Galaxy clustering in the CFHTLS-photometric redshift survey

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Here’s the summary!

- We present in detail a new, very large *photometric* redshift survey of the distant universe, comprising 250,000 galaxies extracted from the four Canada-France-Legacy Survey Fields
- We present initial results from the clustering of galaxies as a function of intrinsic luminosity and type out to z~1

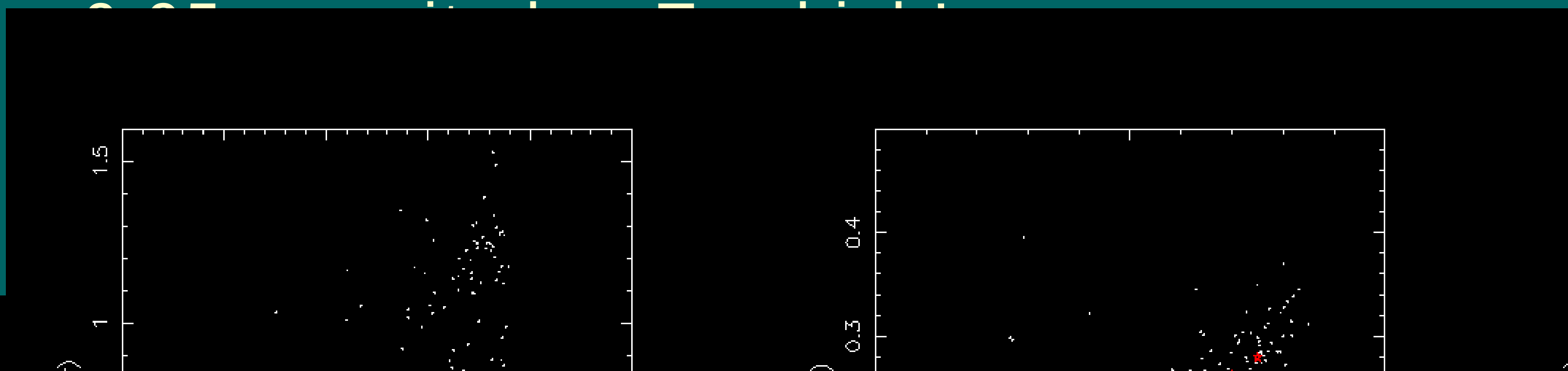
We would like to preserve the quality of “artisinale” (*fatto in casa*!) reductions whilst duplicating them on a very large scale...

The CFHTLS-t02 deep stacks

- All data between taken between June 2003 and December 2004
- Only images with seeing better than 1.1''
- Four independent fields each of which has an effective area of 0.8 deg^2 after masking
- Coverage in five broad band filters (*ugriz*), reaching approximately AB~26 in all bands
- Data released publicly to the French and Canadian communities – see the CADC/TERAPIX web sites

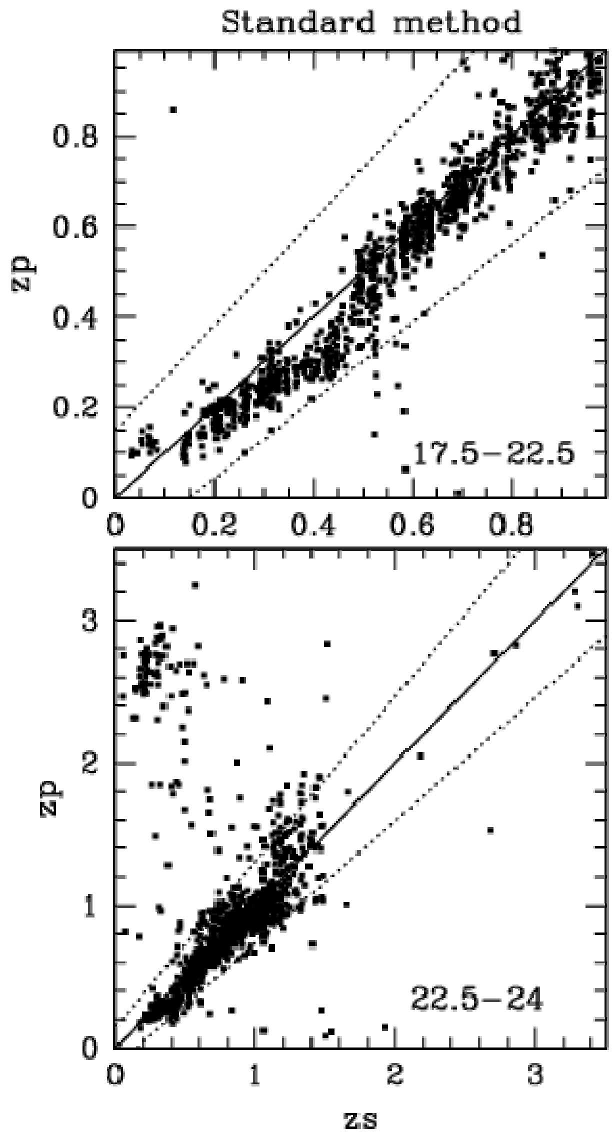
Photometric (re)calibrations

- Photometric calibrations “out of the box” have a systematic field-to-field dispersion of around

