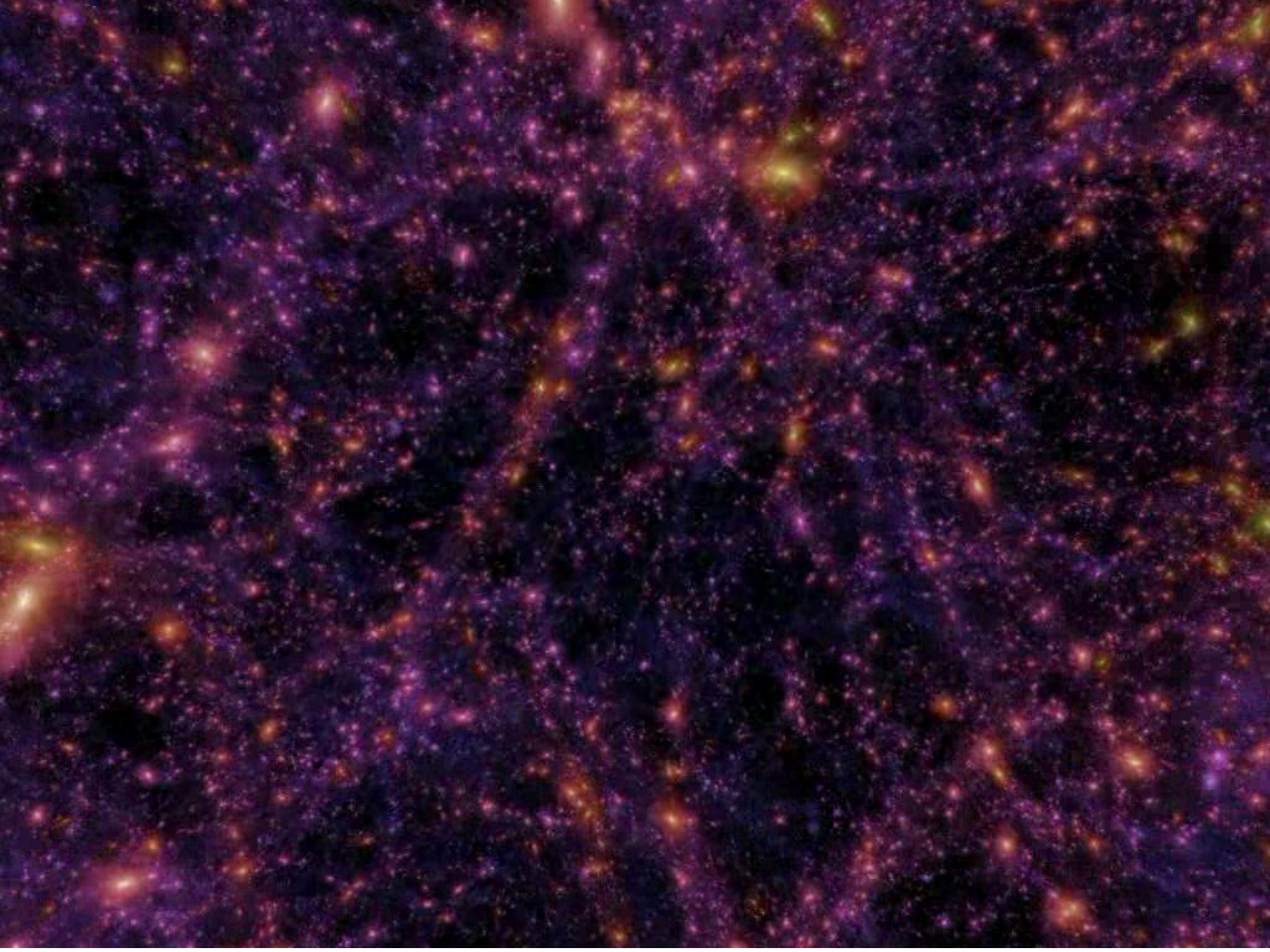
Luminosity bias I : from haloes to galaxies

