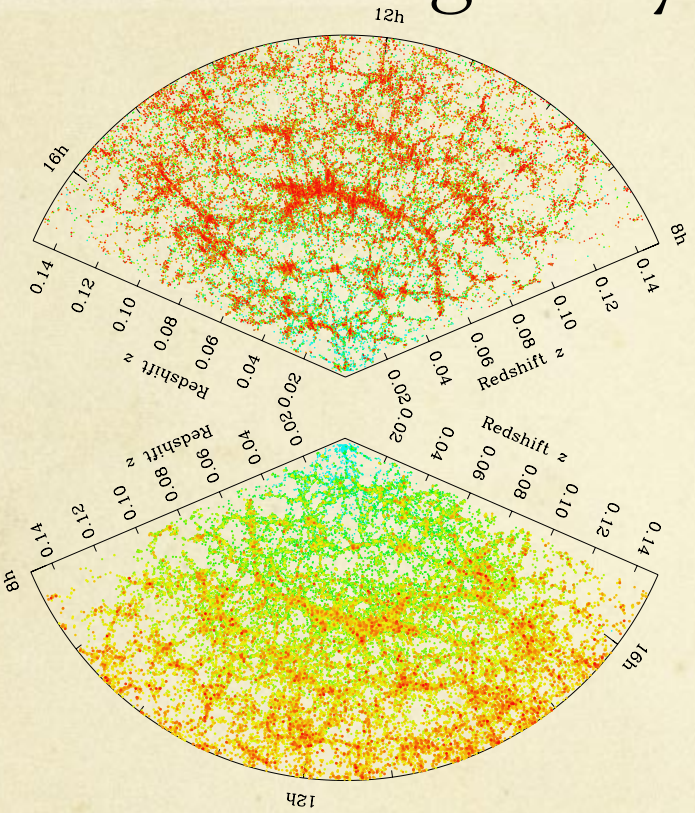
What clustering does tell us about galaxy formation?

Observatoire de Lyon (CRAL), October 18th 2011

Sylvain de la Torre

IfA – ROE

Measuring clustering with large galaxy surveys

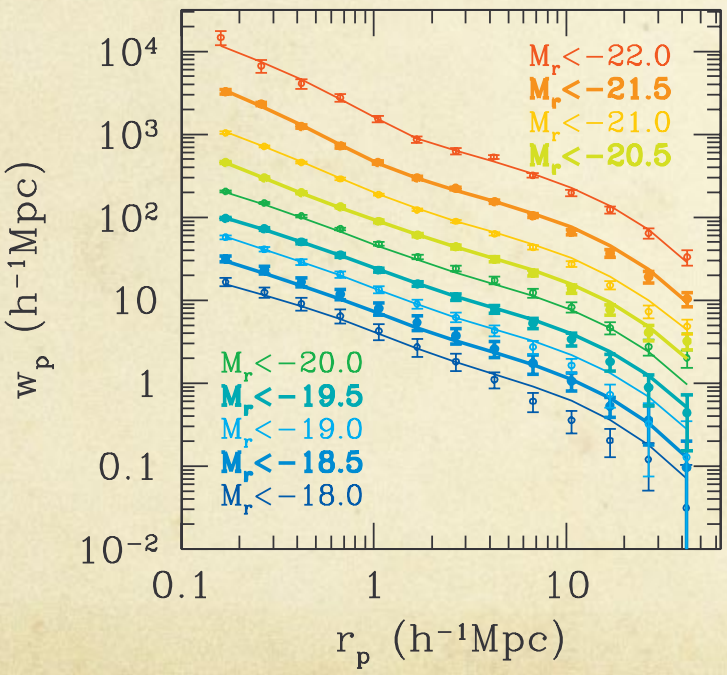


- Galaxy clustering allows to constrain **galaxy evolution** and to study the connection between **galaxy formation and LSS**