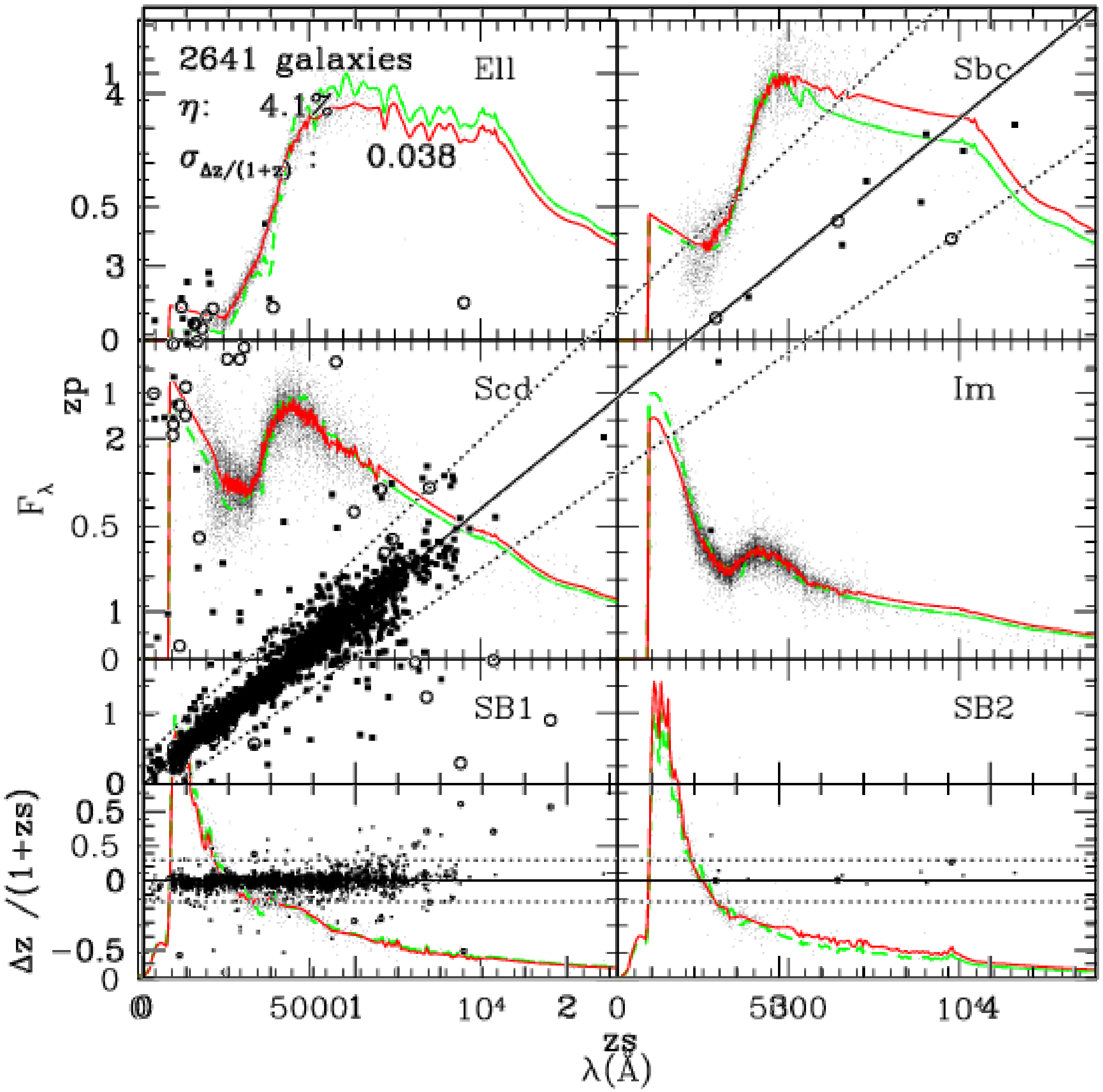


- Minimisations repeated over all four fields taking one field as the reference
- These offsets offsets applied and catalogues re-extracted
- Final catalogues have absolute calibrations at the ~0.025-0.01 magnitude level

Photo-zeds: "Le Phare" (Ilbert/Arnouts)



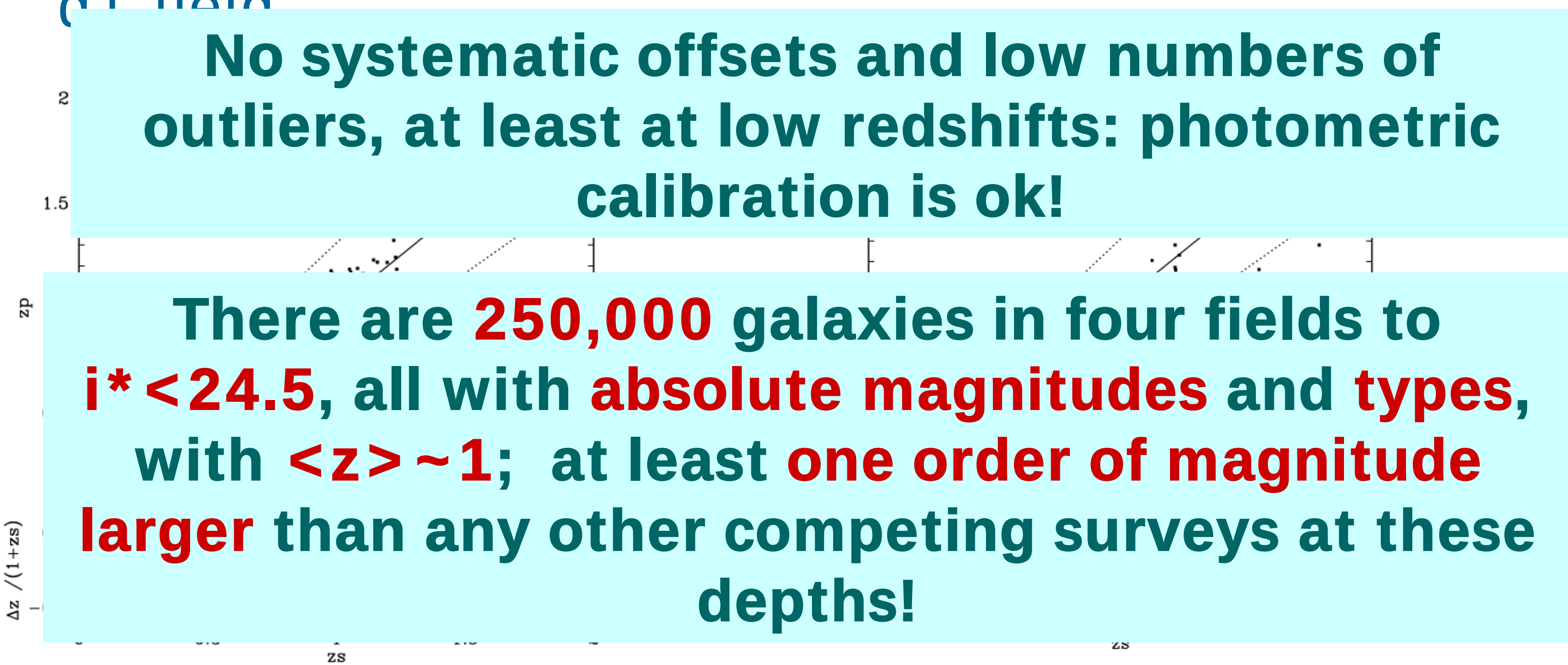
- Chi-squared fitting technique with the standard interpolated Coleman, Wu and Weedman templates (+ starburst type)
- Nasty systematics at low redshift!
- Many catastrophic errors!
- Photometric redshifts demand *precise knowledge* of the instrumental response function – we need to re-calibrate our templates



