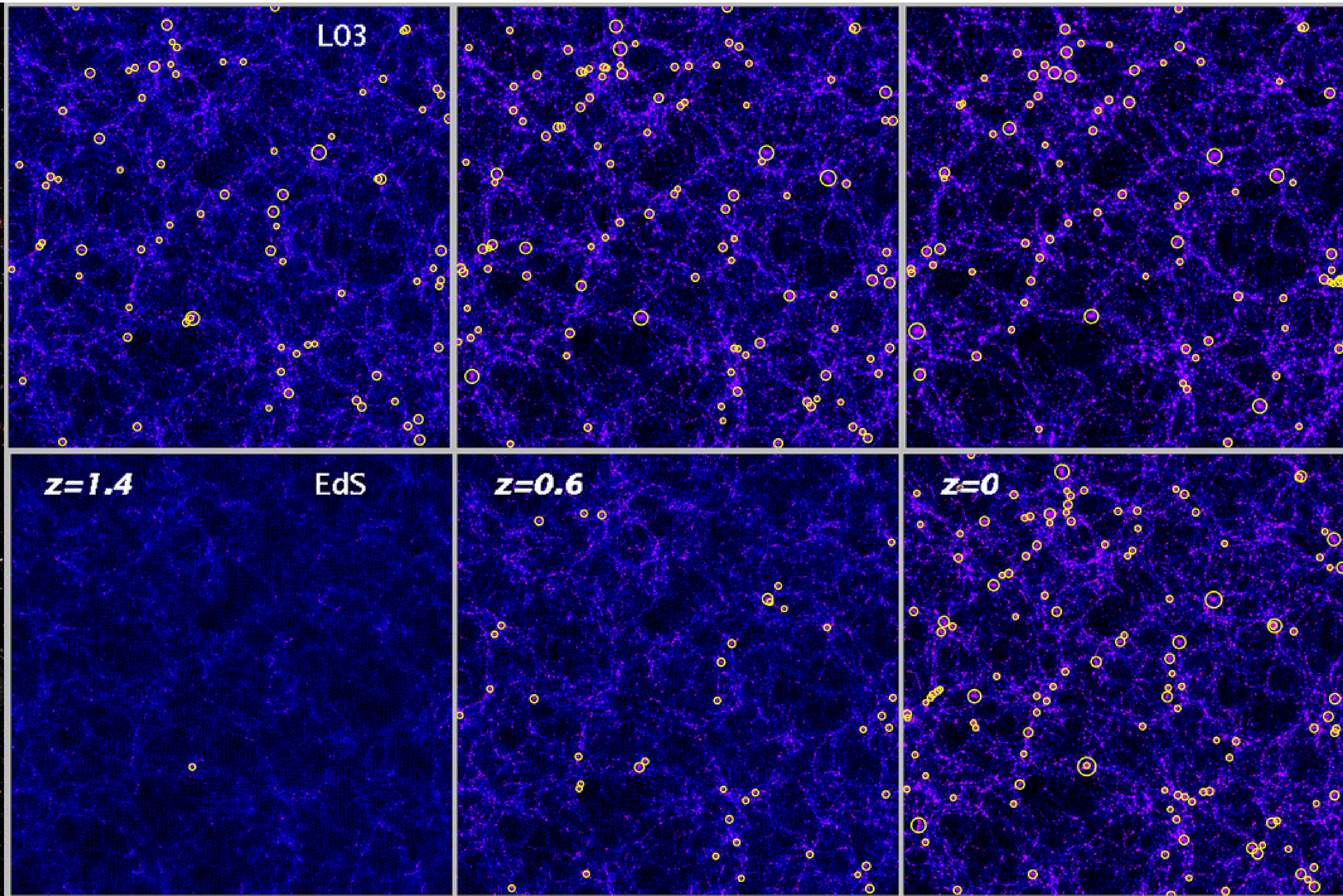
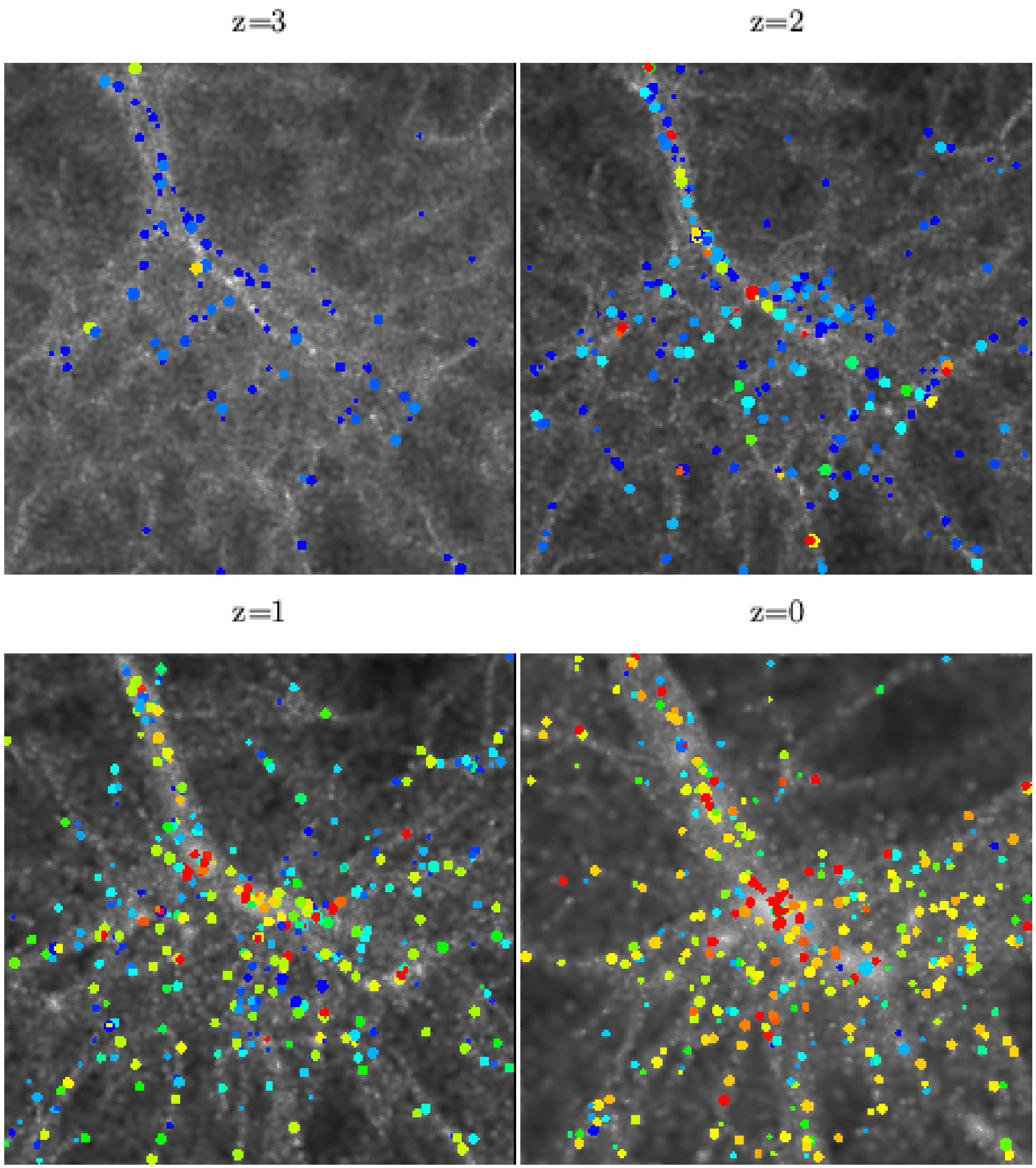
Exploring Large Scale Structure up to z=1 and beyond