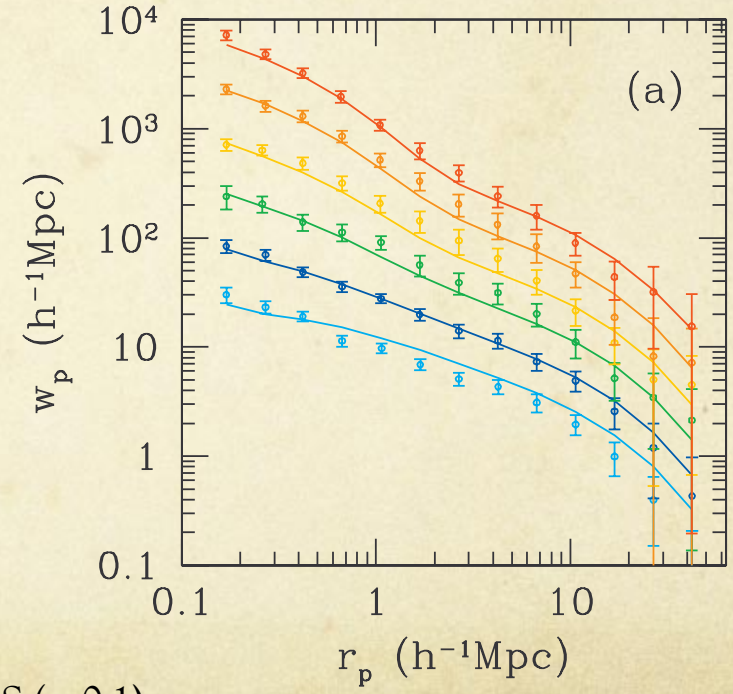
- **Large spectroscopic surveys** are fundamental to map the 3D galaxy distribution and study clustering:
  - *Local Universe*:
    2dFGRS [230k gal. z=0.1]
    SDSS [800k gal., z=0.1]
  - *Distant Universe*:
    VVDS [30k gal., z=0.2-2]
    DEEP2 [50k gal., z=0.7-1.4]
    zCOSMOS [25k gal., z=0.2-2.5]
  - *New on-going surveys*:
    VIPERS, VUDS, GAMA, BOSS, …

How clustering depends on galaxy physical properties?

- In the local Universe, the galaxy clustering properties vary with **luminosity**, **stellar mass**, **colour**, **morphology** ...



Luminosity

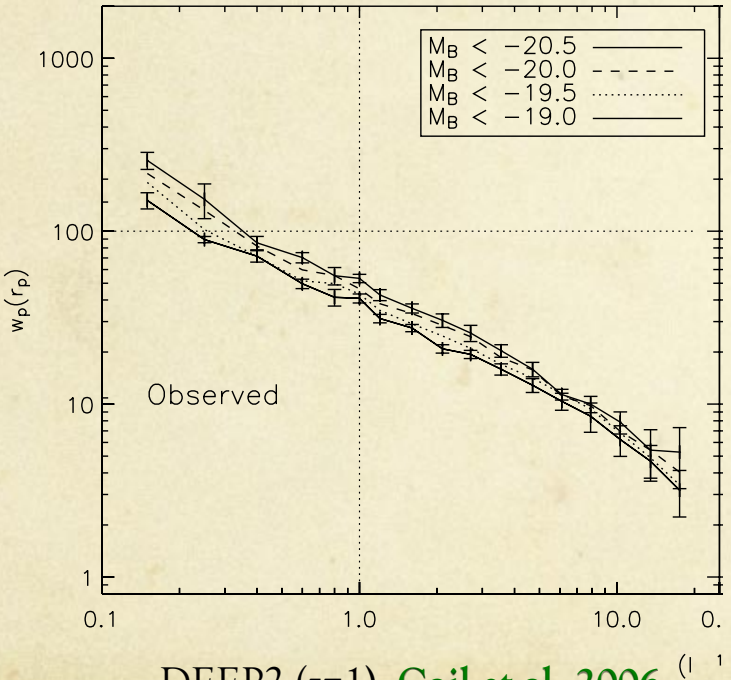


Colour

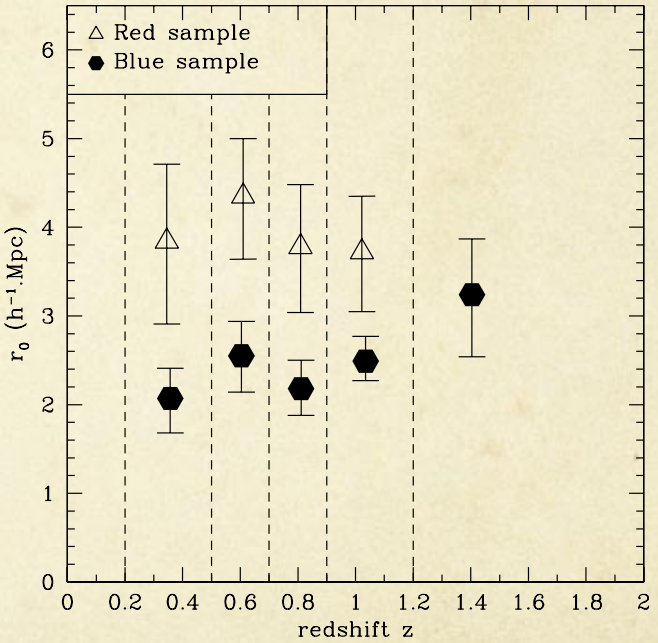
SDSS (z=0.1)
Zehavi et al. 2011

How clustering depends on galaxy physical properties?