Carlton Baugh
Institute for Computational Cosmology
Durham University

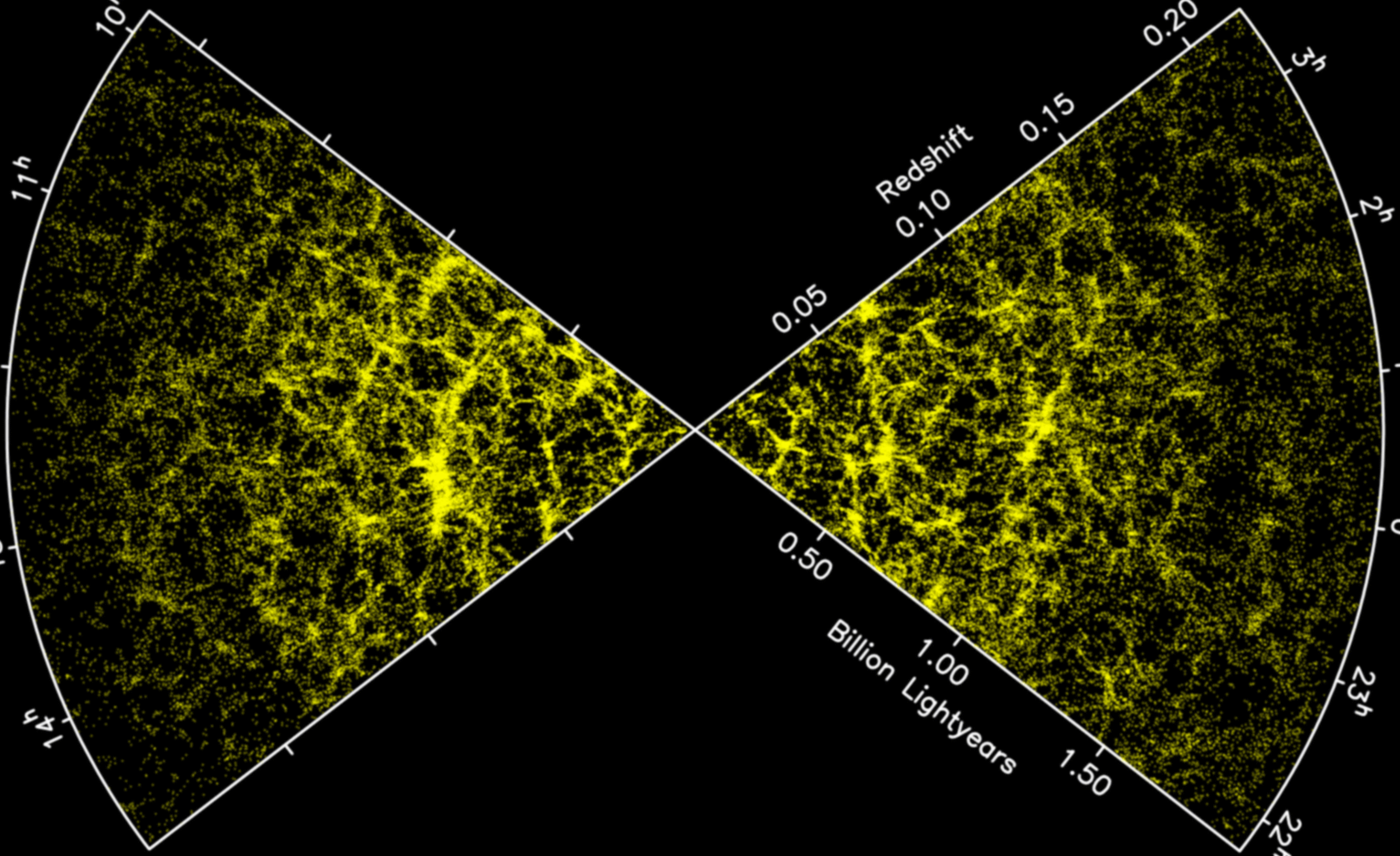
Durham University

Cosmobias workshop Marseille 22nd May 2012

Cosmic architecture: gravity



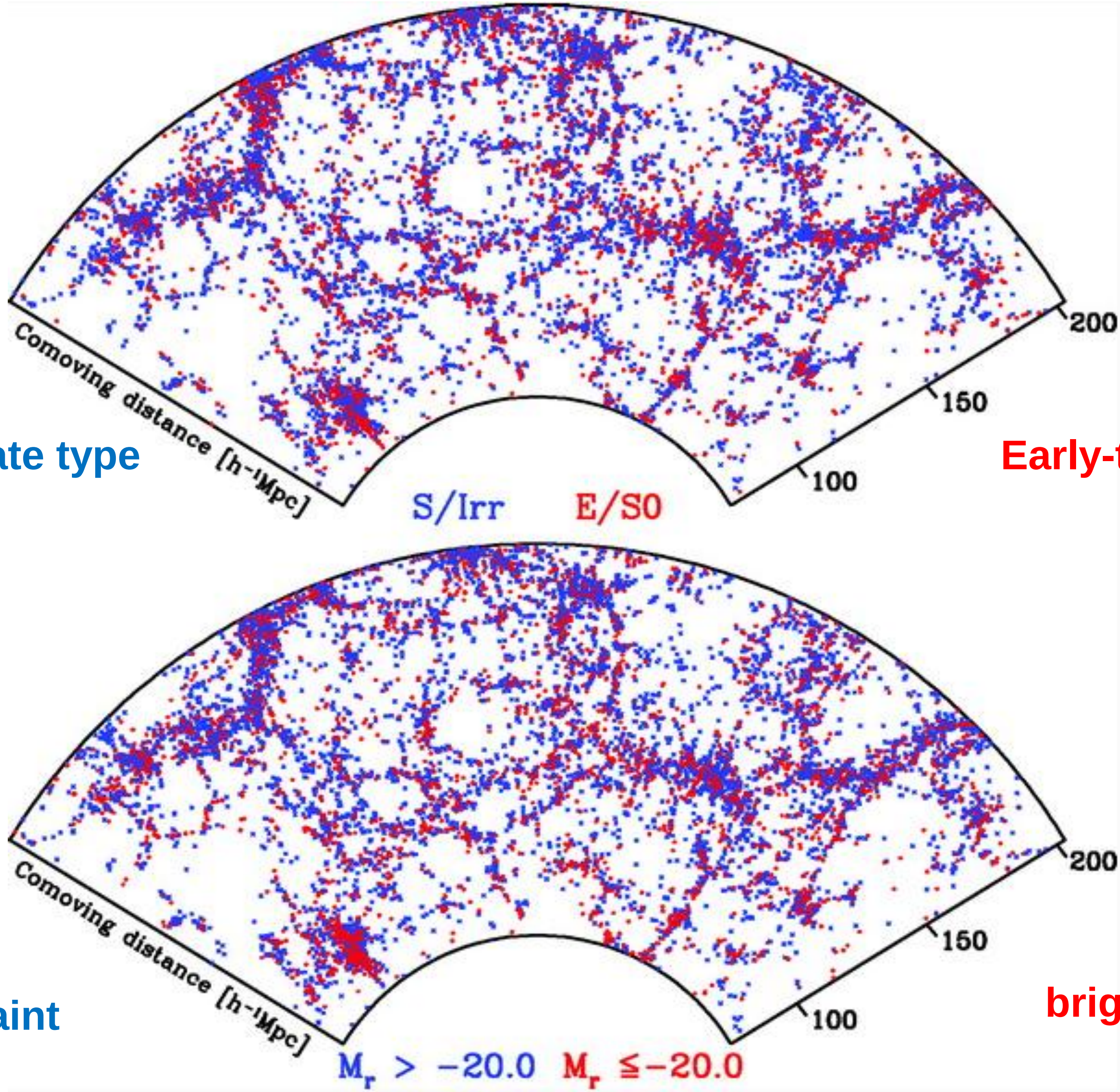
Two-degree Field Galaxy Redshift Survey



Sloan Digital Sky Survey

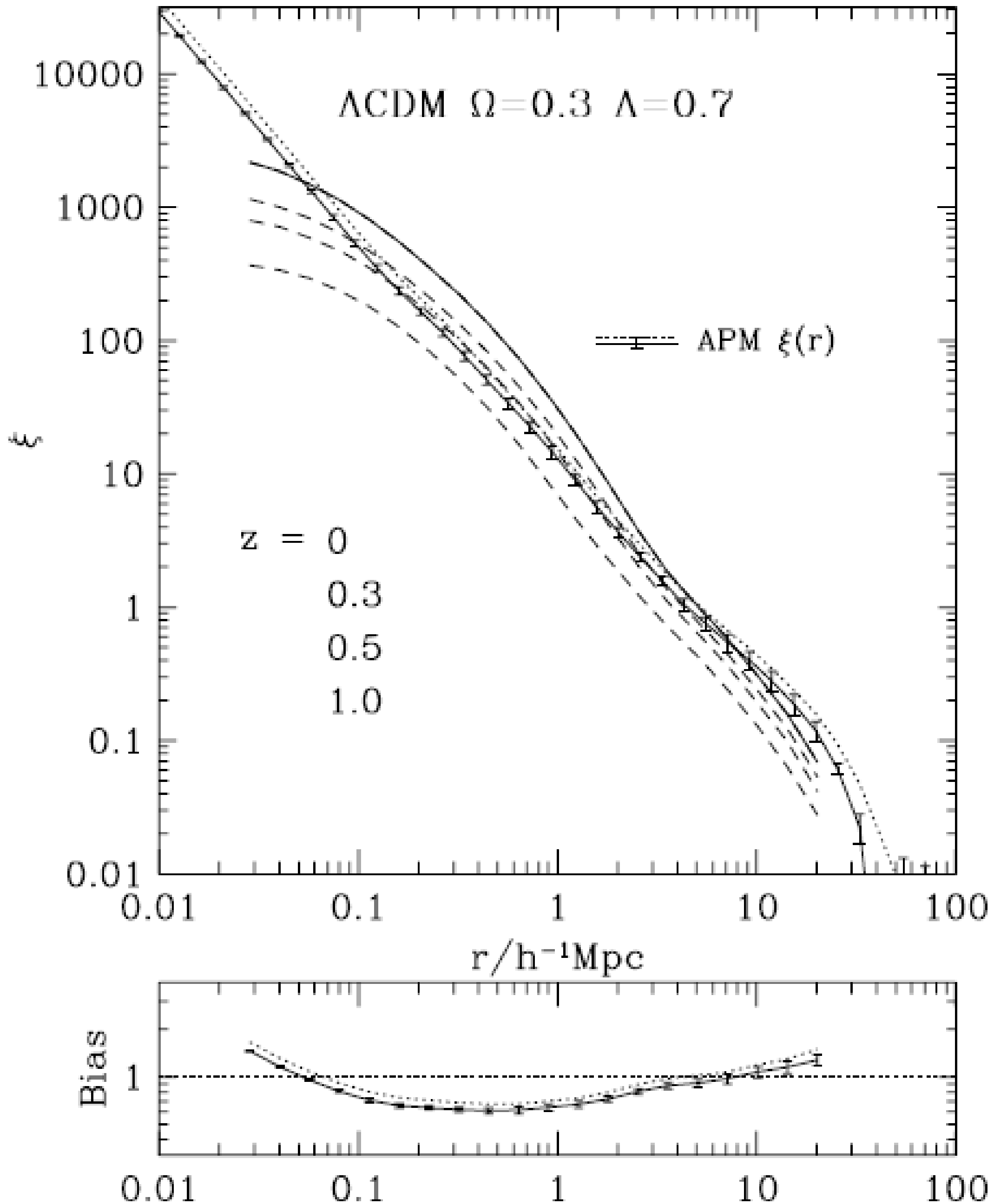
Late type

Early-type



faint

bright

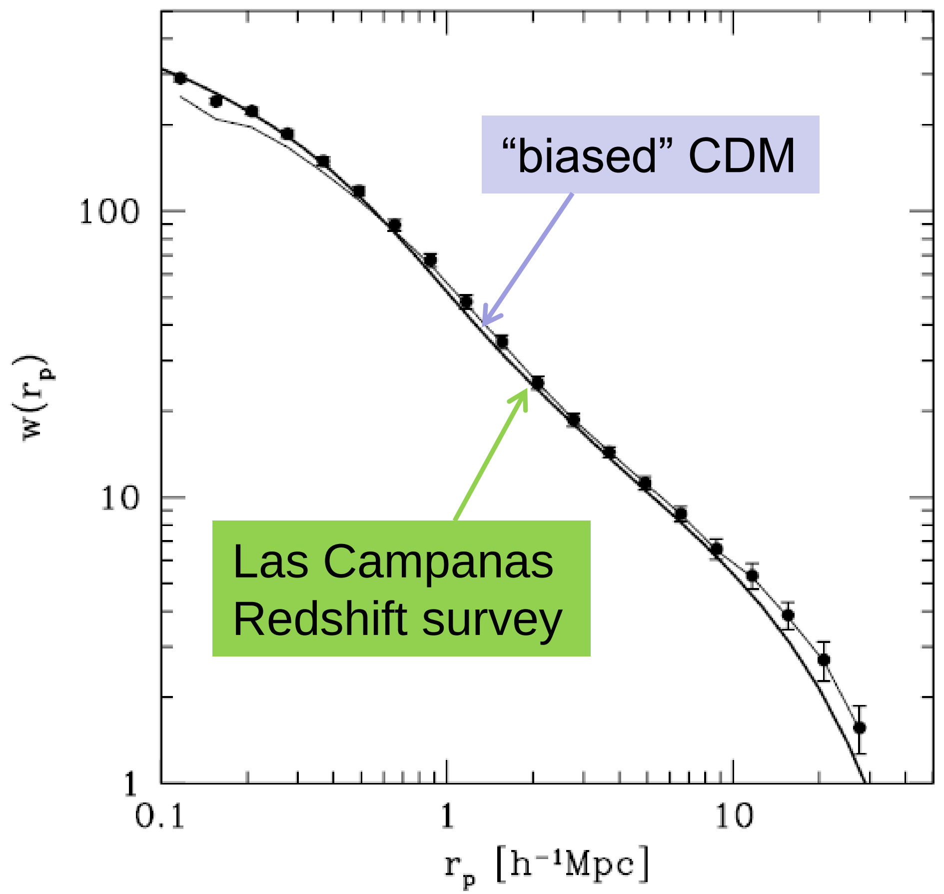


Galaxy clustering vs dark matter clustering

- Galaxy correlation function ~ power law over 3-4 decades in r
- DM correlation function not a power law
- Scale dependent bias

Jenkins et al. 1998

Use DM haloes instead of DM

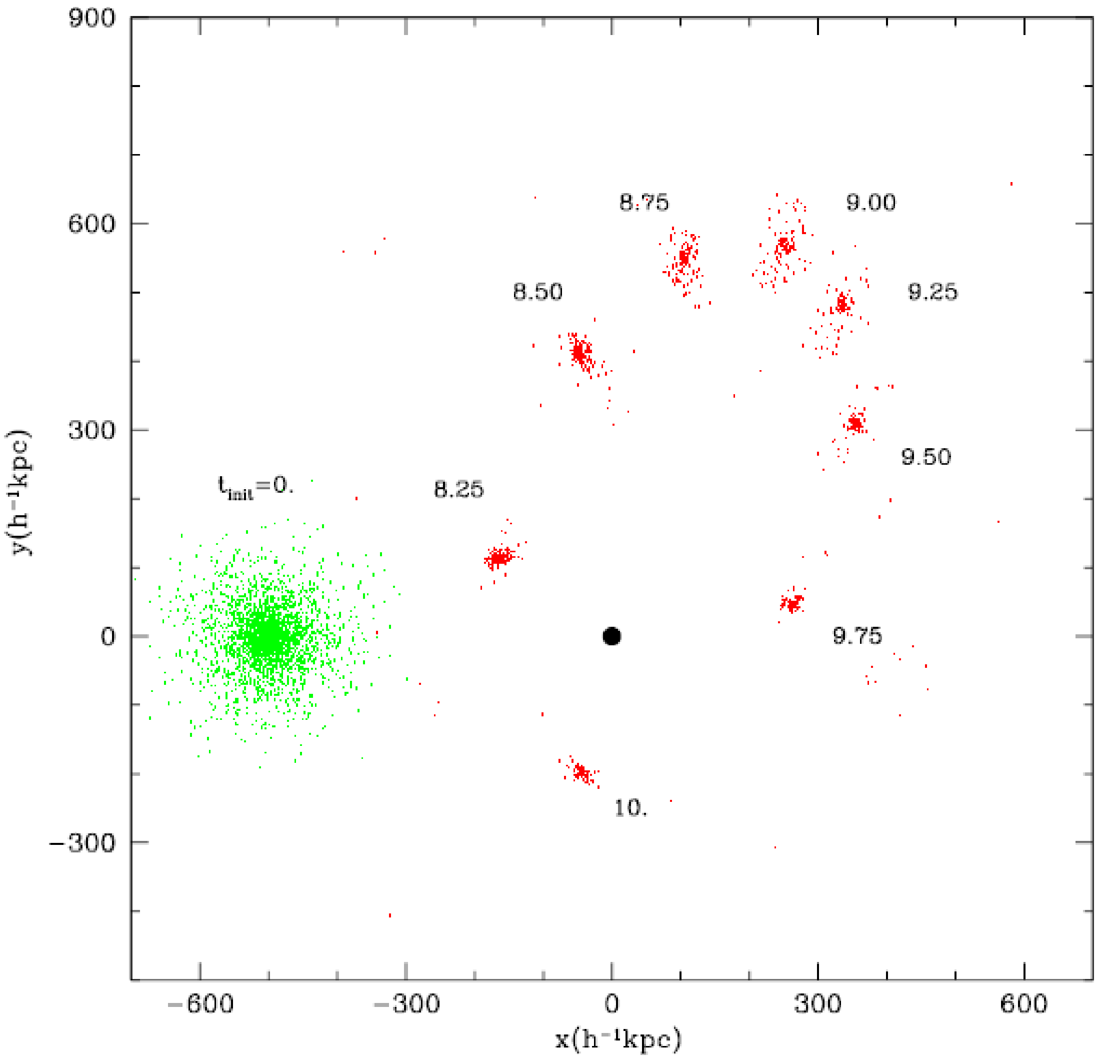


- First "Halo Occupation Distribution" model
- Scale dependent bias
- No low mass cut off
- No split between centrals and satellites

$$N/M \propto M^{-\alpha}$$

Jing, Mo & Boerner 1998

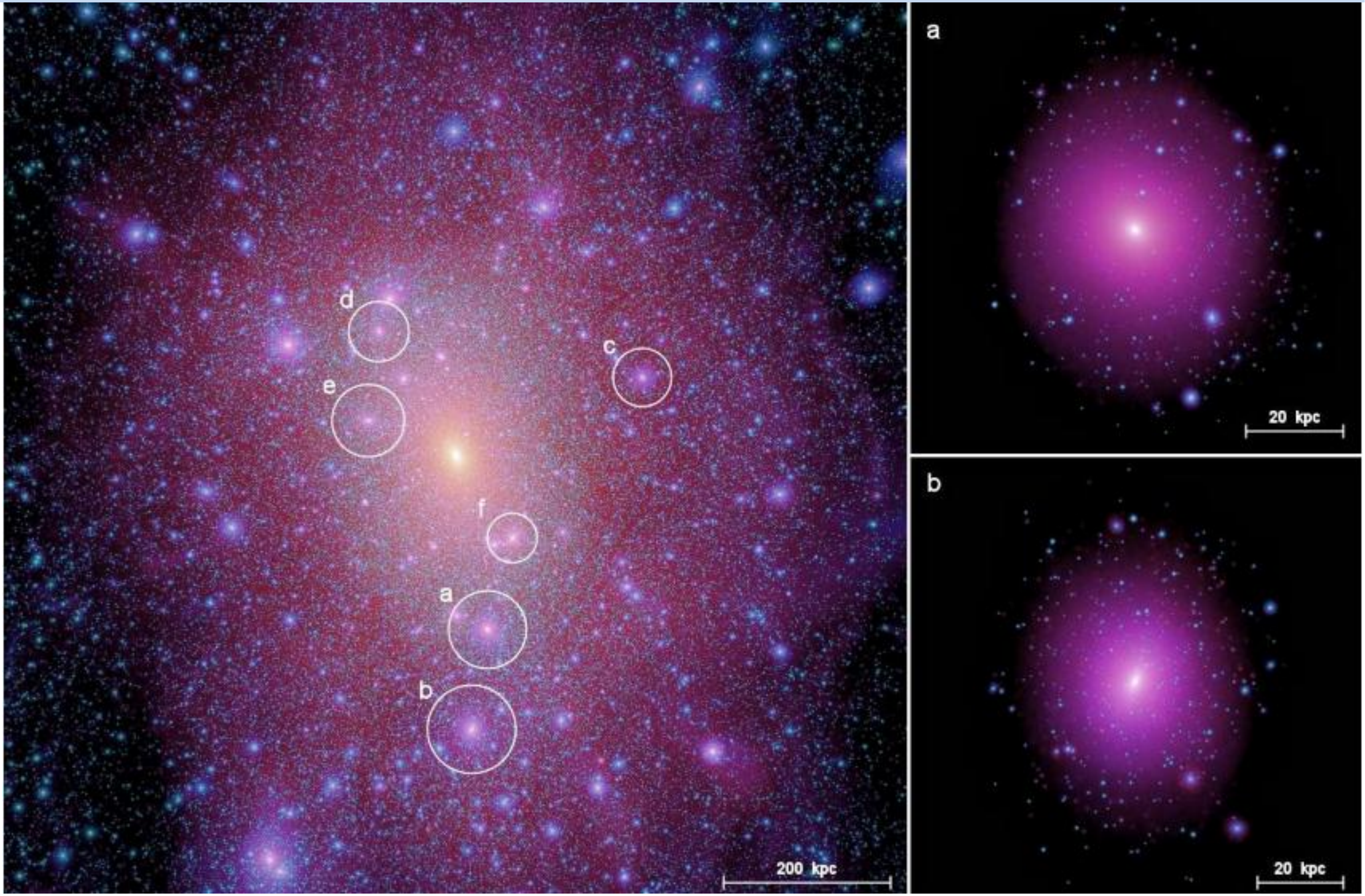
Avoiding “overmerging”



- Should we compare galaxies with haloes or subhaloes?
- Early simulations lacked mass & force resolution to follow subhalos

