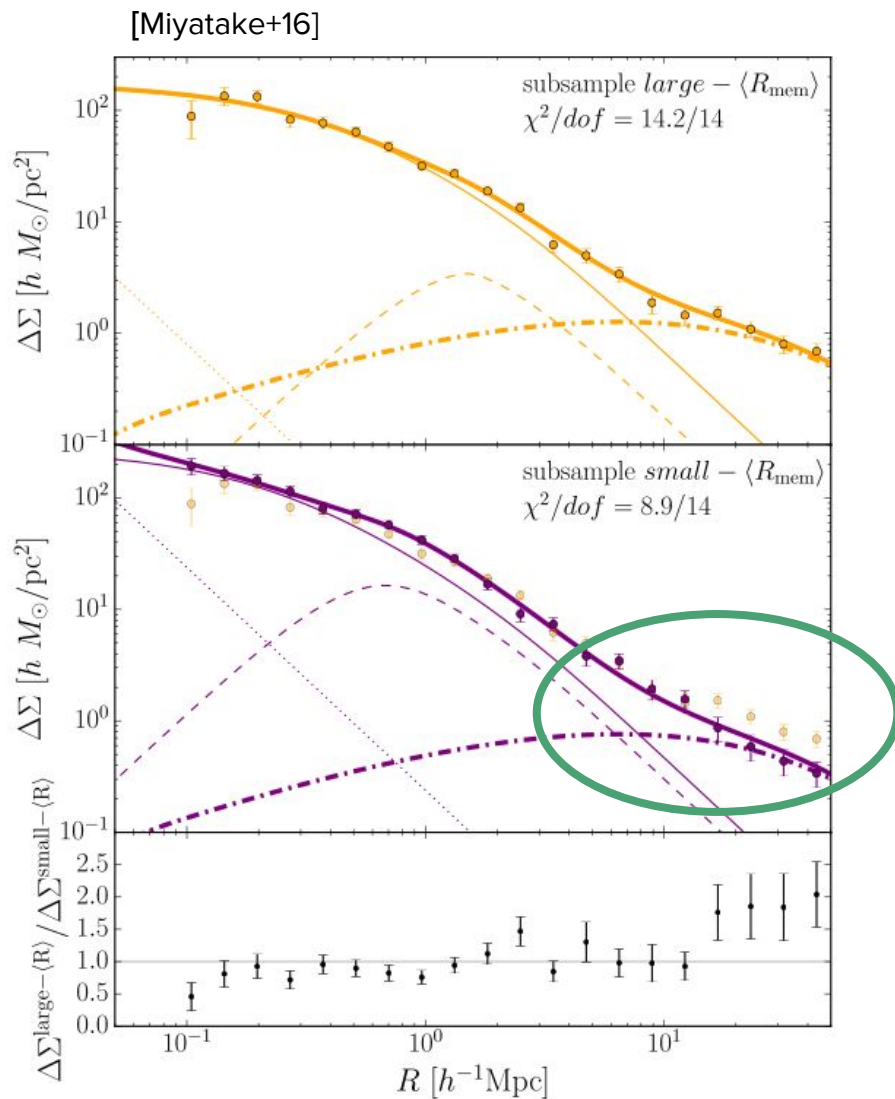
The *classic* halo assembly bias™ as we know it

Li, Mo, van den Bosch & Lin (2007), see also e.g., Gao+2005 and Gao+ 2007



NO significant assembly bias™ above $10^{14} M_{\odot}/h$

On the observational front: R-mem bias?



Have we detected the secondary halo bias signal due to R-mem (average member distance, a.k.a. c-gal) in galaxy clusters?

Maybe?

Miyatake+ 16

More+ 16

Maybe not?

Dvornik+ 17 (talk this session)

Maybe not.

Zu & Mandelbaum 17

Busch & White 17

Surhud's talk on Monday

Projection effects are tricky.

Our approach

- Questions we'd like to answer:
 - Do the lack of assembly biasTM, the inverted concentration bias, and the “R-mem” (c-gal) bias etc. at the cluster scale hold in larger-volume higher-resolution simulations?
 - What are the correlations among these secondary halo properties and how do they interplay with the various secondary halo bias signals?
- Cosmological N -body simulations:
MultiDark Planck 2 (MDPL2, Klypin+16) and Dark Sky Gpc (ds14_b, Skillman+14)
Both are 1 Gpc/h on the side, mass resolution 2-3 times $10^9 M_{\odot}/h$
With Rockstar-Consistent Trees (Behroozi+13ab) halo catalogs
- Use present-day ($z=0$) halos
Select all distinct halos (host halos) with a virial mass ($\Delta \approx 100c$) above $10^{14} M_{\odot}/h$

“Contains 100% pure halos. No artificial galaxies added”

