How empty is empty?

Defining environment, from voids to field to clusters

Darren Croton
Centre for Astrophysics & Supercomputing
Swinburne University

Environment, why we care ...

- we can finally do it well
- who wants to be just “average”
- different environment, different physics

Outline

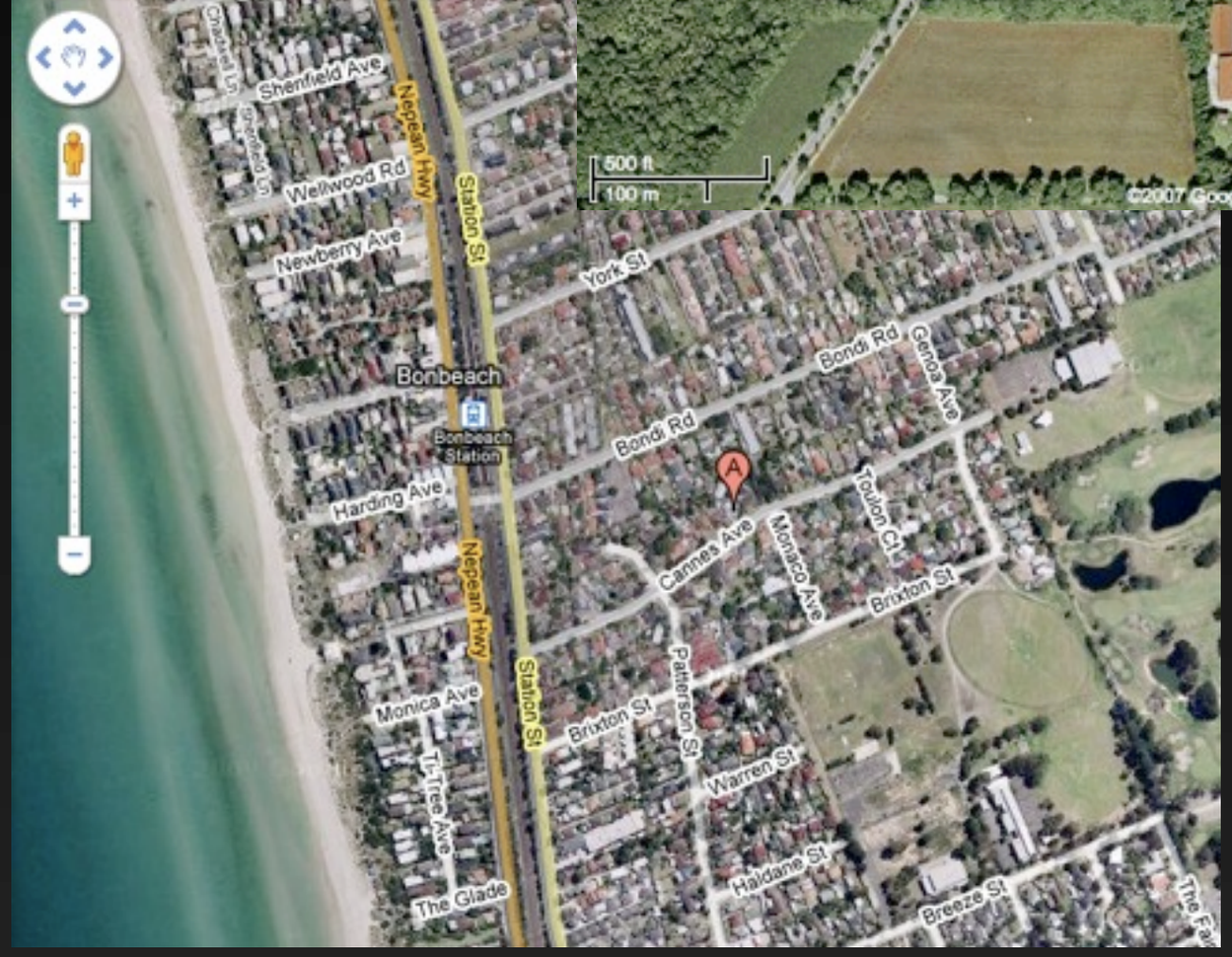
1. How we define environment and voids
2. Physical vs. statistical measures of environment
3. Some of my own results
4. An environment project

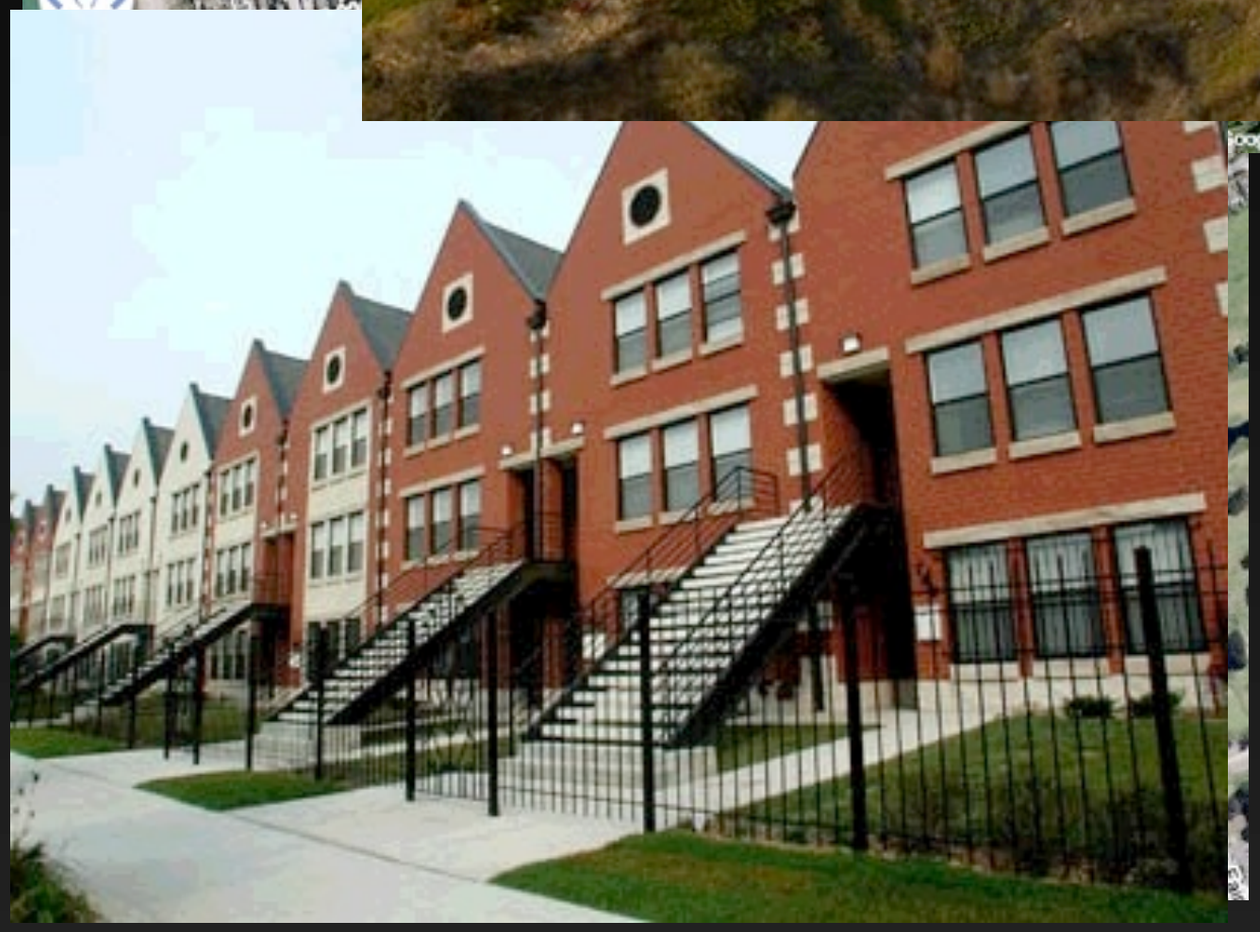
Defining environment

Munich

De ent

Mell ley





Defining environment

"Group" finders:

- Close pairs, friends of friends, ...
- Optimal linking length?
- Won't find voids, but will identify isolated galaxies

Defining environment

N'th nearest neighbour:

- What "n" is optimal?
- How to compare dense with sparse populations?

Defining environment

Fixed aperture:

- What kind of aperture (top-hat, Gaussian, ...)?
- Smoothed on what scale?
- Loss of information on smaller scales (e.g. halo radii typically <2Mpc)

Defining environment

Using the underlying structure itself:

- Halo mass (i.e. bound structures)
- The dark matter density field
- Observation vs. theory
- Dealing with bias

Defining environment

Issues:

- 2D vs. 3D.
- Dealing with selection, incompleteness and volume effects
- Comparing different environment measures

Defining voids

Use the “void finder” algorithm

Defining voids

- "void" galaxies vs. "wall" galaxies (e.g. Hoyle et al. 2005)
- Maximal non-overlapping spheres (e.g. Patiri et al. 2006)
- Grid based (e.g. Colberg et al. 2005)
- Something more clever (talk to Rien)