AstroSiesta **8 Marzo 2007**



Borgani & Guzzo 2001, Nature



Structures evolve with z but galaxies evolve as well !

Kauffmann & Diaferio 1998

What does one need to map joint evolution of LSS and galaxies?

- Spectroscopy at faint magnitude limits
  - **IAB>22 brings peak of N(z) at z>0.5**
- Reduce cosmic variance:
  - **fair volume sampled at high redshift (~100 h-1 Mpc side) → large areas (1-10 deg2)**
- Sample cosmic epochs enough to measure evolution
  - **large sample (10,000 – 100,000 galaxies)**

NEED 8m-class telescope + HIGH MULTIPLEXING

- Understand the inter-play between dark matter and galaxies:
  - Multi-band information (radio,IR,…UBVRIJK…, X-rays)
  - High-resolution imaging (HST)

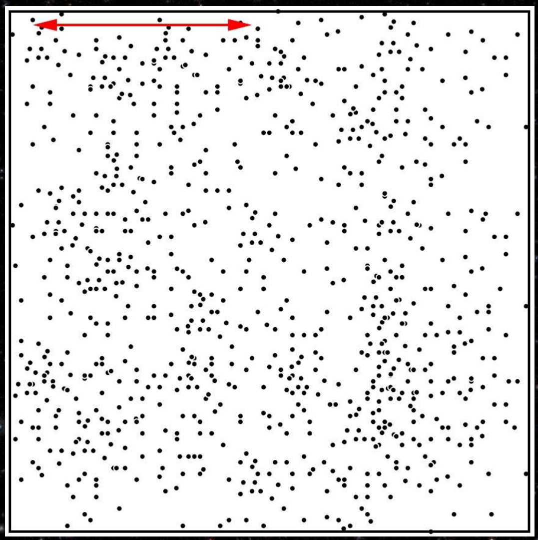
3 projects of this kind currently underway:
VVDS, COSMOS, DEEP2

The 2 point correlation function

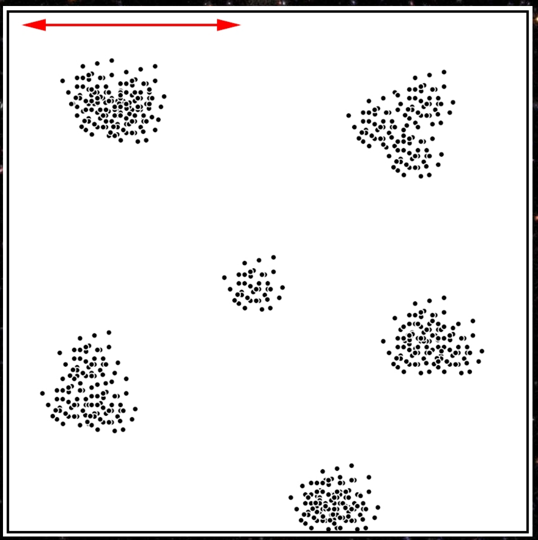
- Excess probability over random that a galaxy has a neighbour at a distance r
  - for a random (uniform) distribution: $\delta P = r_0^2 \delta V_1 \delta V_2$
  - a clustered distribution can be (incompletely) described by:

    $\delta P = r_0^2\, \xi(1+(r_{12}))\delta V_1 \delta V_2$
- In general well described by a single power law between ~1 and ~30 Mpc h^{-1}