- Control sample of 468 galaxies with i*<21.5 and spectroscopic redshifts are used to produced “corrected” templates.
- These corrected templates produce much better photmetric redshifts with *no* systematic effects
- And also with a much smaller number of catastrophic outliers

Computing phot-zeds in the other CFHTLS deep fields

- In the d3 and d4 fields there are a small number of spectroscopic redshifts at lower redshifts from other surveys (SDSS, CFRS) which allow us to validate the templates derived from the cfhtls-d1 field



No systematic offsets and low numbers of outliers, at least at low redshifts: photometric calibration is ok!

There are 250,000 galaxies in four fields to i*<24.5, all with absolute magnitudes and types, with <z>~1; at least one order of magnitude larger than any other competing surveys at these depths!

Computing the comoving correlation length-I

$$\omega(\theta) = \frac{H_0 H_\gamma}{c}\, \theta^{1-\gamma}\, \frac{\int_0^\infty N^2(z)\, r_0^\gamma(z)\, [x(z)]^{1-\gamma}\, E(z)\, F(z)\, dz}{[\int_0^\infty N(z)\, dz]^2}$$

Relativistic limber equation

$$\omega(\theta) = A_\omega \theta^{-\delta}$$

Assuming w(θ) is a power law...

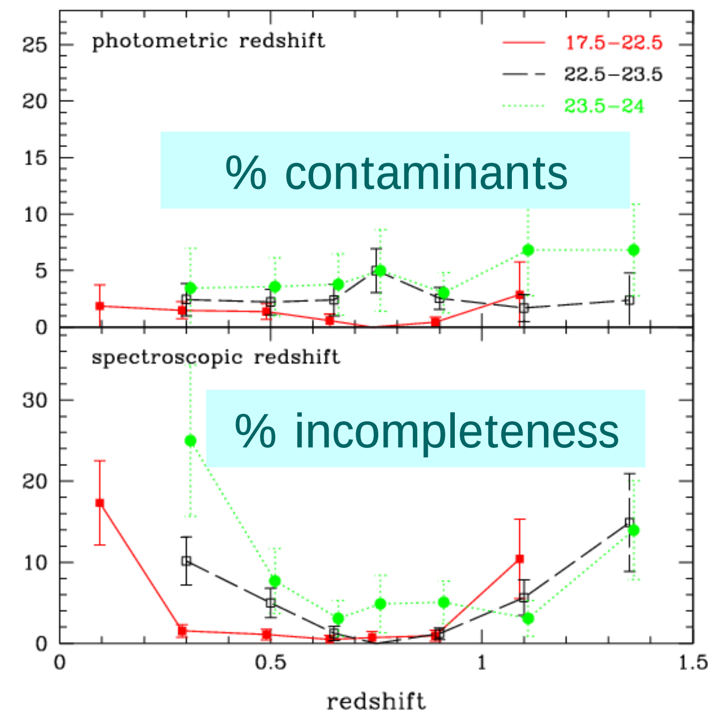
$$r_0^\gamma(z_{\rm eff}) = A_\omega \left[\frac{H_0 H_\gamma}{c}\, \frac{\int_{z_1}^{z_2} N^2(z)\, [x(z)]^{1-\gamma}\, E(z)\, dz}{[\int_{z_1}^{z_2} N(z)\, dz]^2}\right]^{-1}$$

$$\omega(\theta) = \frac{DD - 2DR + RR}{RR},$$

Which you get from computing pair counts on your catalogue....

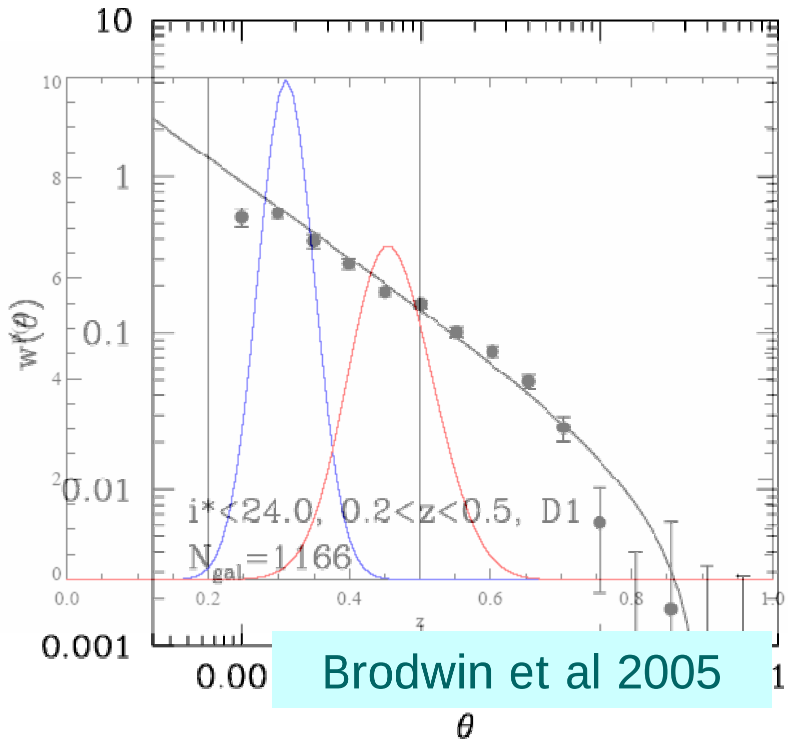
Computing comoving correlation lengths-II

- We compute the **projected correlation function w(θ)** fo each field and for each magnitude slice.
- We select galaxies in redshift slices corresponding the range where our photometric redshifts have the highest accuracy (lowest numbers of catastrophic outliers)
- For the moment, we consider galaxies with **0.2<z<1.2**



Computing the comoving correlation length-III

- For each galaxy in each redshift slice we compute the area under that galaxy's probability distribution function
- These areas are used as weights in the correlation function measurement
- This ensures that **all** information about the reliability of each photometric redshift is used
- The resulting measurements are then fitted with a power law with the appropriate finite-volume correction.

