Cosmological Voids

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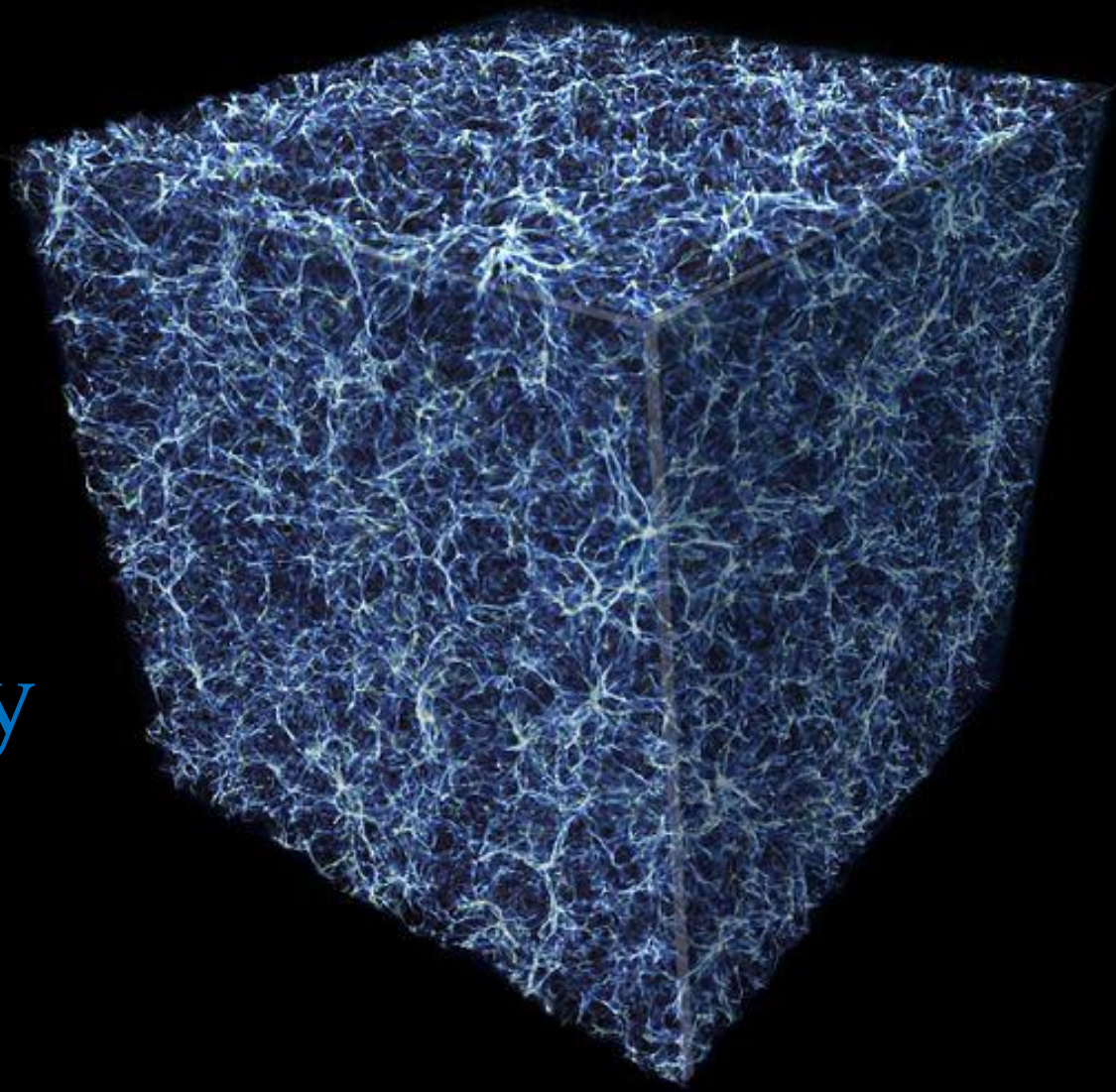
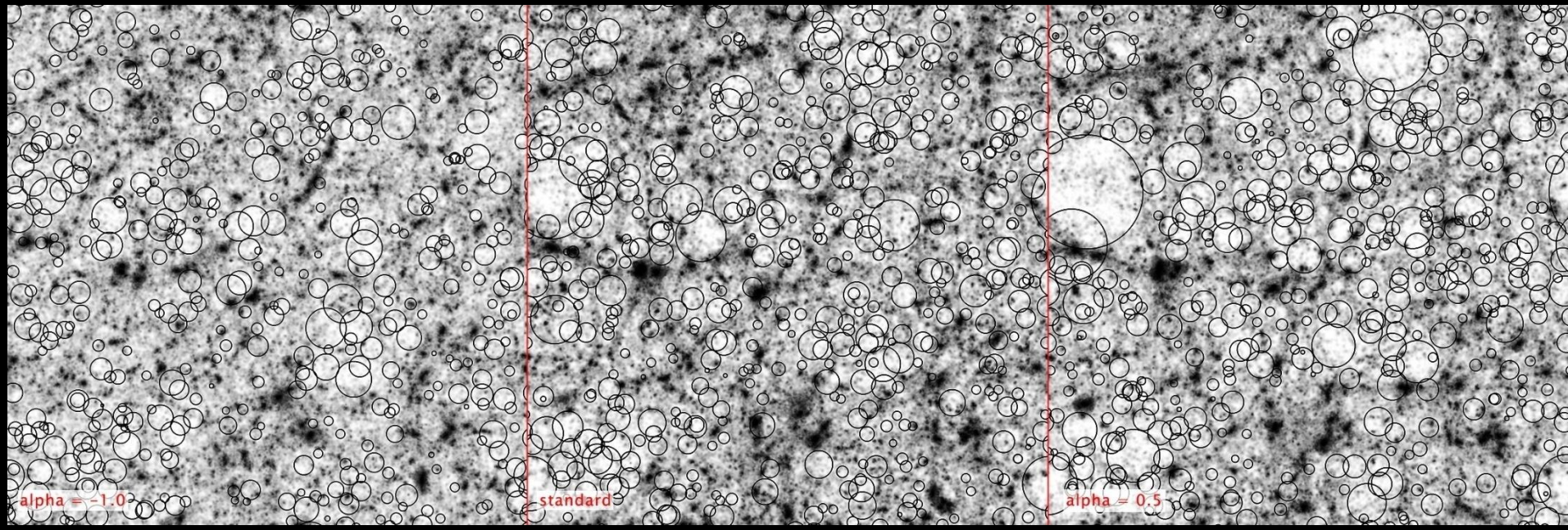
Big Bangle Cosmology



‘Modified’ gravity theories

Martino & Sheth 2009

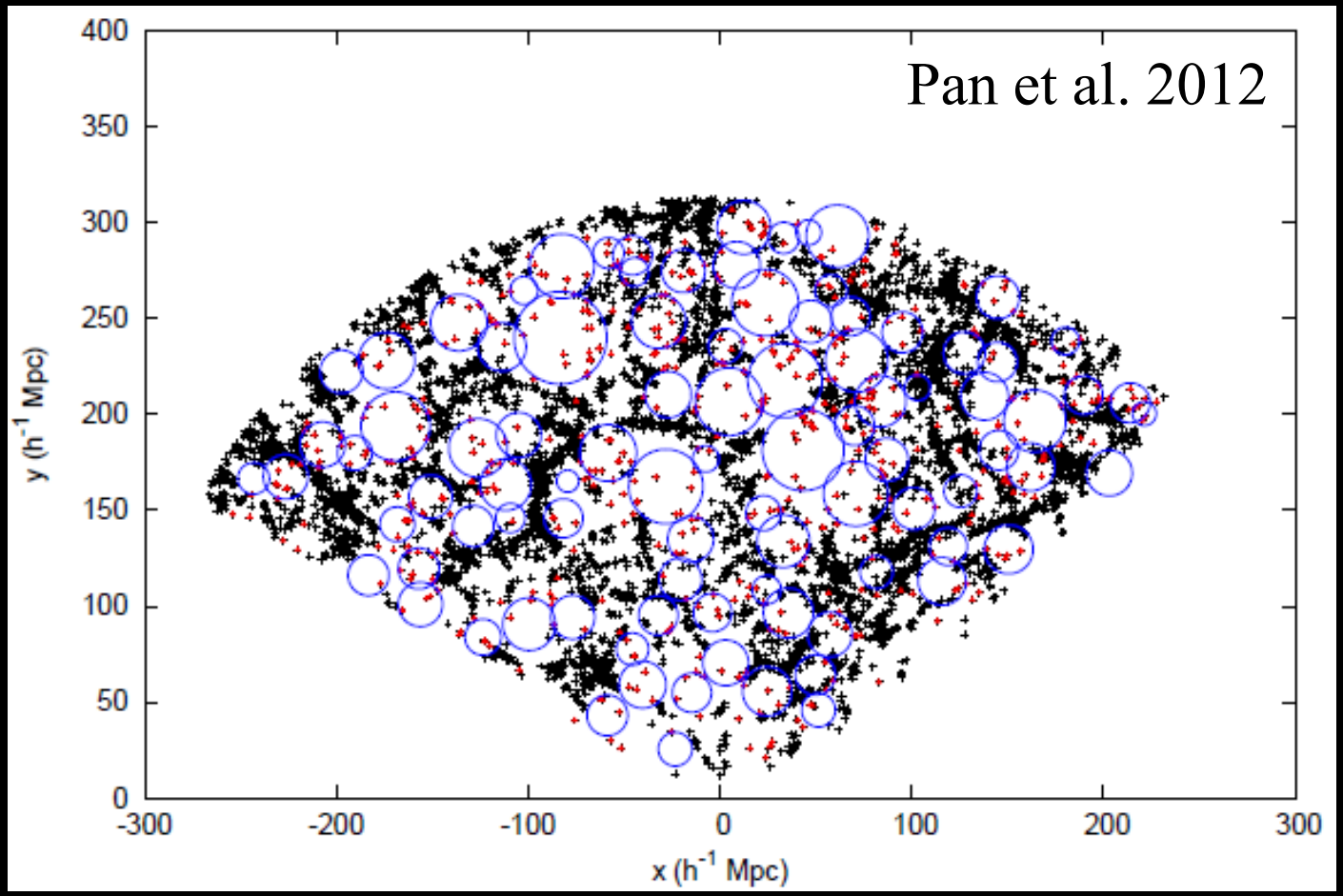


weaker gravity on large scales stronger gravity

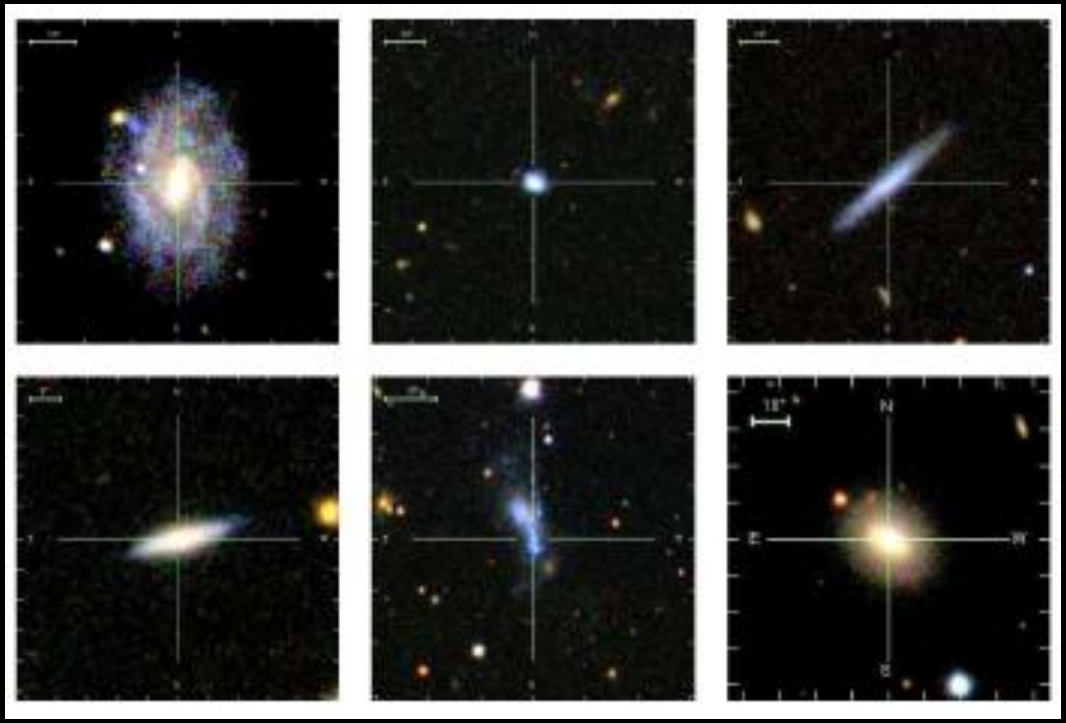
Voids/clusters/clustering are useful indicators