- These **clustering segregations are present up to z=1-1.5**, although the strength of the effects is shallower



DEEP2 (z=1), **Coil et al. 2006**

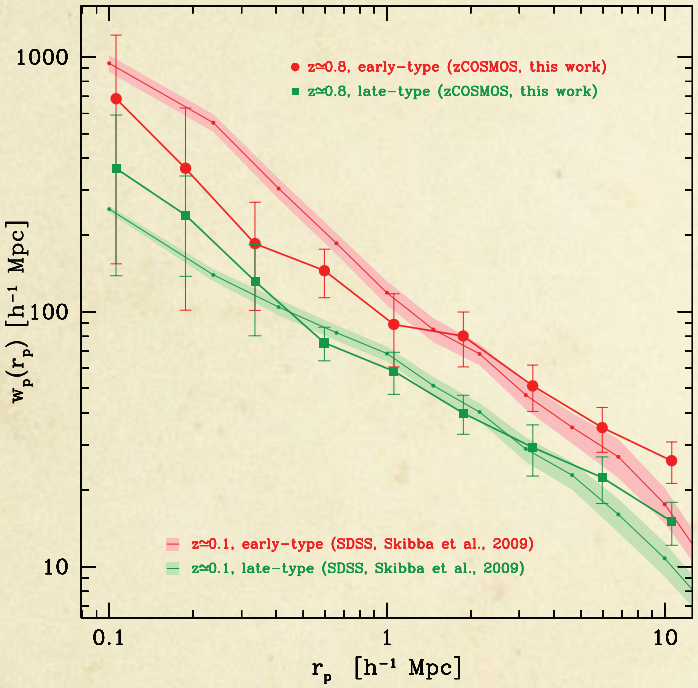


VVDS (z=0.2-2.0), **Meneux et al. 2006**

Luminosity

Colour

What can we learn by comparing the clustering at different epochs?