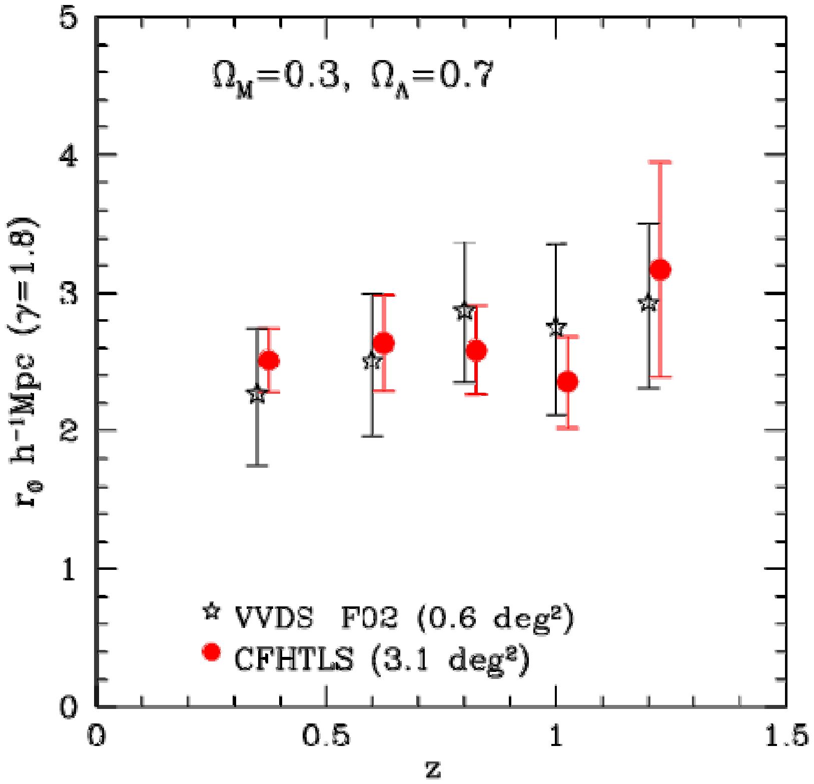


Brodwin et al 2005

$$\omega(\theta) = \frac{DD - 2DR + RR}{RR},$$

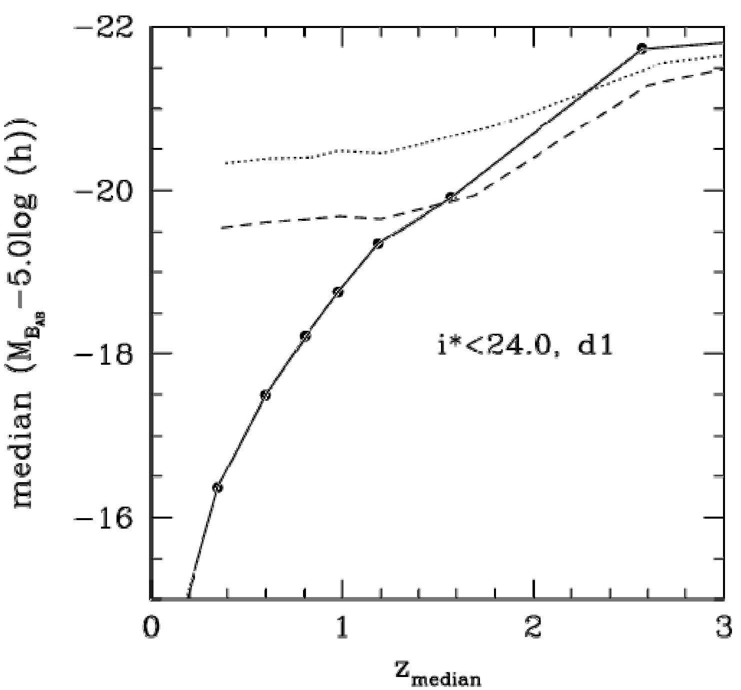
Comoving correlation length as a function of redshift

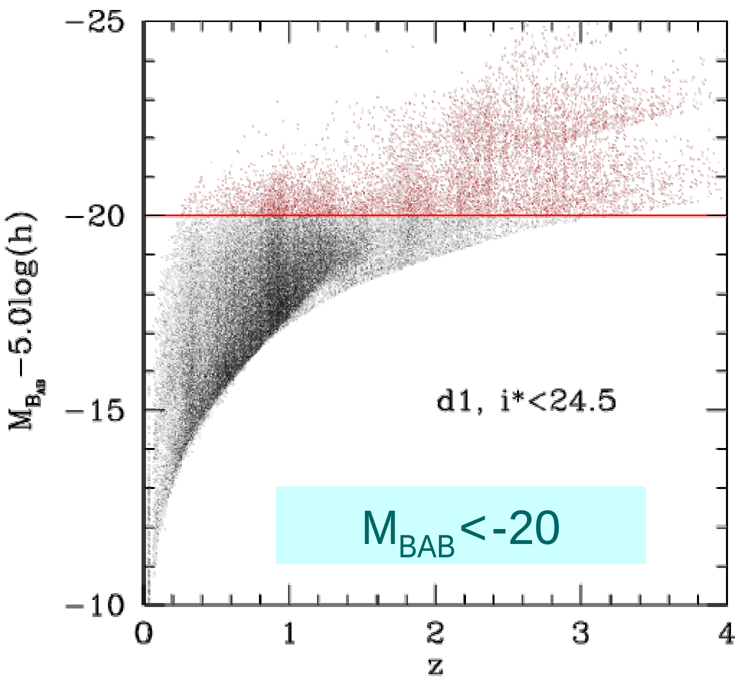
- We compute r_0 as a function for z for all four fields of the CFHTLS
- Error bars computed from the field-to-field variance – they are true “cosmic” error bars
- Remarkably good agreement with the VVDS spectroscopic survey measurements (which enclose one of the cfhtls survey fields)