6 secondary properties & their mass-normalized marks

Mass-normalized mark value

0.0

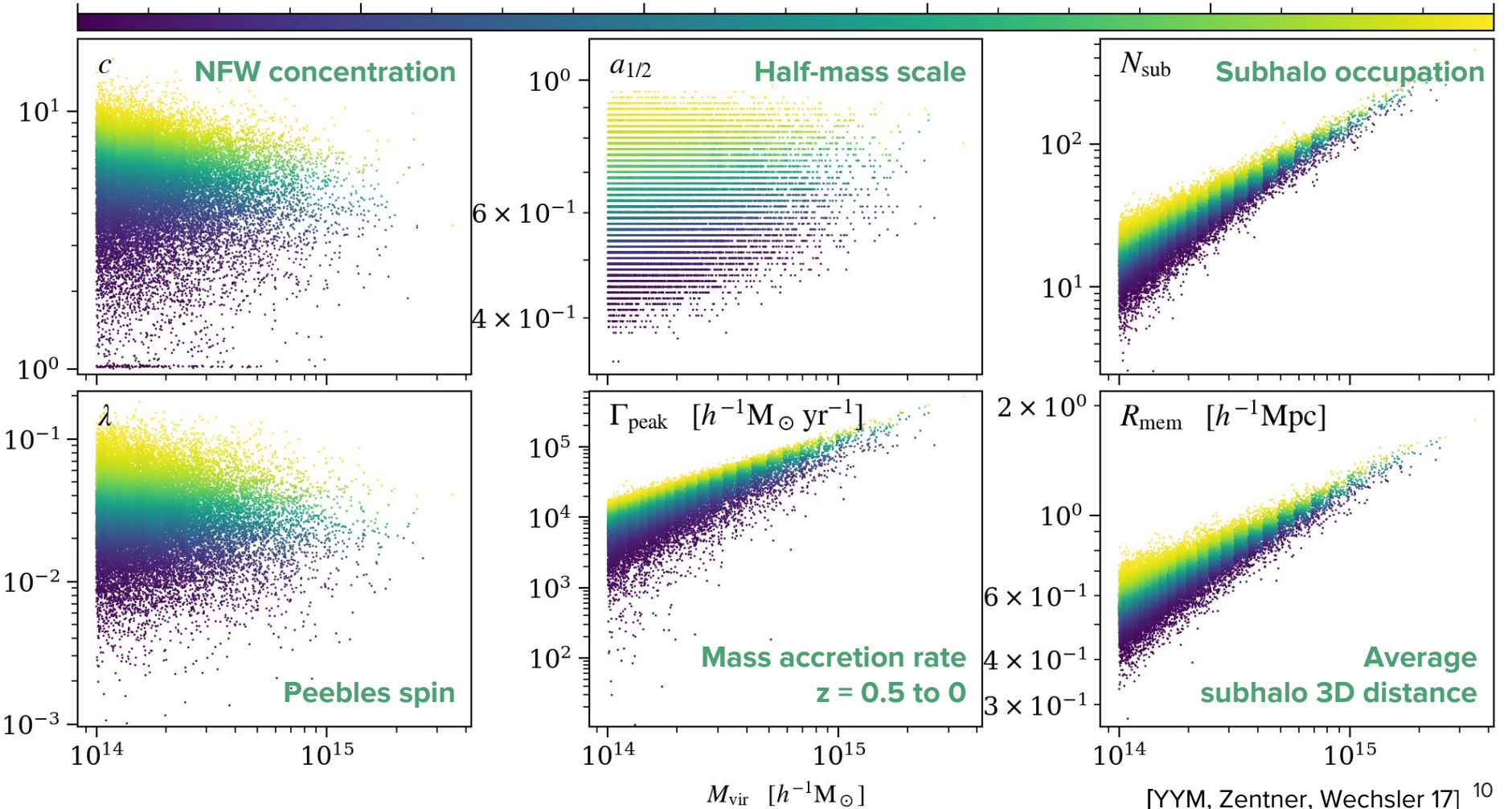
0.2

0.4

0.6

0.8

1.0



Secondary bias signals (bias function)

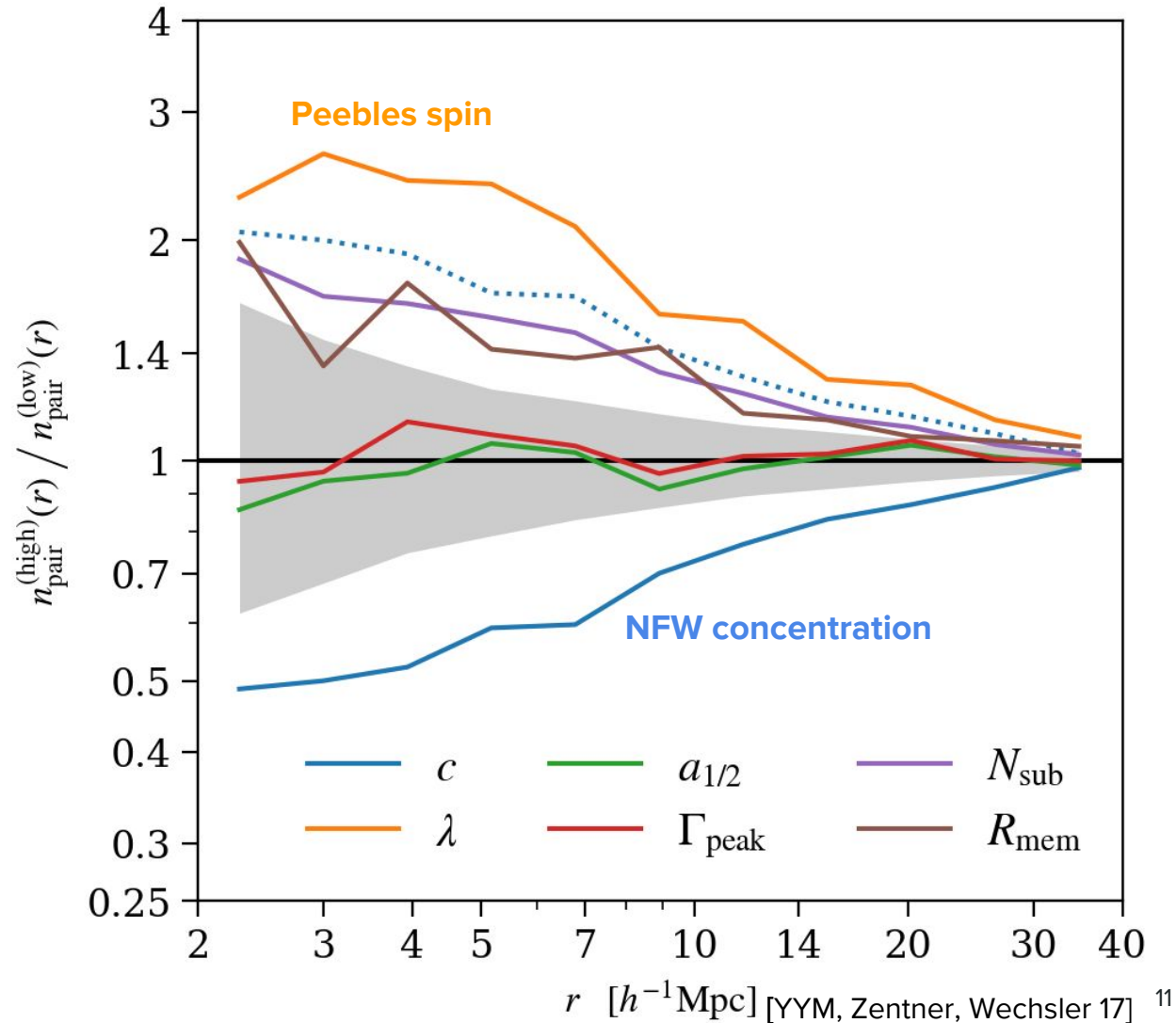
High-mark halos *more* clustered



Ratio b/w the pair-counting function of 50% high-mark halos to that of 50% low-mark halos