e.g. Zivick et al 2014; Cai et al. 2014; Padilla et al. 2014

Voids in galaxy distribution



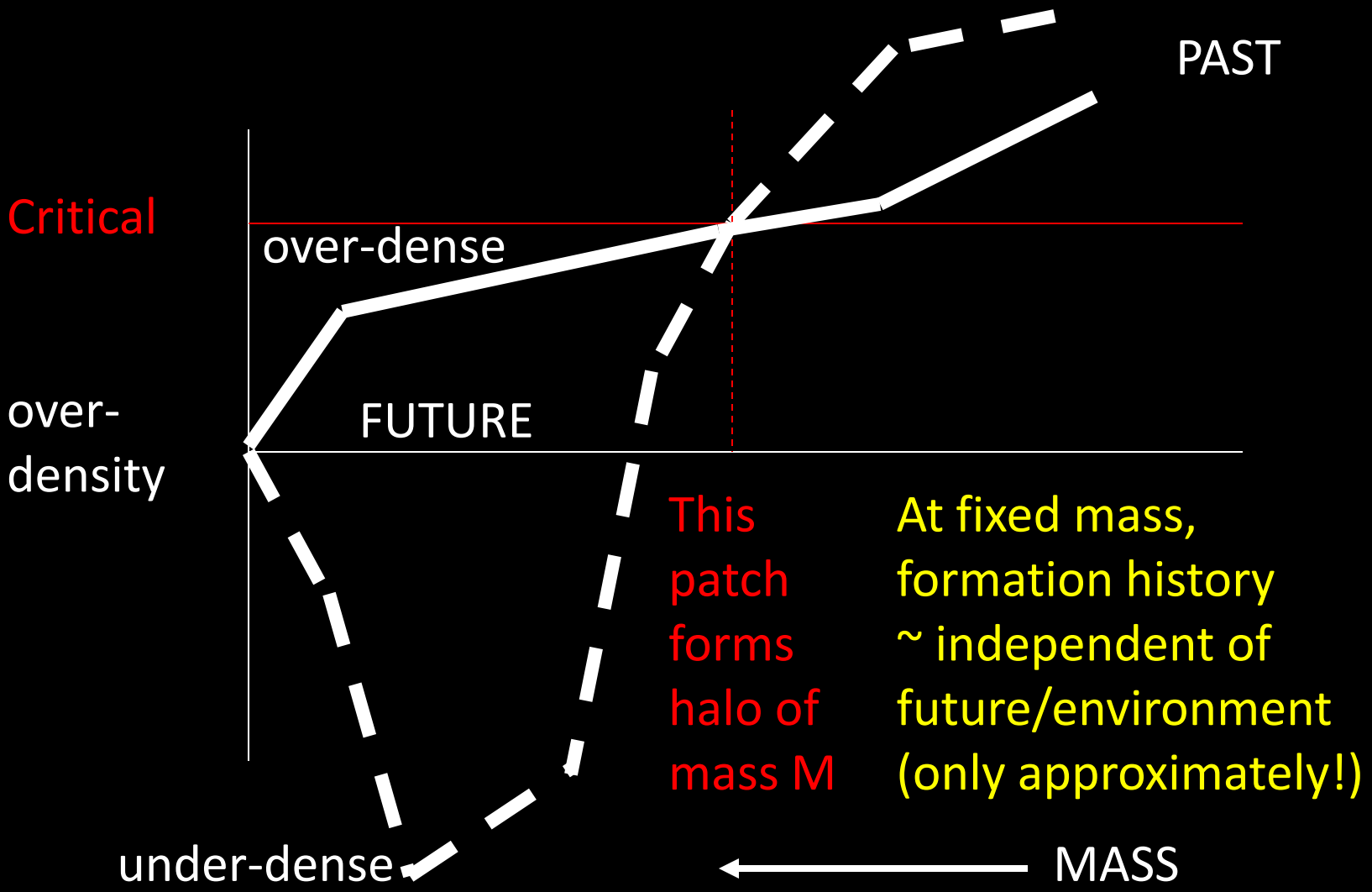
Voids are not ‘void’



Kreckel et al 2014

Void galaxies are gas rich, low luminosity, blue disk galaxies, with optical and HI properties that are not unusual for their luminosity and morphology

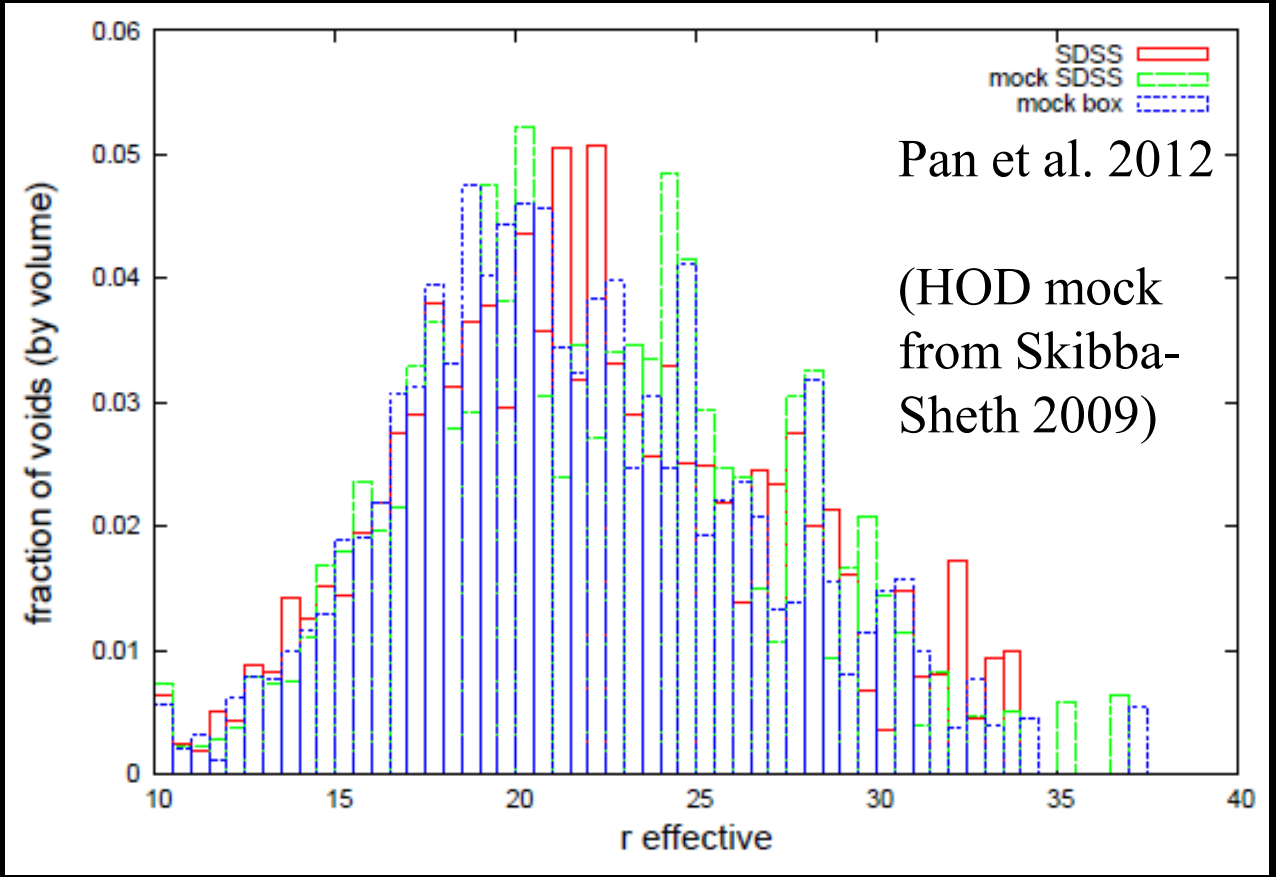
Correlations with environment



Environmental effects

- In hierarchical models, close connection between evolution and environment (dense region ~ dense universe ~ more evolved)
- Gastro-physics determined by formation history of halo
- Observed correlations with environment test hierarchical galaxy formation models where all environmental effects because massive halos populate densest regions