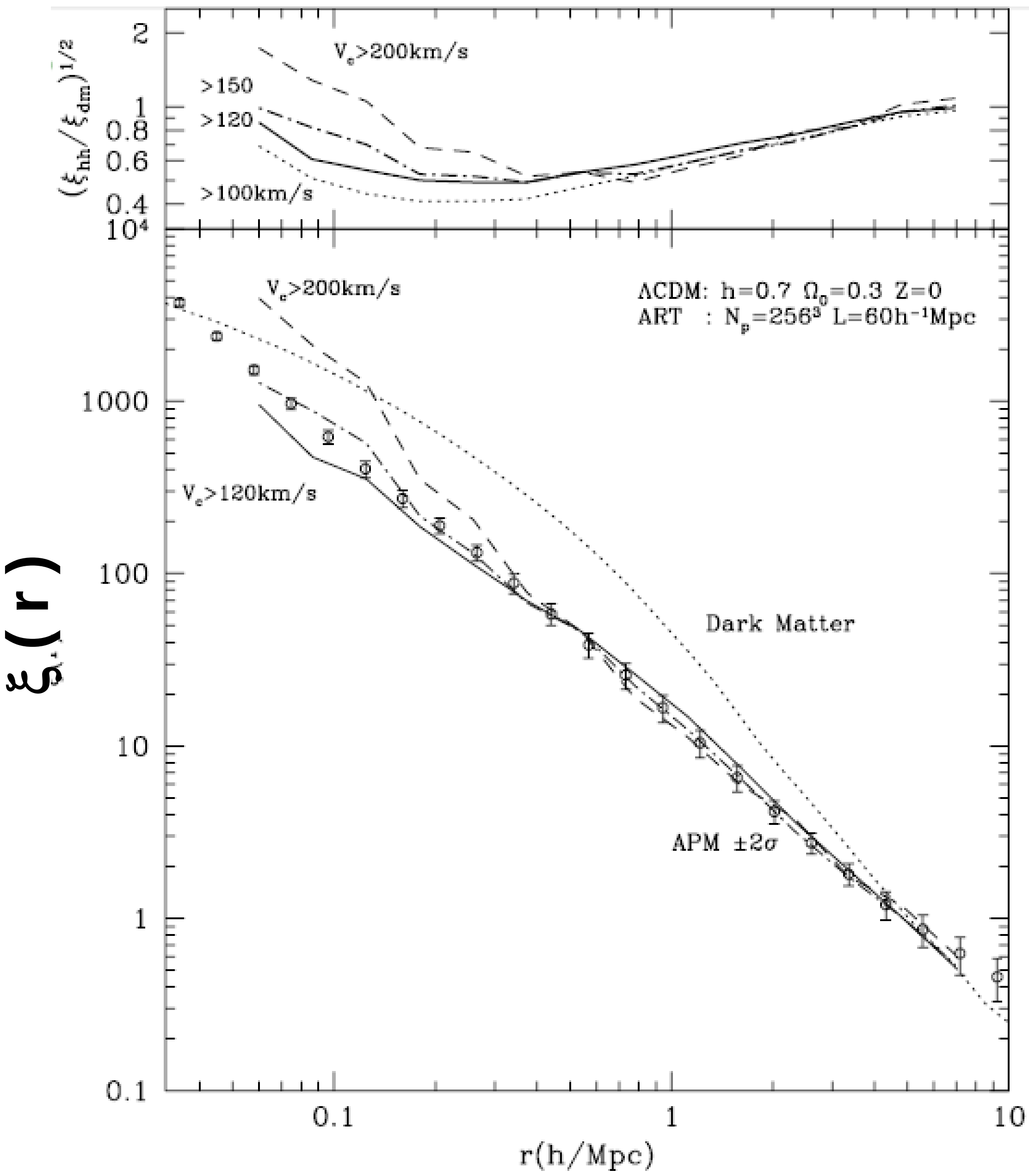
Klypin et al. 1999

Hierarchies of substructure



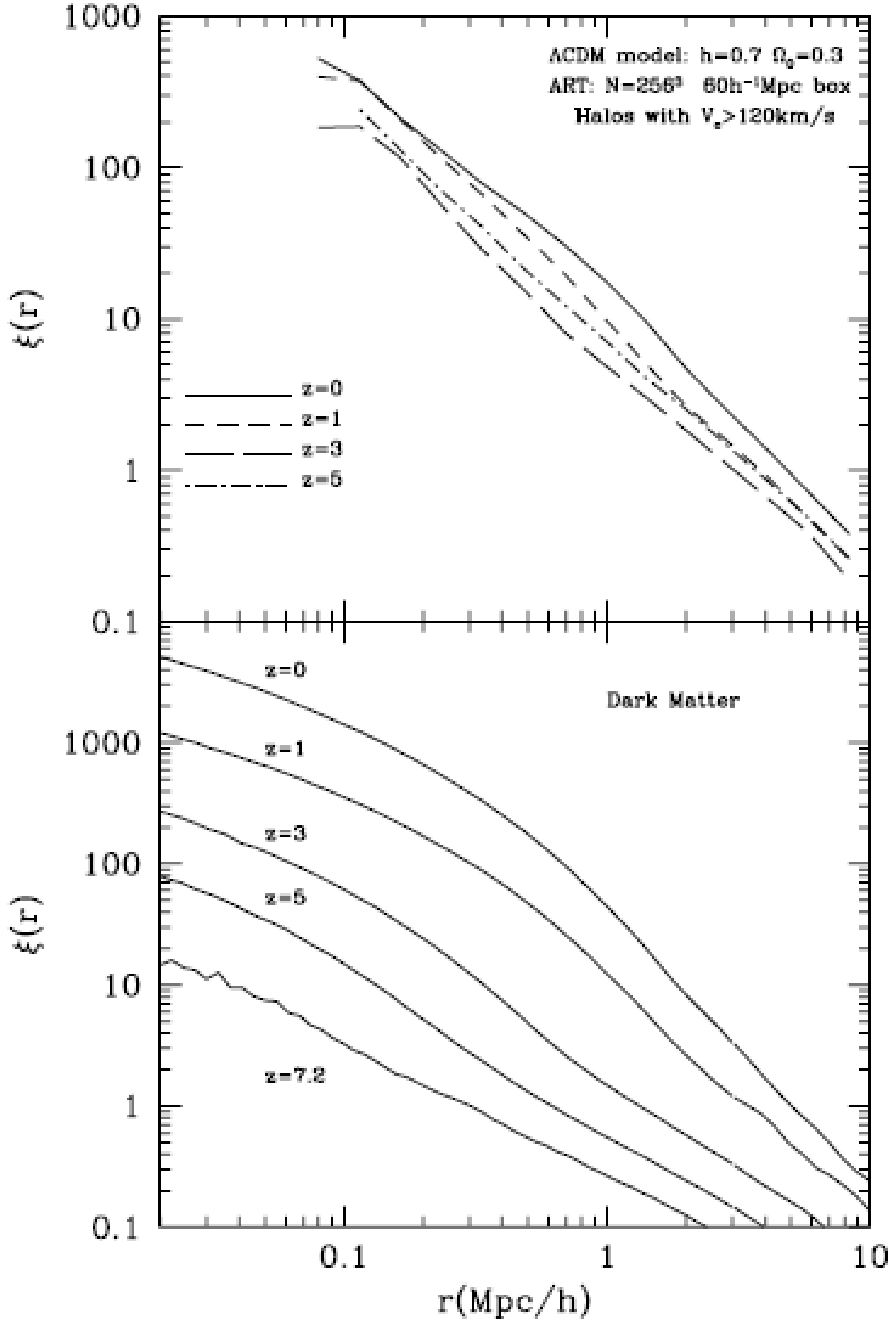
Springel et al 2008

Matching sub-haloes to “galaxies”



- Put cut on subhalo circular velocity
- Associate subhaloes with galaxies
- Early version of SHAM

Colin et al. 1999
Klypin et al. 1999
Kravtsov et al. 2004

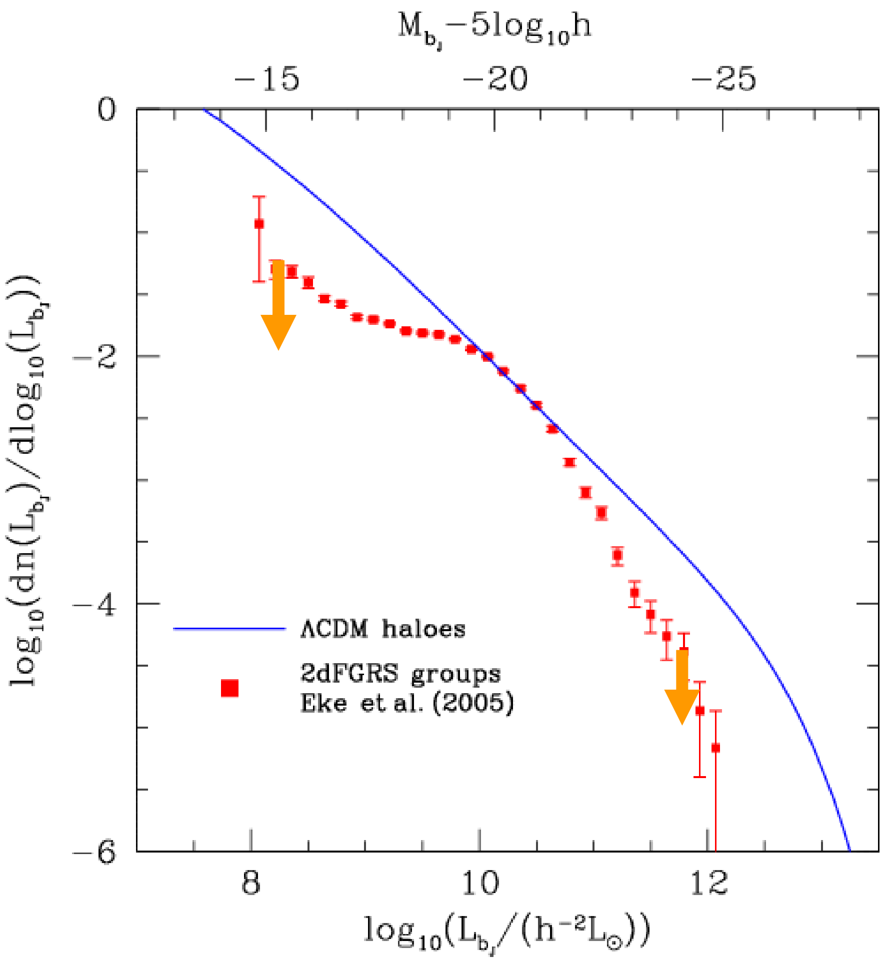


Clustering evolution

- Apply fixed Vc threshold on subhaloes
- Find little evolution in “galaxy” clustering
- Contrast with strong evolution in DM clustering
- Evolution in galaxy bias

Colin et al 1999

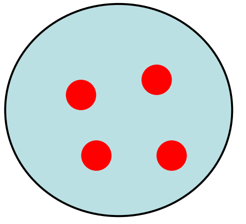
Can we compute N(M)?



abundance

Total group luminosity

Galaxy group luminosity function
Measured from 2dFGRS by
Eke et al. 2004, 2005



$L_{group} = \Sigma L_{galaxy}$

Simple prediction:
Take CDM halo mass function
plus fixed M/L ratio

↓

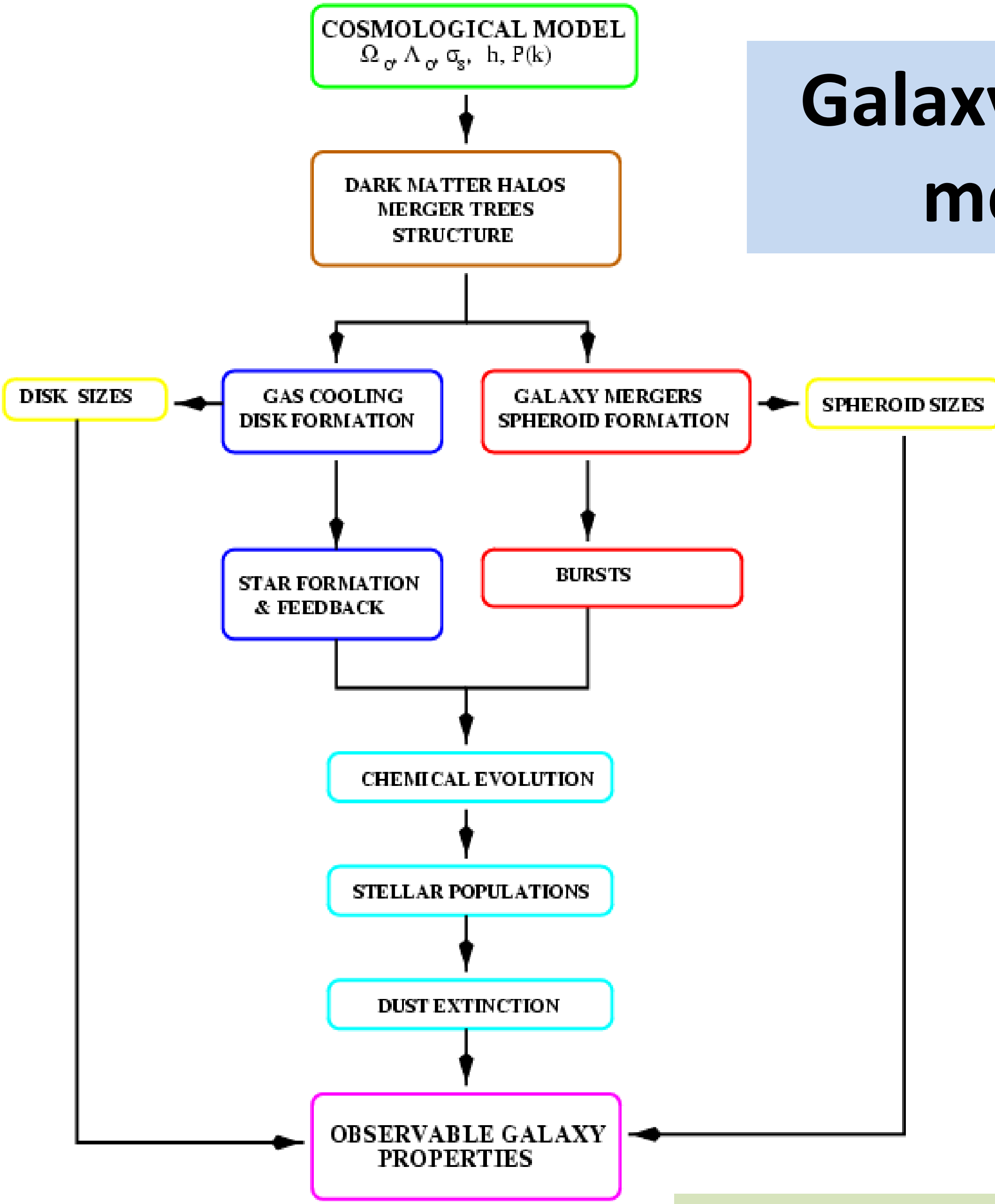
Galaxy formation TOO efficient
in both low and high mass haloes

↓

Different physical processes
affect efficiency of galaxy
Formation as function of M