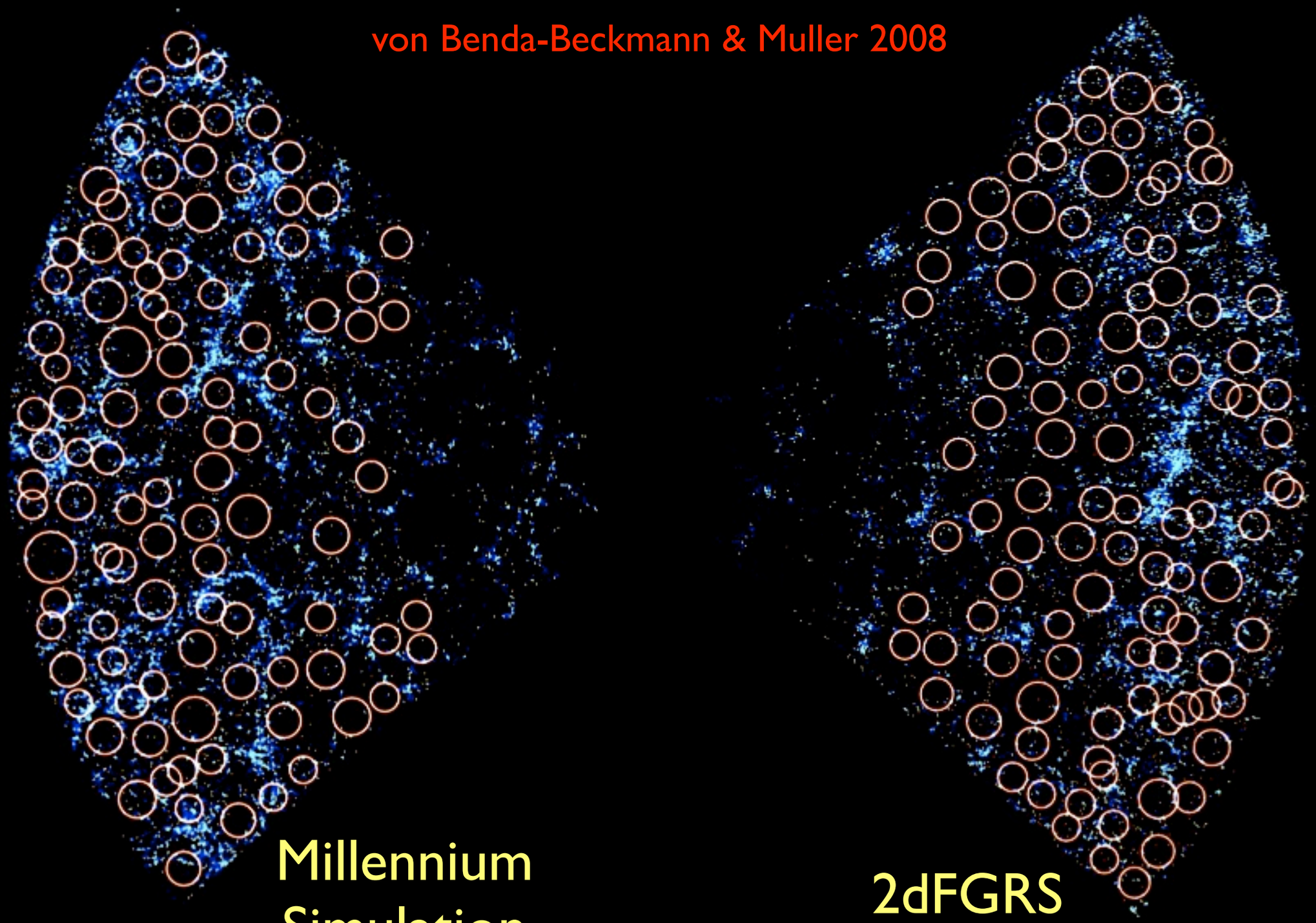
Defining voids

Issues:

- Selection, incompleteness and volume effects
- How empty do you have to be to be a void ($\delta<-0.6$, $\delta<-0.9$)?
- Comparing different void measures

Do they work?

von Benda-Beckmann & Muller 2008



Millennium Simulation

2dFGRS

Statistical measures of environment

- 2-pt clustering - amplitude links to both environment and halo mass
- Shape statistics - voids, filaments, sheets, clusters
- voids can be just as clustered as clusters

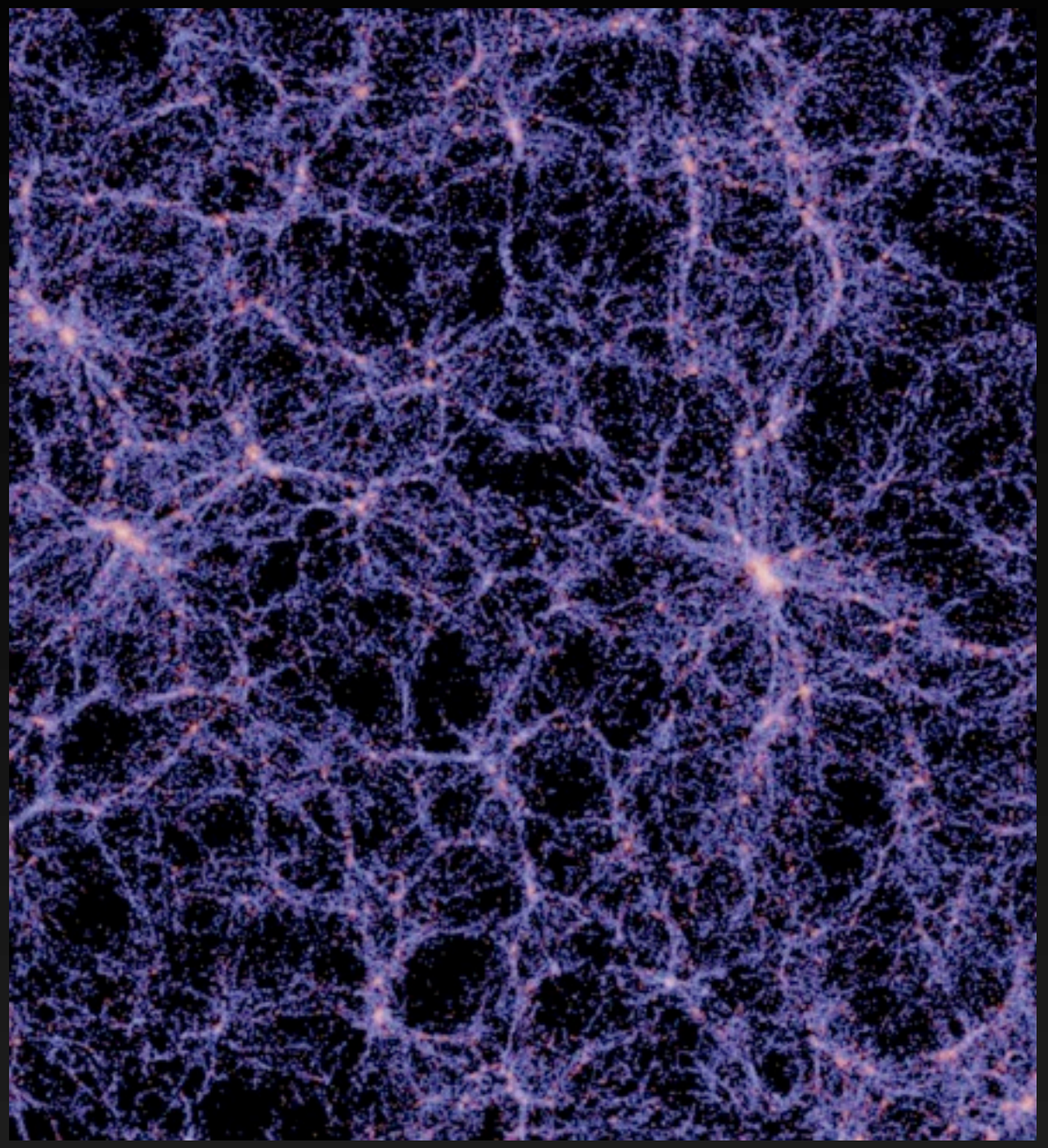
Environment dependent quenching?

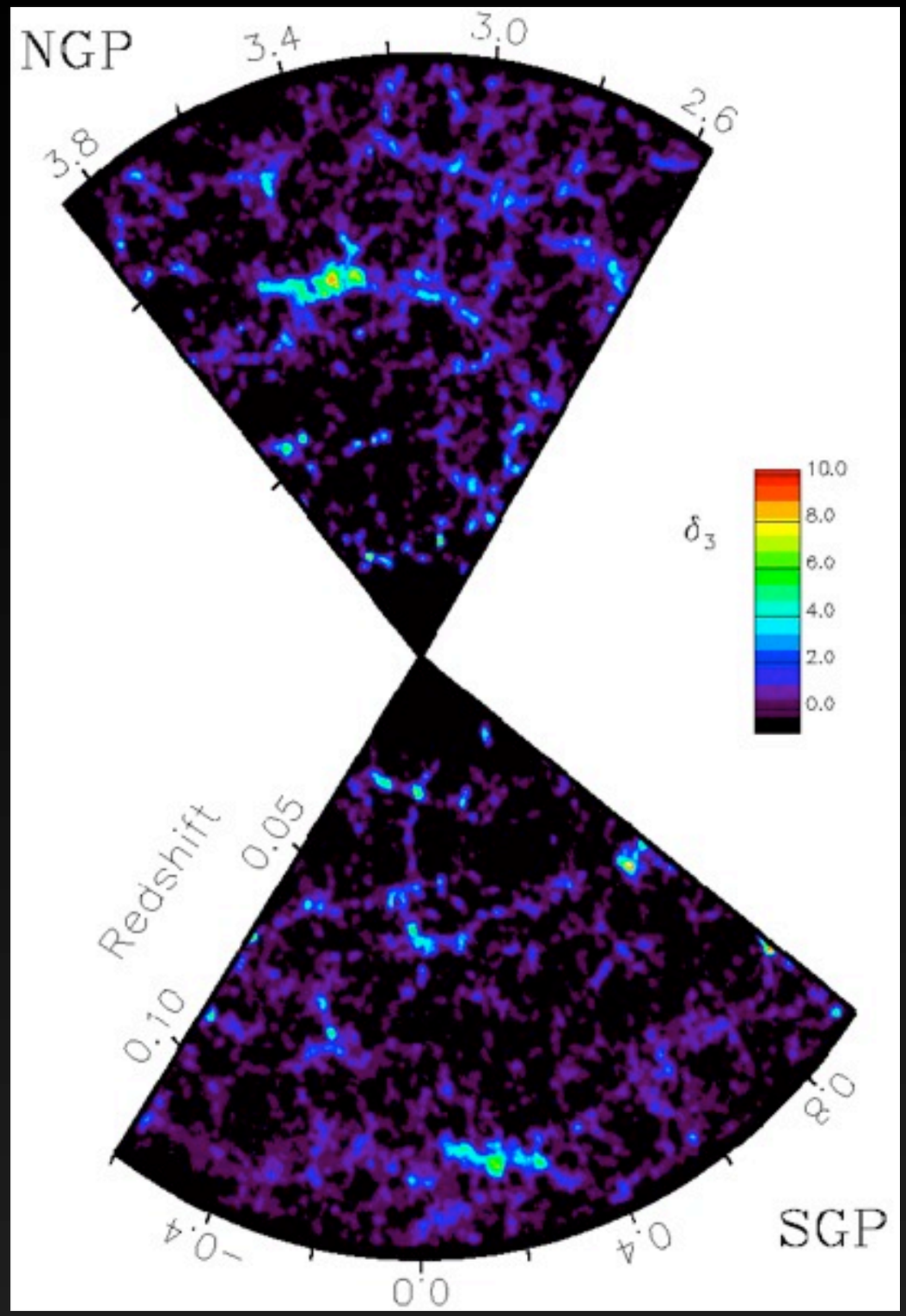
When I say "environment"
this is what I mean ...