Voids in mock catalog which has no assembly bias same as in data

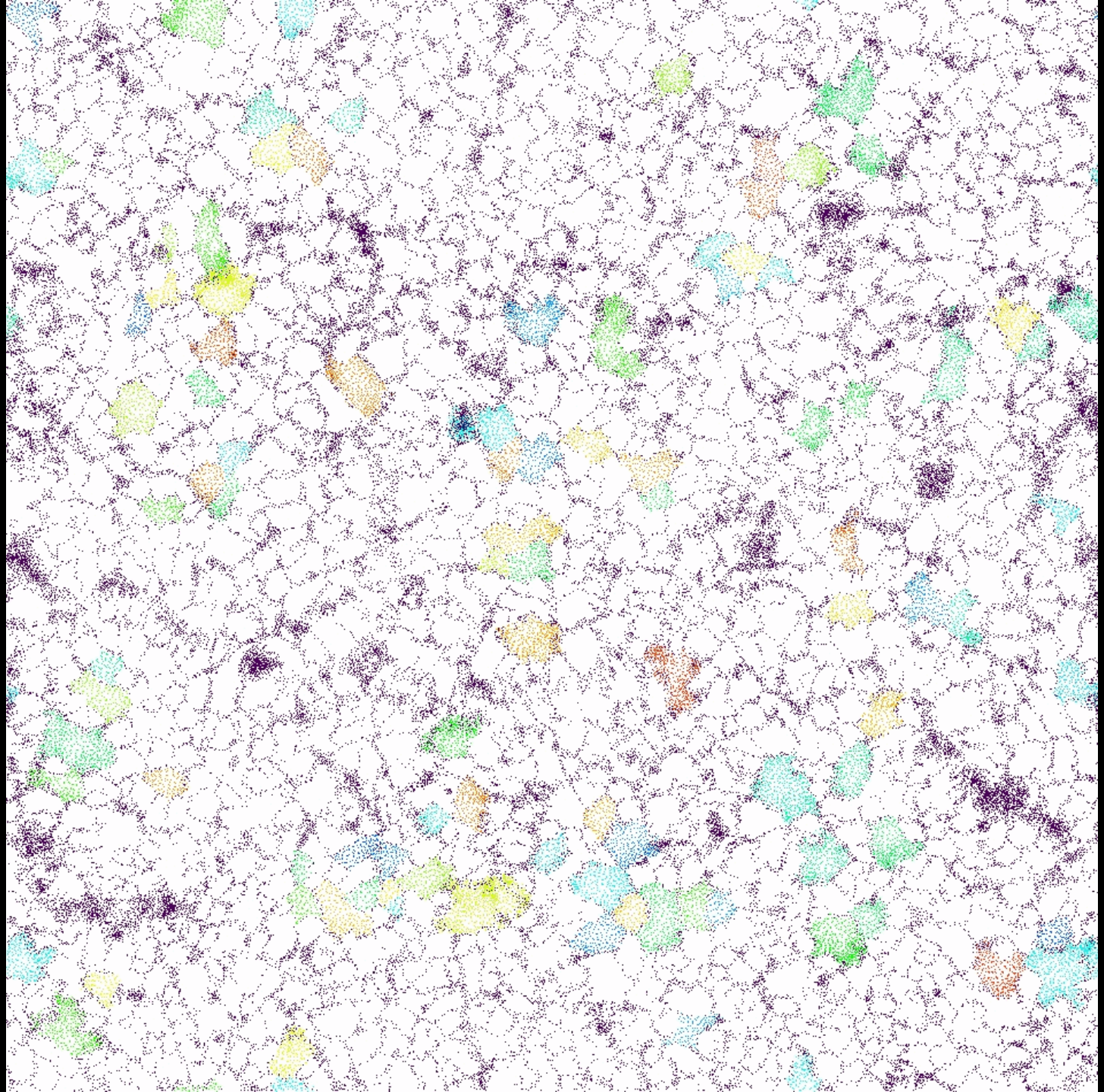


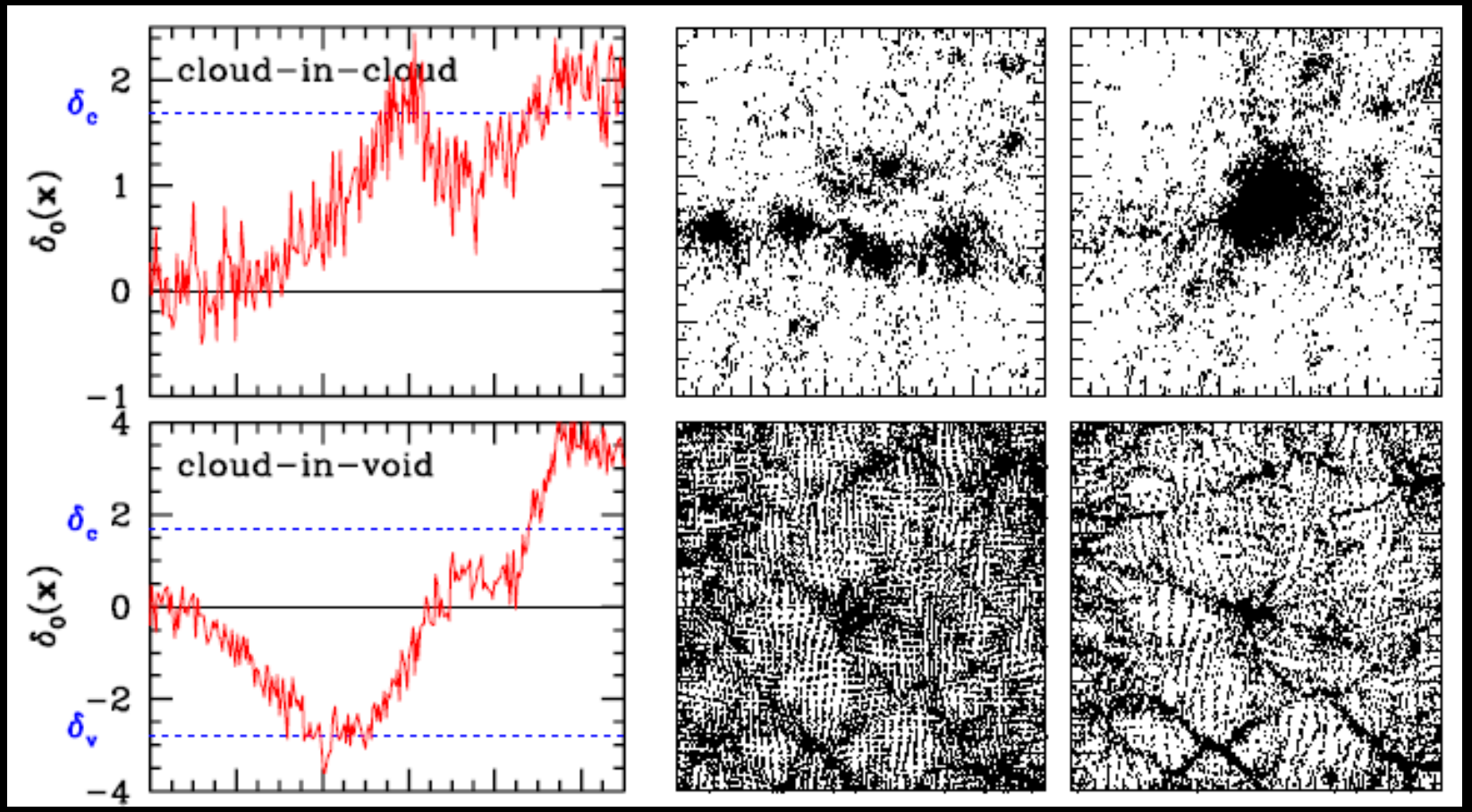
Voids

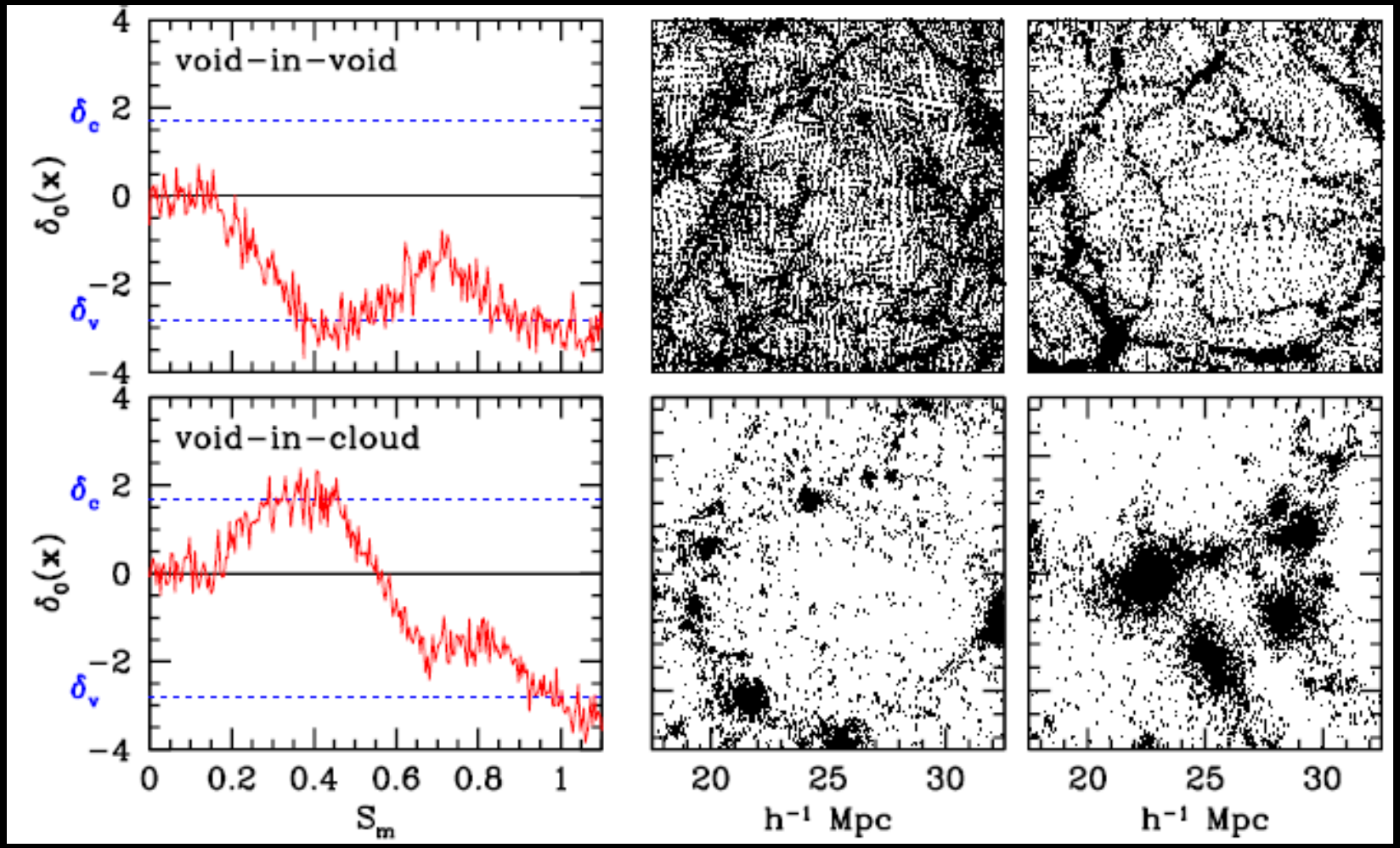
- Just change sign, so can do almost same cosmology with voids as with clusters:
  - cluster mass function → void size function
  - halo clustering/bias → void clustering/bias
  - halo profiles/concentration → void profiles
- Must be a little careful since small voids can be crushed if surroundings sufficiently overdense (Sheth, vdWeygaert 2004)
- Change of sign interesting because

$$b^E = 1 + b^L \quad \text{can equal zero for certain voids}$$

whereas $b^E > 0$ for all halos.