$$\xi(r) = (r/r_0)^{-\gamma}$$

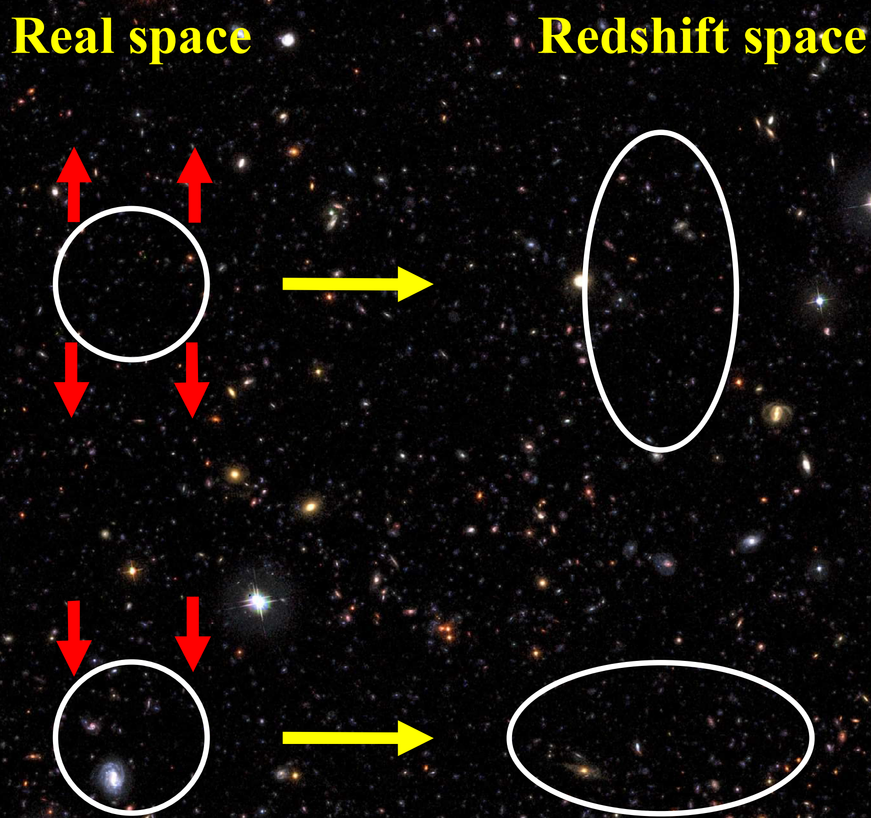


small r_0



large r_0

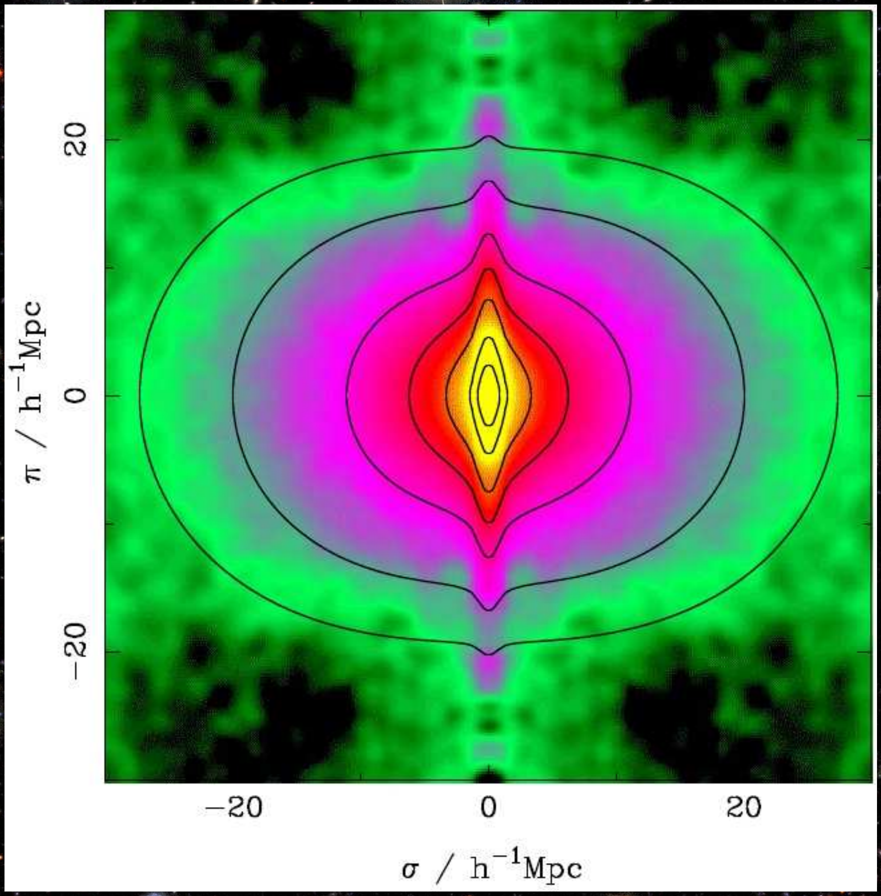
Distorsions in the redshift space



- *Finger-of-God* on small scale (peculiar velocities)
- **Coherent infall of galaxies on large scale (Kaiser, 1987)**

courtesy of B.Meneux

The projected correlation function



Peacock et al., 2001 (2dFGRS)

Summing along the line-of-sight to recover the real-space correlation function (Davis & Peebles, 1983)

$$w_p(r_p) = 2\int_0^\infty \xi(r_p,\pi)d\pi$$
$$= 2\int_0^\infty \xi\left[\left(r_p^2+y^2\right)^{1/2}\right]dy$$