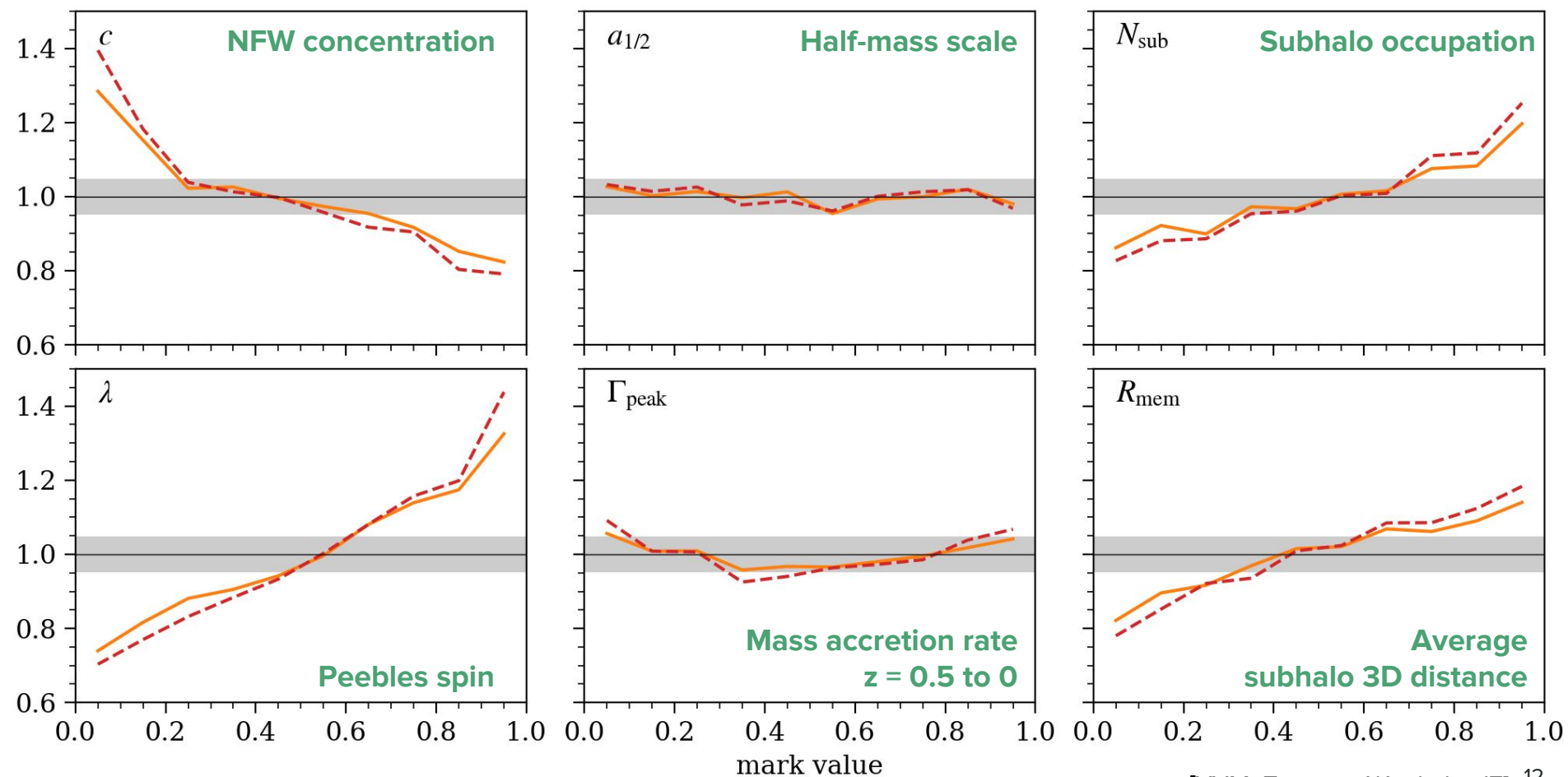
High-mark halos *less* clustered



Secondary bias signals (mark distribution)

Demography of paired halos:

mark distribution for (cluster-size) halos that have a neighbor halo within 10 Mpc/h



‘Kay, all sounds good...

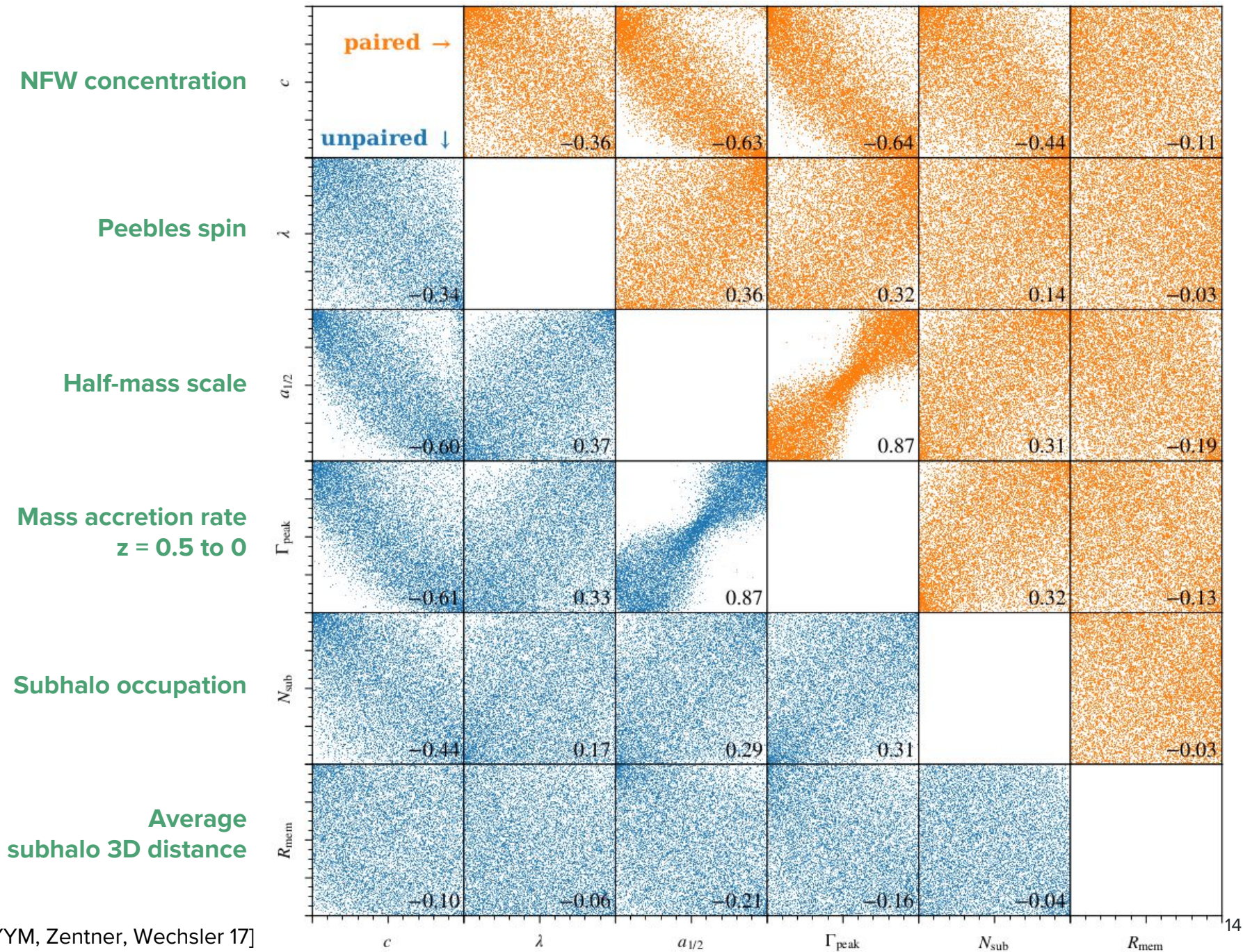
Consistent with previous studies.