cloud−in−cloud
δ_c
$\delta_o(x)$
2
1
0
−1
cloud−in−void
δ_c
δ_v
$\delta_o(x)$
4
2
0
−2
−4


void−in−void
void−in−cloud
δ_c
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4
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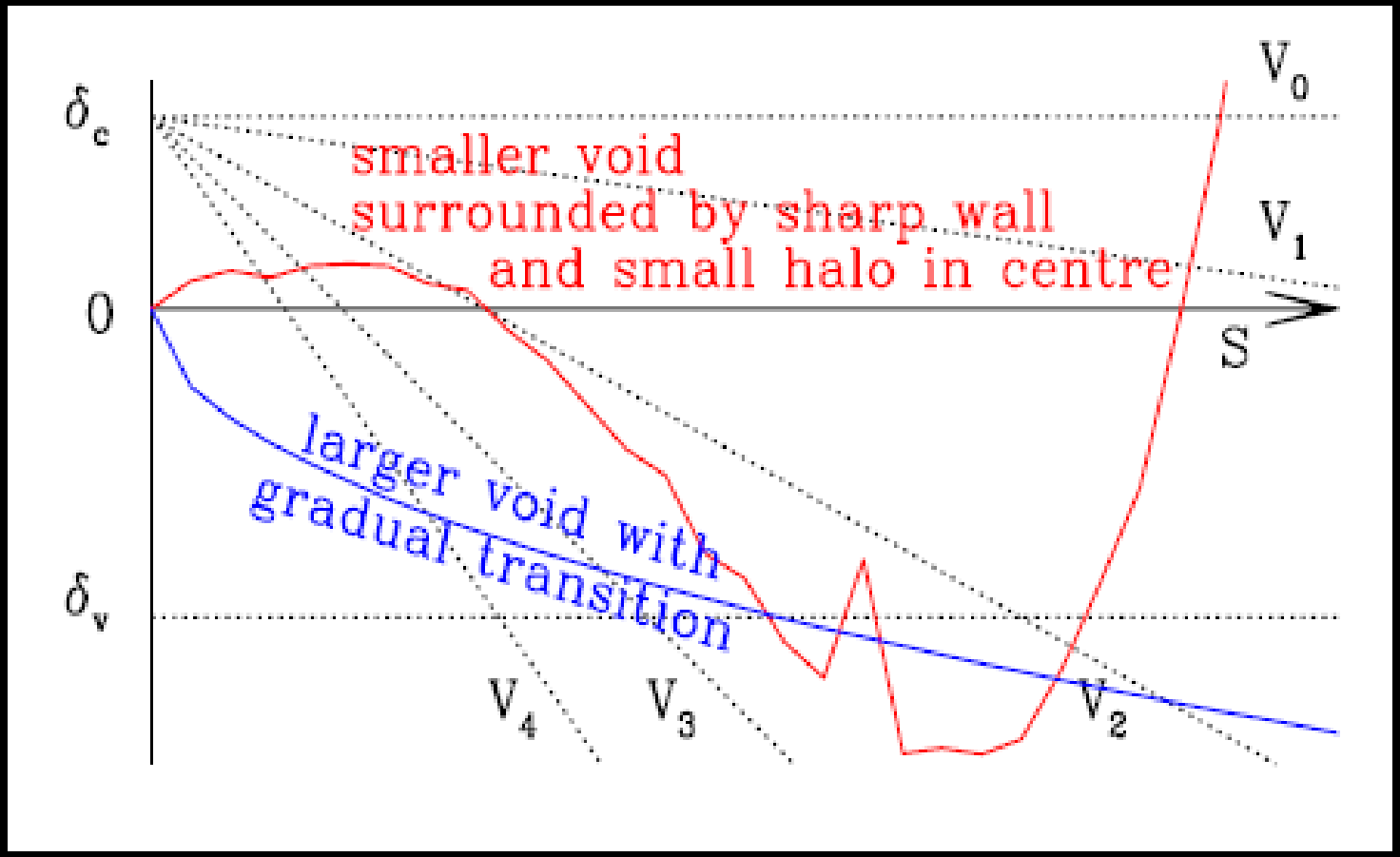
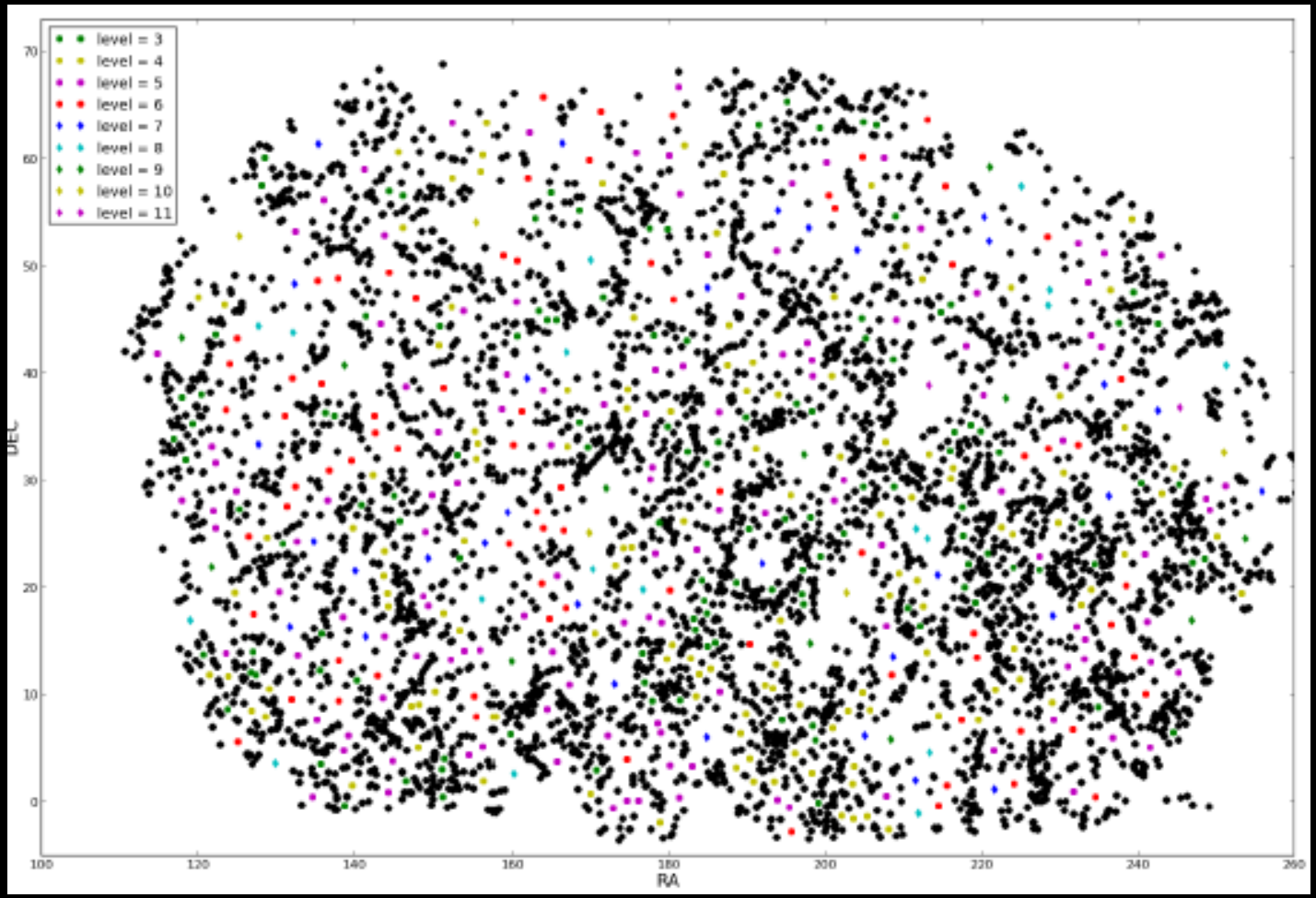
h^{-1} Mpc

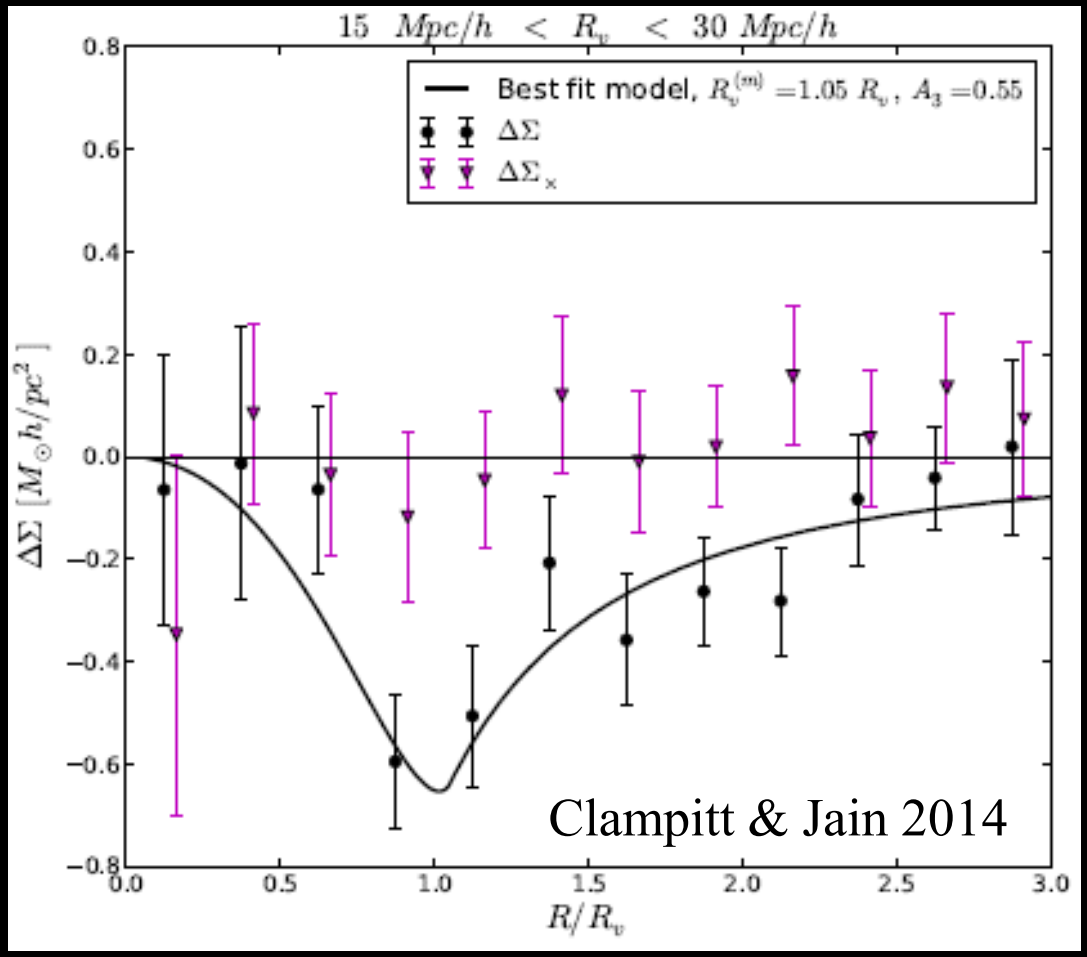


Paranjape et al 2012

Stack ‘voids’ in galaxy distribution



Lensing around ‘stacked’ voids …

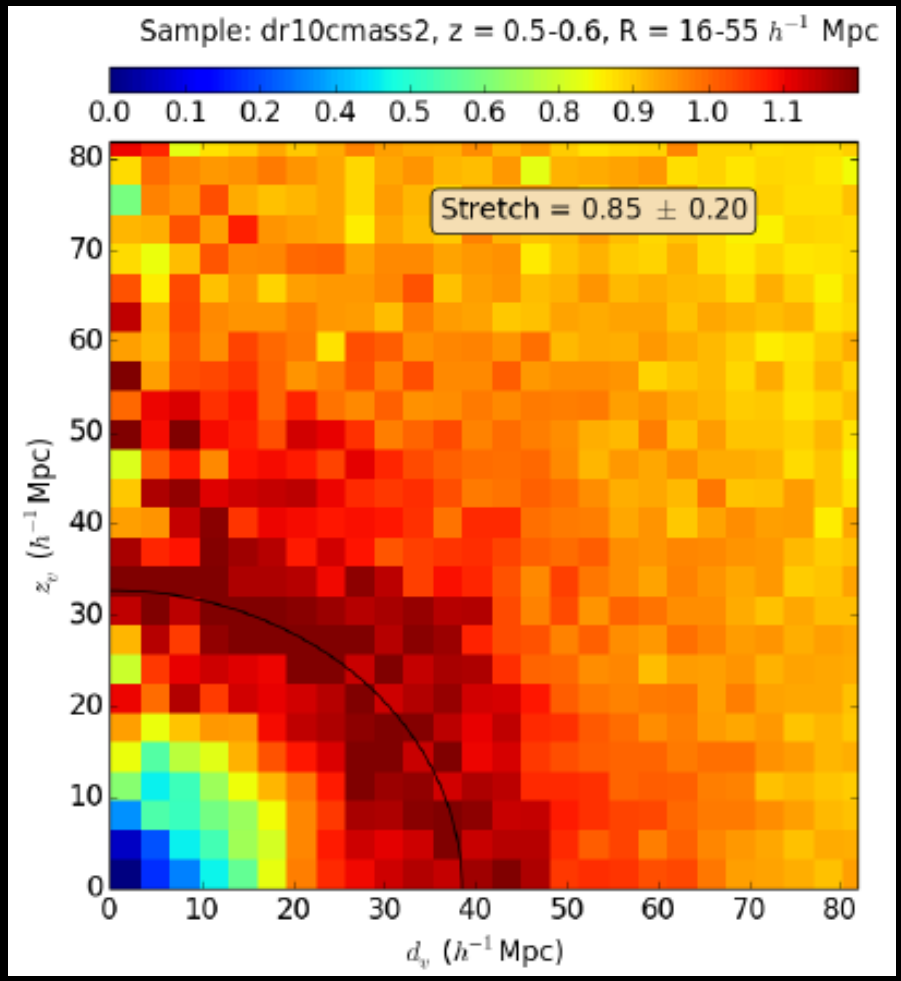


… does indeed have opposite sign.