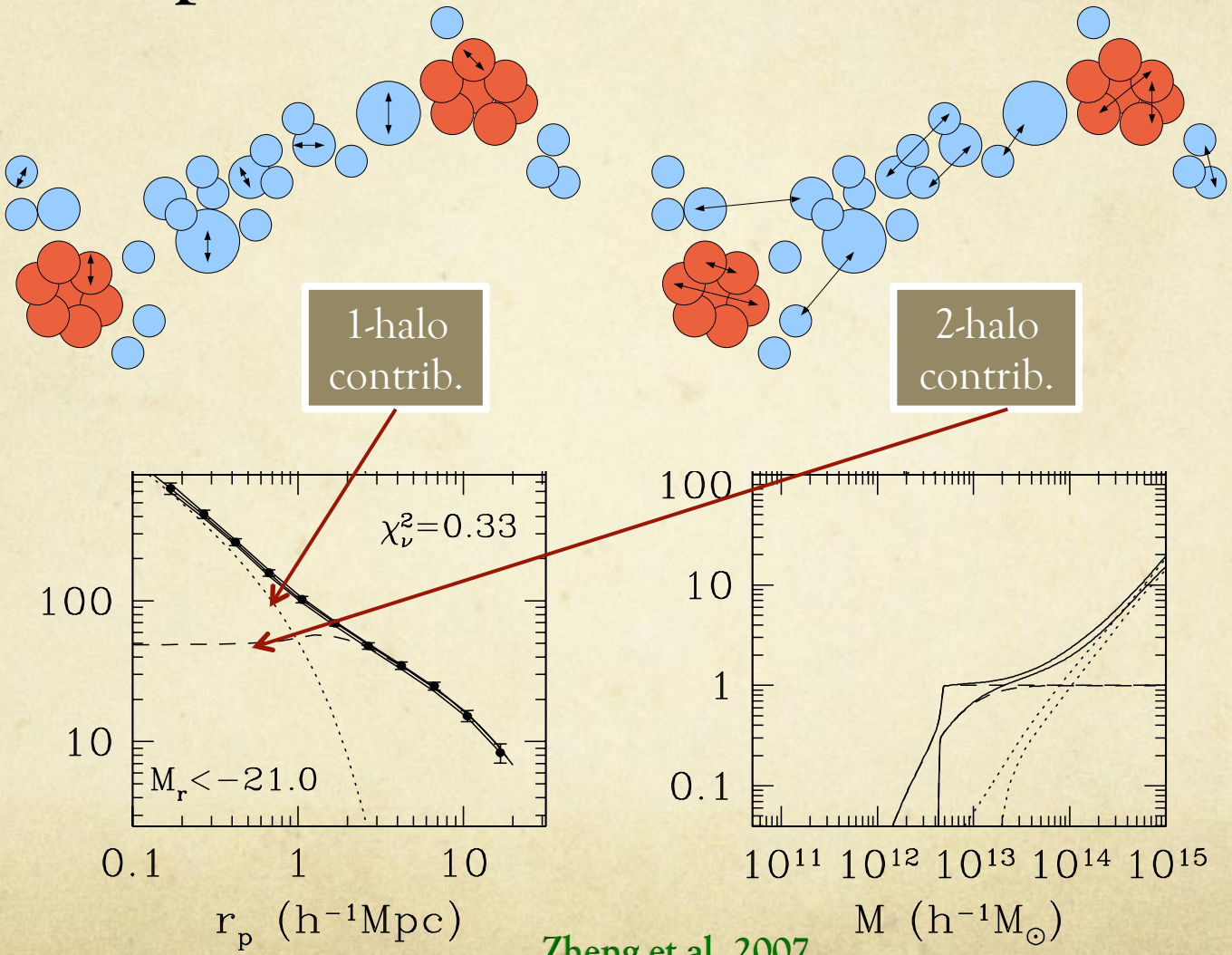


zCOSMOS (z=0.8)
de la Torre et al. 2011a

- Evolution of the **clustering of early and late morphological types**
- The difference in clustering does not evolve significantly since z=0.8, except on small scales
- **A large fraction of early-type galaxies were already formed** in intermediate and dense environments at z=0.8

Morphology

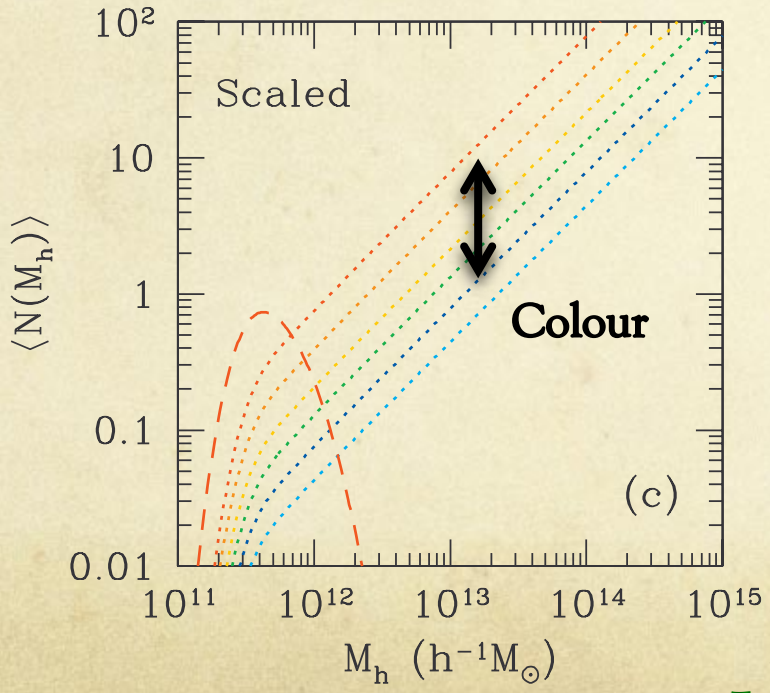
Interpreting galaxy clustering: halo occupation distribution (HOD)