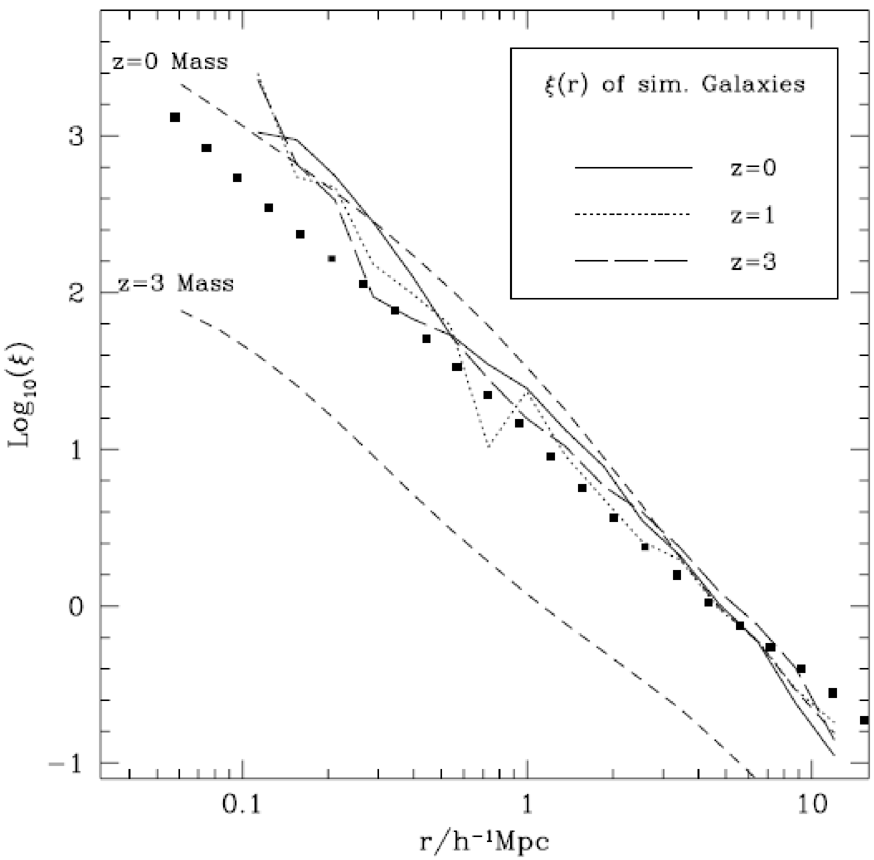
Baugh 2006

Galaxy formation modelling



Cole et al. 2000; Baugh 2006; Benson 2010

Galaxy clustering from gas dynamics



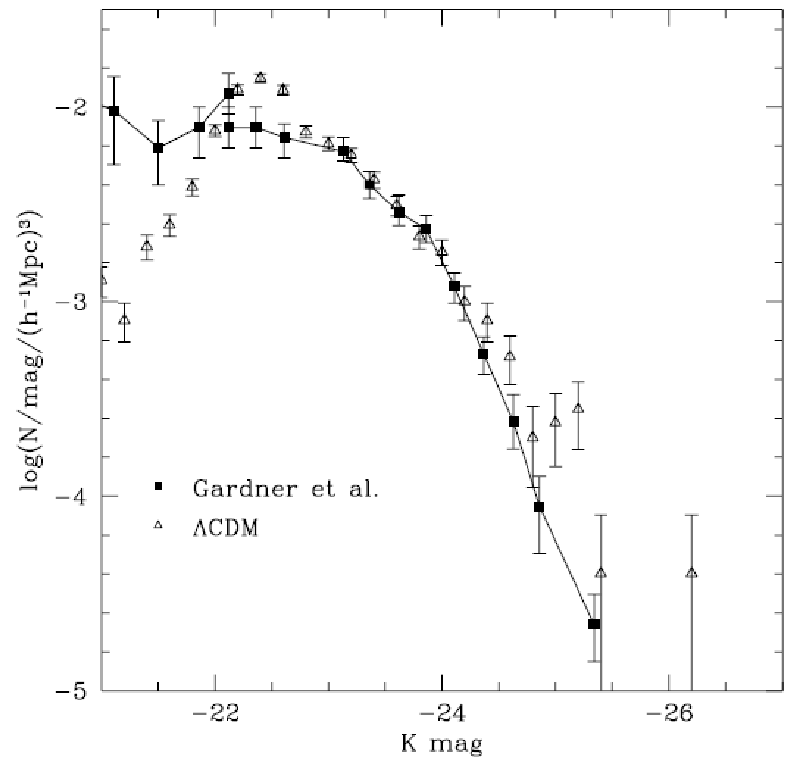
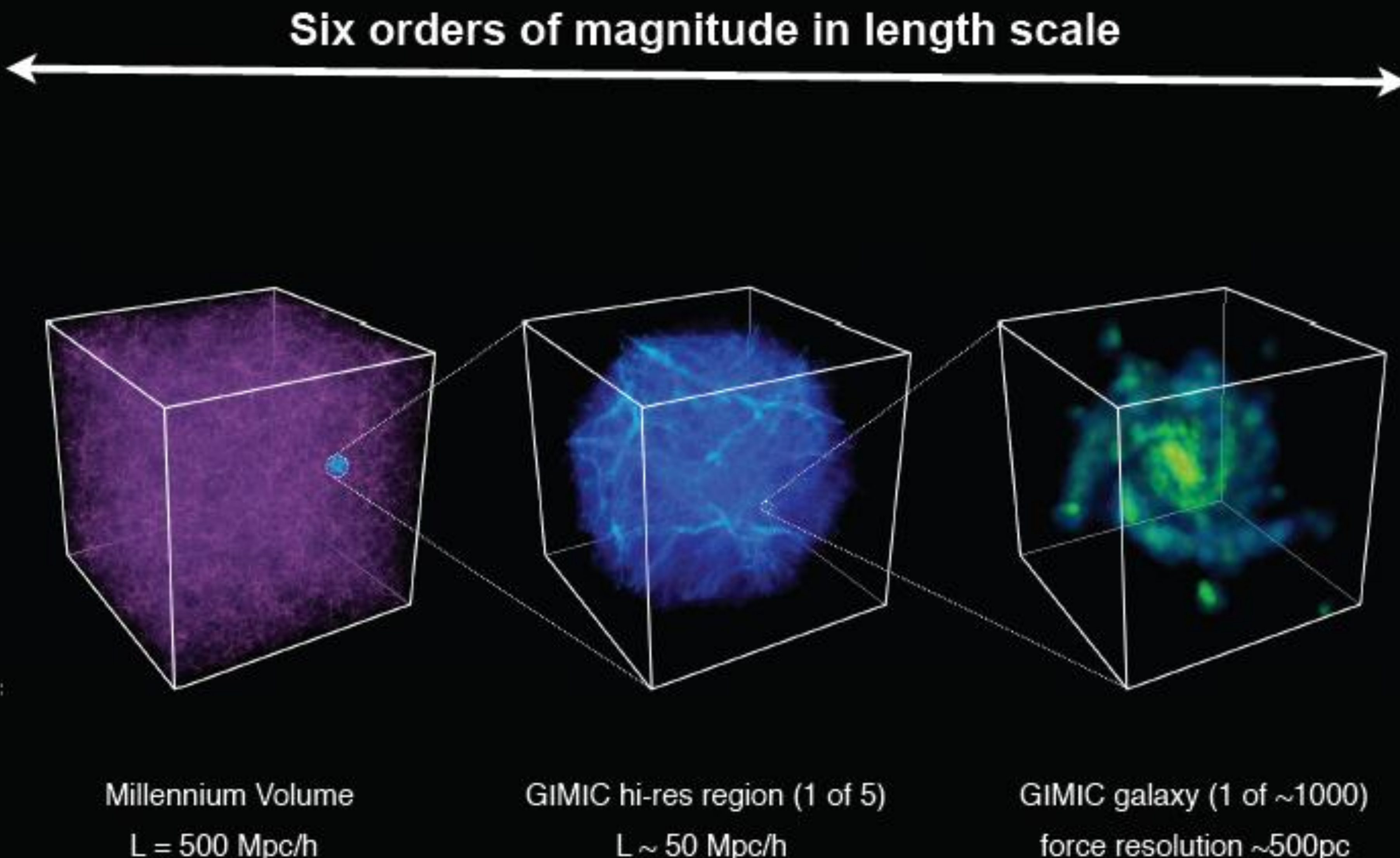


Fig. 3. A comparison between the K-band galaxy luminosity function in the simulation with observations. The simulation data are shown by open triangles and the data from Gardner *et al.* (1997) by filled squares. A luminosity normalization factor of $\Upsilon = 2.8$ has been assumed. Poisson errors are shown.

Pearce et al. 1999



Crain et al. 2009

Gas simulations vs. Semi-analytic modelling

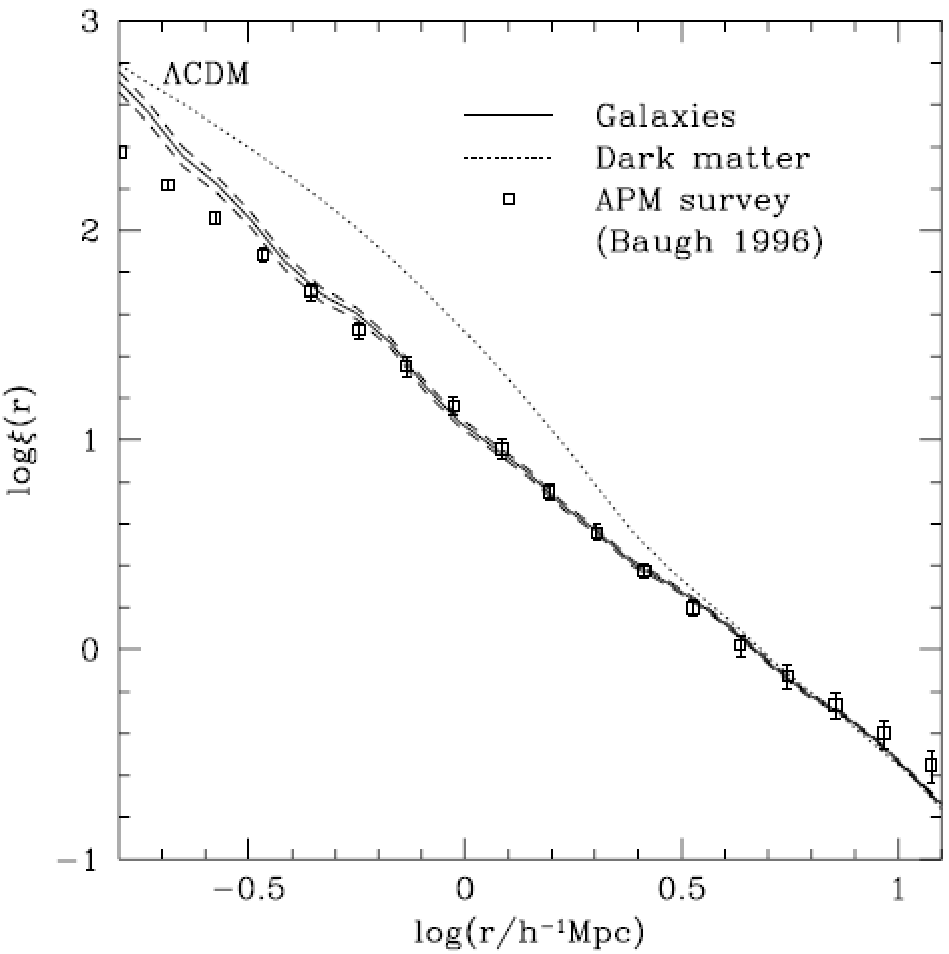
Gas simulations:

- More direct
- (Sometimes) more information
- Challenged by dynamic range
- Still use 'sub-grid' physics (=semi-analytics)

Semi-analytic models:

- More generalised calculation e.g. Spherical symmetry
- Faster
- Flexible
- Modular
- Can populate huge volumes without losing accuracy in baronic physics

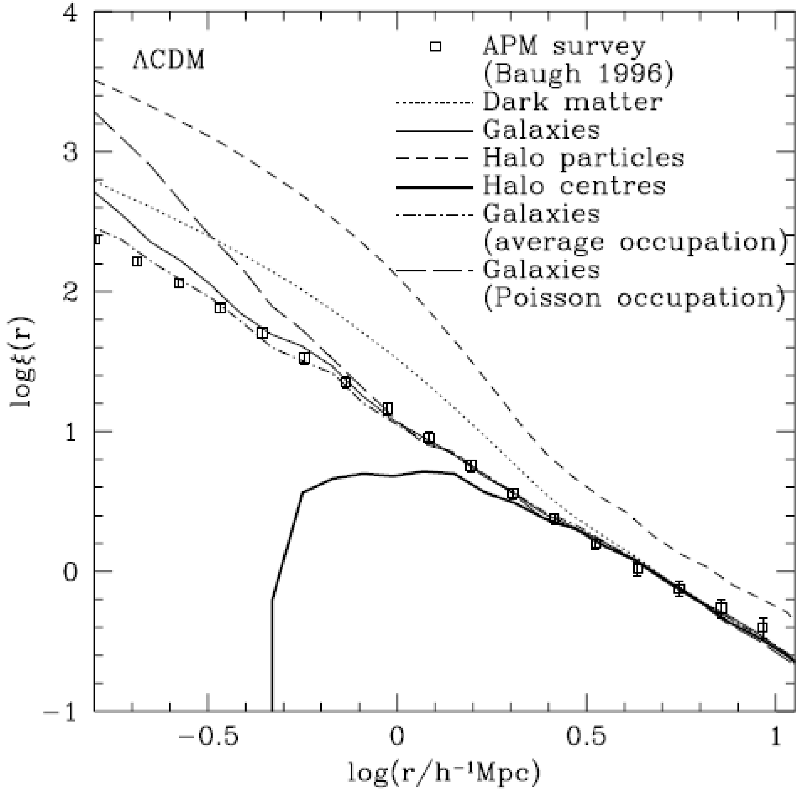
Galaxy clustering in SAMs

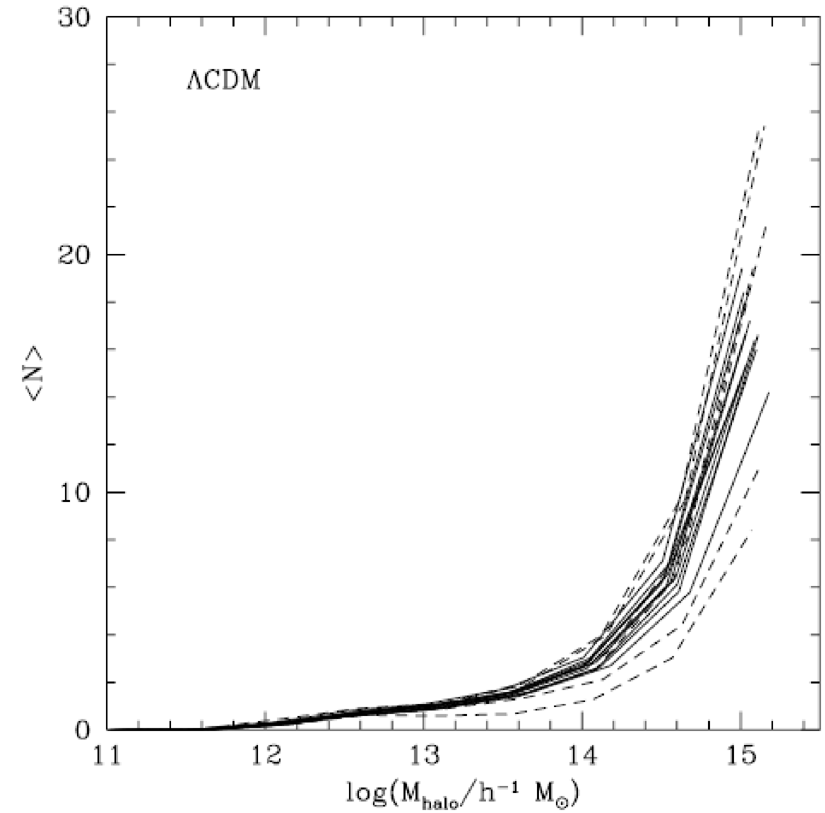


- Models that match LF give robust predictions for correlation function
- Can recover power-law simply by predicting number of galaxies per halo