Alcock-Paczynski effect?

- Current measurement has ‘wrong’ sign!
- Must account for redshift space distortions

- Need a model …



Sutter et al. 2014

Void-mass cross-correlation = void profile

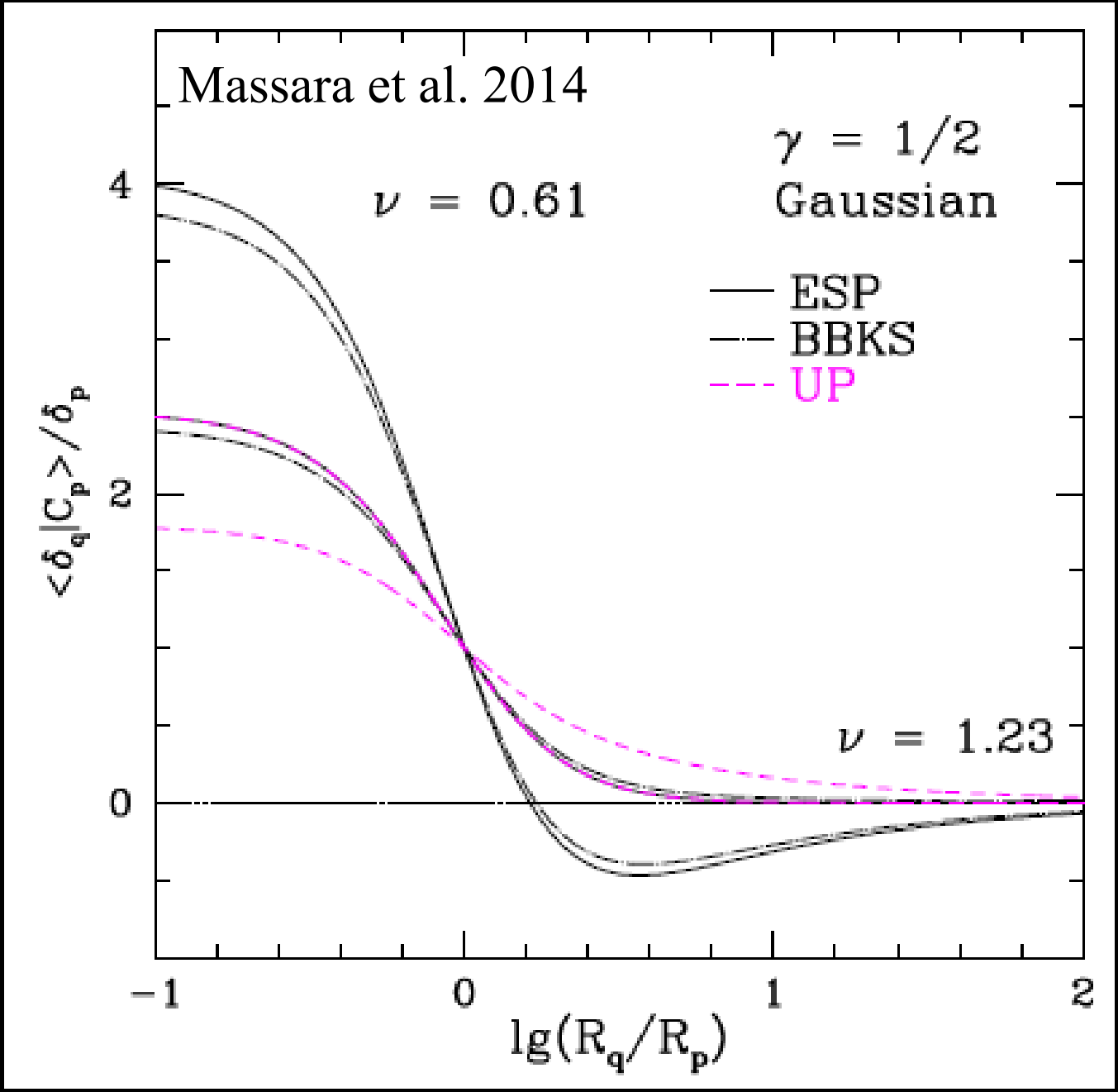
- So we really care about 'void bias' for which we have reasonable models:

$$\text{bias}(k) = (b_{10} + b_{01}\, k^2) W(kR_h)$$

- Generically, b10 and b01 depend on halo mass/void size
  - There are 'consistency relations' between coefficients (Musso et al. 2013)

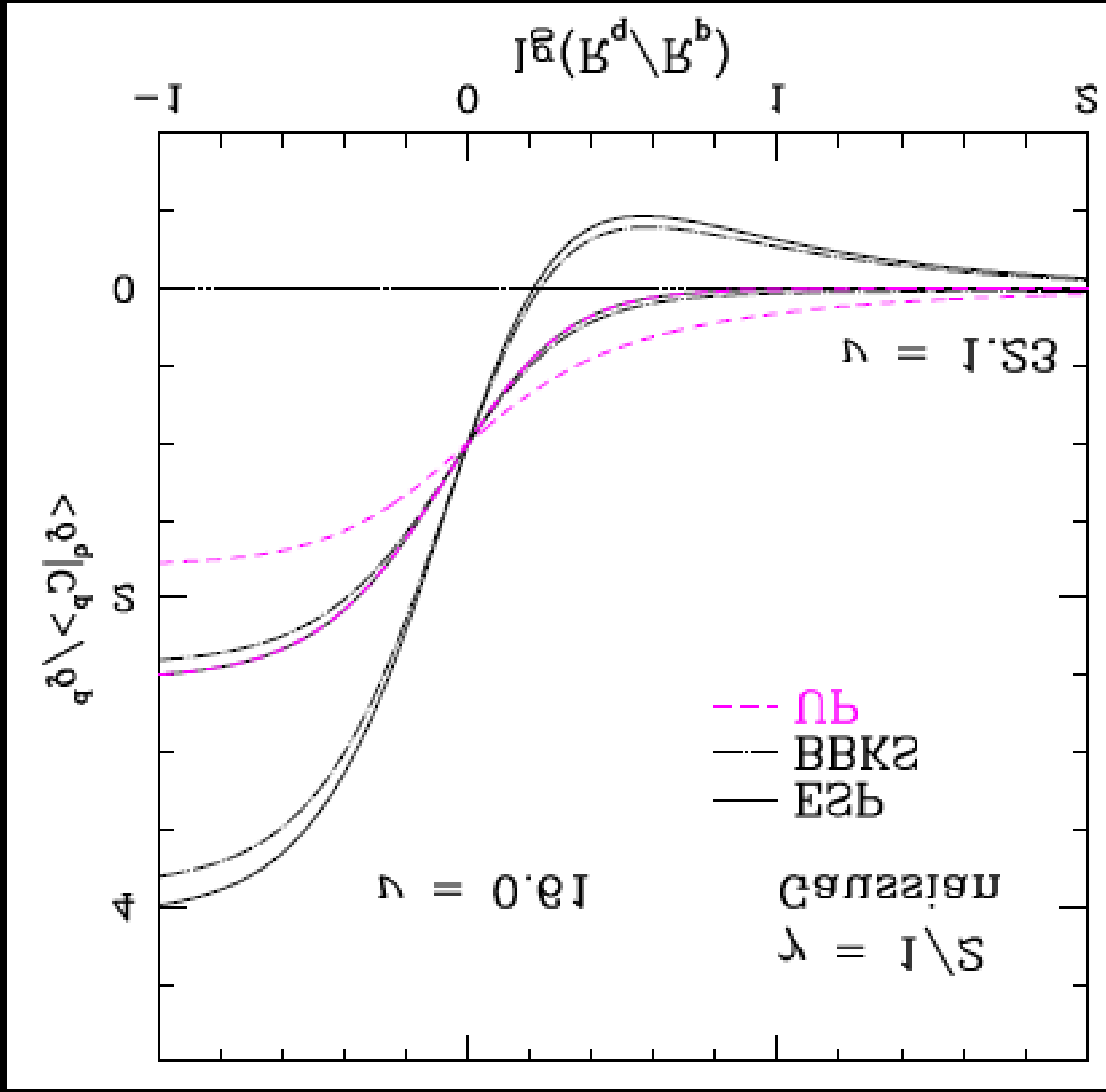
Density profile = cross correlation between peak and mass