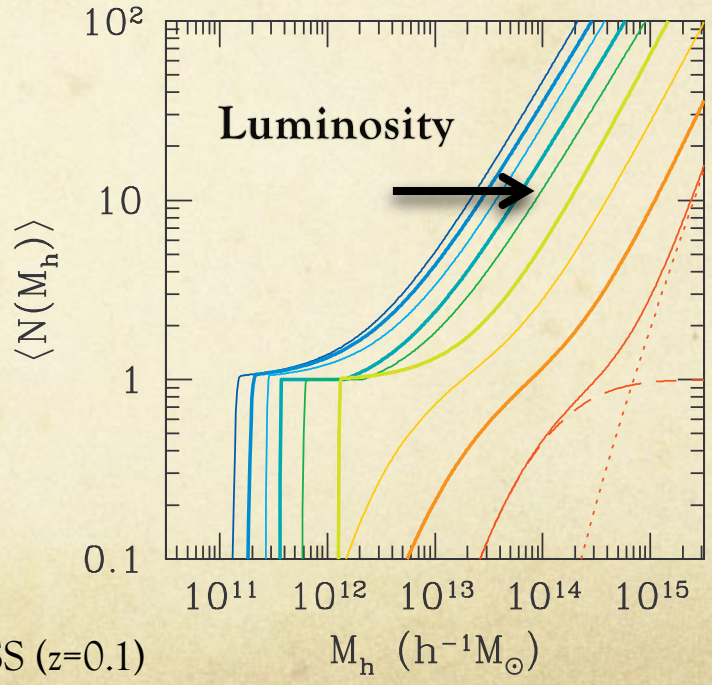


Zheng et al. 2007

Dependence of HOD on luminosity and colour

- **Luminosity**: shift of the HOD towards higher masses
- **Colour**: increase/decrease of the relative fraction of satellites with respect to the fraction of central galaxies



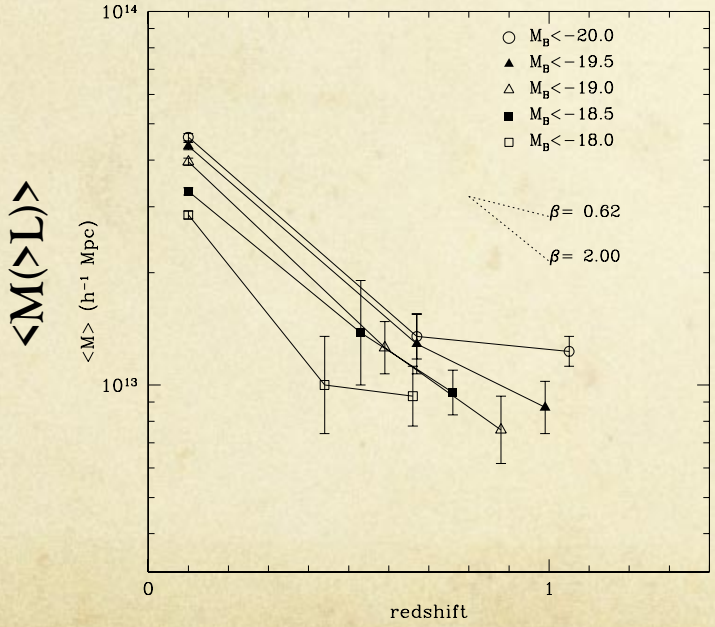


SDSS (z=0.1)

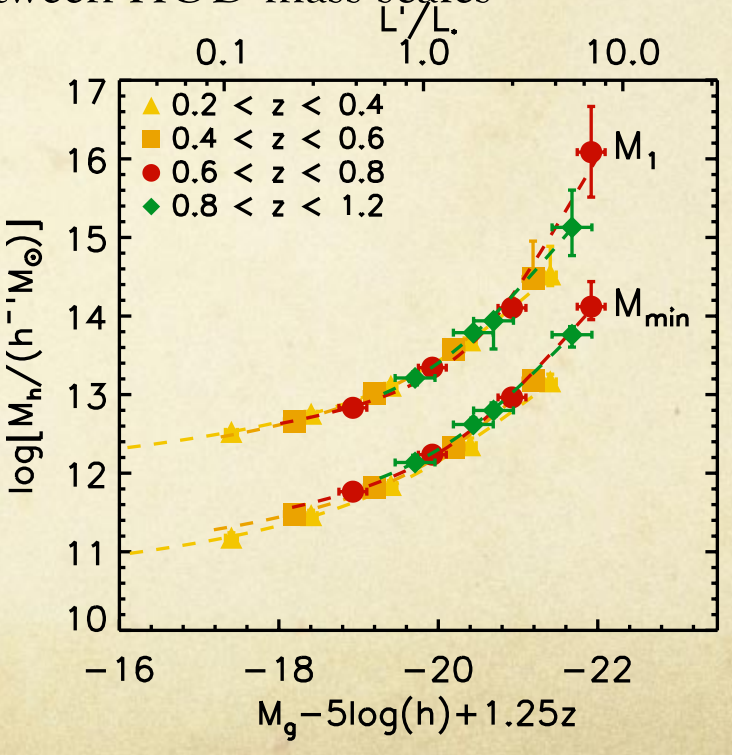
Zehavi et al. 2011

Redshift evolution of the halo occupation

- Derived **halo parameters** (average mass, satellite fraction) **do evolve** at fixed luminosity/stellar mass since z=1
- **Universal (??) scaling relation** between HOD mass scales