Local (number) density is determined in top-hat spheres of radius $8h^{-1}$Mpc:

$$\delta_8 = \delta\rho_g / \langle\rho_g\rangle$$

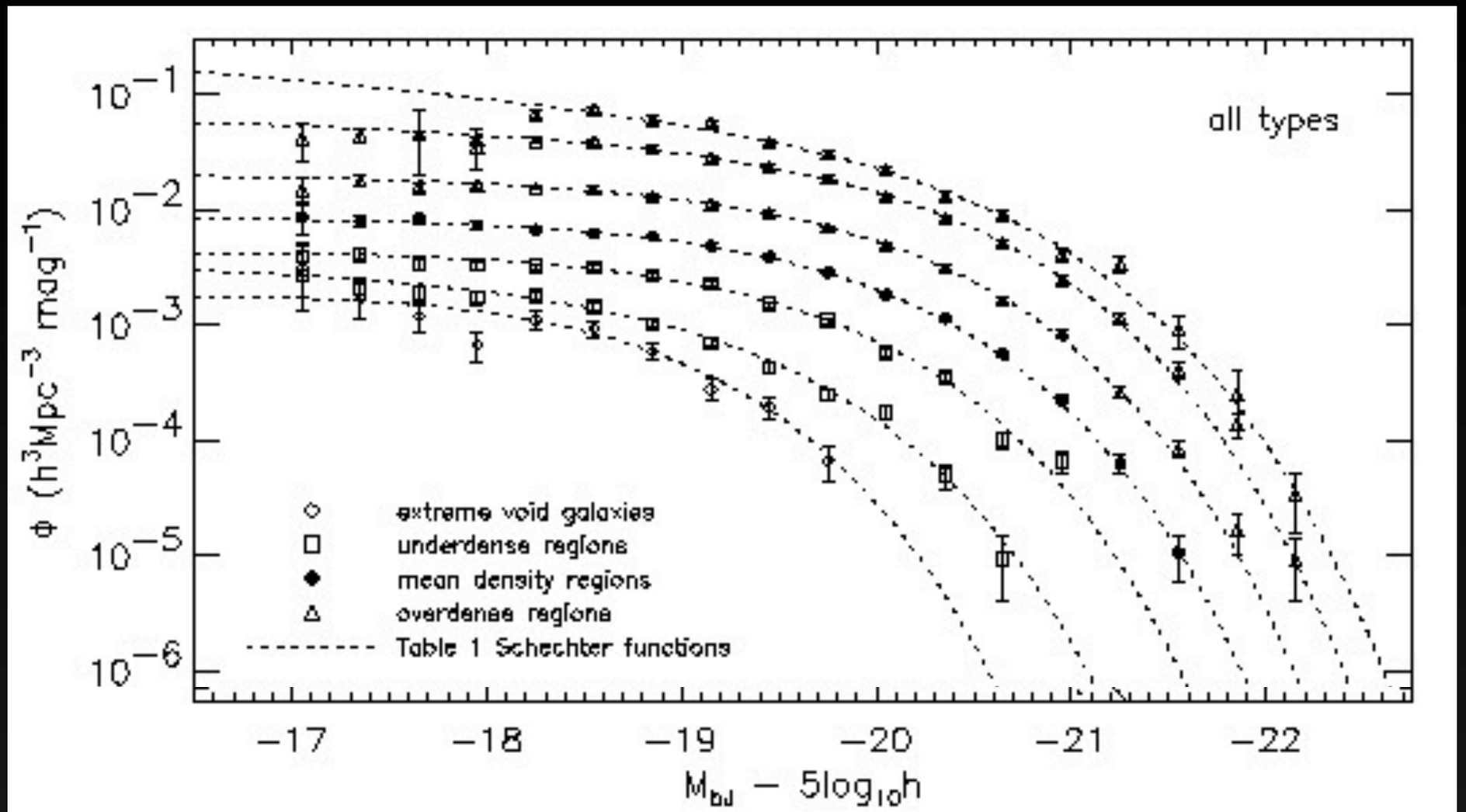
Millennium Simulation
semi-analytic model