With the assumption that ξ(r) is a power-law, then

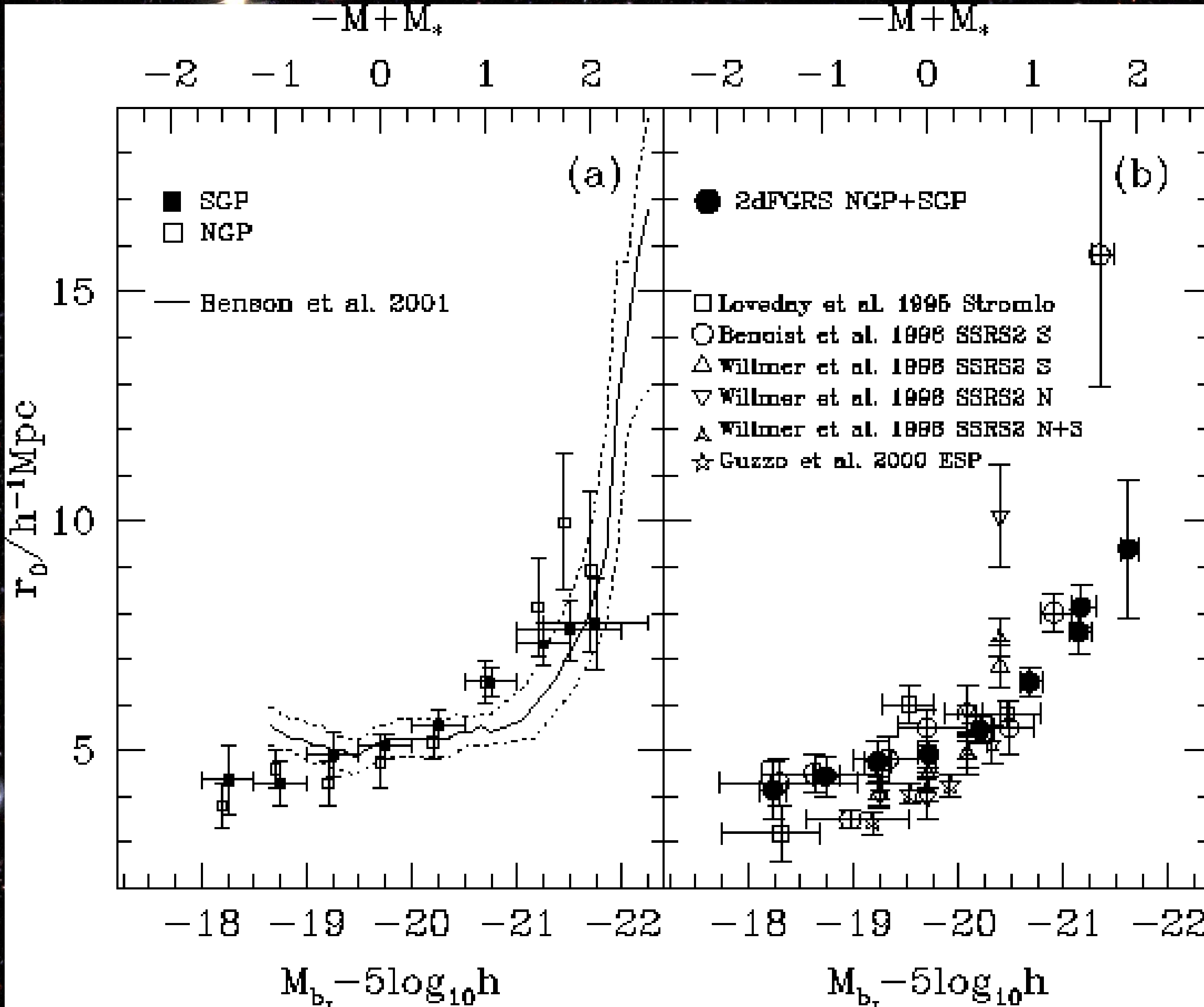
$$w_p(r_p) = r_p\left(\frac{r_0}{r_p}\right)^\gamma \times \frac{\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{\gamma-1}{2}\right)}{\Gamma\left(\frac{\gamma}{2}\right)}$$

courtesy of B.Meneux

Local Universe (2dFGRS)