No significant assembly biasTM at cluster scale.

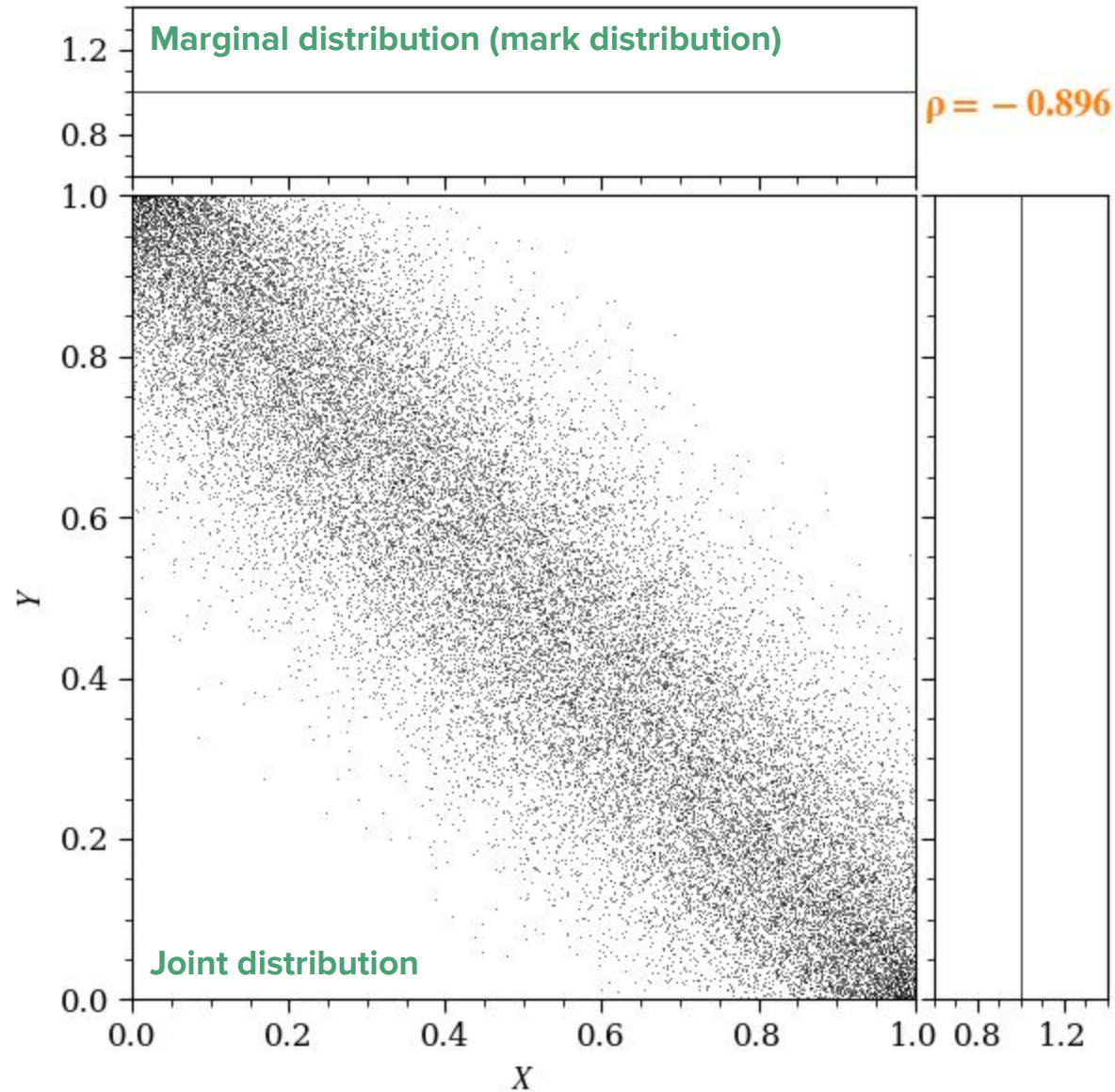
Secondary biases due to concentration, spin, subhalo occupation, and average subhalo distance.

Wait, isn't halo formation time correlated with halo concentration?

And also with spin, subhalo occupation, and average subhalo distance?