2dFGRS

2dFGRS luminosity function



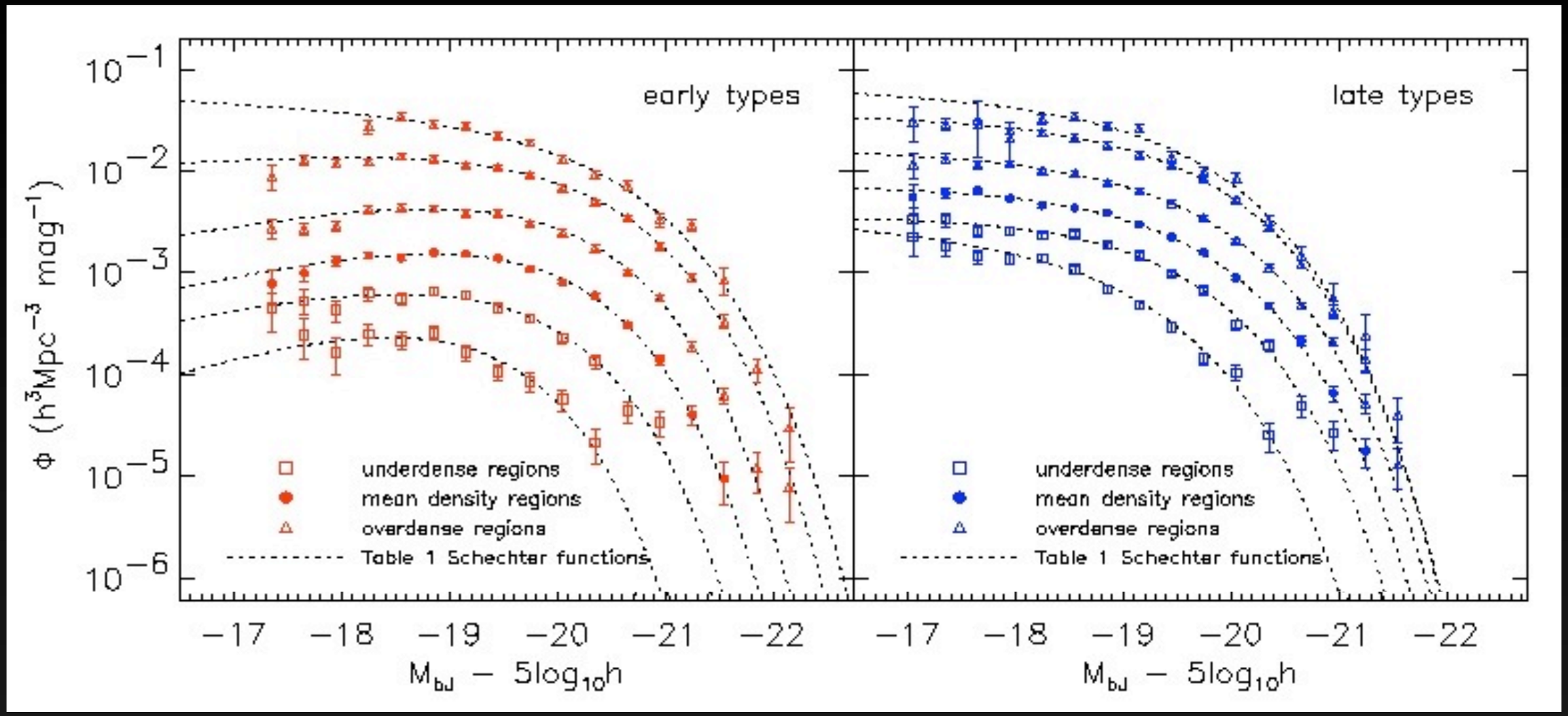
Extreme void: $-1.0 < \delta_8 < -0.9$

Void: $-1.0 < \delta_8 < -0.75$

Mean: $-0.43 < \delta_8 < 0.32$

Cluster: $\delta_8 > 6.0$

2dFGRS luminosity function

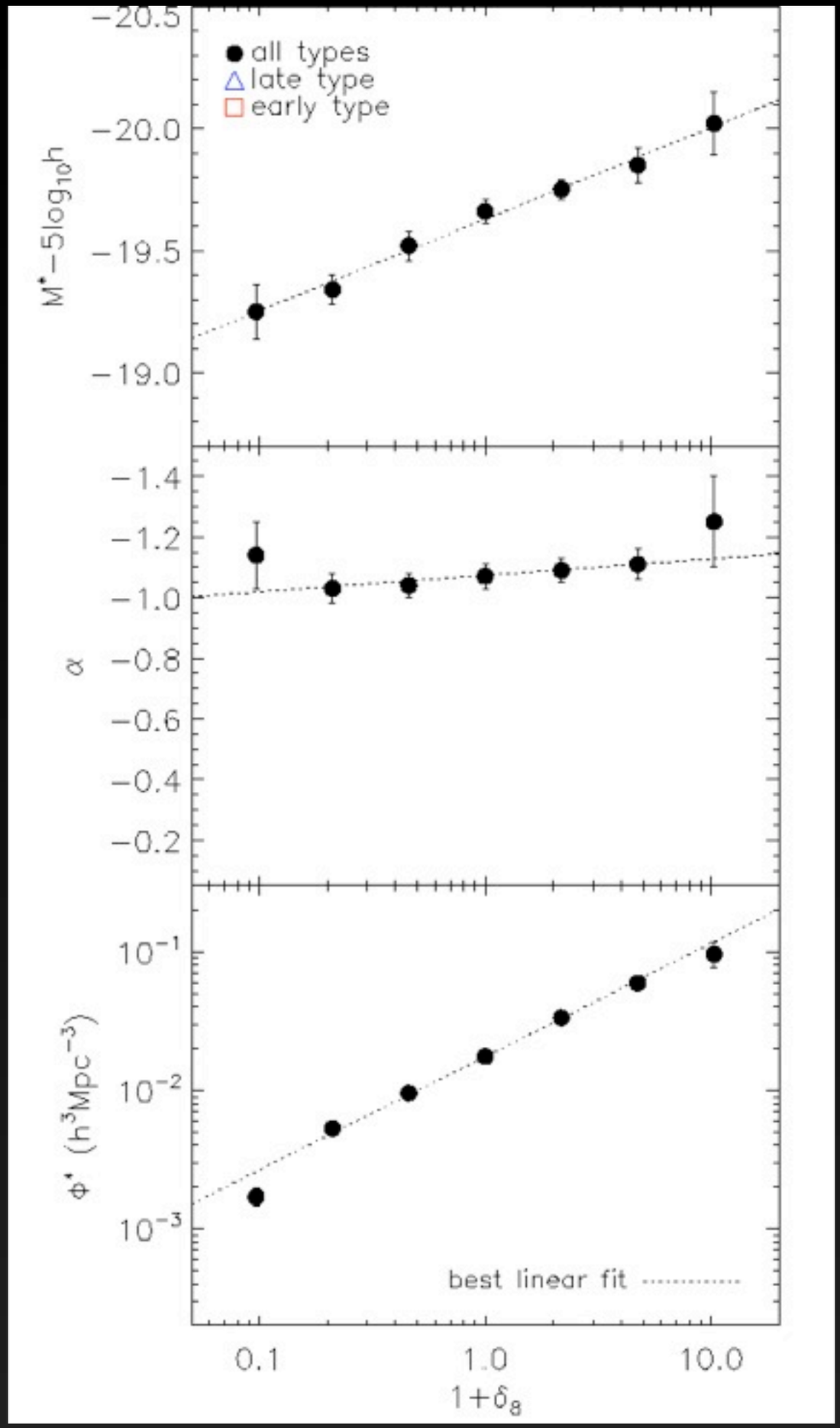


Void: $-1.0 < \delta_8 < -0.75$

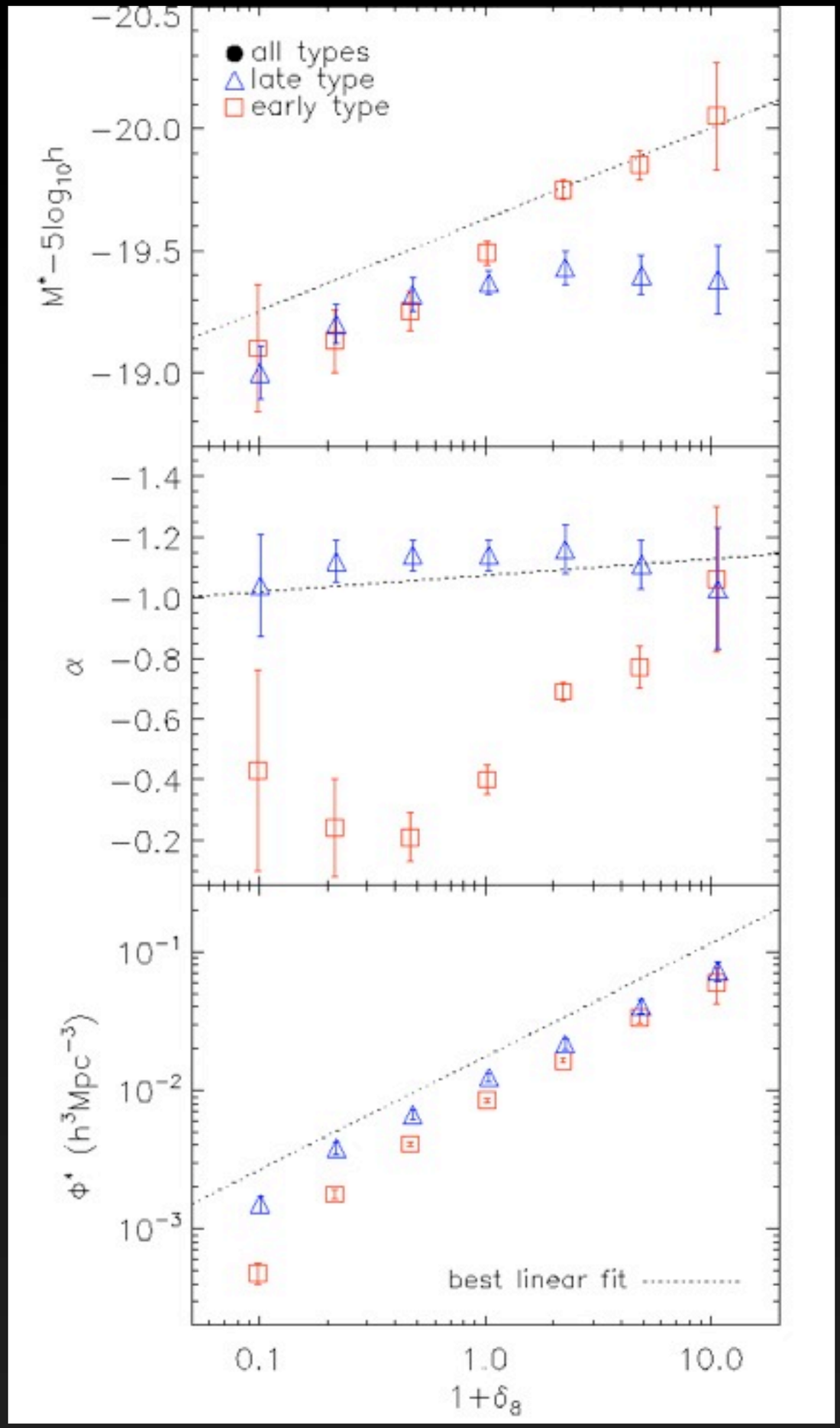
Mean: $-0.43 < \delta_8 < 0.32$

Cluster: $\delta_8 > 6.0$

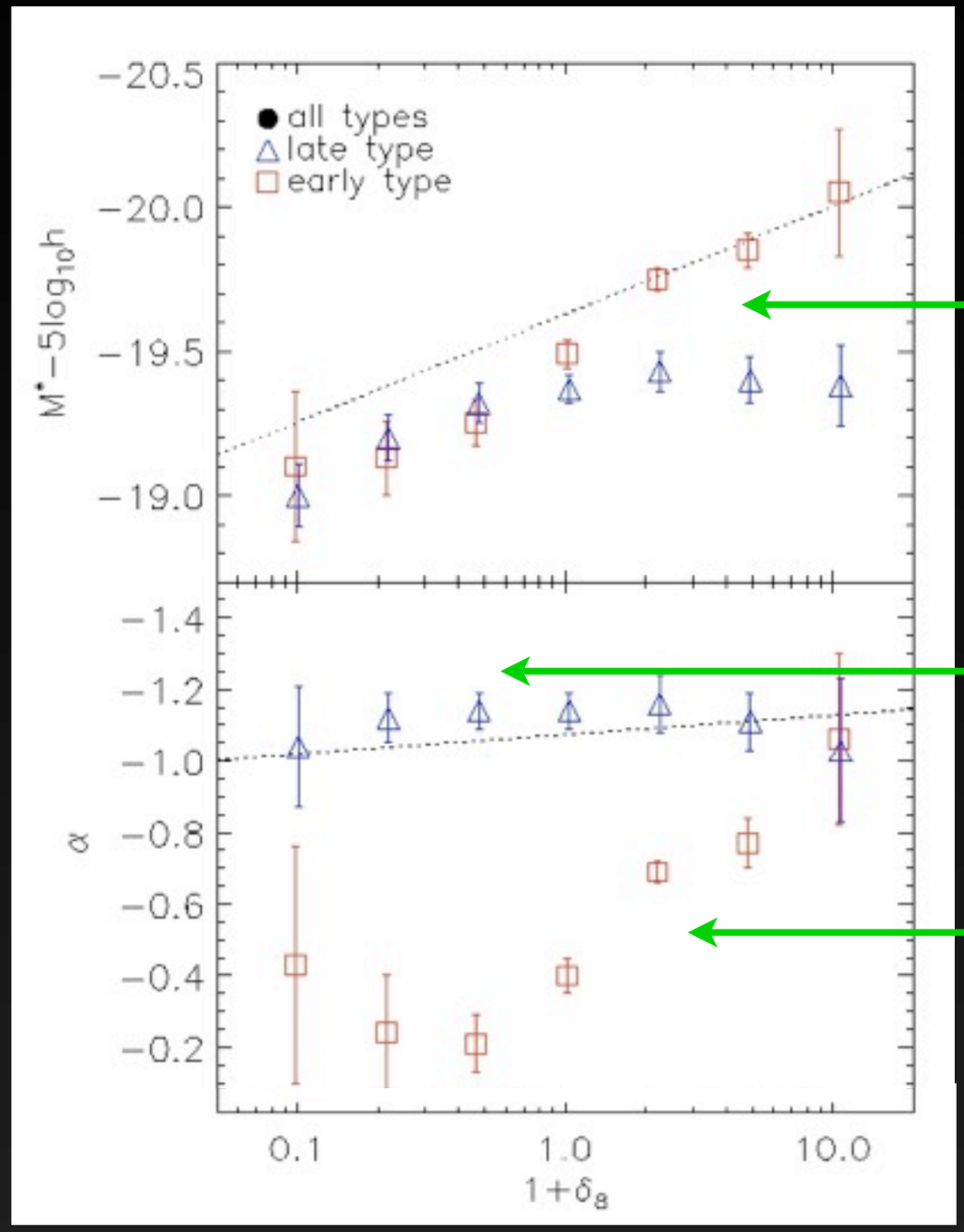
2dFGRS
Schechter parameters
vs.
environment