Wp(rp) analysis vs. Luminosity

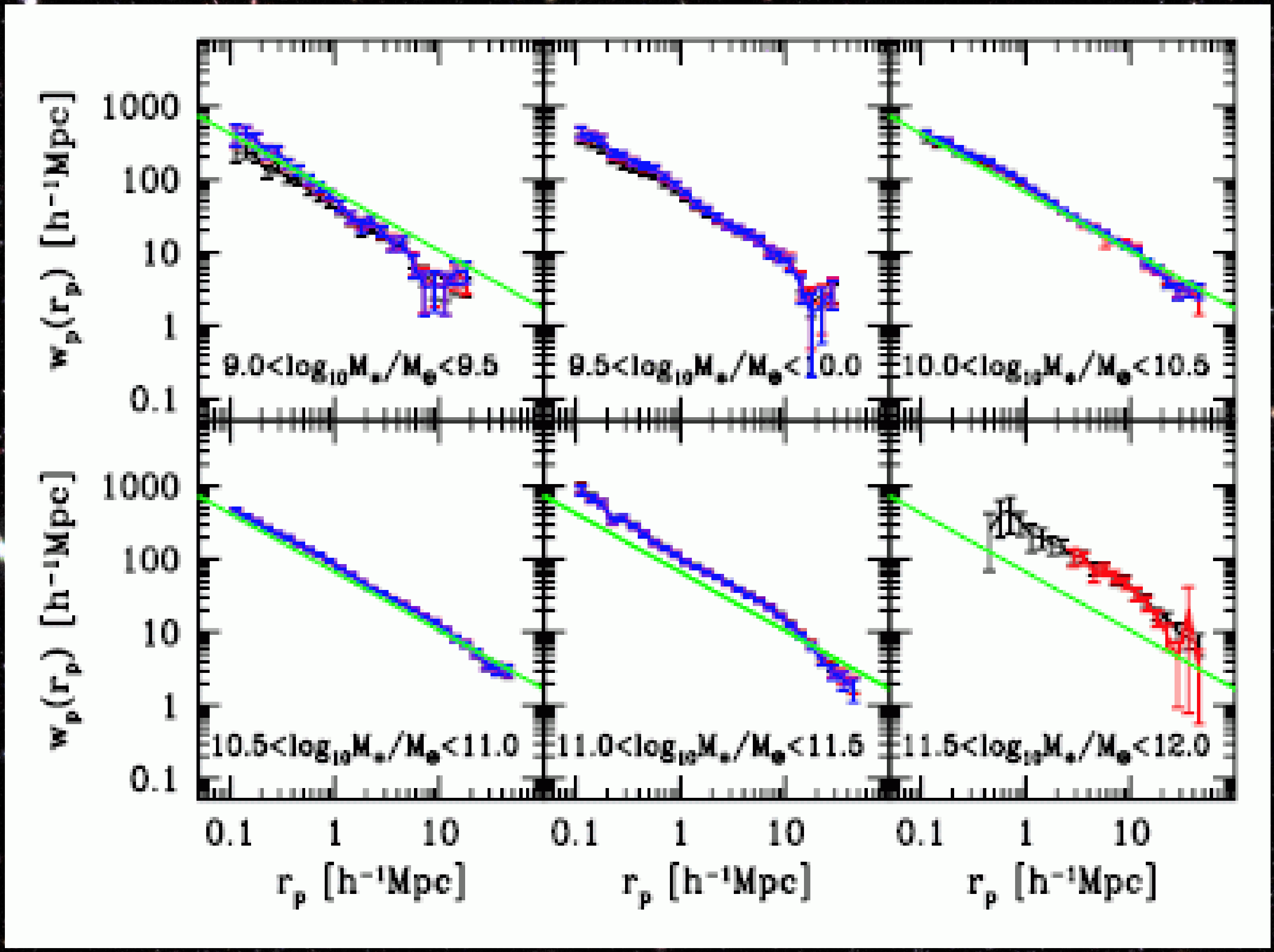
Norberg et al. 2003



Local Universe (SDSS)