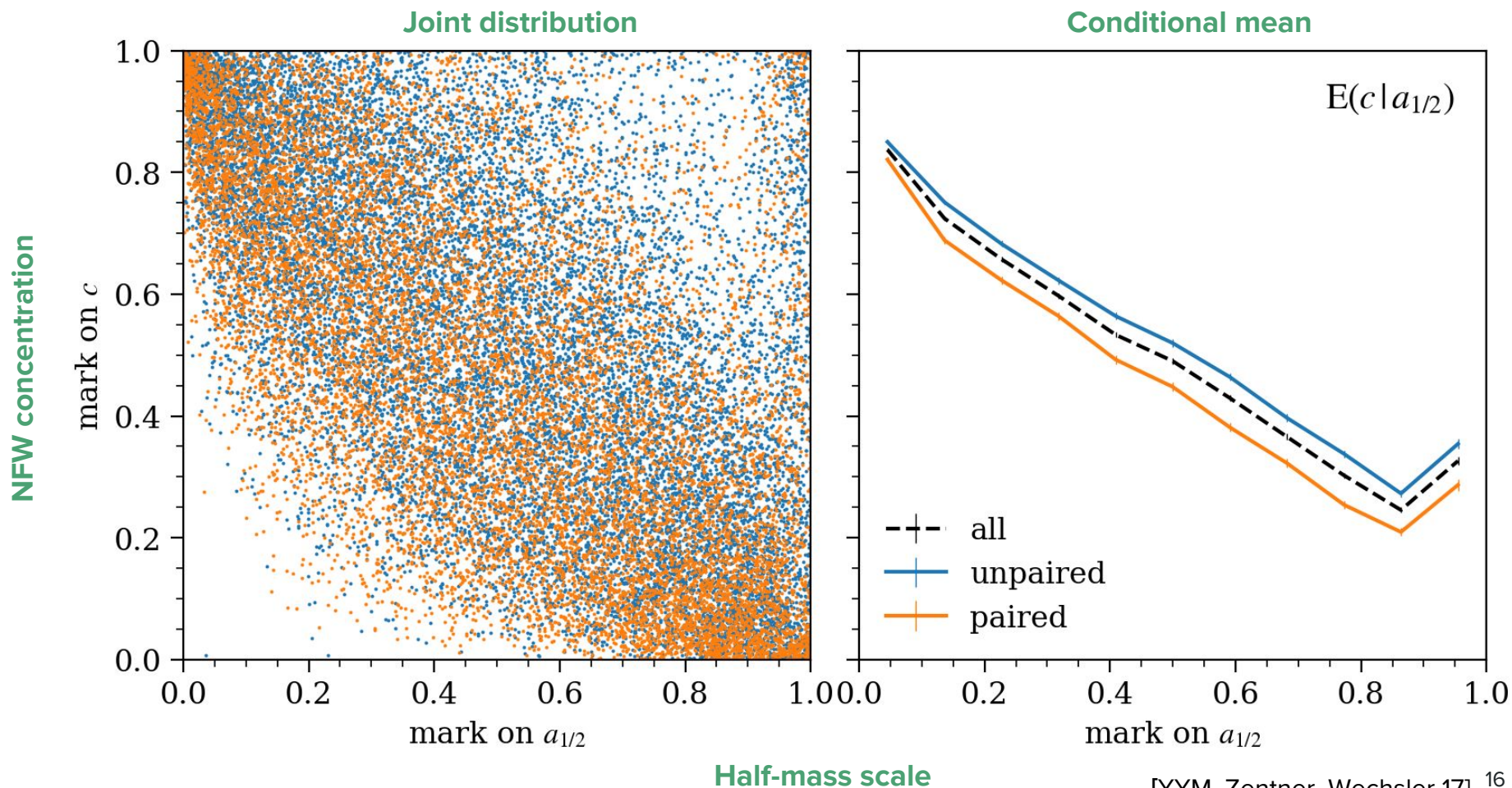


Highly (anti)correlated X and Y exhibit different bias signal (like concentration and half-mass scale)