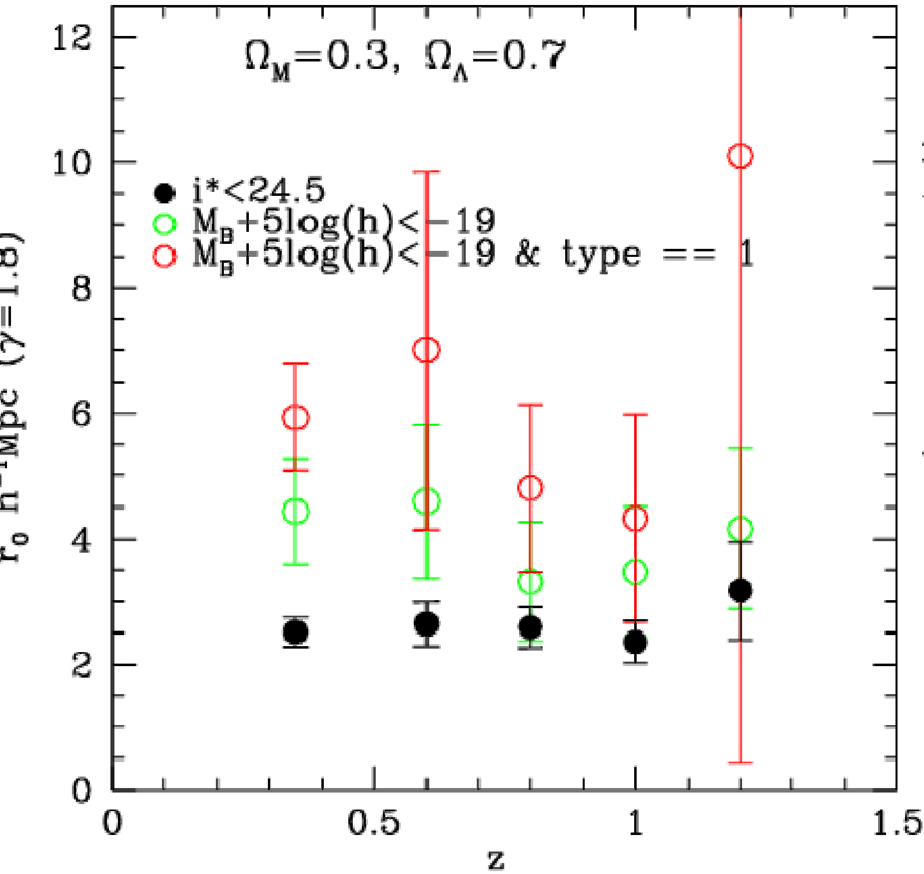


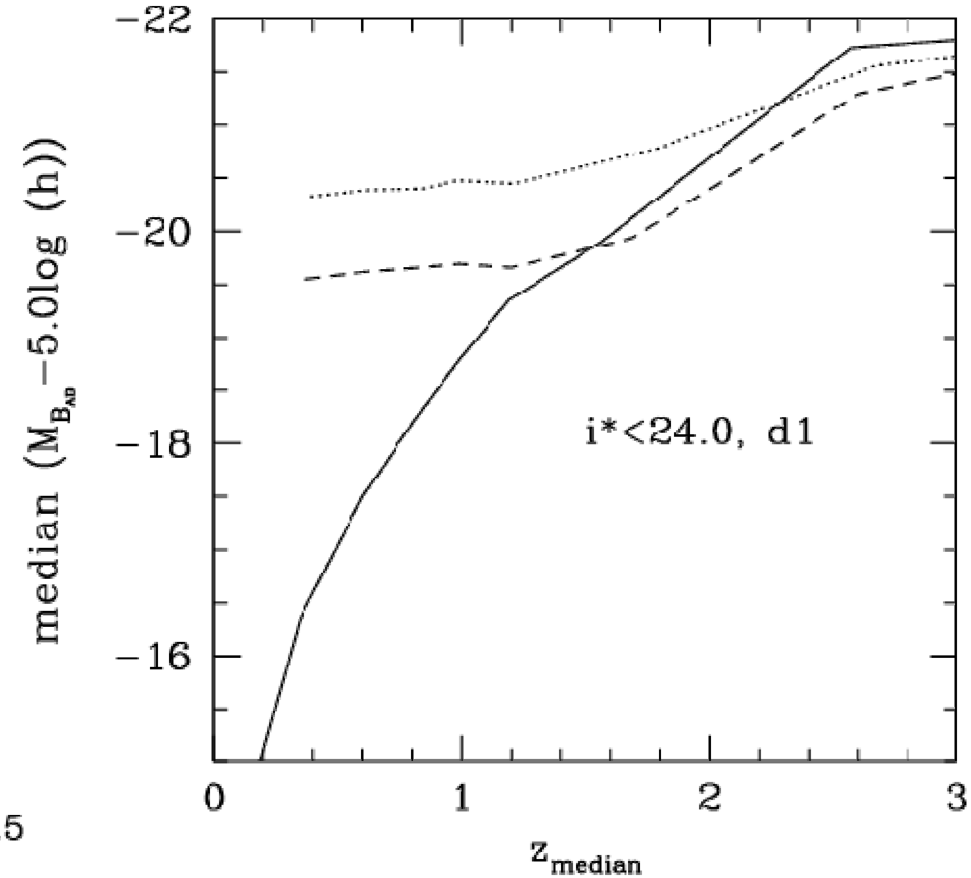
Luminosity limited samples

- Median luminosity in redshift slices is a strong function of redshift…
- Making luminosity-limited samples creates volume-limited samples