Benson et al. 2000
Kauffmann et al. 1999a, b

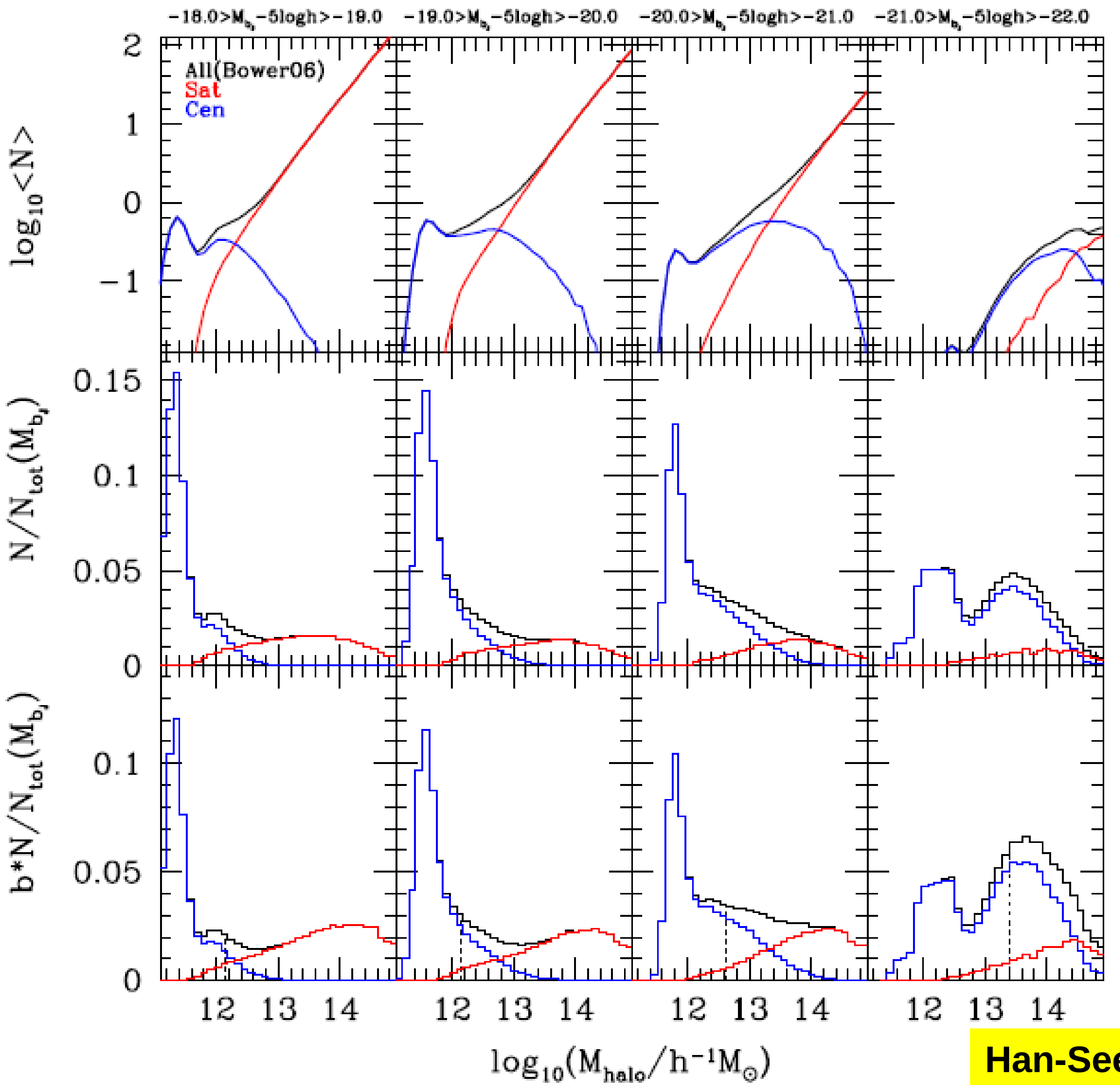
Explaining the form of the correlation function