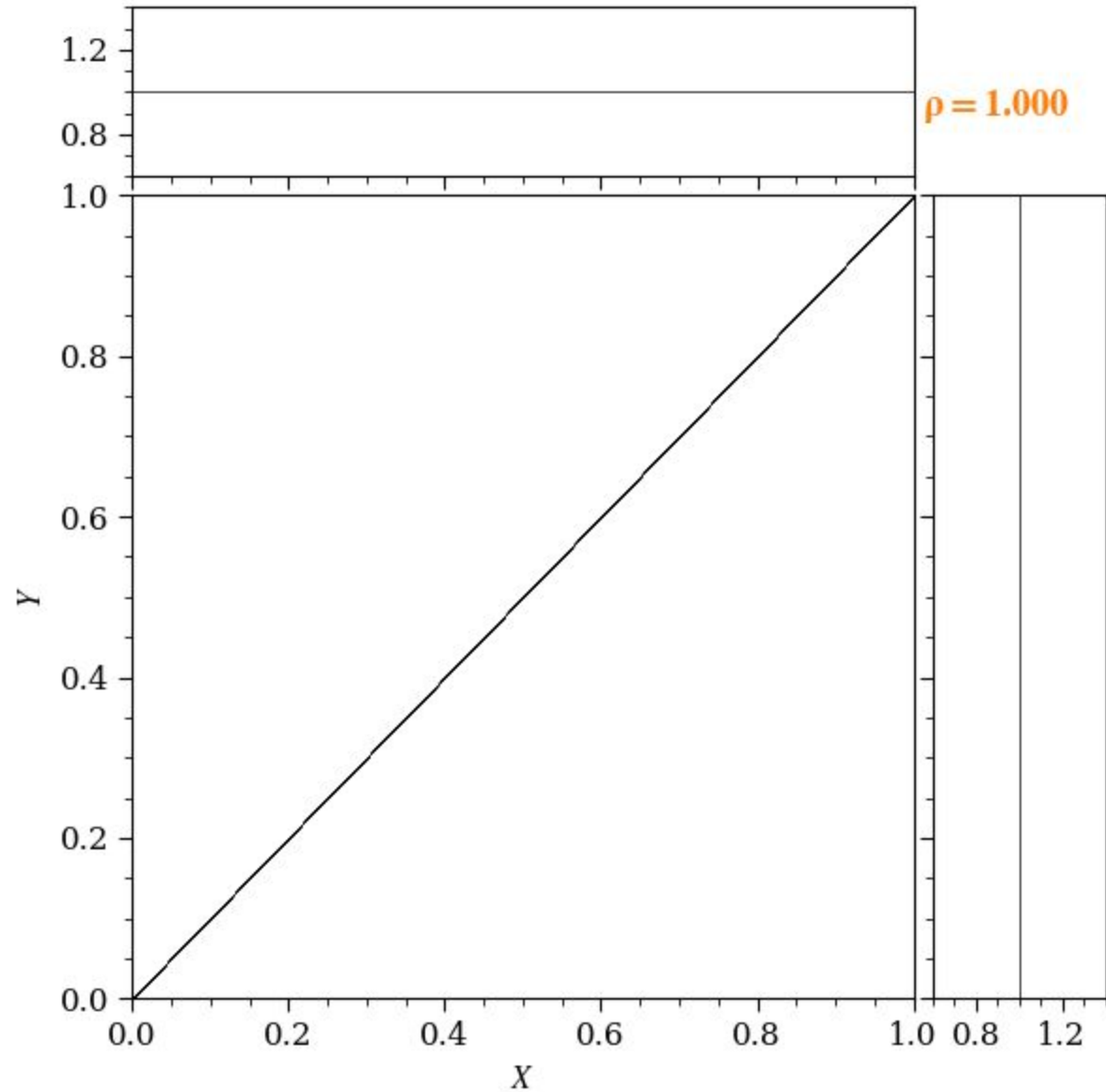


The case of concentration v. half-mass scale

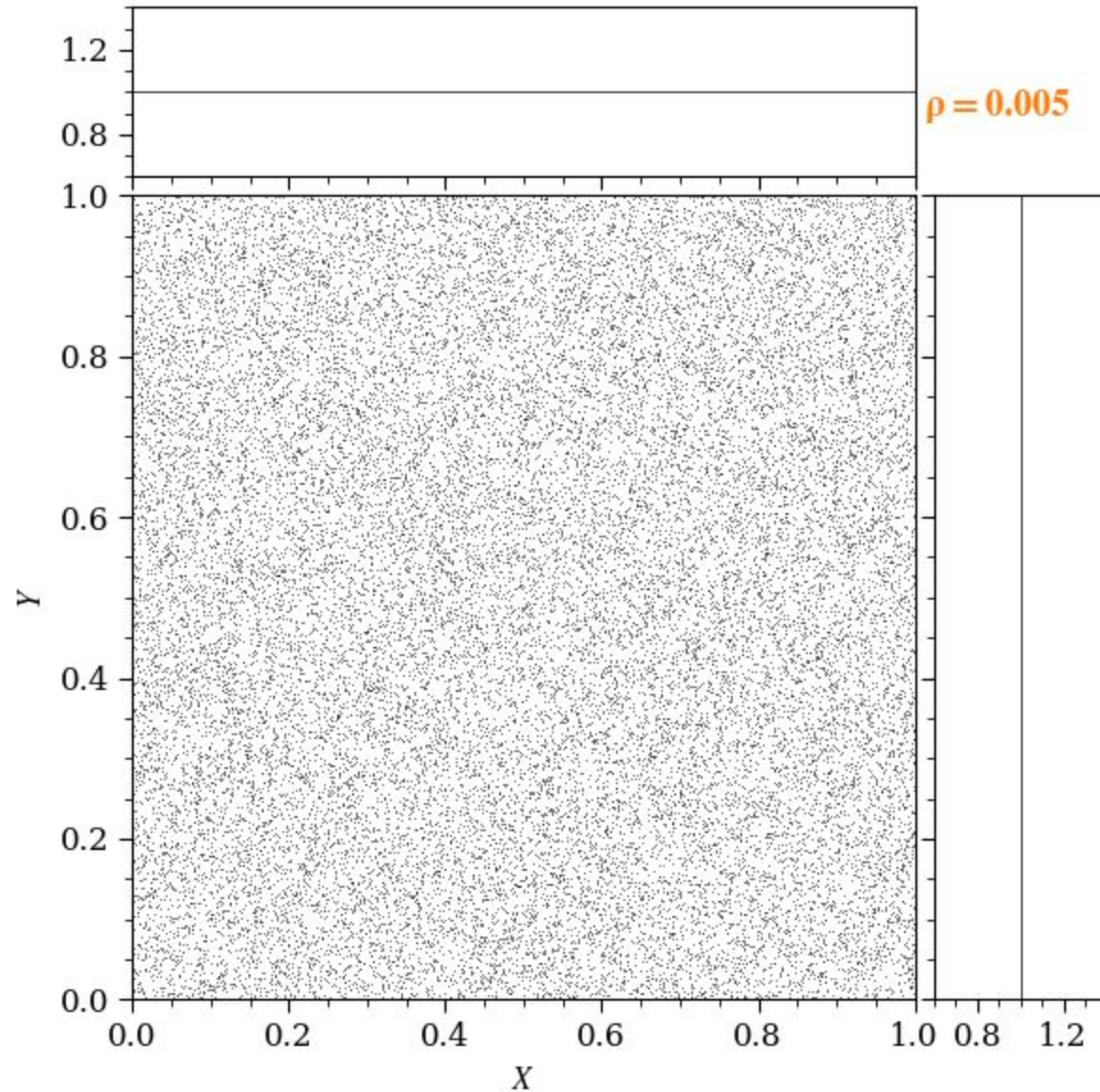
The conditional distribution shifts for paired and isolated halos in a way that concentration and half-mass scale result in different secondary halo bias signals



Perfectly correlated X and Y; both exhibit same bias signal (what people usually have in mind)



Not correlated X and Y; both exhibit same bias signal (like concentration and average subhalo distance)



What do we learn and what's the implication?

Because scatter (even if it's small) exists in the relation of two properties, their correlation does NOT provide information about whether or not they exhibit similar secondary halo biases (and vice versa).

Mathematically speaking, the marginal distributions provide little information about the joint distribution.

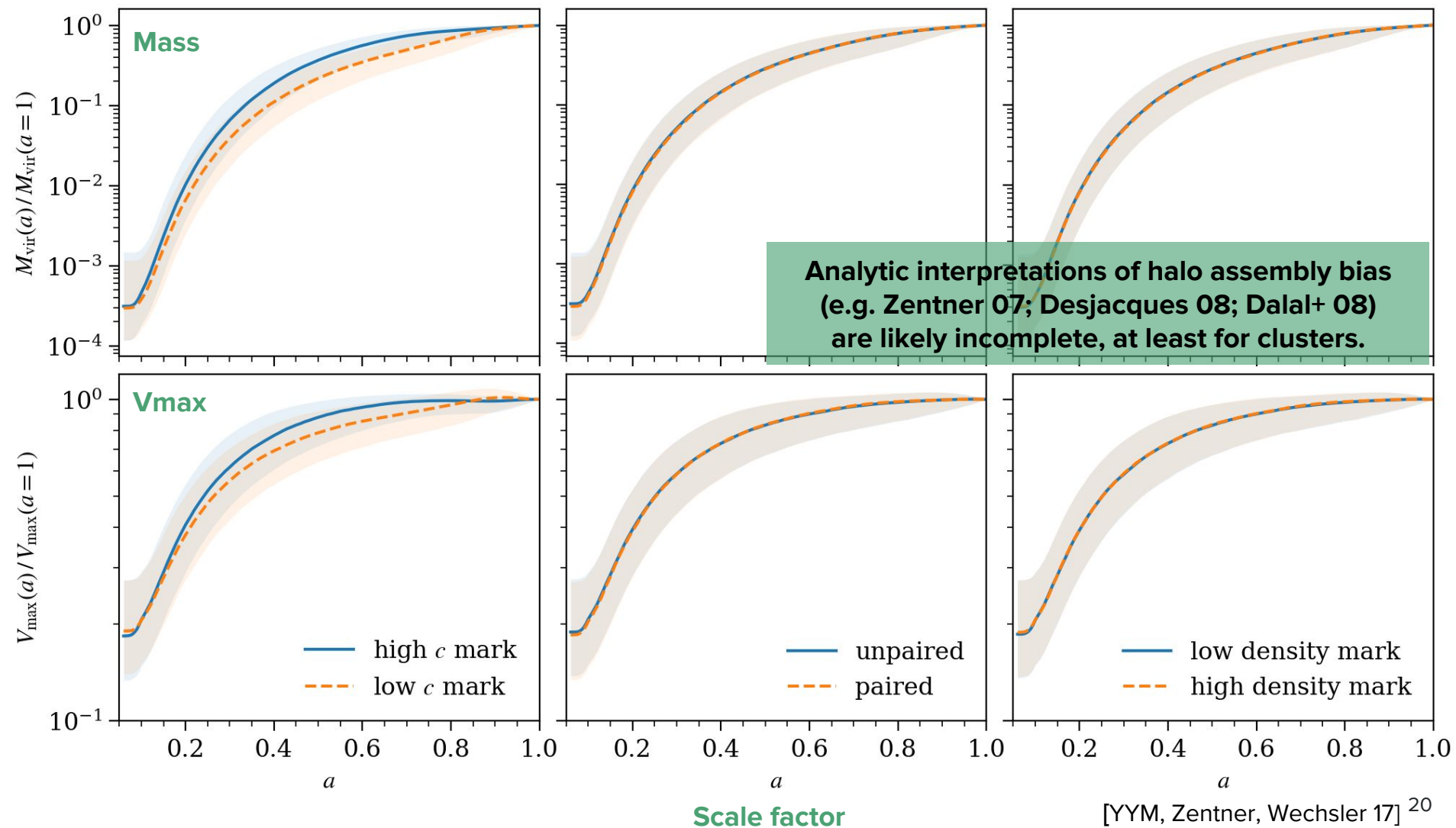
Implications:

- Halo assembly (secondary) bias is NOT halo assembly bias™ **But, like, really?**
- Using a proxy property to study secondary halo bias can be misleading
- The statement “*galaxy property depends on a halo property that exhibits secondary halo bias*” does NOT imply that “*galaxy clustering depends on galaxy property at a fixed halo mass*” (and vice versa)

A cautionary tale for studying galaxy assembly bias! What's the way forward?

Is there really no assembly bias™ at cluster scale?

Full, stacked, main-branch **halo assembly history** for halo mass (top) and maximal circular velocity (bottom), split by concentration (left), paired or isolated (middle), and 10 Mpc/h “matter density” (right)



Two takeaways

1. Halo assembly bias™ does *not* exist for cluster-size halos;

In fact, the full assembly histories for paired and isolated halos are nearly identical

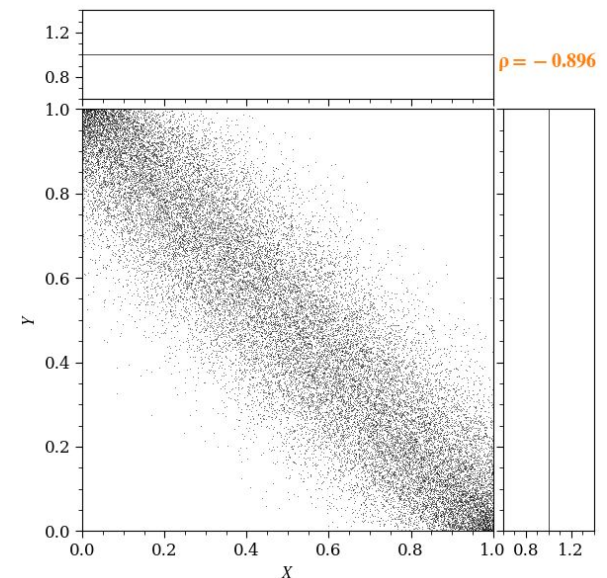
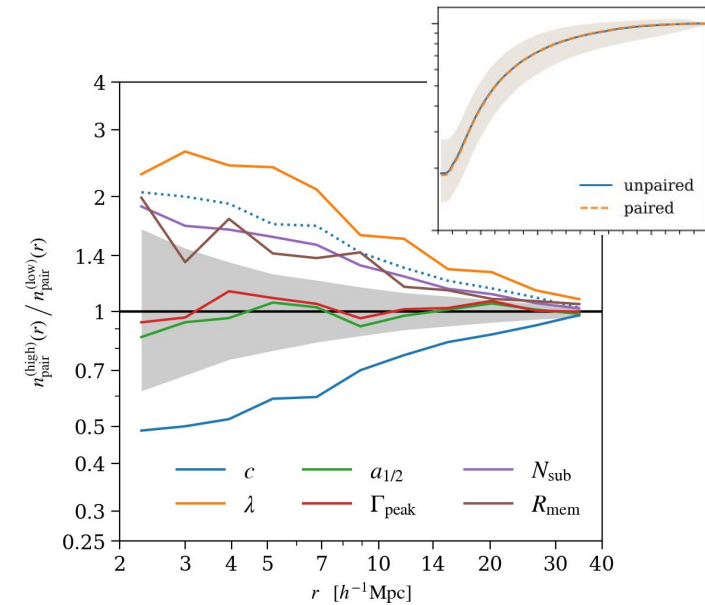
however, there exist other secondary halo biases.

Biases due to concentration, spin, subhalo occupation, average subhalo distance

2. Correlation between two properties has *nothing* to do with whether these two properties exhibit similar secondary bias (and vice versa).

For example the case of concentration v. half-mass scale.

A cautionary tale for studying galaxy assembly bias!



Thank you!

Secondary bias signals (for other 6 *similar* properties)