Generic: Low mass = more concentrated



Density profile = cross correlation between void and mass

Generic: Small void = obvious wall

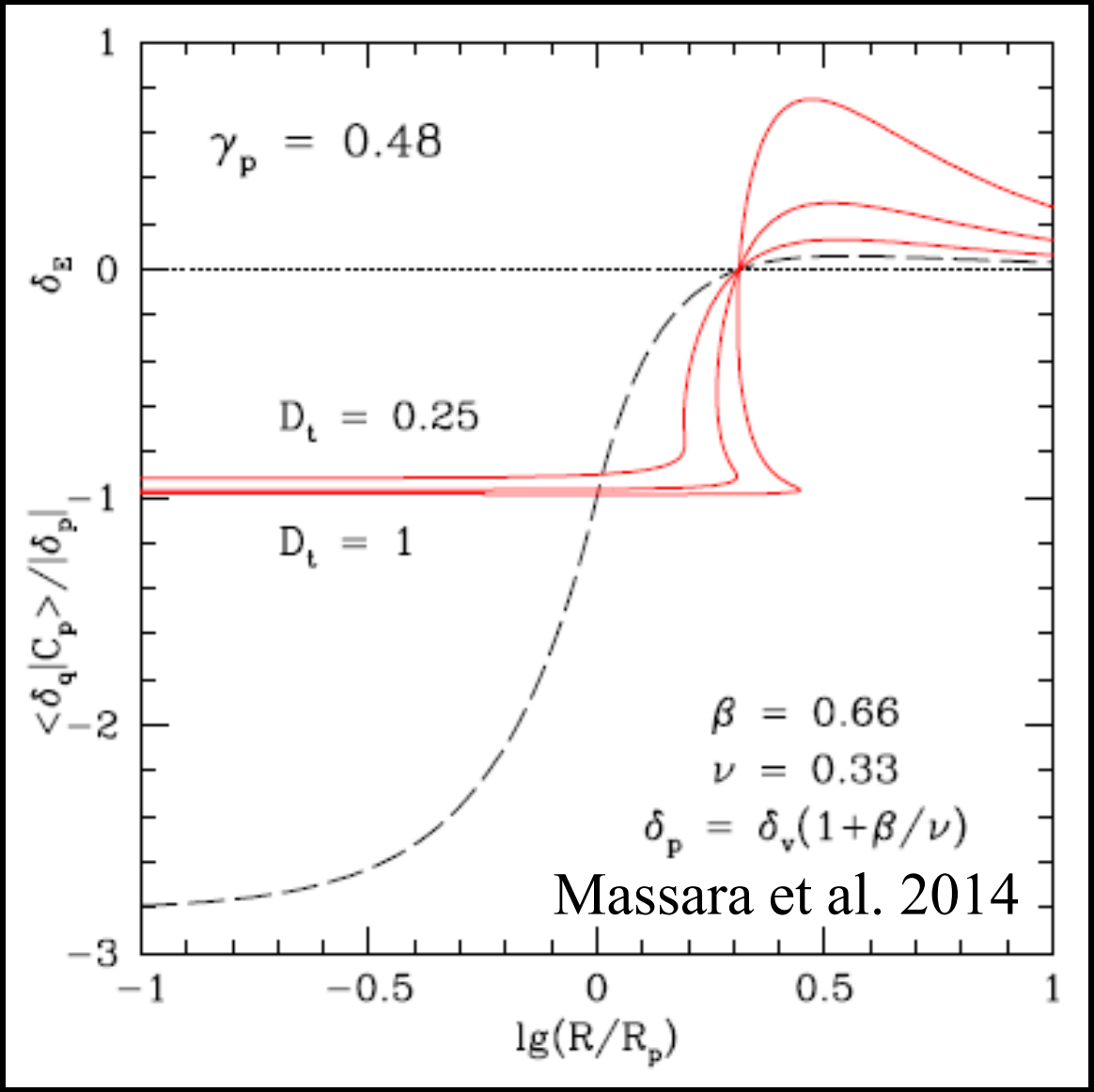


Evolution from spherical model:

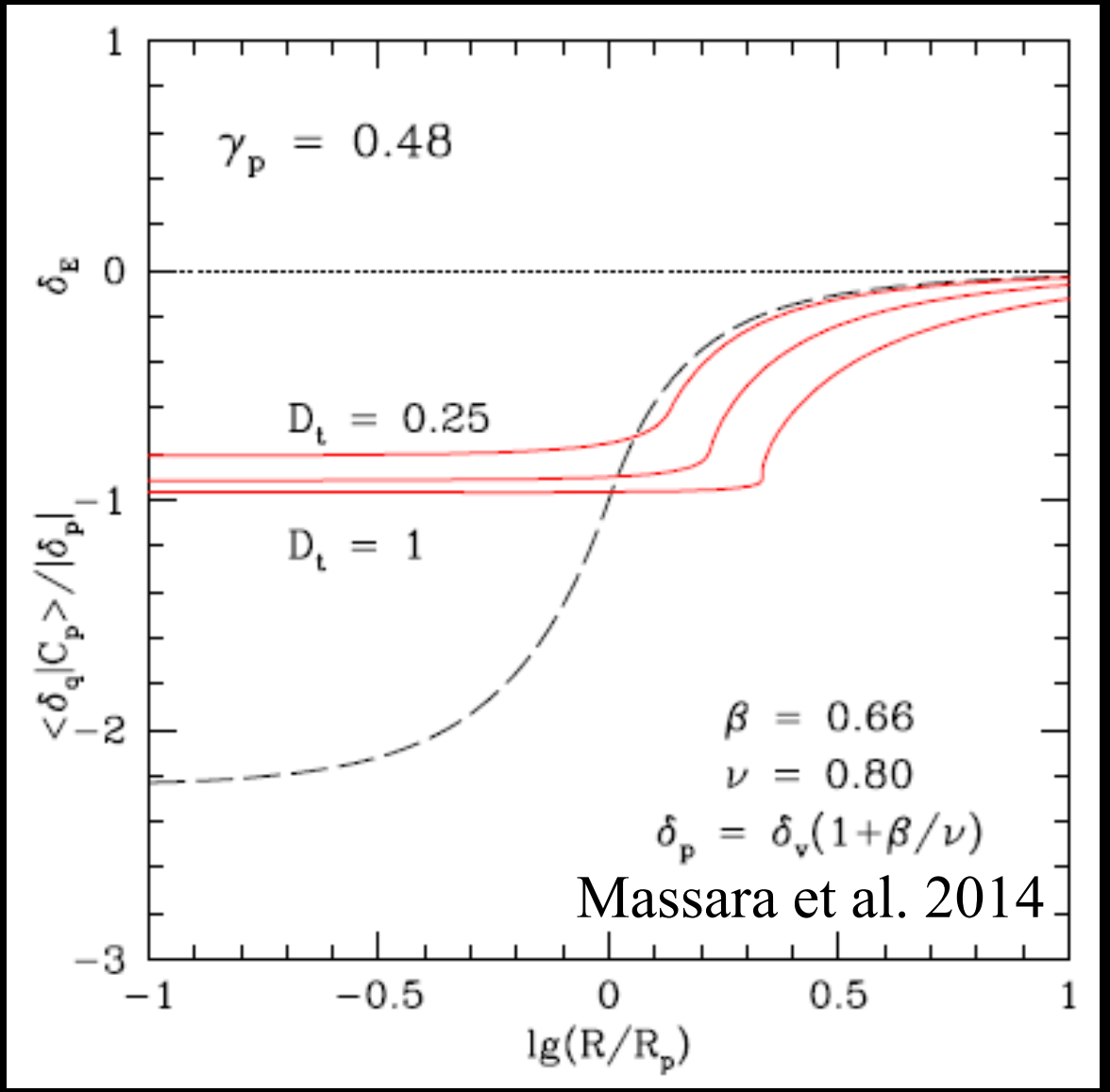
$$(1 - D(t)\delta_{init}/\delta_{sc})^{-\delta sc} \approx 1 + \delta(t)$$

$$R(t)/R_{init} = (1 + \delta)^{-1/3}$$

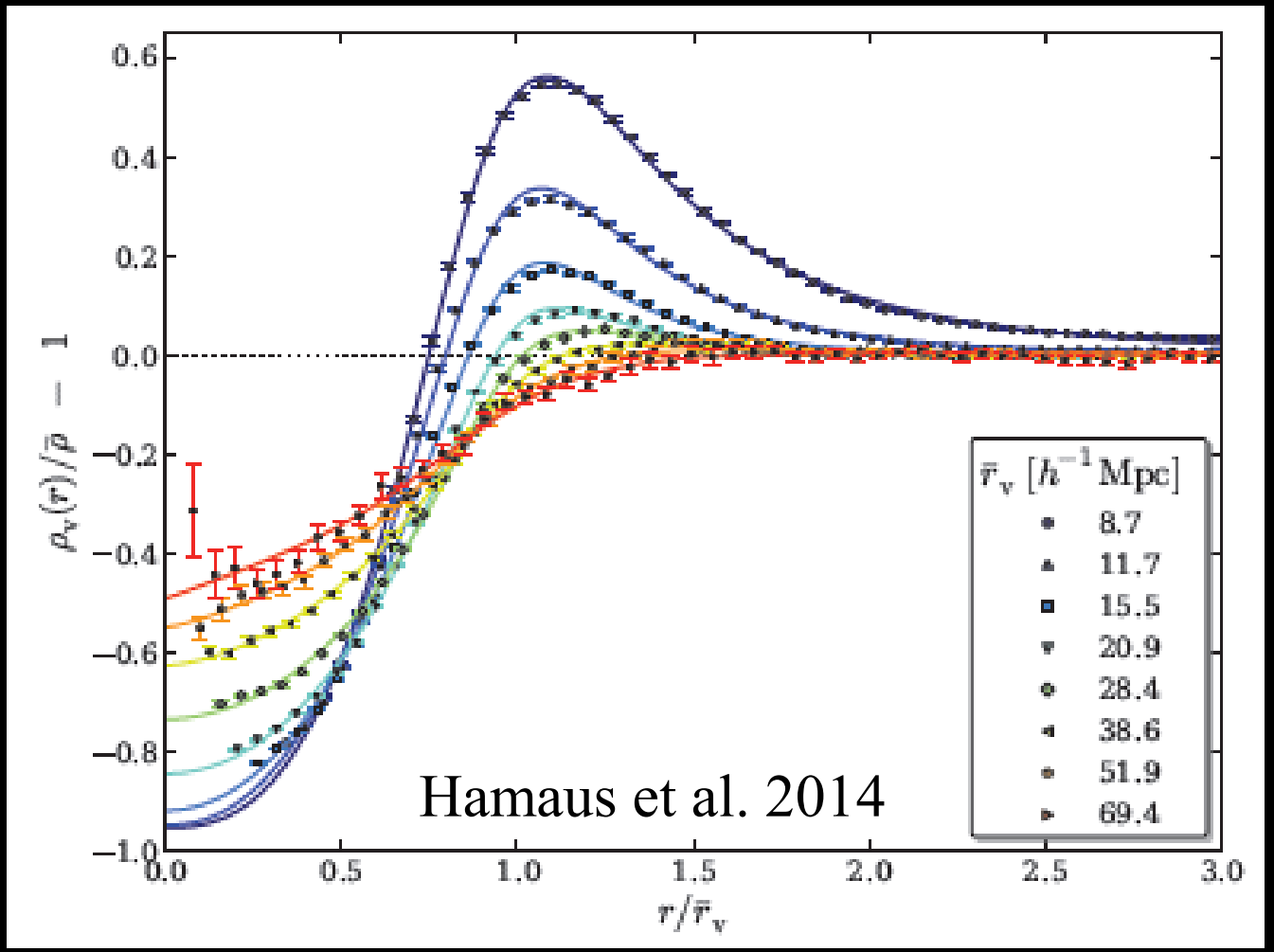
Small voids will have obvious walls and bias > 0