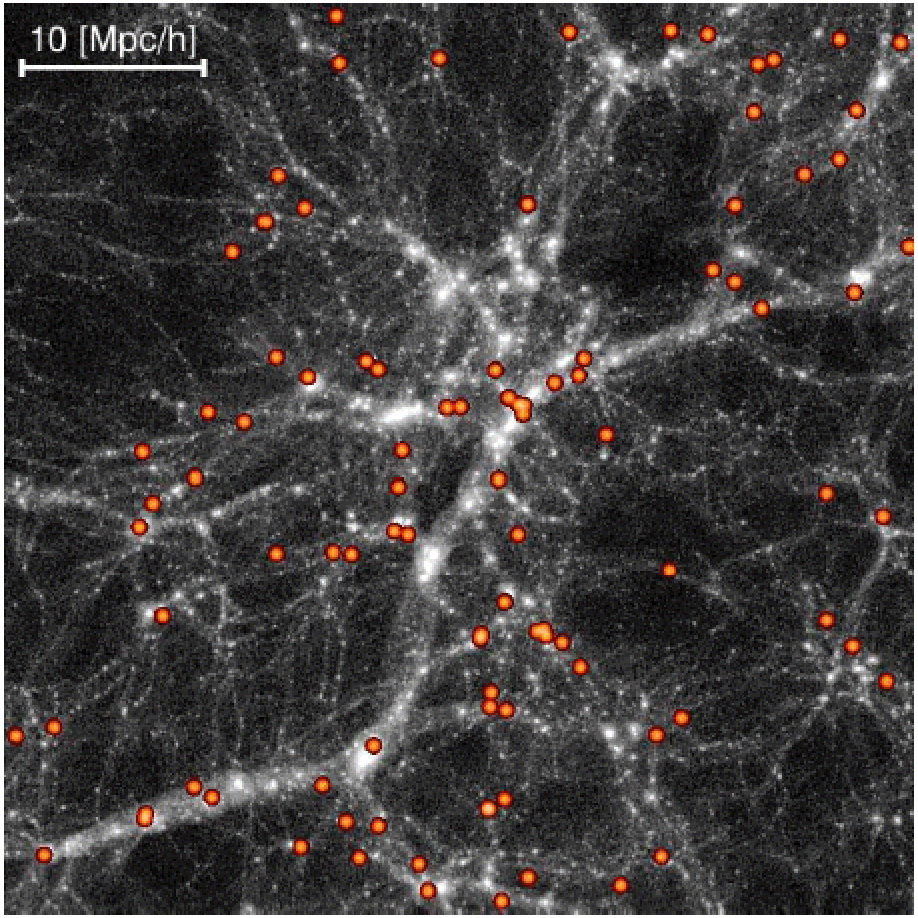
Benson et al. 2000

Models predict HOD

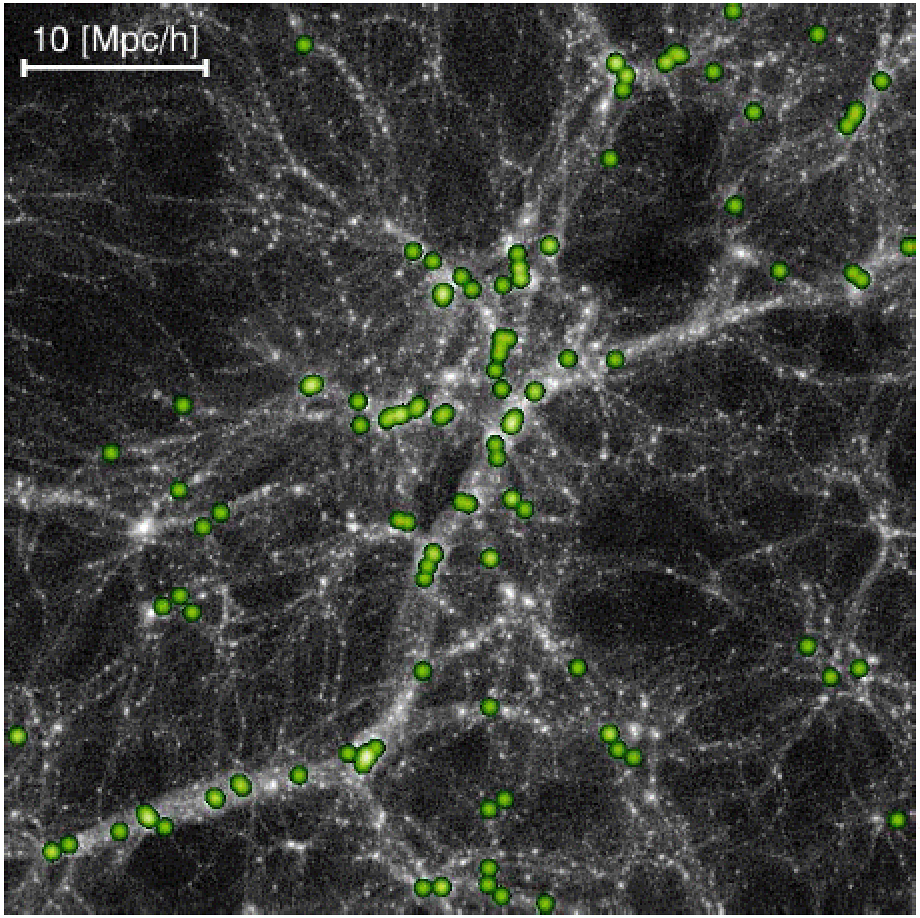


Han-Seek Kim et al. 2009

Predict connection between different galaxy samples and dark matter



H-α selection



H-band selection

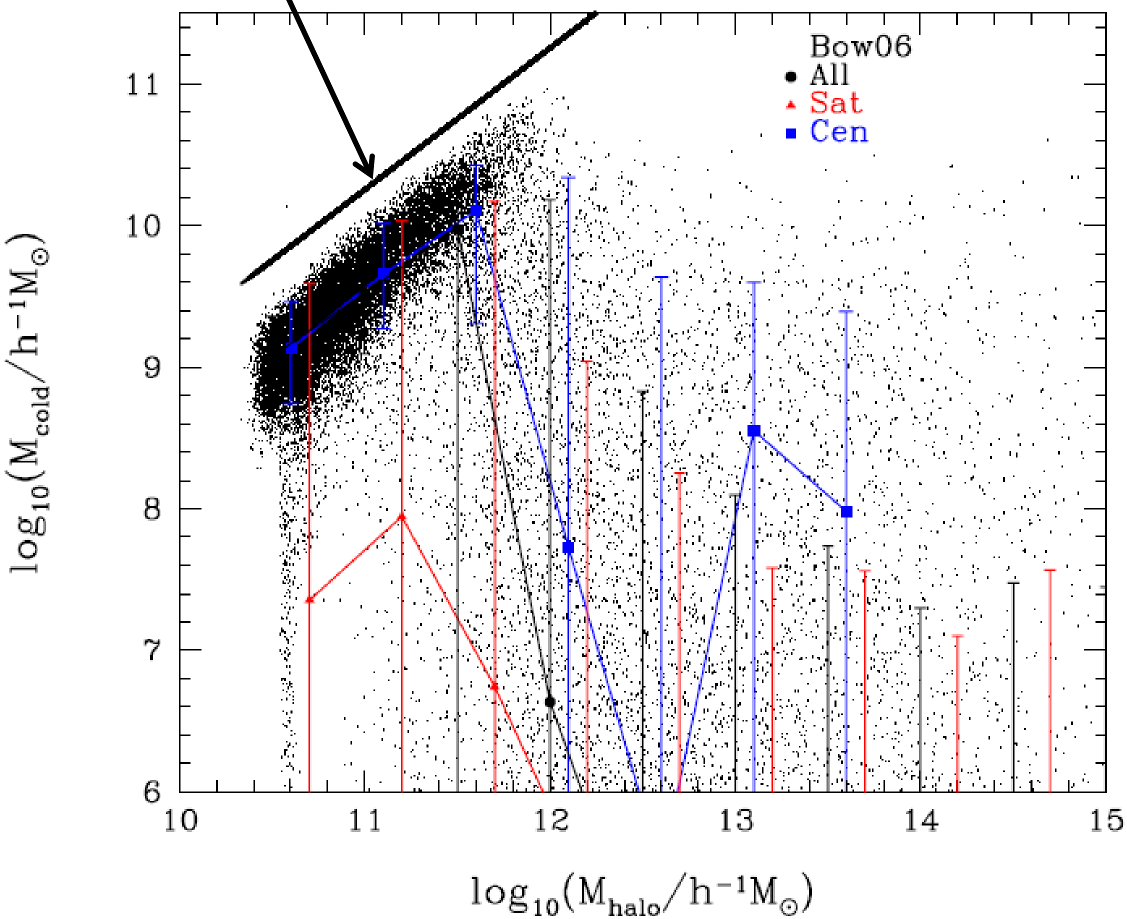
z=1

Orsi et al. 2009

Predict clustering for different selections: e.g. cold gas mass

Universal baryon fraction in cold gas in one object

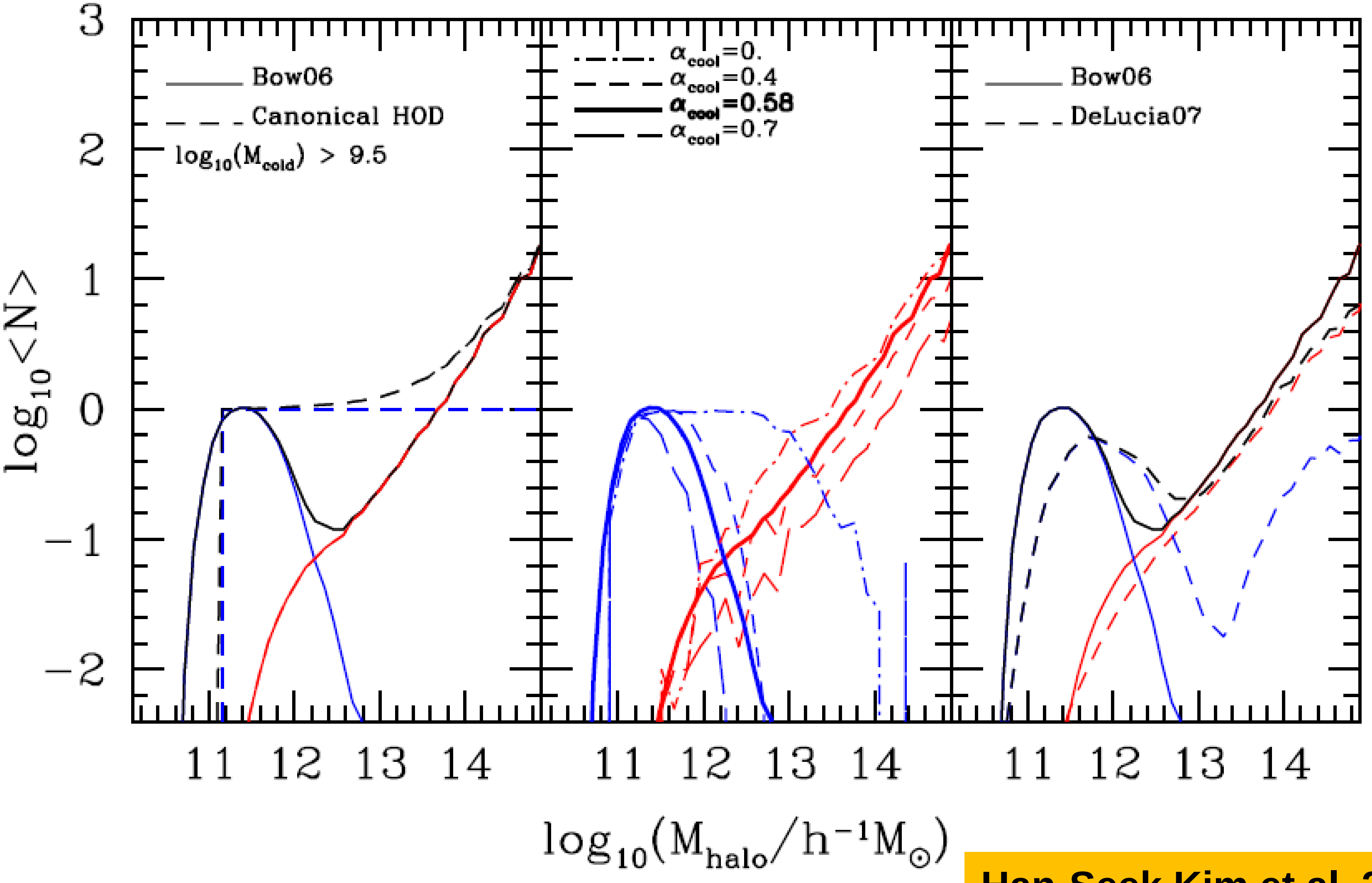
Galaxy cold gas mass



Mass of host DM halo

Han-Seek Kim et al. 2011

Predict HOD for cold gas samples

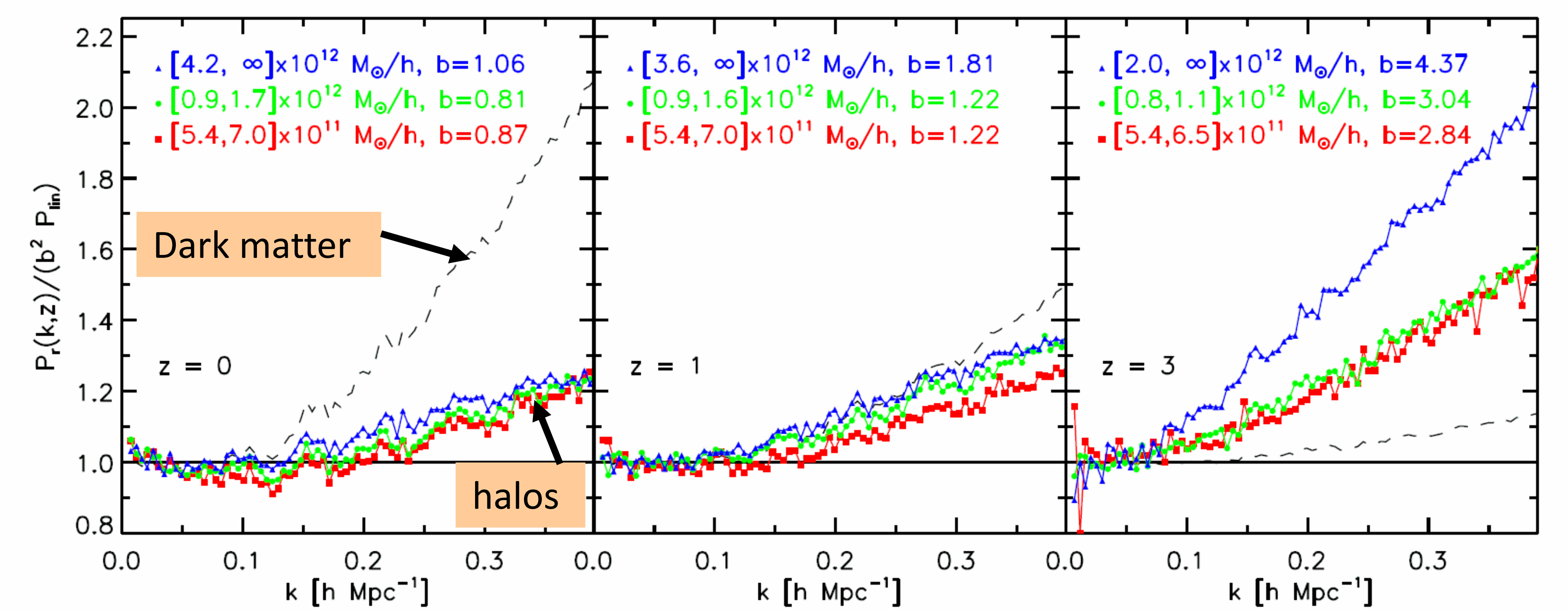


Han-Seek Kim et al. 2011

Implications for galaxy clustering

Scale-dependent bias: DM haloes

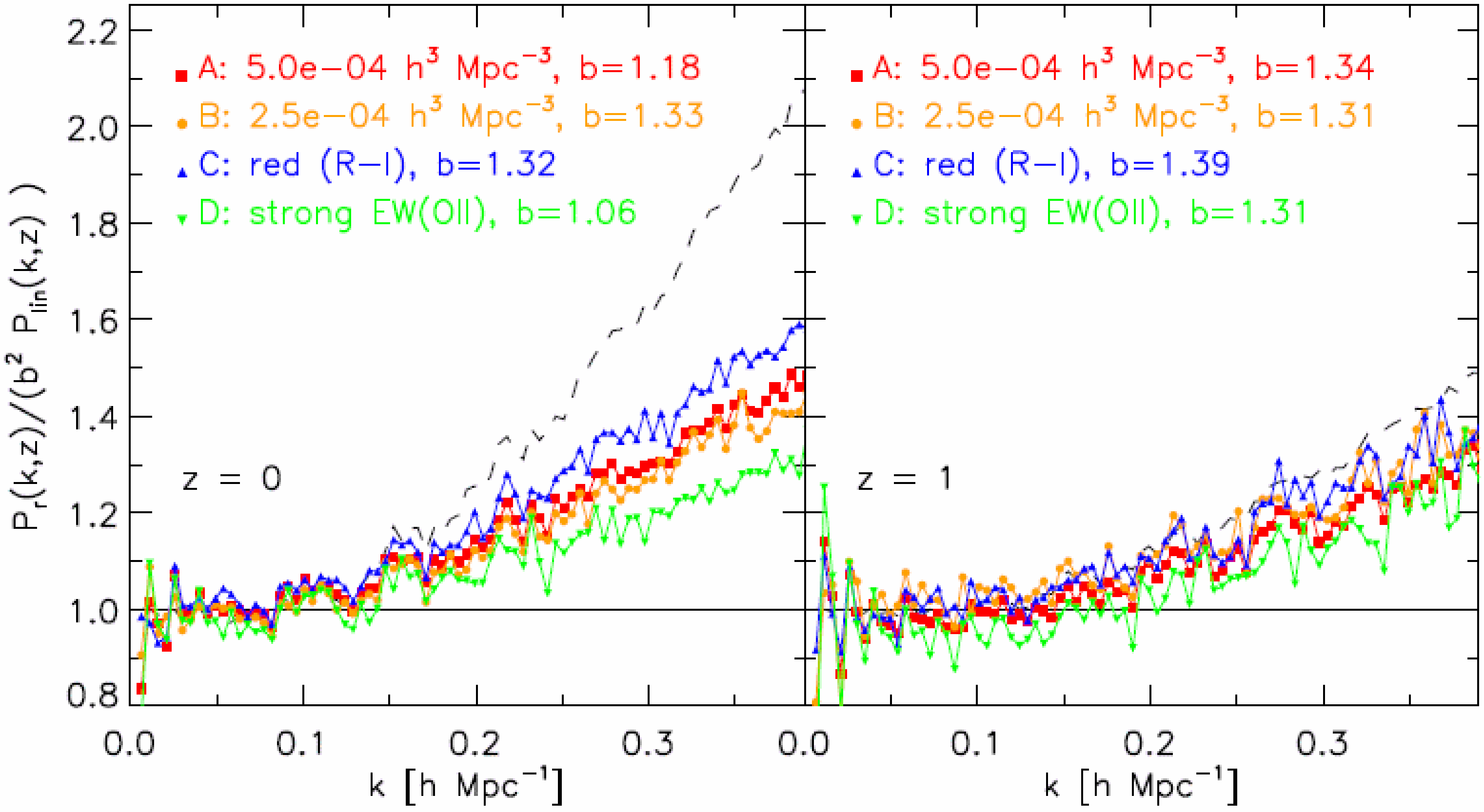
Deviation from unity is a deviation from linear theory
Deviation from dashed line = scale dependent bias



Strength of scale dependence of bias depends on peak height M/M*

Angulo et al. 2008; see also Smith et al. , Crocce et al.