2dFGRS
Schechter parameters
vs.
environment



HOD model interpretation

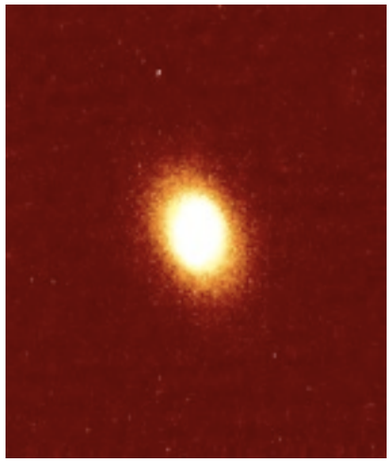


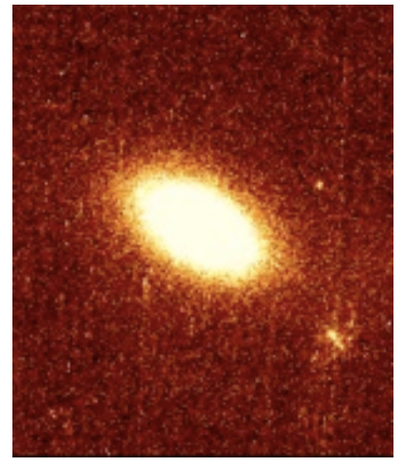
- denser regions exhaust the gas supply faster, resulting in redder objects

- faint later-type galaxies tend to live in less massive halos, which are present in all density environments

- faint ellipticals tend to mostly reside in cluster-sized halos

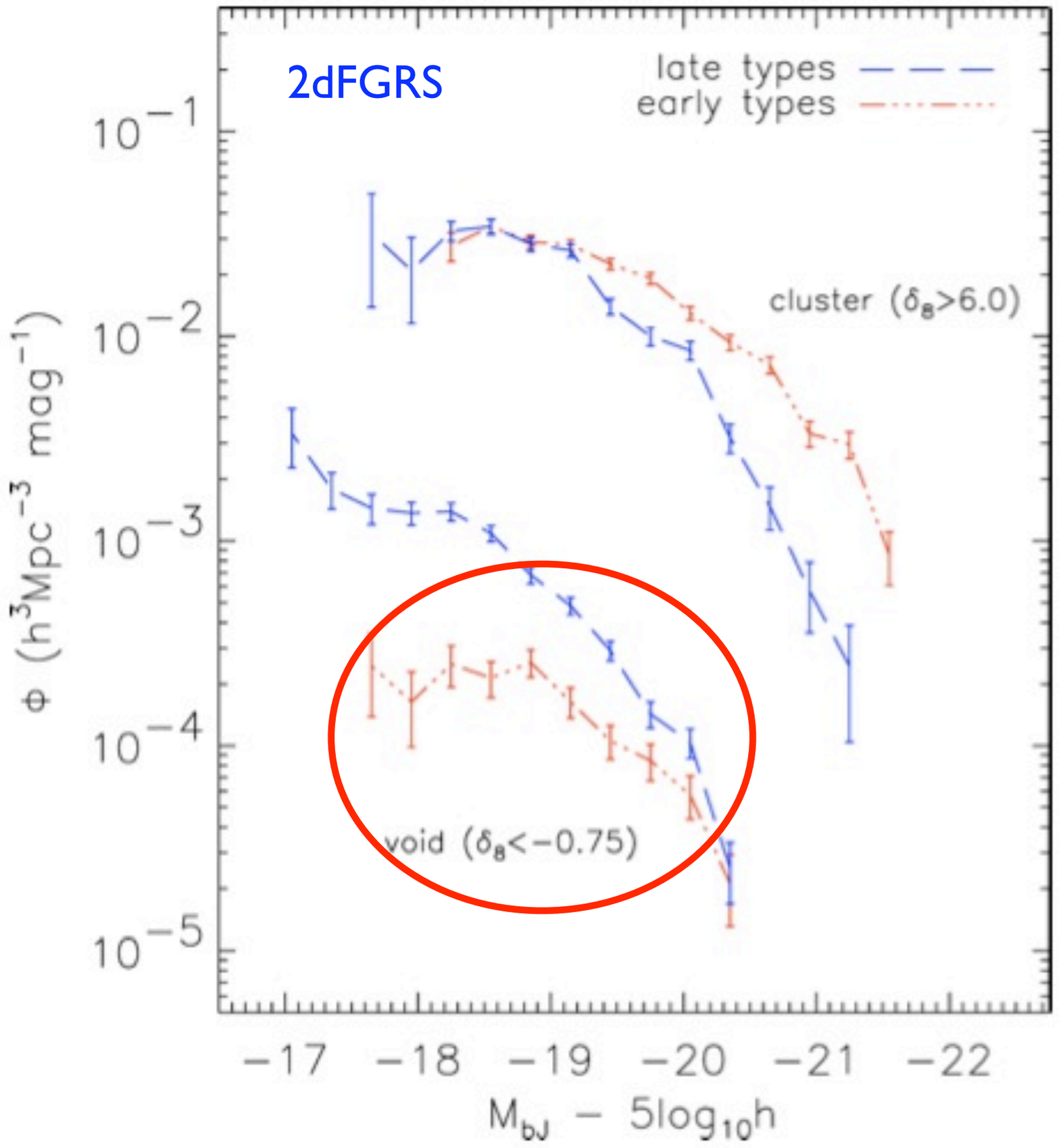
The environment dependence of galaxy properties can be accounted for by the dependence of halo mass on environment