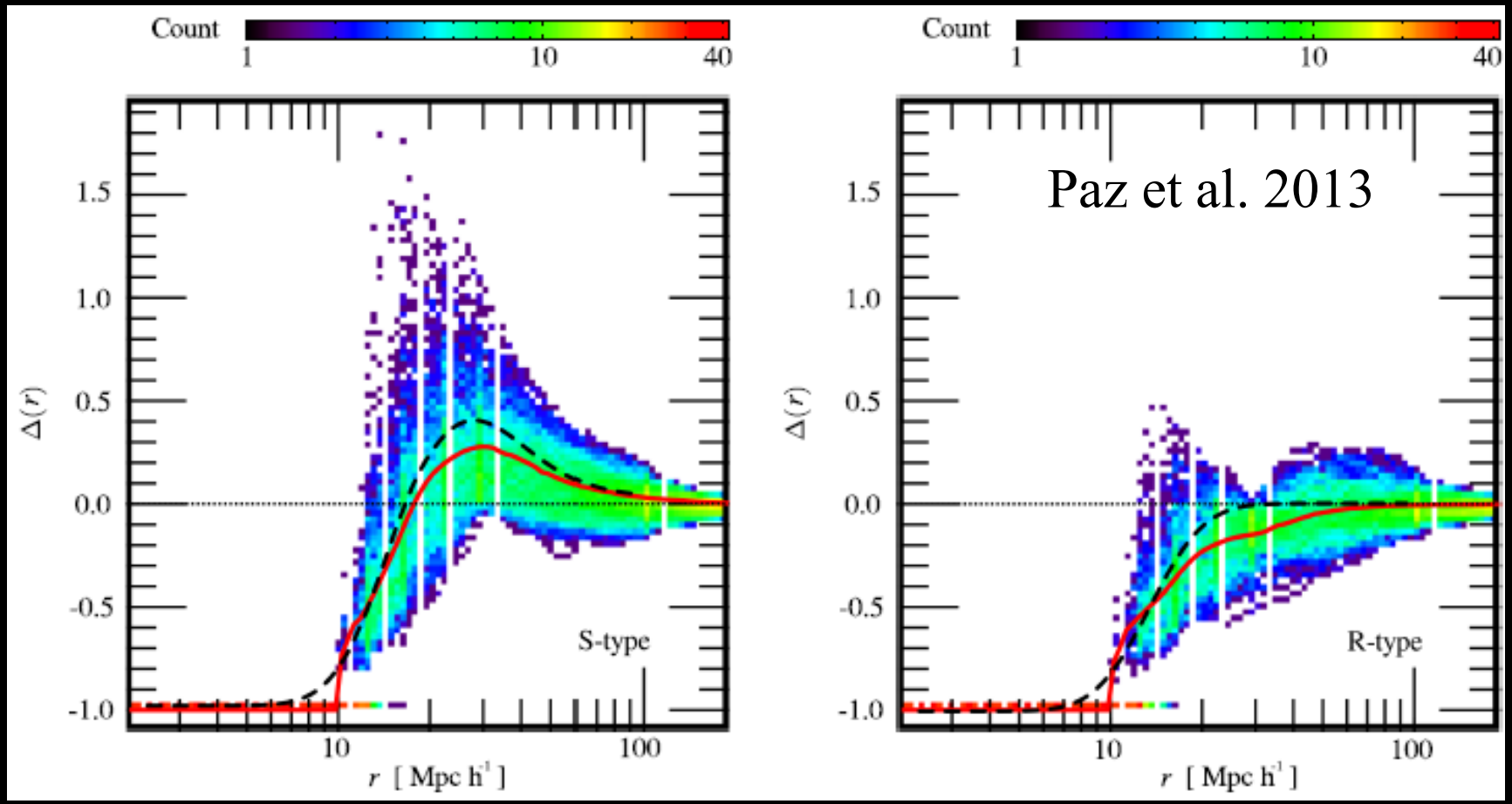
Big voids will have bias < 0 and less obvious walls



Seen in simulations …



… and in data

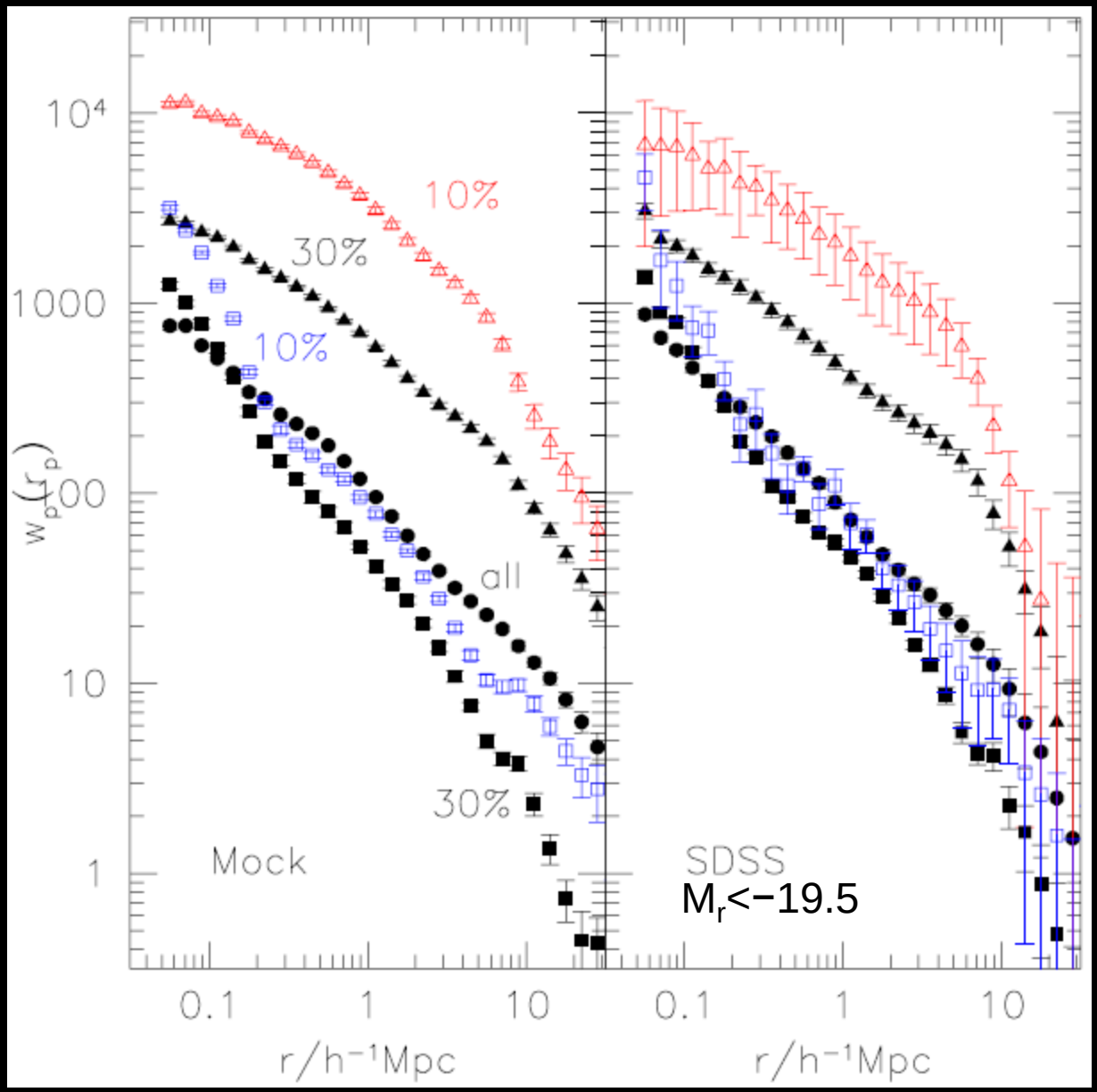


Work in progress to see if model also quantitatively OK

Since some voids have $b>0$
and others $b<0$,
some ‘voids’ have bias = 0.

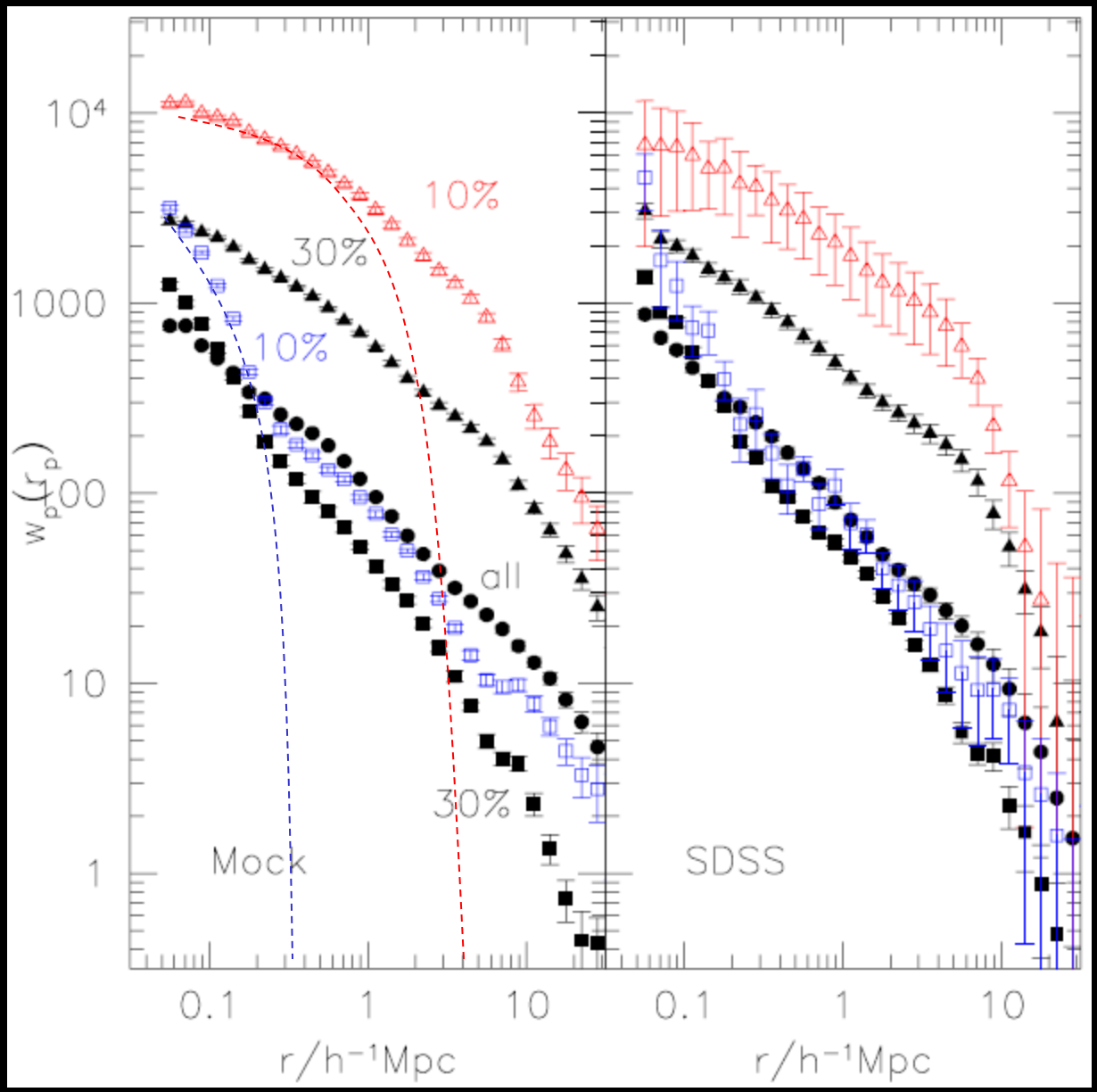
Generically, bias=0 is possible for sufficiently large sufficiently underdense regions.