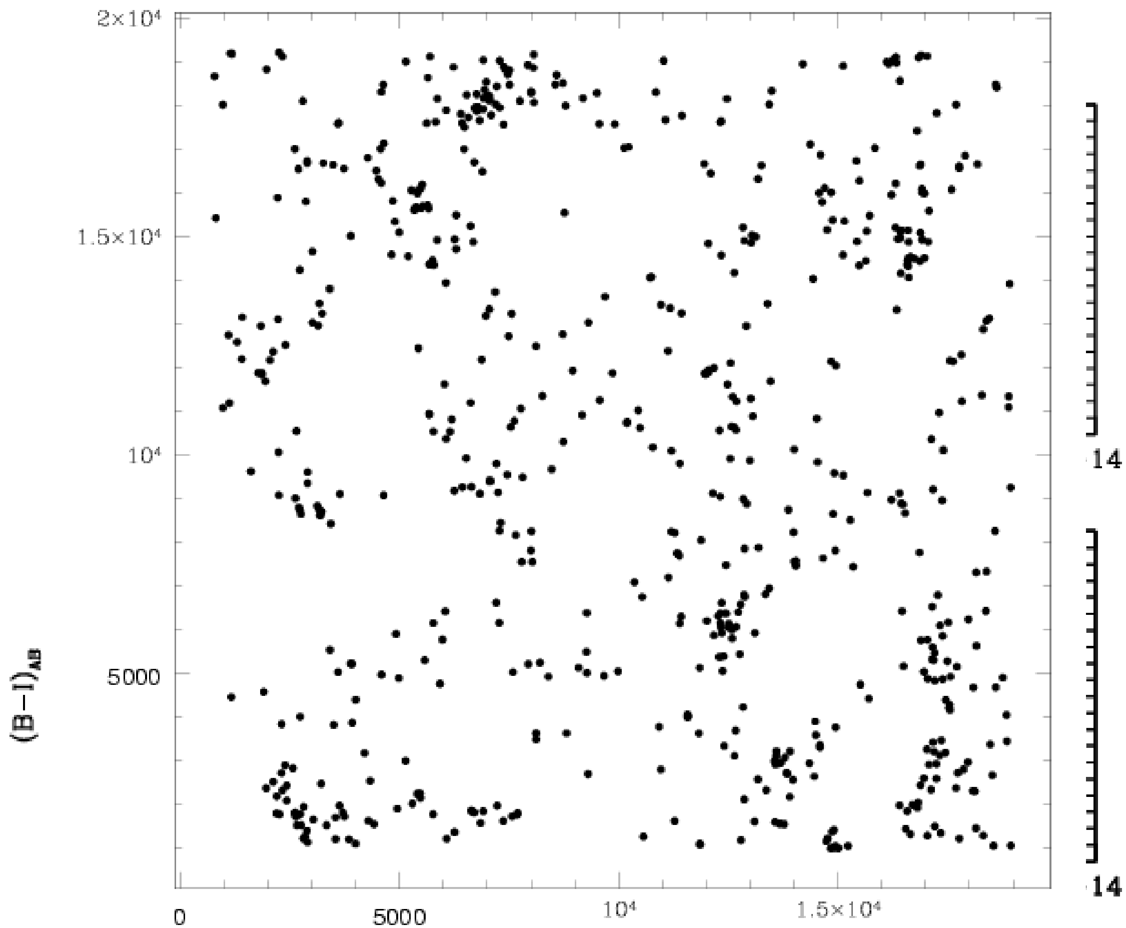




- Clustering amplitudes much higher than the magnitude limited sample, because the mean absolute magnitude is higher; bias depends on luminosity
- Does r0 decrease for these galaxies? (you might expect this if they were weakly biased...

Clustering by type to z~1

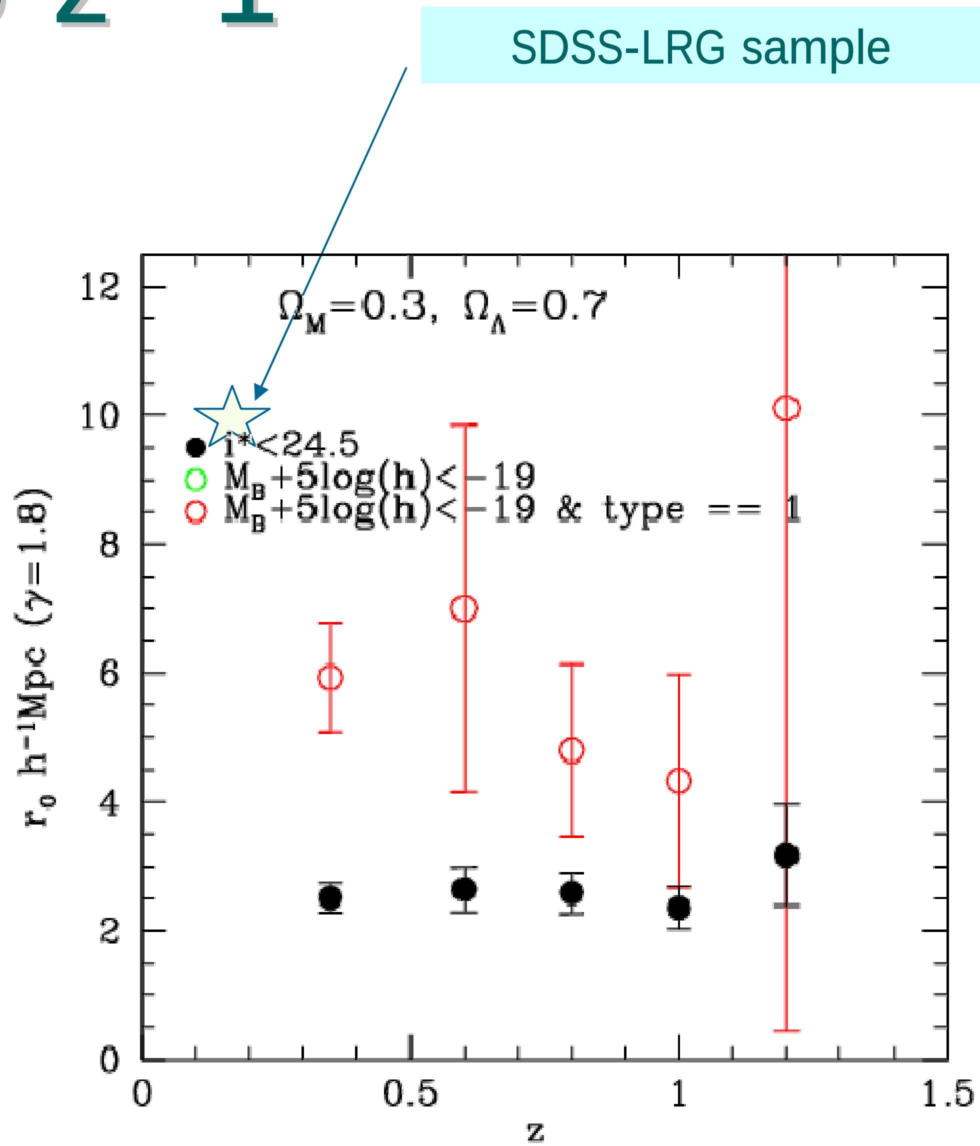
- What about the colour and type evolution of galaxies?
- Photometric redshift code provides *types* of best fitting templates
- These objects are **even more strongly clustered**