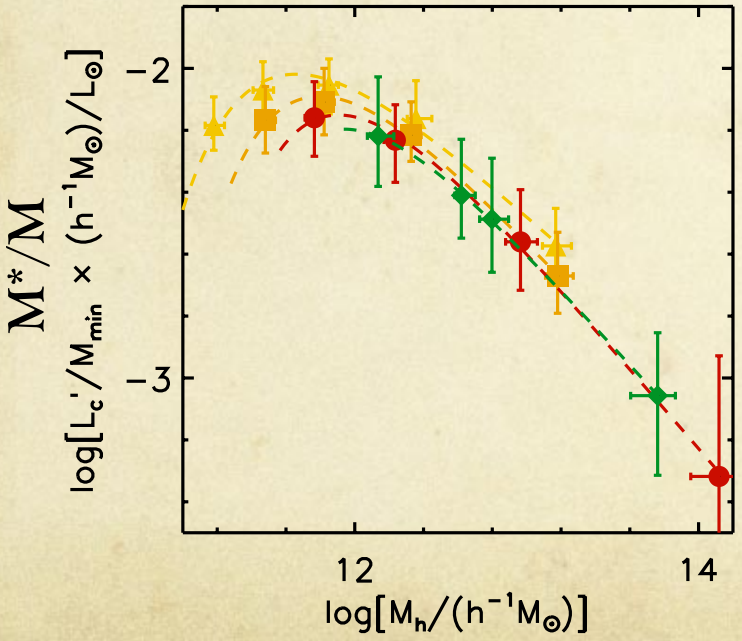
VVDS (z=0.2-1.2)
Abbas, de la Torre, et al. 2010

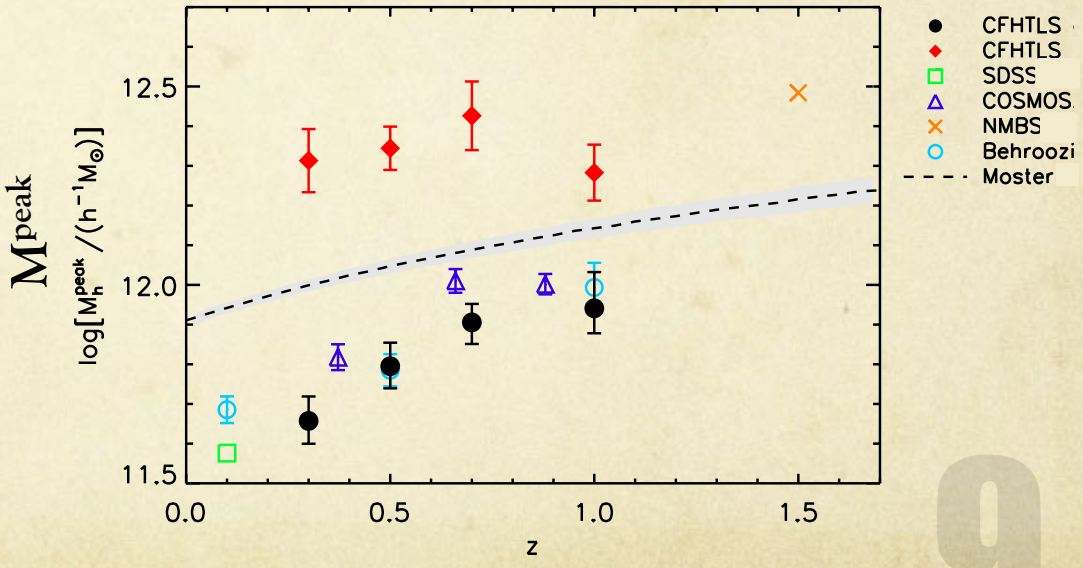


CFHTLS (z=0.2-1.2), Coupon et al. 2011

Evolution of stellar formation efficiency

- **Stellar-to-halo mass ratio** (SHMR): halo mass at which star formation and merging are the most efficient at assembling stellar mass
- SHMR does evolve with redshift and peaks at z=1.0: **halo downsizing**