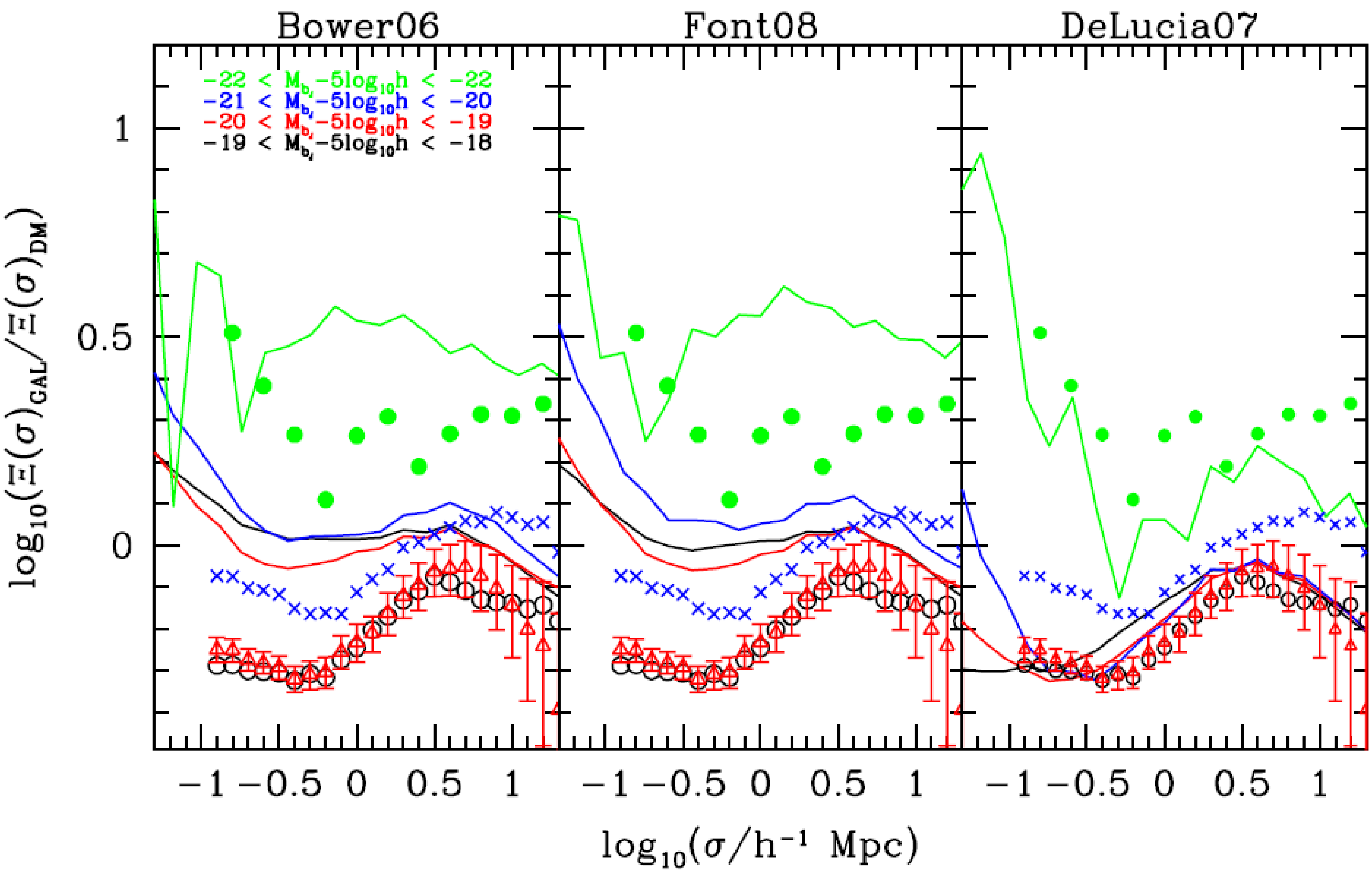
Bias for different galaxy samples



Driven by prediction for N(M) by following baryonic physics

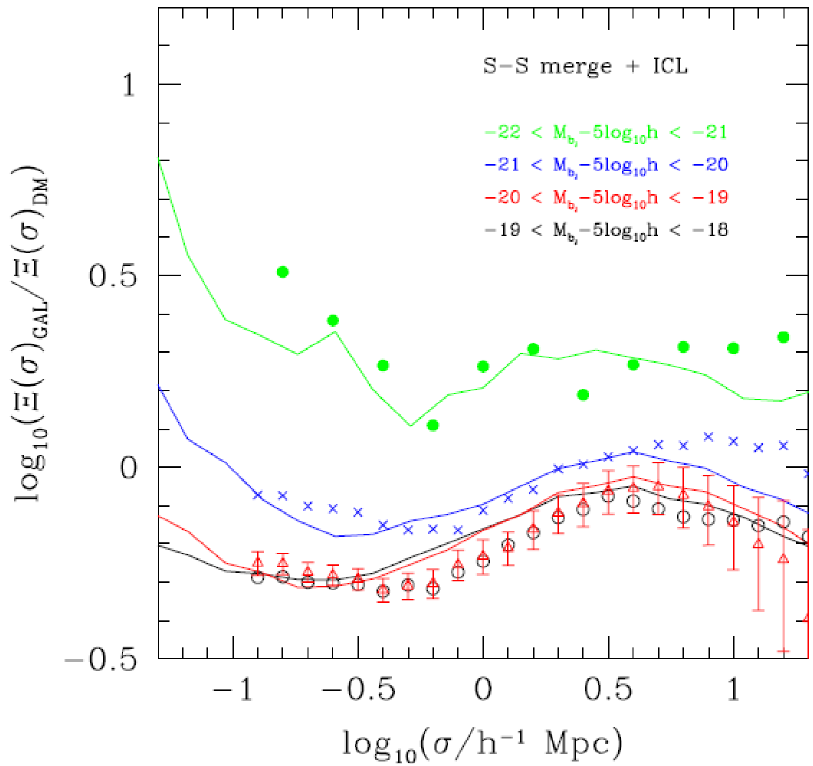
Angulo et al. 2008

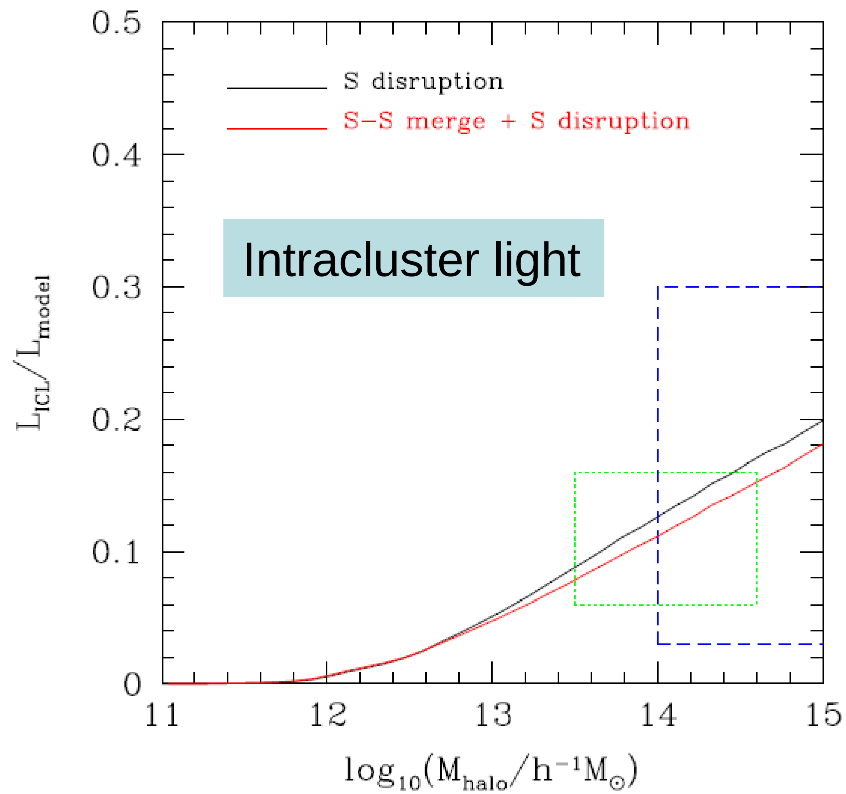
Luminosity dependent clustering



Han-Seek Kim et al. 2009

A need for new physics?

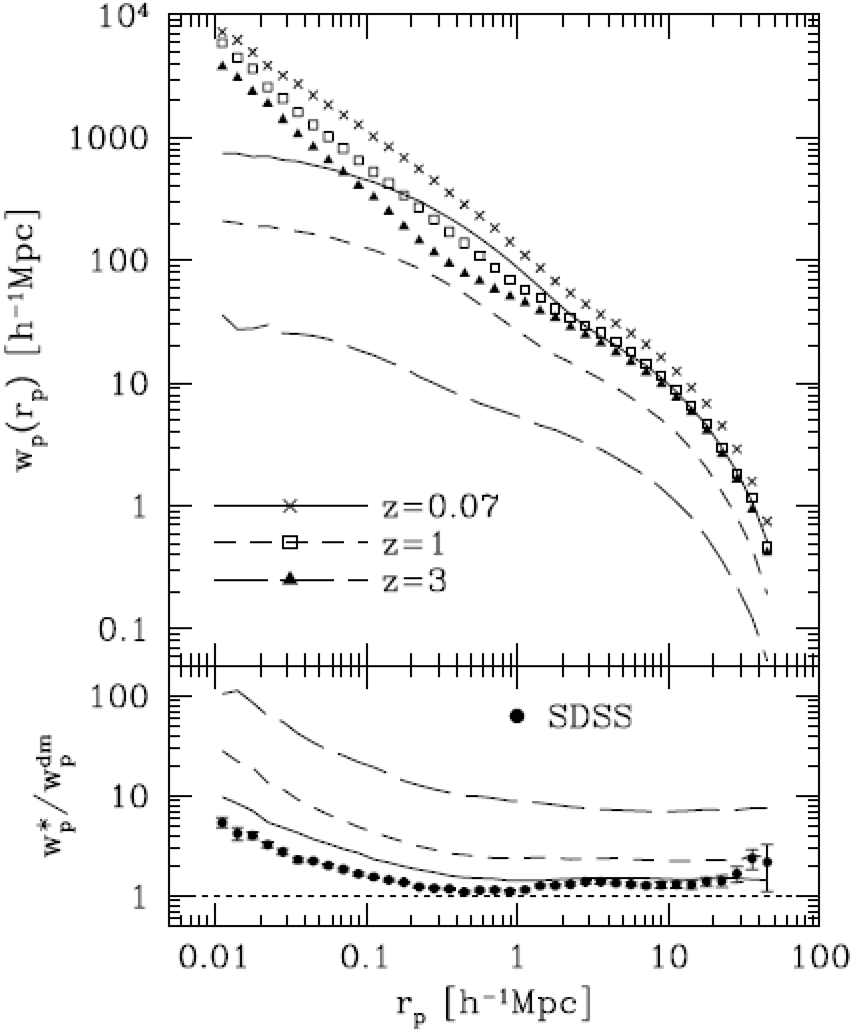


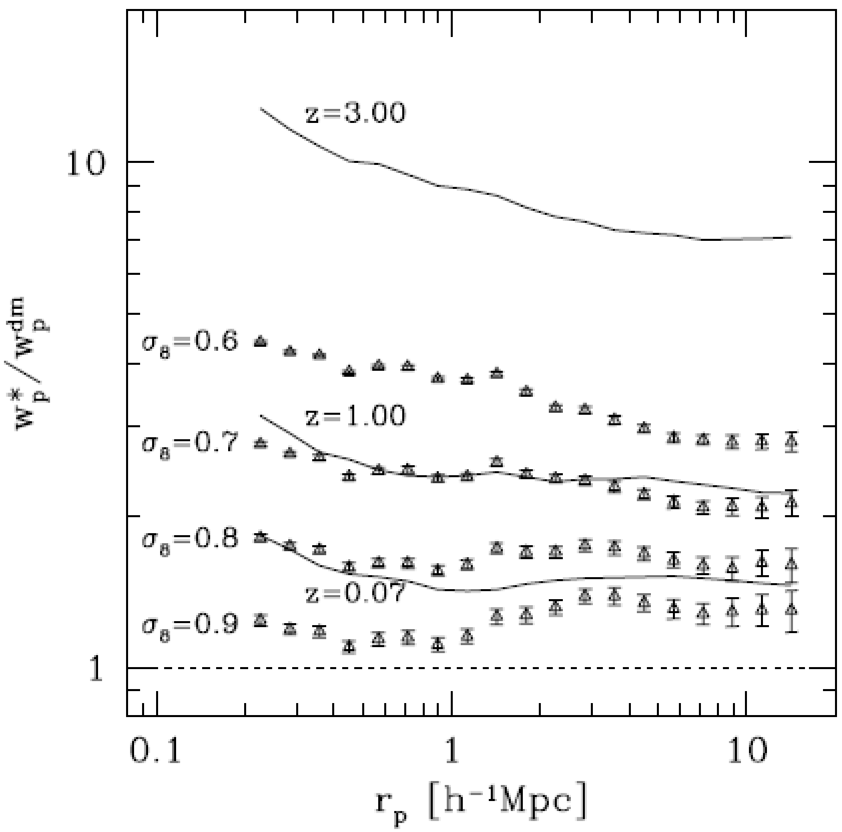


Extended model with fewer satellites: satellite-satellite mergers and tidal disruption

Han-Seek Kim et al. 2009

Or a revision to cosmological parameters?





Li & White 2009
De Lucia & Blaizot 2007

Use models to calibrate empirical methods
e.g. HOD, SHAM

SHAM – sub-halo abundance matching

KEY ASSUMPTIONS:

- Assume a monotonic relation between (sub)halo mass and galaxy luminosity

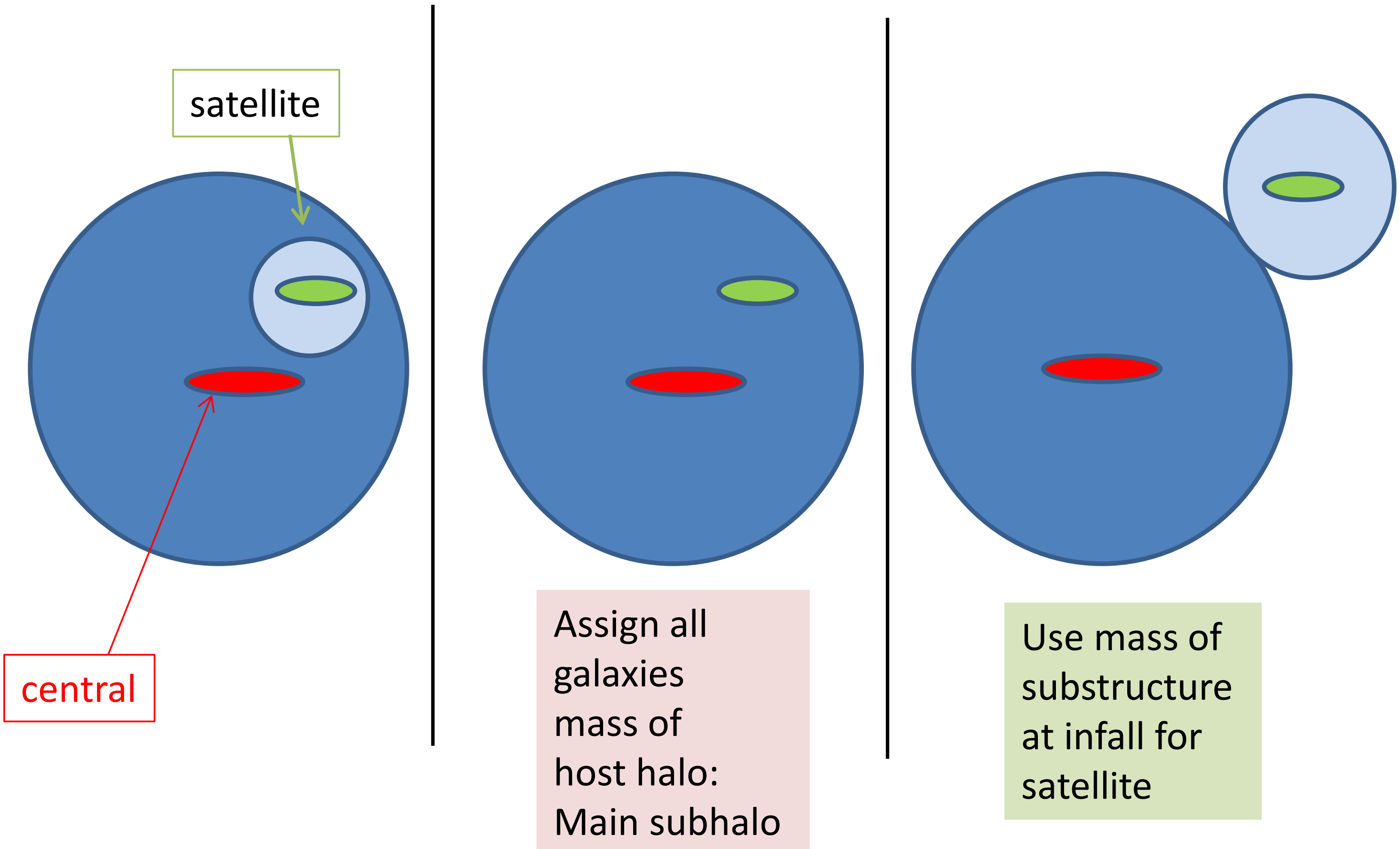
(Vale & Ostriker 2004; 2006; 2008)

$$n_S(> M_S) = n_H(> M_H)$$

Durham University

ICC

Which halo mass to assign?



SHAM – sub-halo abundance matching

KEY ASSUMPTIONS:

- Assume a monotonic relation between (sub)halo mass and galaxy luminosity

  (Vale & Ostriker 2004; 2006; 2008)

$$n_S(> M_S) = n_H(> M_H)$$

- For central galaxy, use host halo mass
- For satellite galaxies, use sub-halo mass at time of accretion (Kravtsov et al 2004; Nagai & Kravtsov 2005)

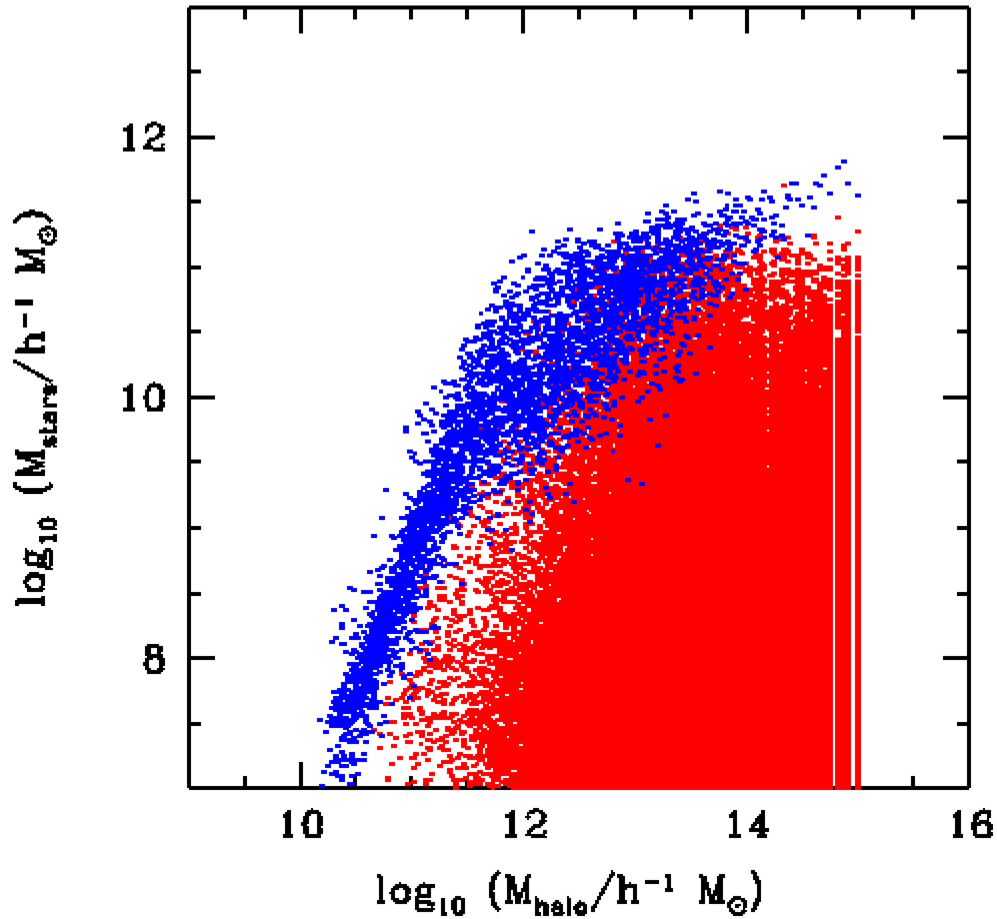
$$M_H = \begin{cases} M_{\rm halo}(z=0) & \text{for distinct halos,} \\ M_{\rm halo}(z=z_{\rm sat}) & \text{for subhalos,} \end{cases}$$