Elliptical galaxies in the cfhtls-d1 0.2<z<0.5 redshift slice

Clustering of early types to z~1

- Clustering of early types at z~1 is even higher than the luminosity limited samples at the same redshifts



What does it all mean?

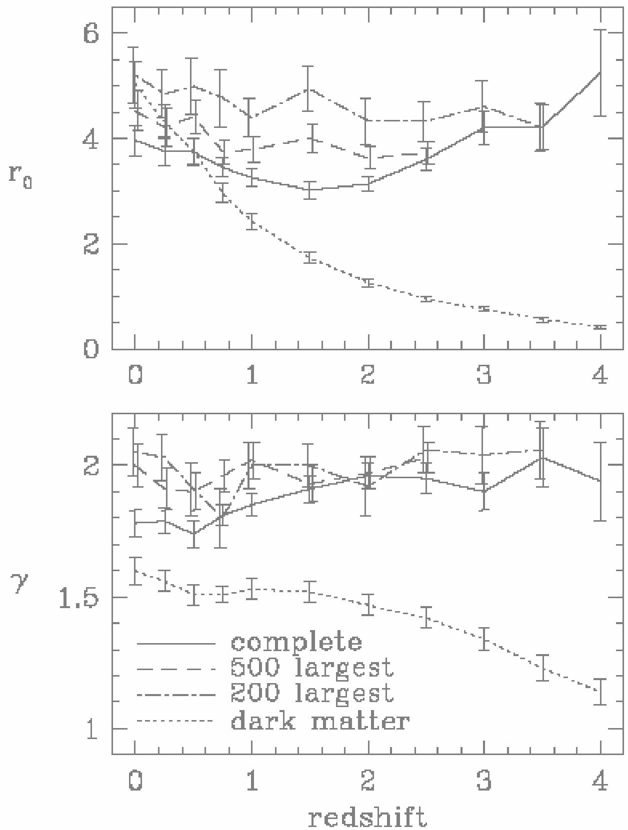


FIG. 5.—Evolution of the correlation length r_0 (in comoving h^{-1} Mpc) and power-law index γ, for all galaxies (*solid line*), the 500 most massive galaxies (*dashed line*), the 200 most massive galaxies (*dot-dashed line*), and the dark matter (*dotted line*). Error bars are obtained from the power-law fits, using the jackknife errors on $\xi(r)$. Lines for the 500 largest galaxies stop at $z = 2.5$, since the complete sample contains fewer than 500 galaxies at higher redshift; likewise, lines for the 200 largest galaxies stop at $z = 3.5$.

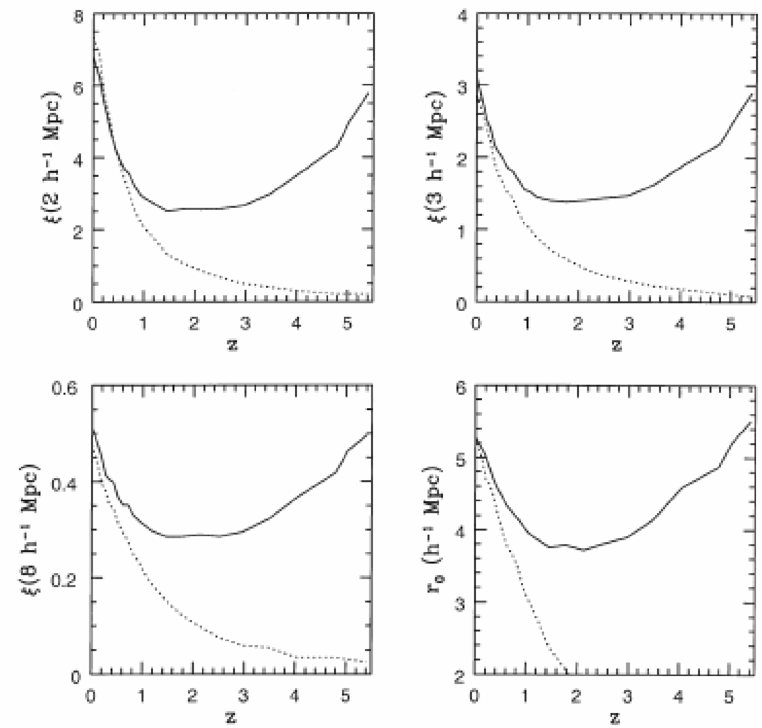
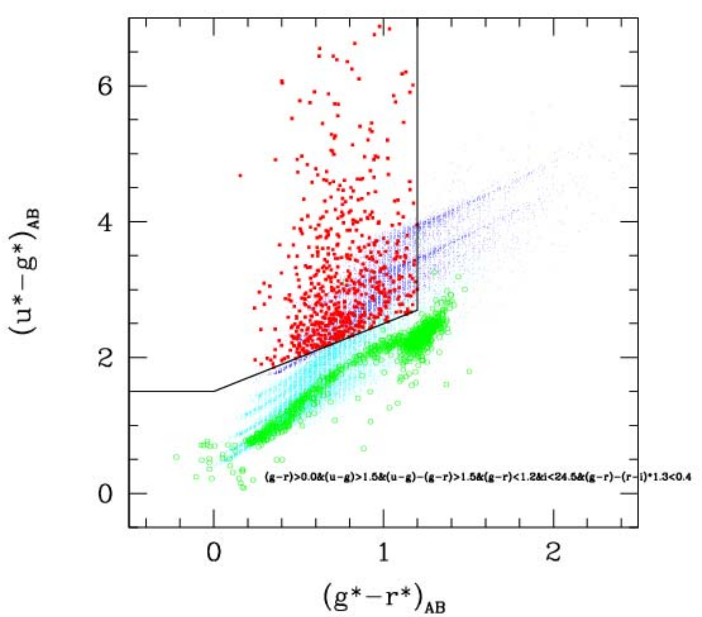