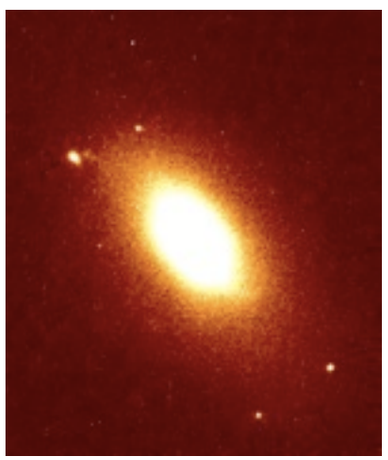


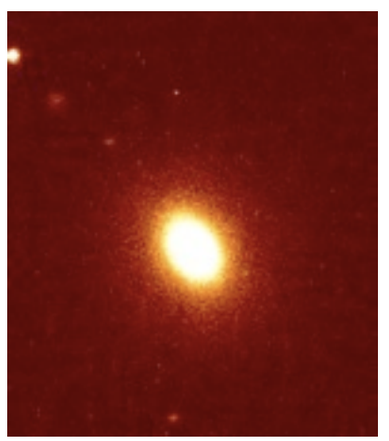


Croton et al. 2005

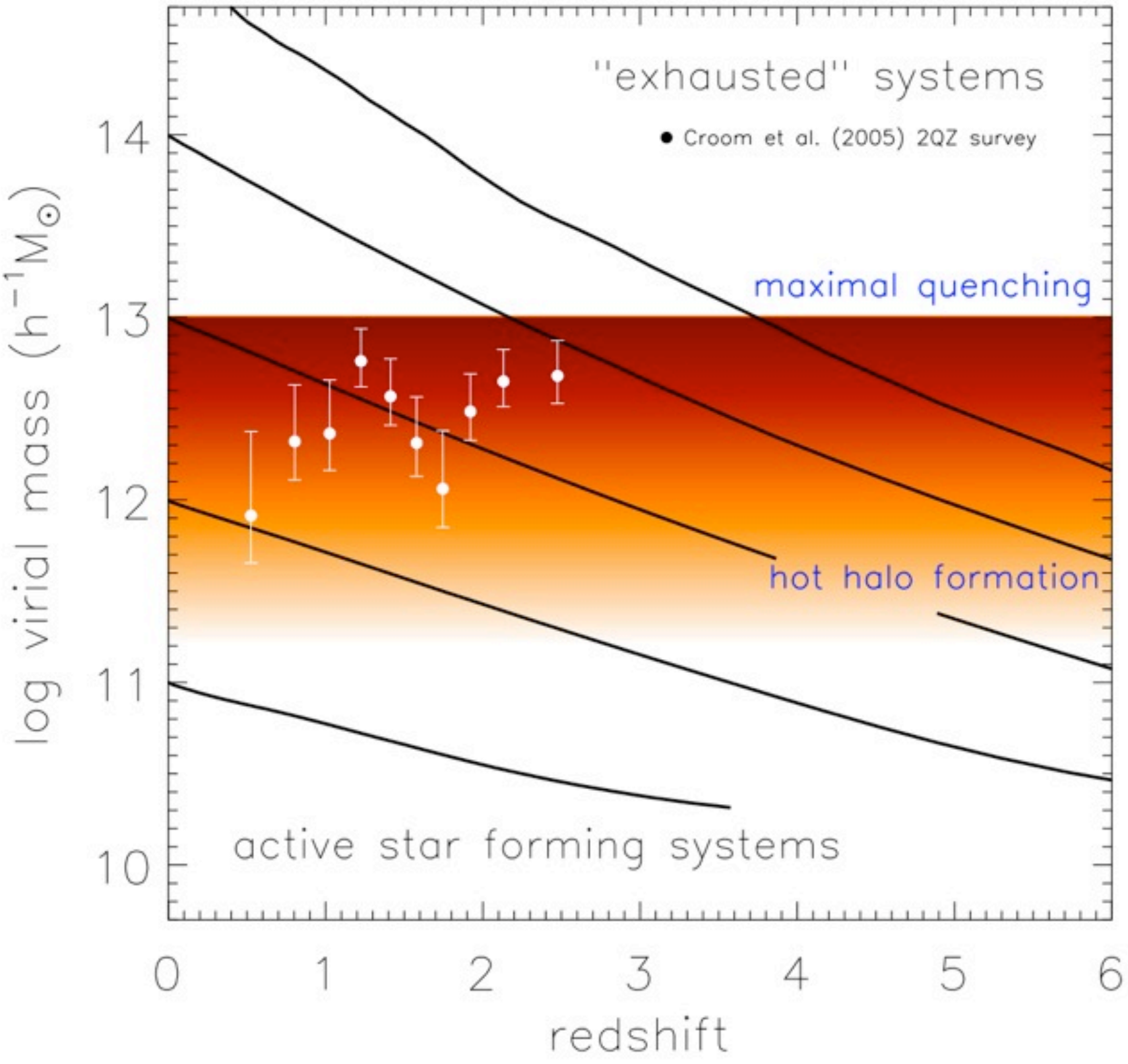
2dFGRS







Galaxy formation models

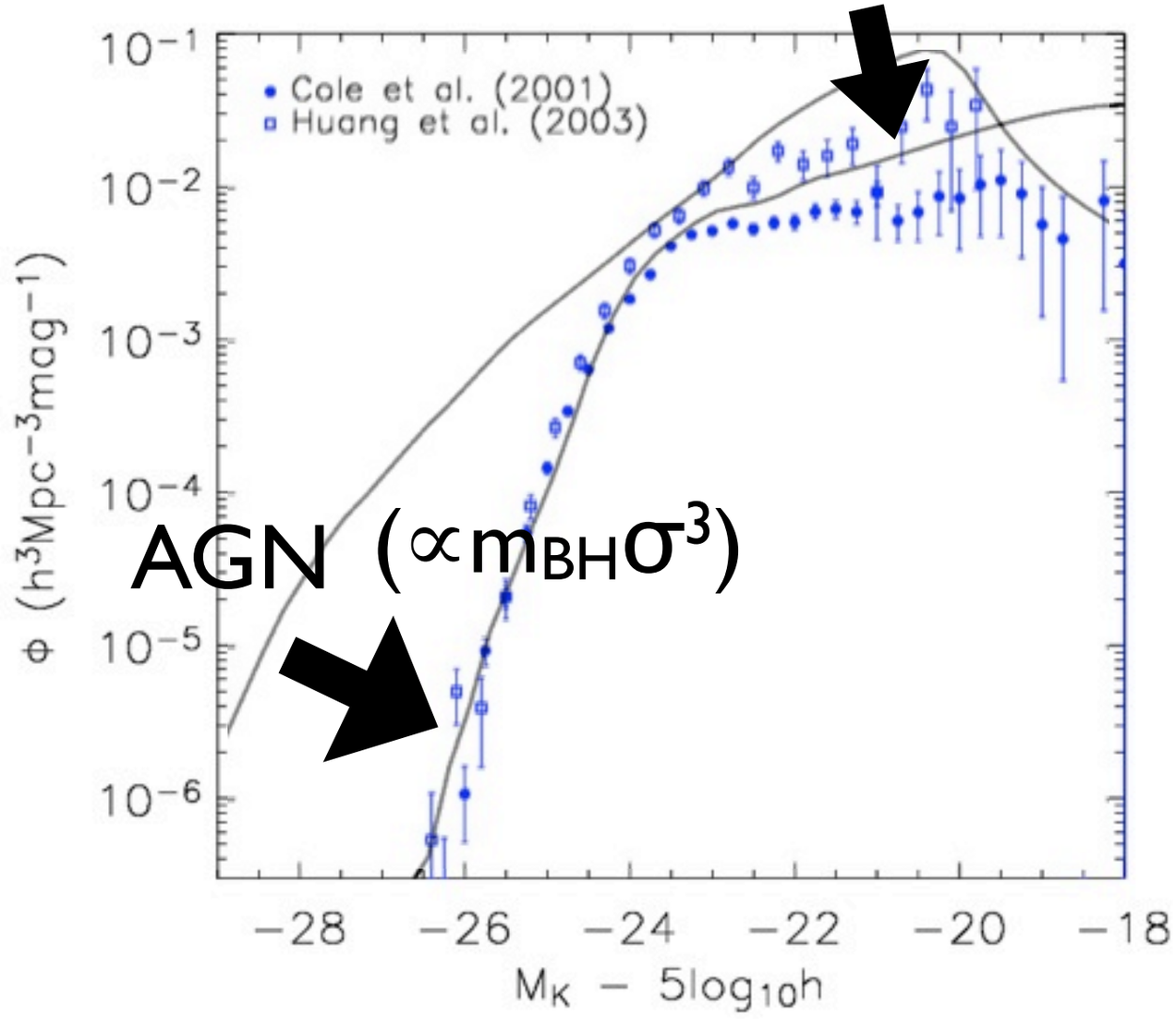


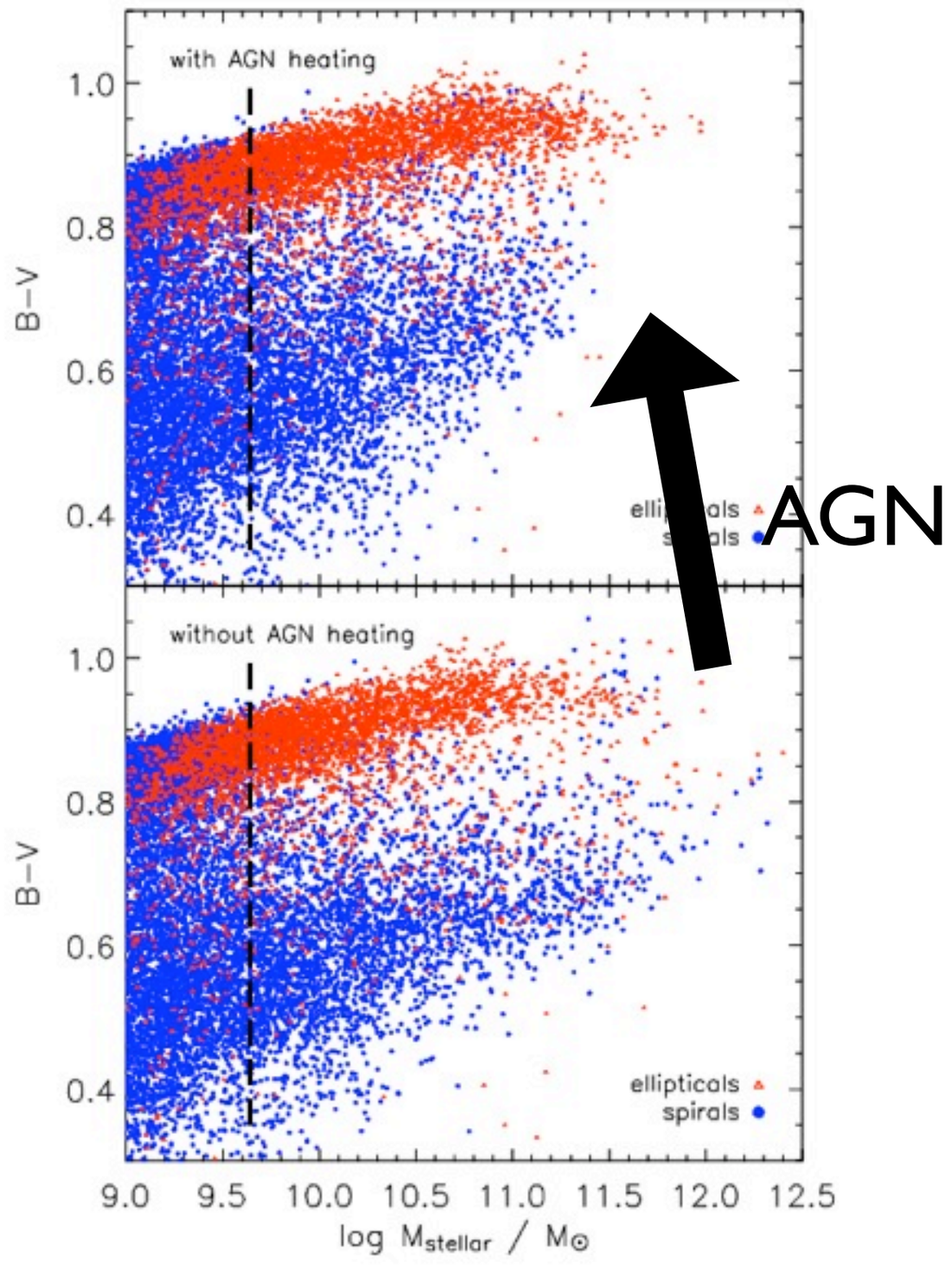

be, so watch it!”

Galaxy formation models

SN (∝SFR)

AGN (∝$m_{BH}\sigma^3$)