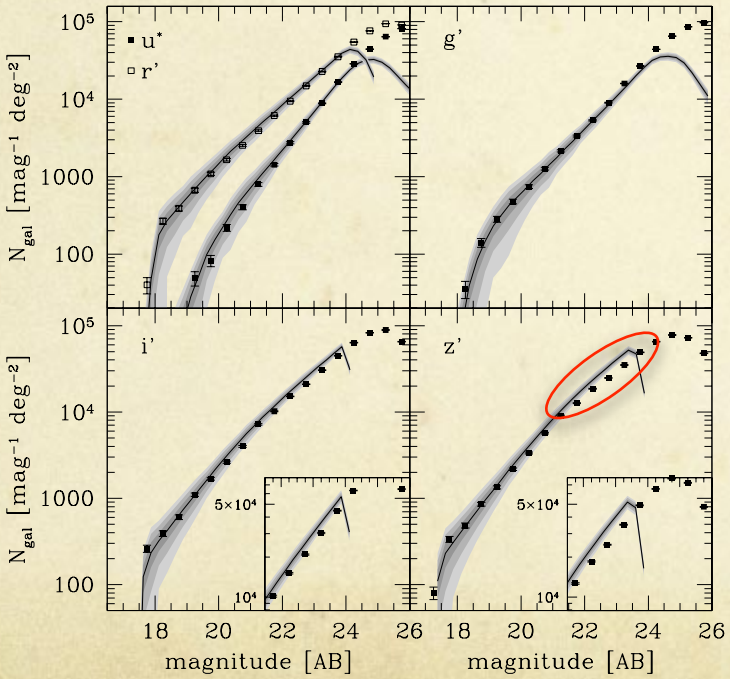




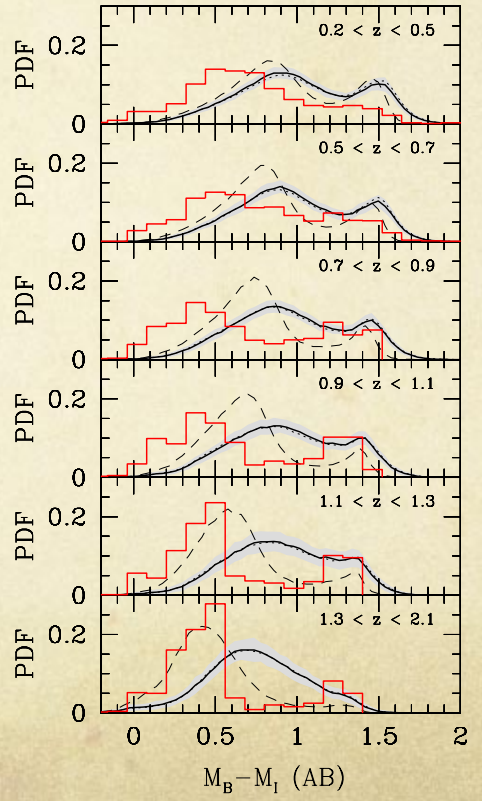
CFHTLS (z=0.2-1.2), **Coupon et al. 2011**

Constraining galaxy formation models with clustering measures

- **Magnitude counts: good agreement** except for faint red galaxies
- **Different colour bimodality** in the SAM: galaxies are much redder than observed