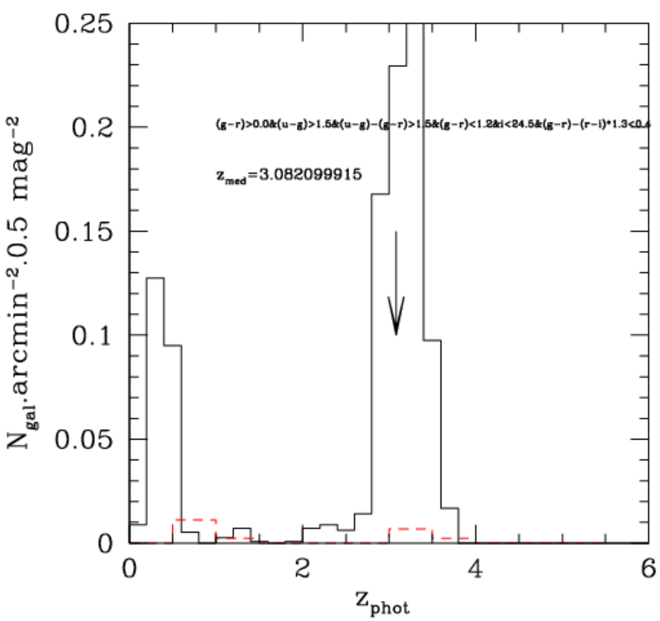
Figure 4. Evolution of clustering the the ΛCDM model. In the first three panels, the clustering amplitude is plotted against redshift for galaxies with rest frame *B*-band magnitudes brighter than $-19 + 5 \log h$ (solid lines) and for the dark matter (dotted lines). Results are shown for $\xi(r)$ evaluated at $r = 2$, 3 and $8\, h^{-1}$ Mpc^{-1}. In the fourth panel, the comoving correlation length r_0 is plotted against redshift both for the galaxies and for the dark matter.

Kaufmann et al 1999

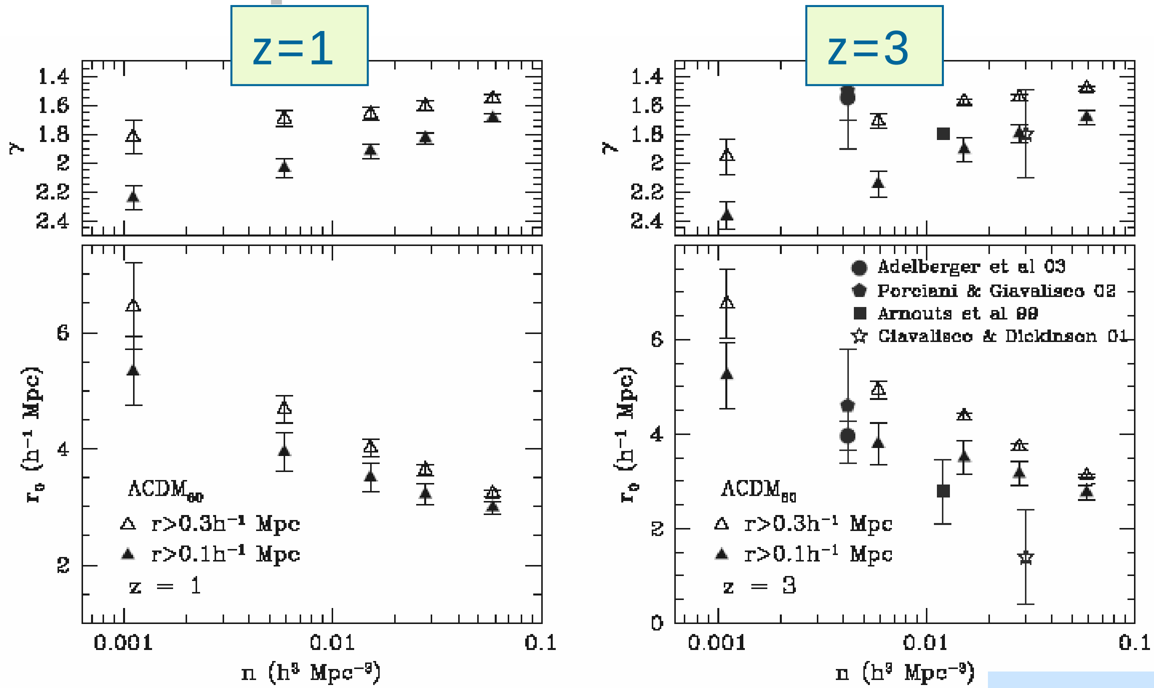
What's next: lyman-break galaxy samples

- There are several thousand z~4 and z~3 lyman-break galaxies in the CFHTLS survey fields...
- Megacam is very efficient in u*





Measuring the halo occupation function



Kravstov et al 2003

- Modelling the occupation function of dark matter haloes perhaps can provide some insight into how galaxies cluster at small separations where traditionally predictions are very difficult
- Does this explain the deviation from the power law behaviour seen for objects at z~4?
- We should be able to make a direct measurement of this quantity with the CFHTLS-zphot survey