Durham University

ICC

Stellar mass vs **host** halo mass

Stellar mass



centrals

satellites

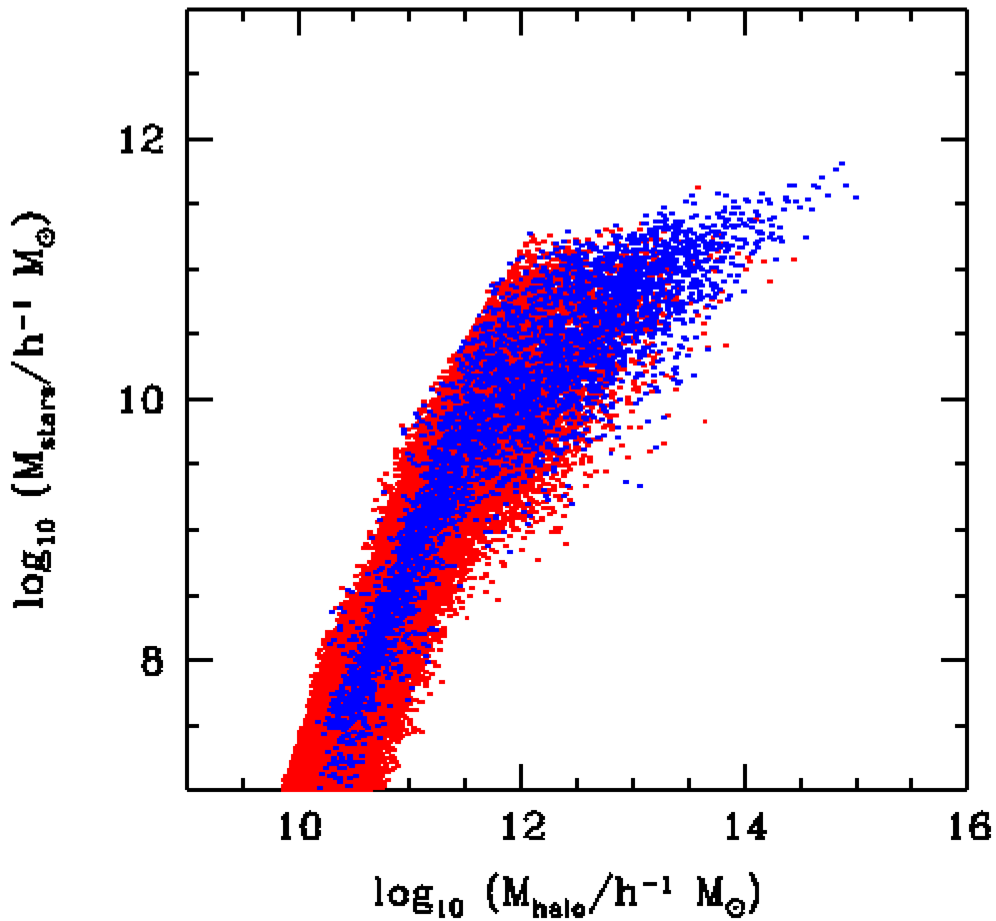
Bower et al. 2006
z=0

Host halo mass

Durham University

ICC

Stellar mass vs (sub)halo mass



Stellar mass

(sub)halo mass

centrals

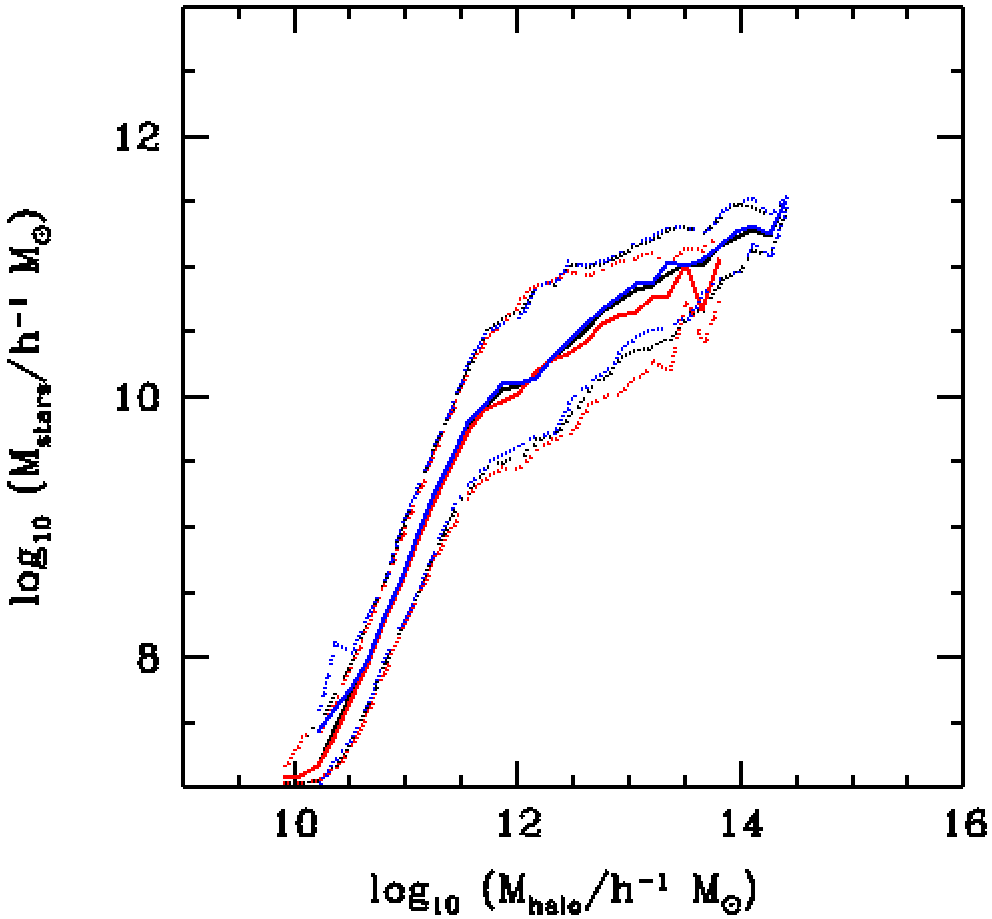
satellites

Bower et al. 2006
z=0

Durham University

ICC

Stellar mass vs (sub)halo mass



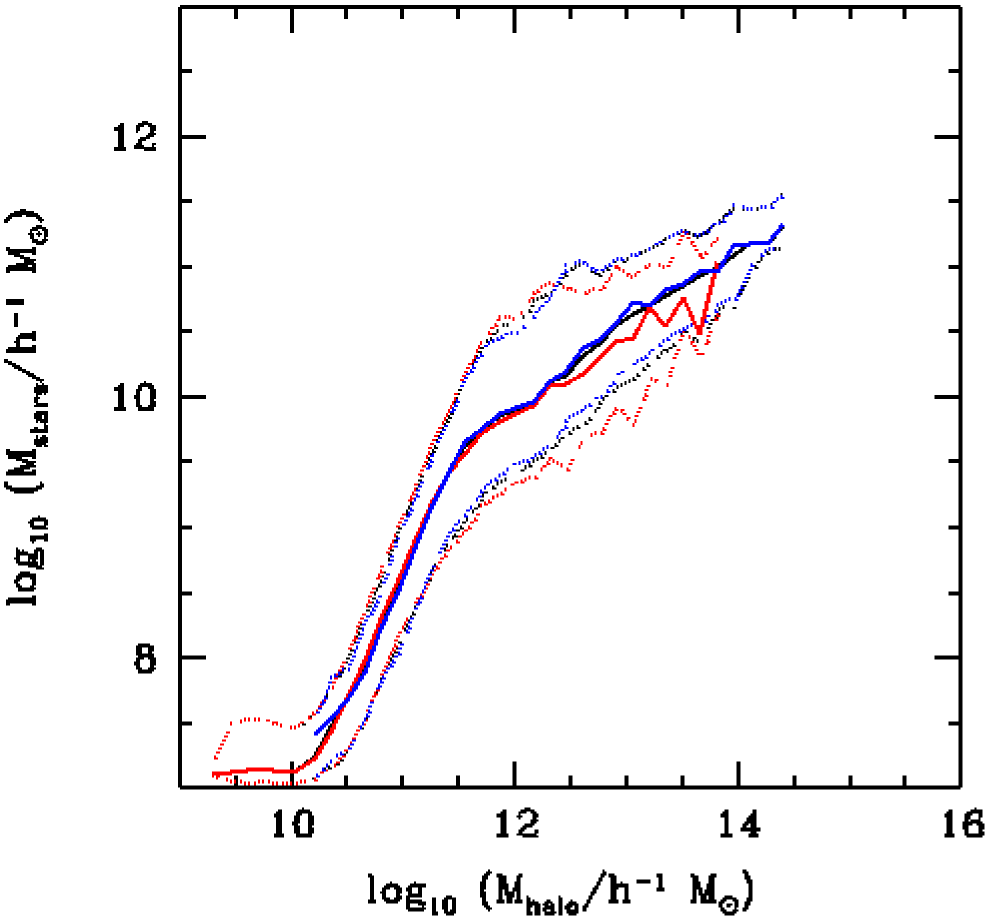
centrals

satellites

all galaxies

Medians, 10-90 percentile limits

Different gas cooling in satellites

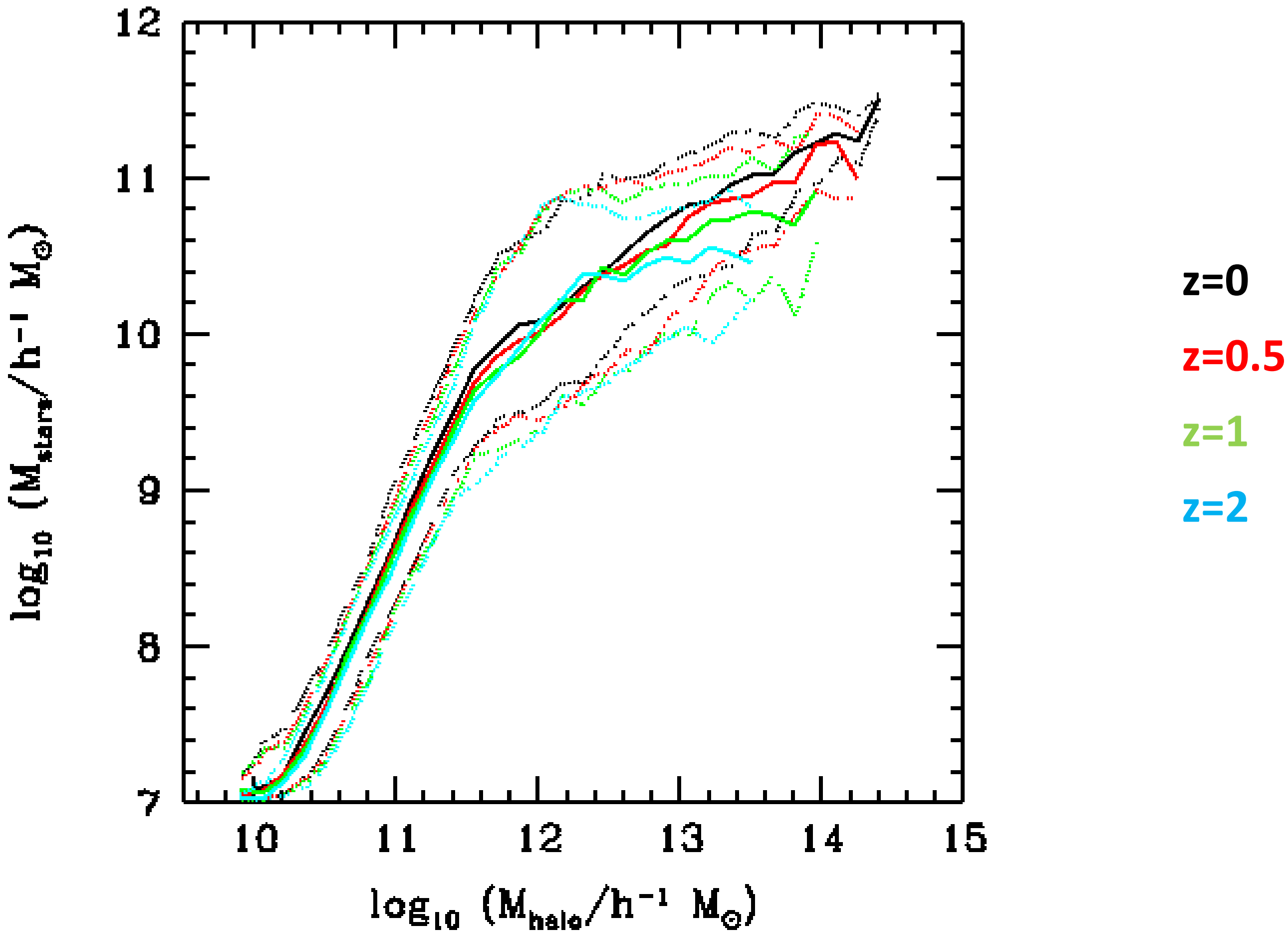


Durham University

Font et al. 2008

ICC

Stellar mass – (sub)halo mass evolution



Bower et al. 2006 – redshift evolution

Summary

- Galaxy clustering: approx. power-law
- DM clustering: not a power-law
- Idea of using haloes, then sub-haloes
- Empirical approaches: HODs, SHAM
- Physical approaches: gas dynamics, semi-analytics
- Semi-analytics currently only way to populate large volumes with compromising baryonic physics
- Predict scale dependent bias from how galaxies populate haloes

Durham University

ICC