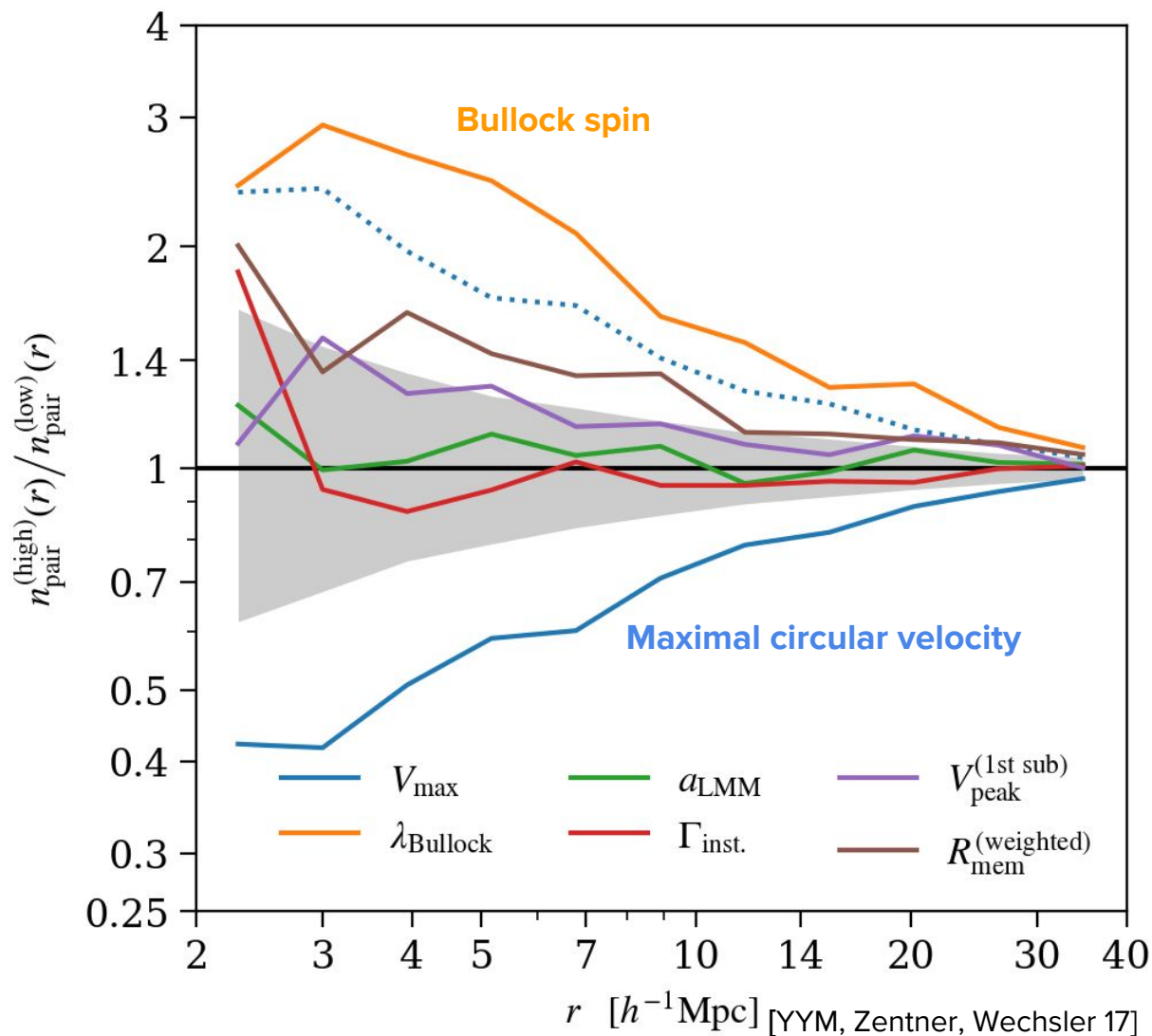
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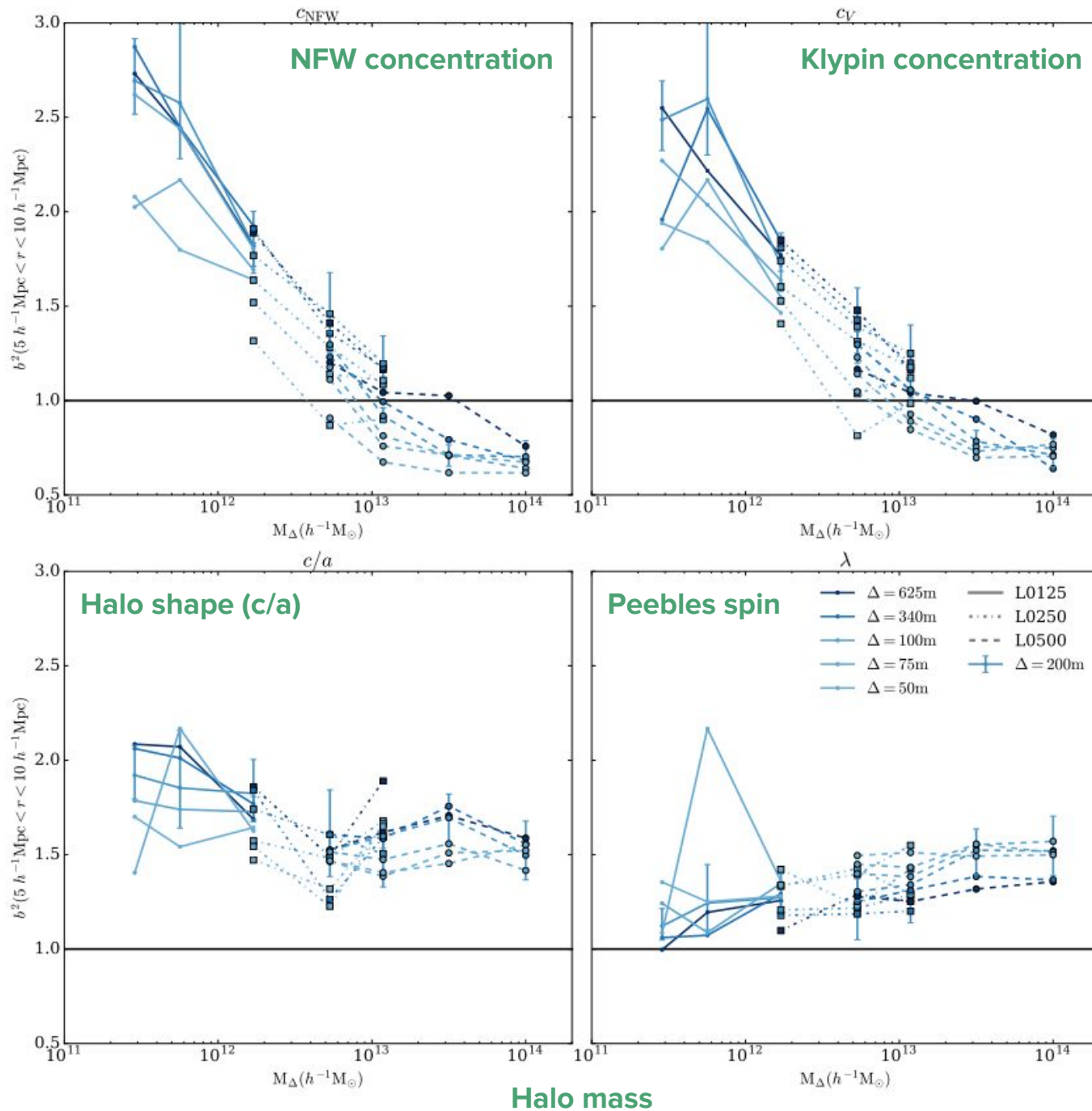
High-mark halos *less* clustered



More clustered



Less clustered



[1705.04327]
“The Immitigable Nature
of Assembly Bias”
by Villarreal, Zentner,
YYM et al.

Halo mass