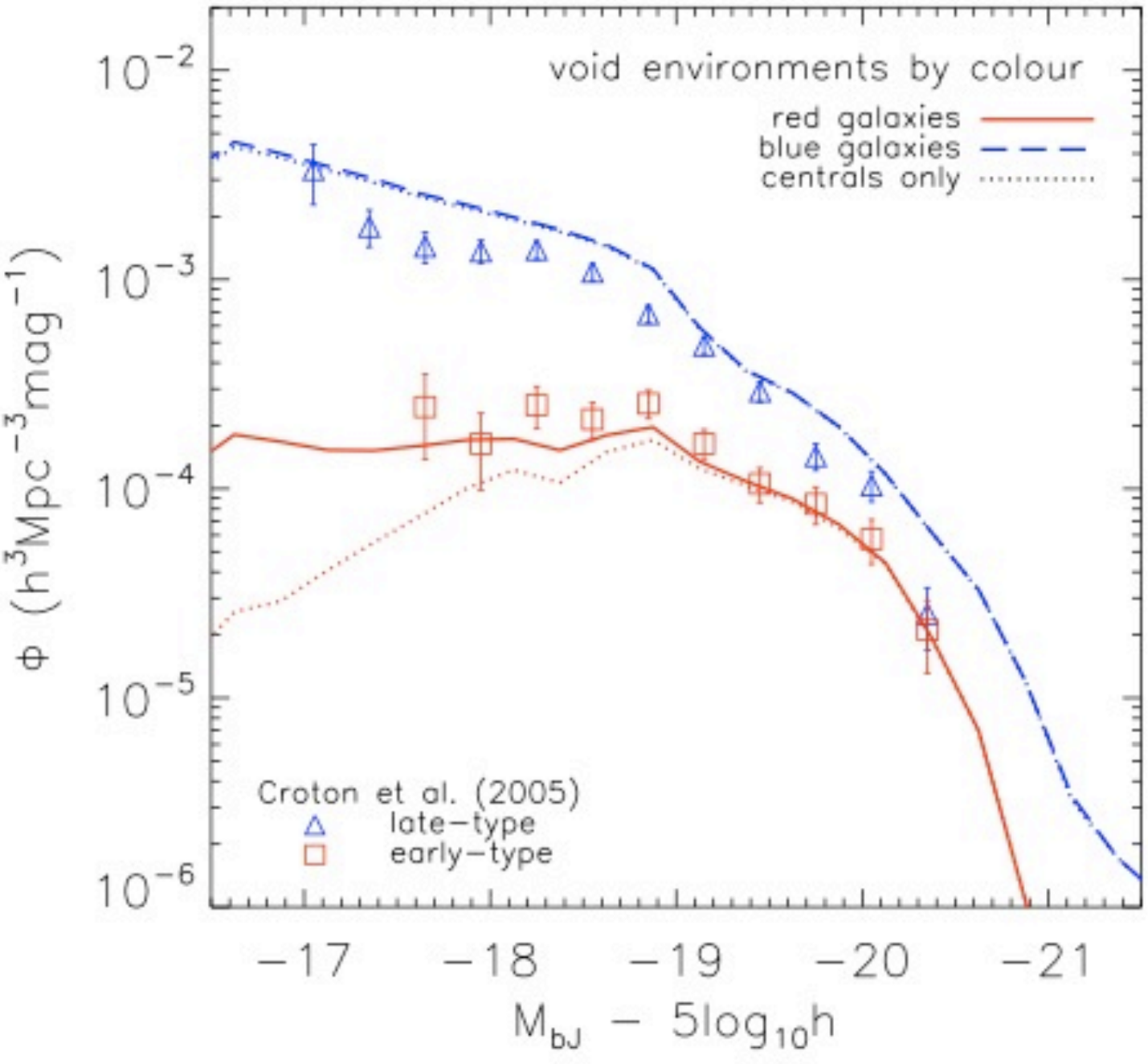




AGN

Croton et al. 2006

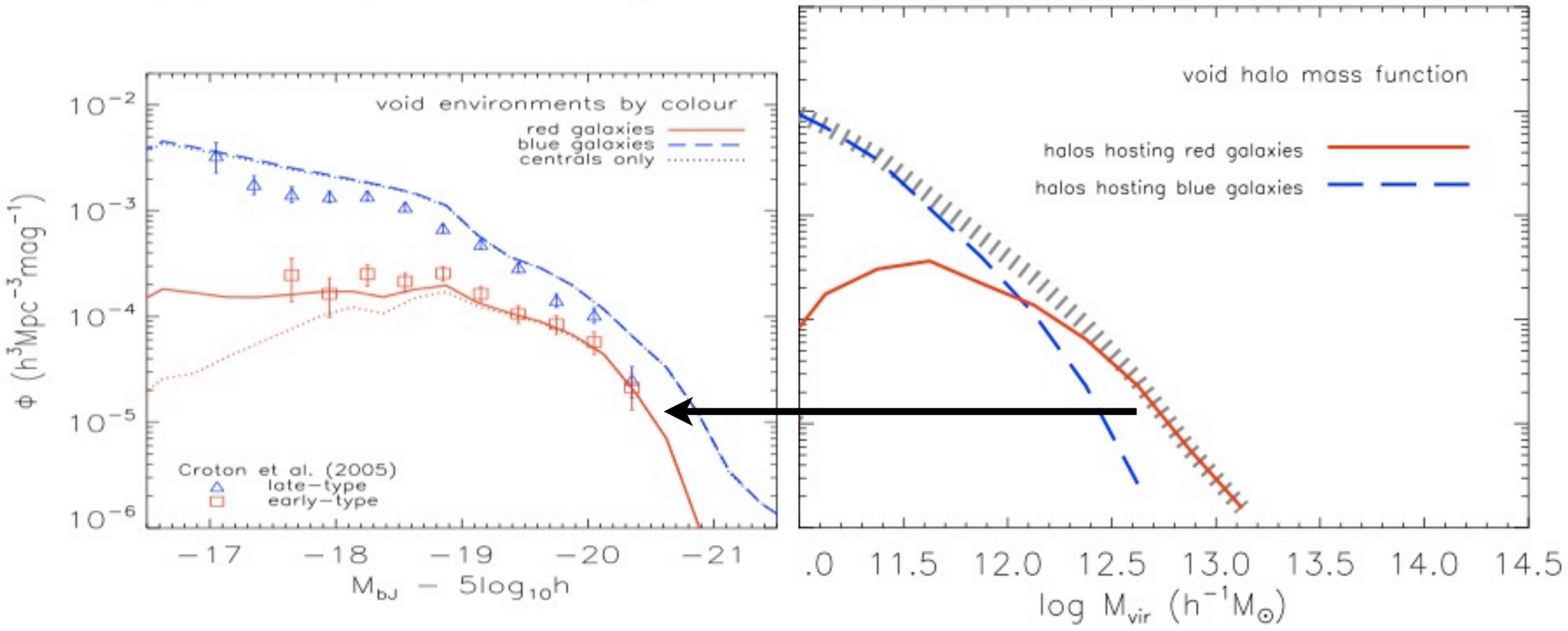
Croton & Farrar (2008)



The Millennium Simulation semi-analytic galaxy formation model

So what's special about early-type void galaxies?

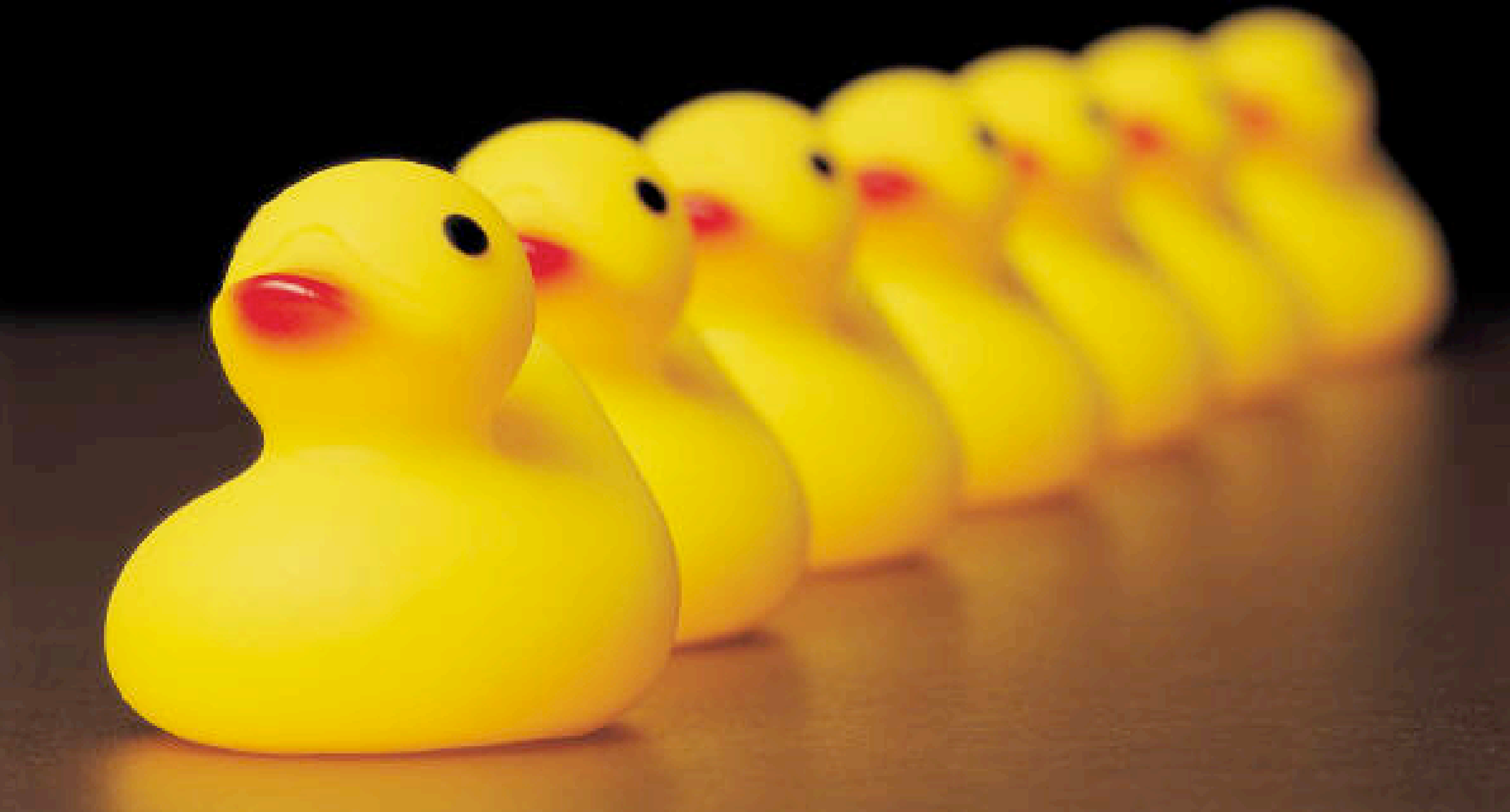
Croton & Farrar (2008)



Halo mass function in different environments

The red/blue void galaxy abundance can be accounted for by the dependence of halo mass on environment