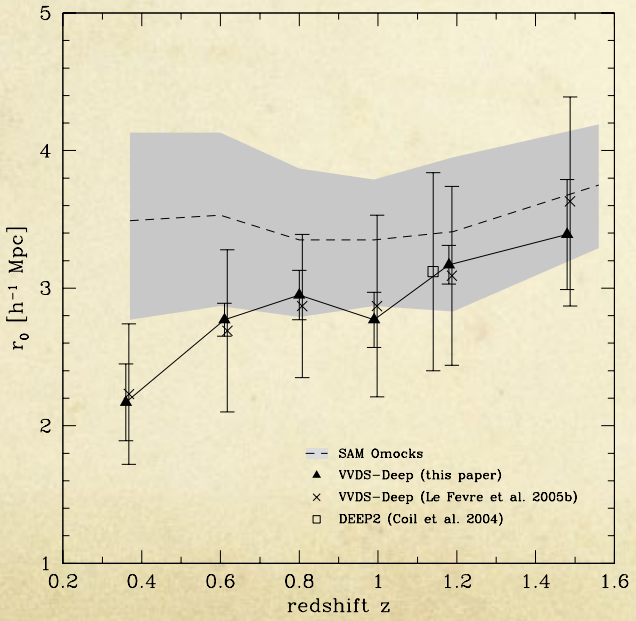


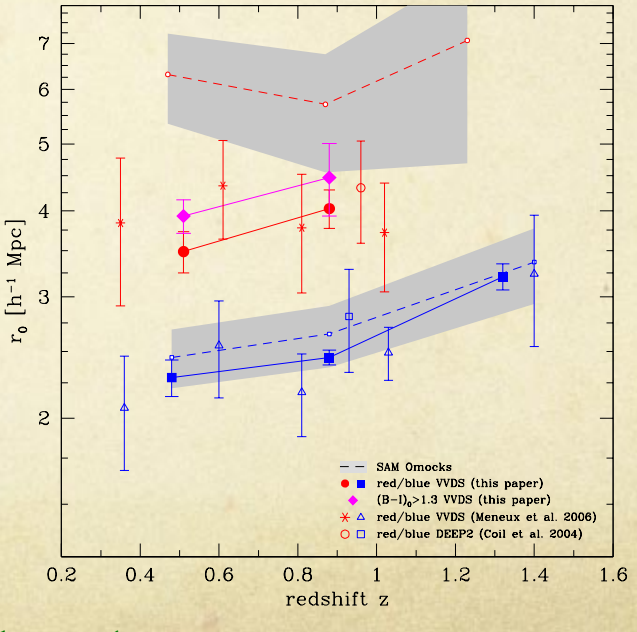
de la Torre et al. 2011b



Constraining galaxy formation models with clustering measures

- SAM tends to **overestimate the clustering strength** for all galaxies at z<1.5
- Primarily due to a strong **overestimation of the clustering strength of red galaxies**

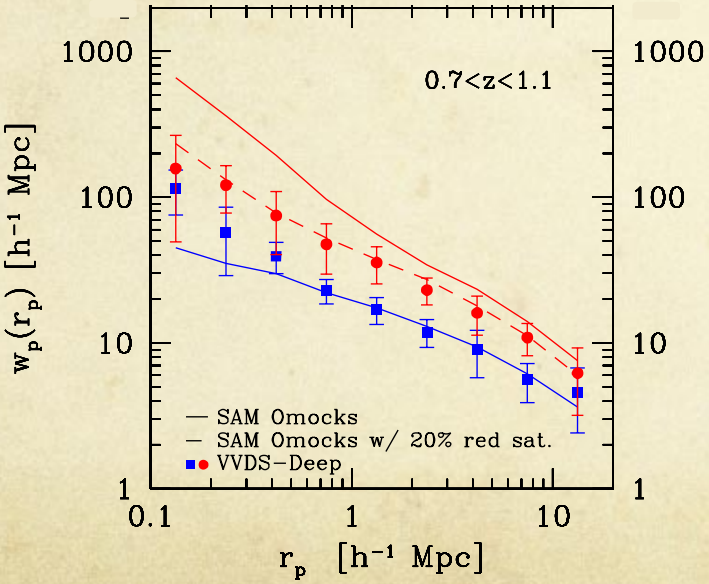


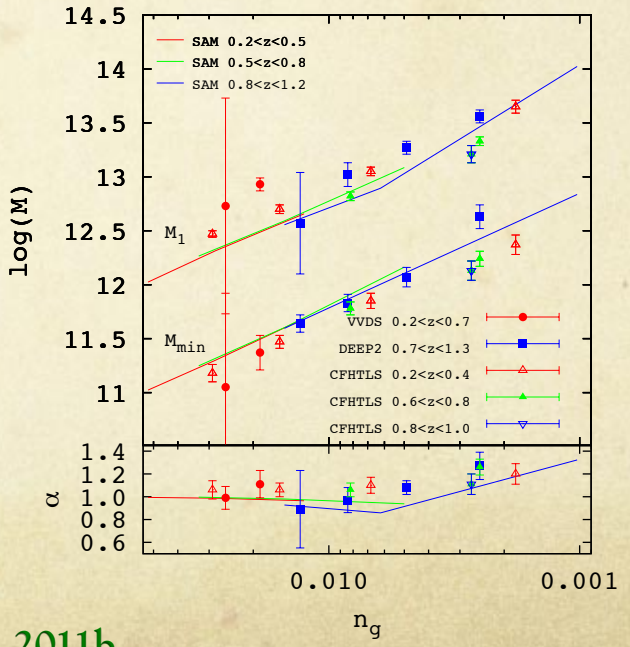


de la Torre et al. 2011b

Constraining galaxy formation models with clustering measures

- Differences in the SAM can be interpreted as a **deficit of blue sat. and an overabundance of red sat.**
- **Disruption/merging of satellite galaxies** and **quenching of star formation** not well modelled by the SAM





de la Torre et al. 2011b

Conclusions

- **Galaxy clustering** (and its evolution) is a **powerful tool** to probe galaxy evolution and understand the connection between galaxy formation and the properties of the underlying mass distribution
- **Halo occupation models** allow to quantify the relation between galaxy physical properties and hosting halo properties: halo mass scales, average halo mass/luminosity evolution, satellite & central fractions
- The comparison of clustering predictions with observations provides strong constraints on the models
- Clustering observations give a **consistent evolutionary picture up to *z*=1** but a lot of details have still to be investigated and understood, e.g. environmental effects, assembly bias ...
- **New clustering observations** are needed **at high redshift** in particular at z>1.5 where galaxy clustering properties are still poorly known