- Assume cosmology → halo profiles, halo abundance, halo clustering
- Calibrate $g(m)$ by matching n_{gal} and $\xi_{gal}(r)$ of full sample
- Make mock catalog assuming same $g(m)$ for all environments
- Measure clustering in sub-samples defined similarly to SDSS



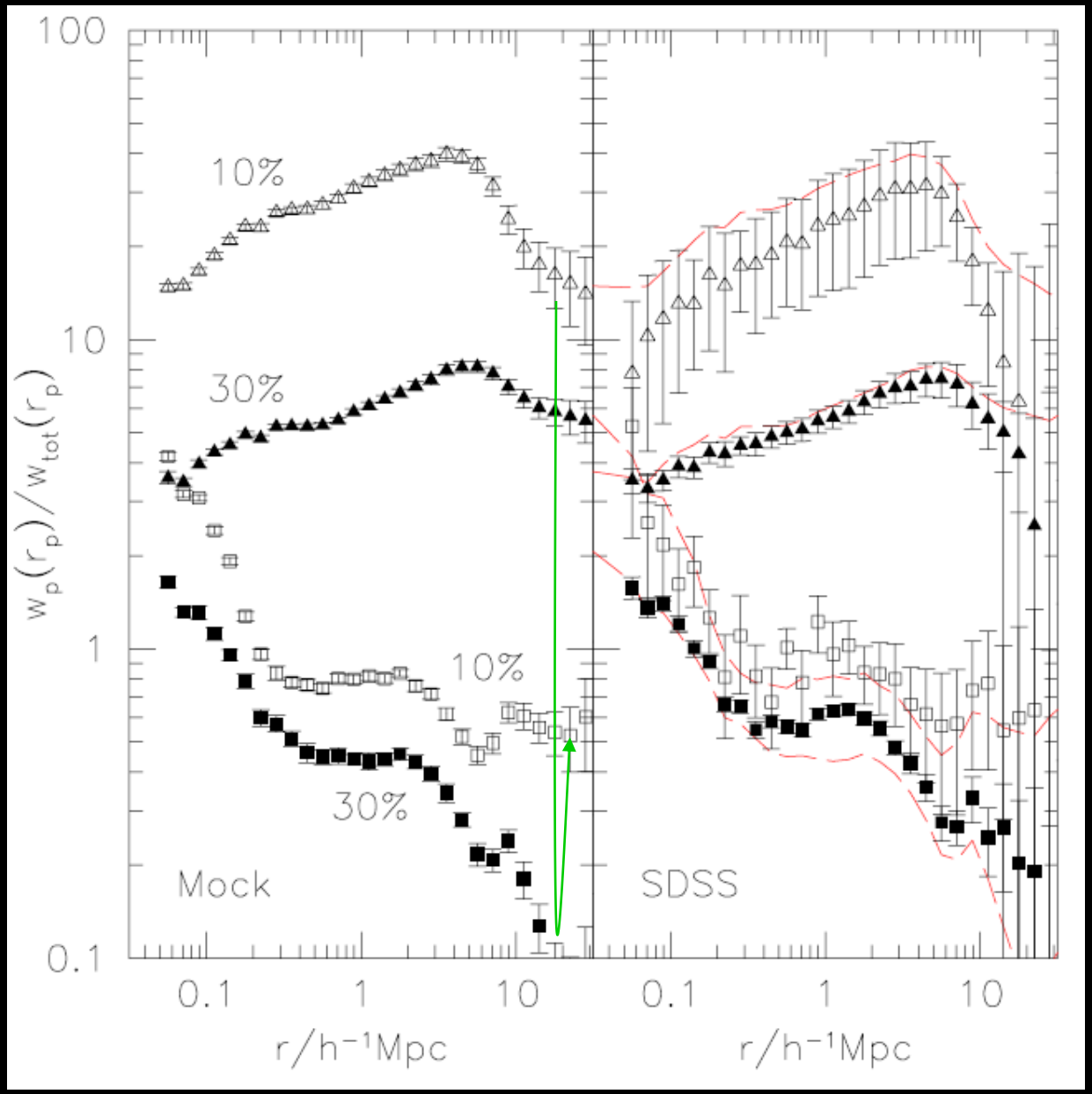
Abbas & Sheth 2007

- Environment = neighbours within 8 Mpc
- Clustering stronger in dense regions
- Dependence on density NOT monotonic in less dense regions
- Same seen in mock catalogs; little room for extra effects

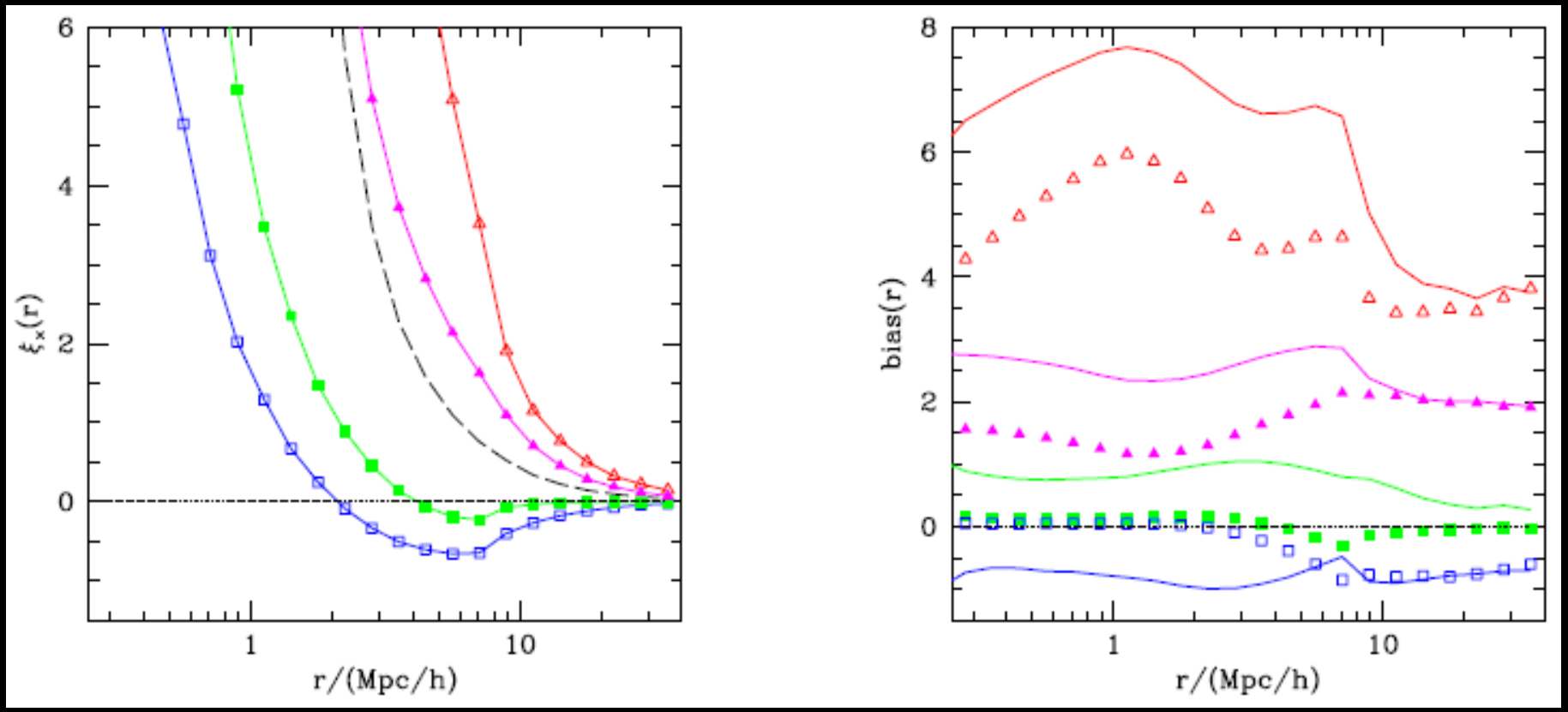


Abbas & Sheth 2007

- Galaxy distribution remembers that, in Gaussian random fields, high peaks and low troughs cluster similarly (but with opposite signs)



Auto-correlation only sees b^2



Bias from cross correlation $\propto$ b is indeed monotonic, and crosses 0

Some interest in using b=0 objects as standard rods (Hamaus et al. 2013)

- These will depend on tracer population.
- SDSS Main Galaxy sample in Abbas-Sheth had b~1, so underdense patches of size 8Mpc/h in this sample had $b_{void}=0$.
- In LRG sample, galaxies have b~2, so $b_{void}=0$ for voids of size 20 Mpc/h.

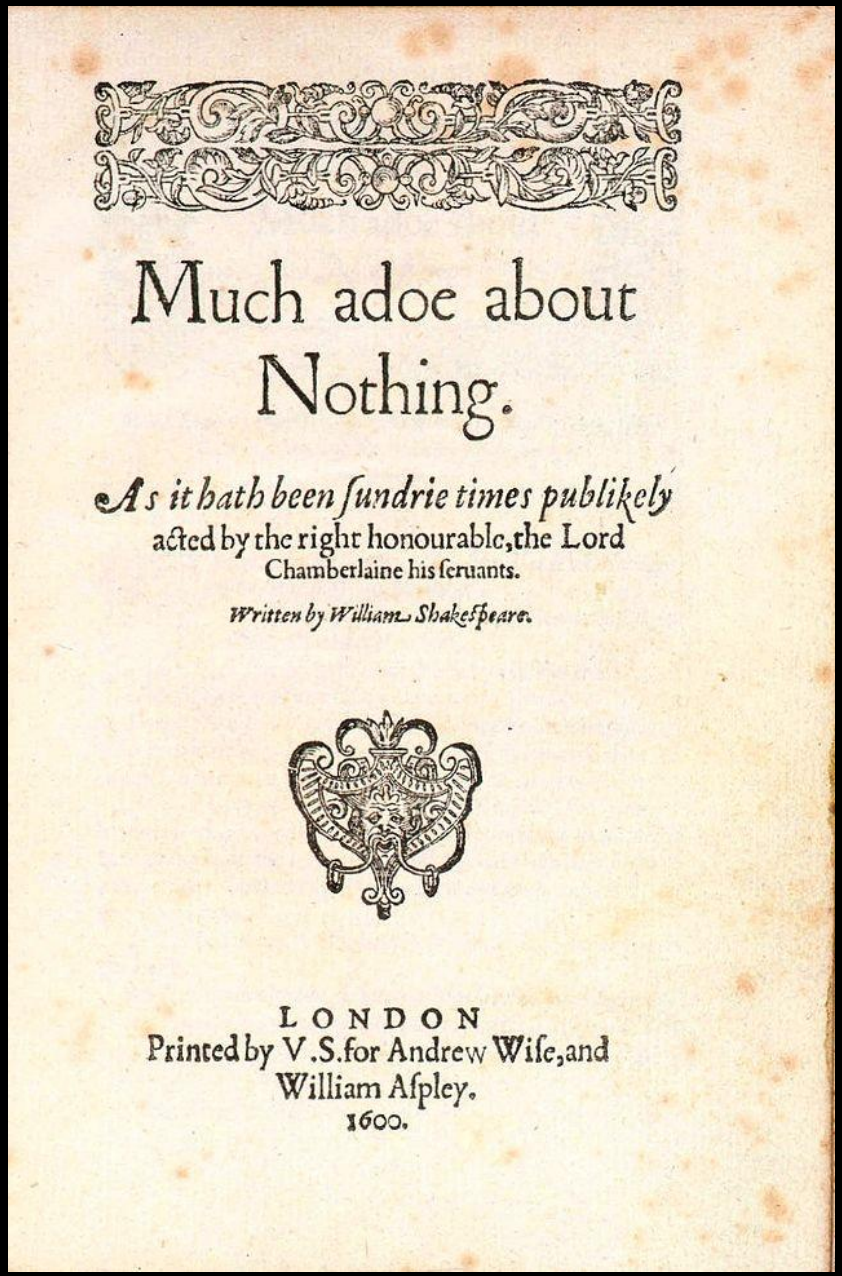
Summary:

- Just change sign, so can do almost same cosmology with voids as with clusters:
  - cluster mass function → void size function
  - halo clustering/bias → void clustering/bias
  - halo profiles/concentration → void profiles
- Must be a little careful since small voids can be crushed if surroundings sufficiently overdense (Sheth, vdWeygaert 2004)
- Change of sign interesting because

$$b^E = 1 + b^L \quad \text{can equal zero for certain voids}$$

whereas $b^E > 0$ for all halos (Sheth & vdWeygaert 2004).

A victory is twice itself when the achiever brings home full numbers.



Much adoe about Nothing.

As it hath been ſundrie times publikely
acted by the right honourable, the Lord
Chamberlaine his ſeruants.

Written by William Shakeſpeare.

LONDON
Printed by V.S. for Andrew Wiſe, and
William Aſpley.
1600.