An environment project



An environment project

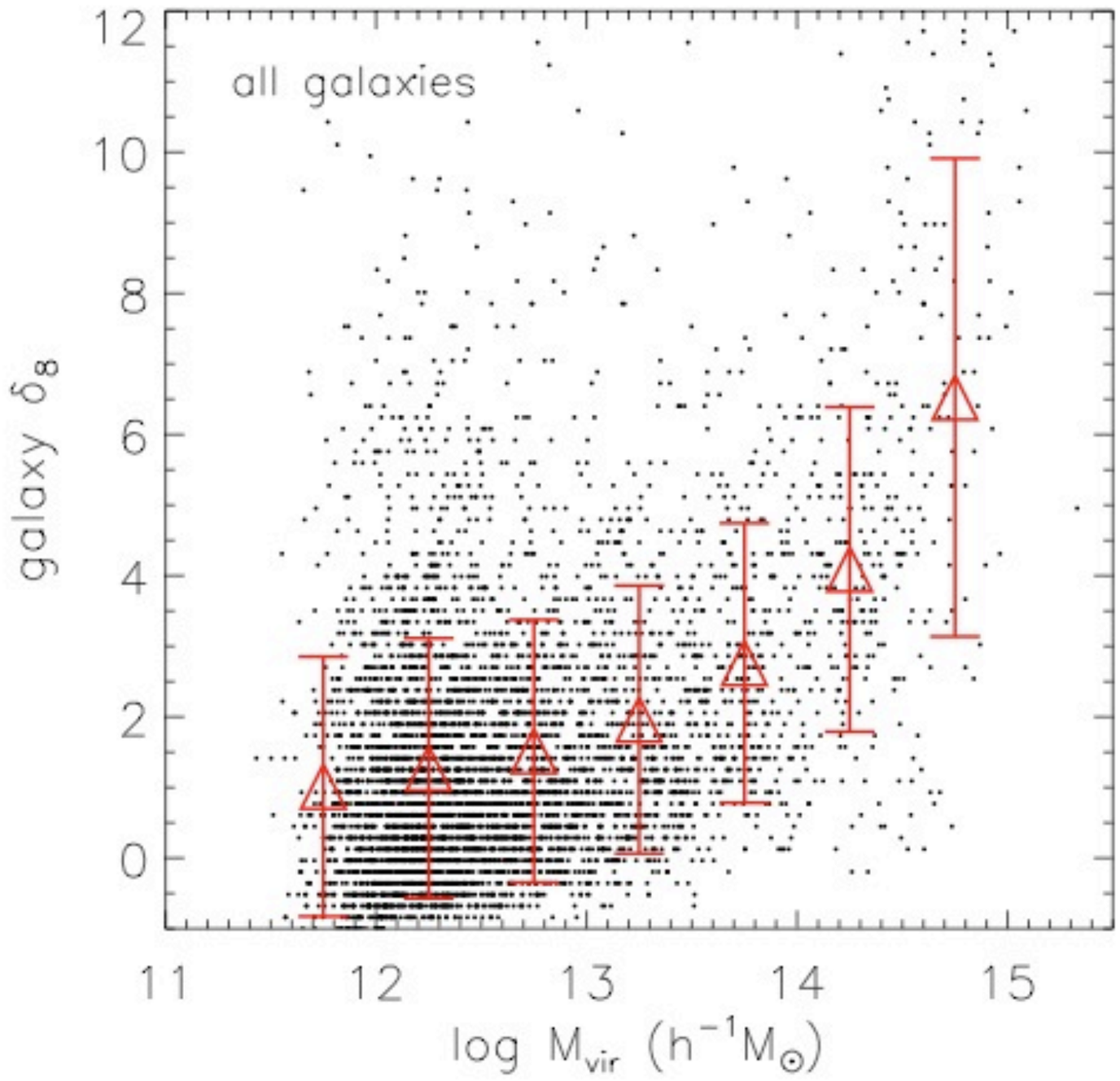
Apply multiple environment/isolated/void measures to a common mock catalogue:

- How do different measures of environment compare?
- How are our end results coloured by the environment measures we use?

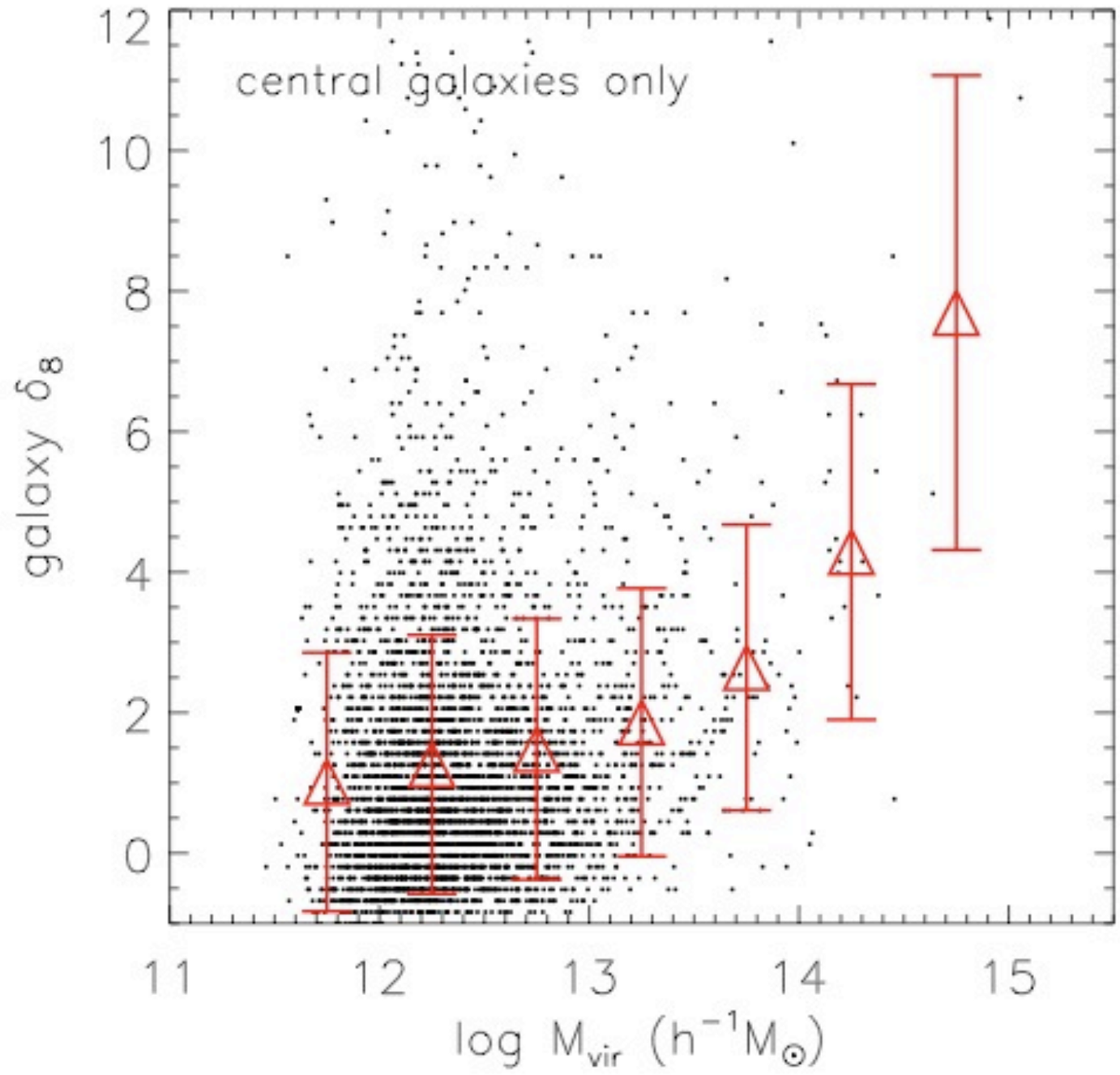
An environment project

- fixed aperture (spherical, cylinder) on small and large scales
- N'th nearest neighbour
- group finders and isolation criterion
- halo mass and the underlying DM density field
- 2D vs 3D measures
- others?

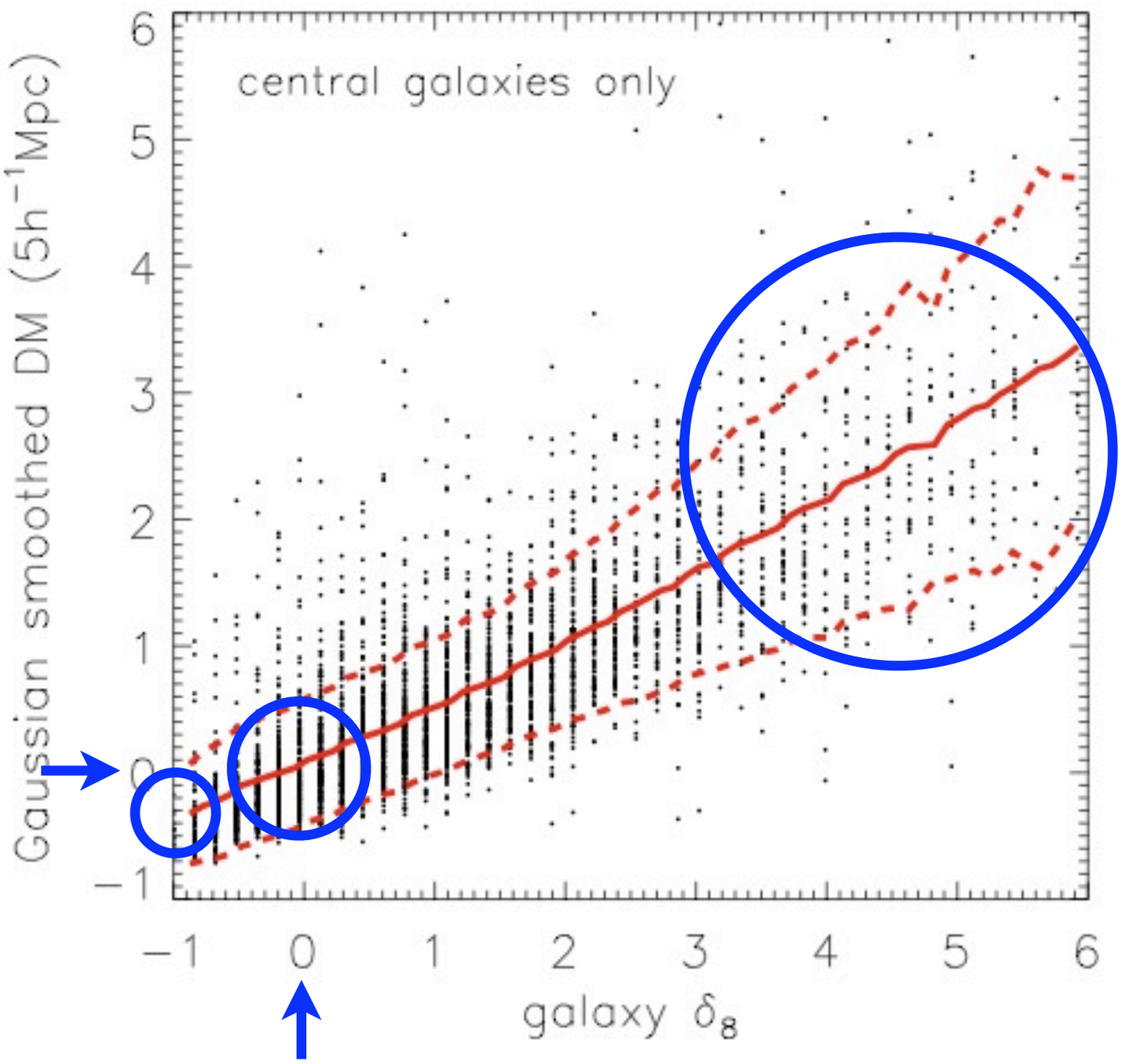
An environment project



An environment project



An environment project



Please join us!