- Wp(rp) analysis vs. Mass

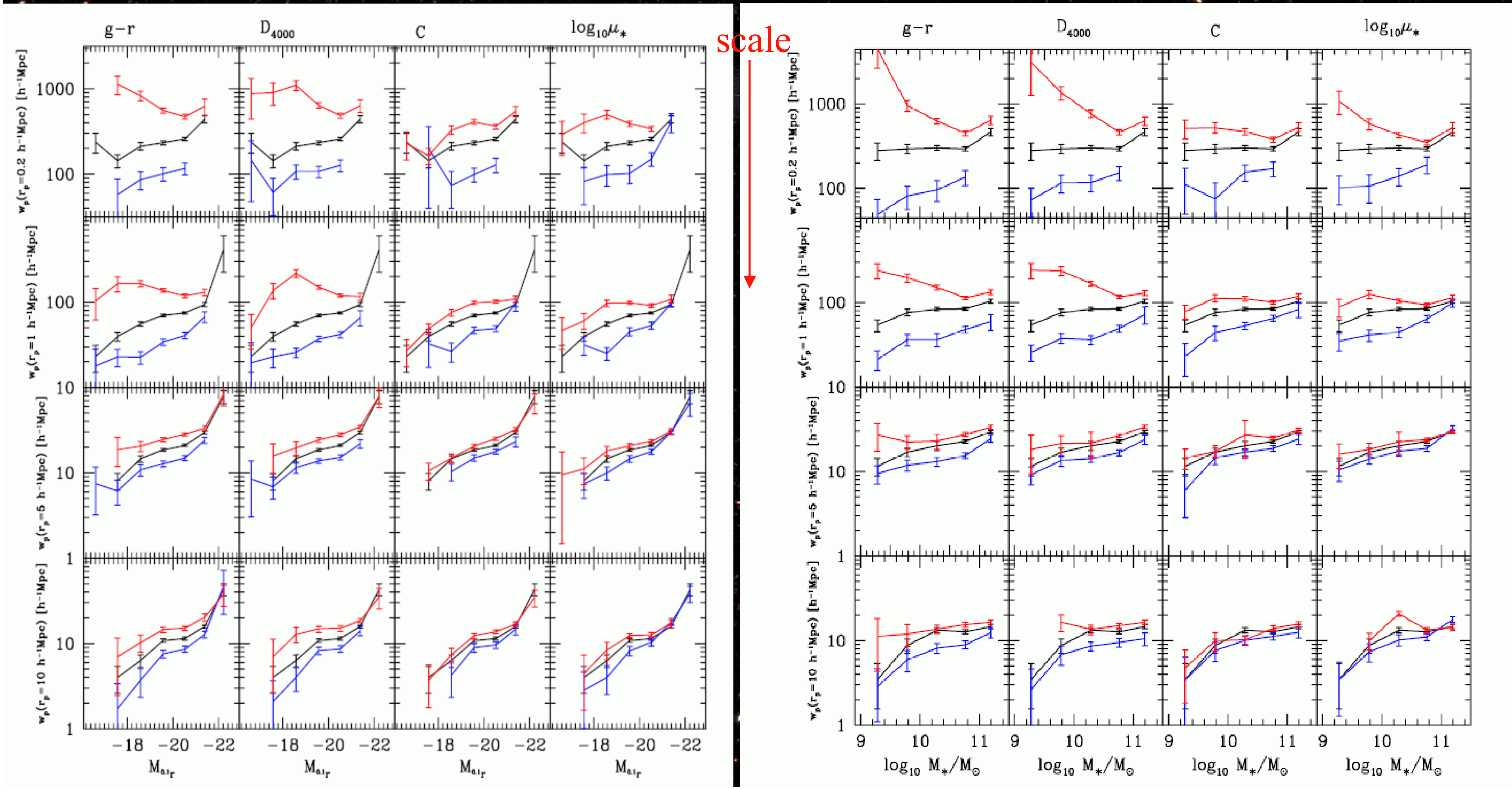
Li et al. 2006



Local Universe (SDSS)

- Wp(rp) analysis vs. D4000, morphology (C), stellar mass surface density

Li et al. 2006

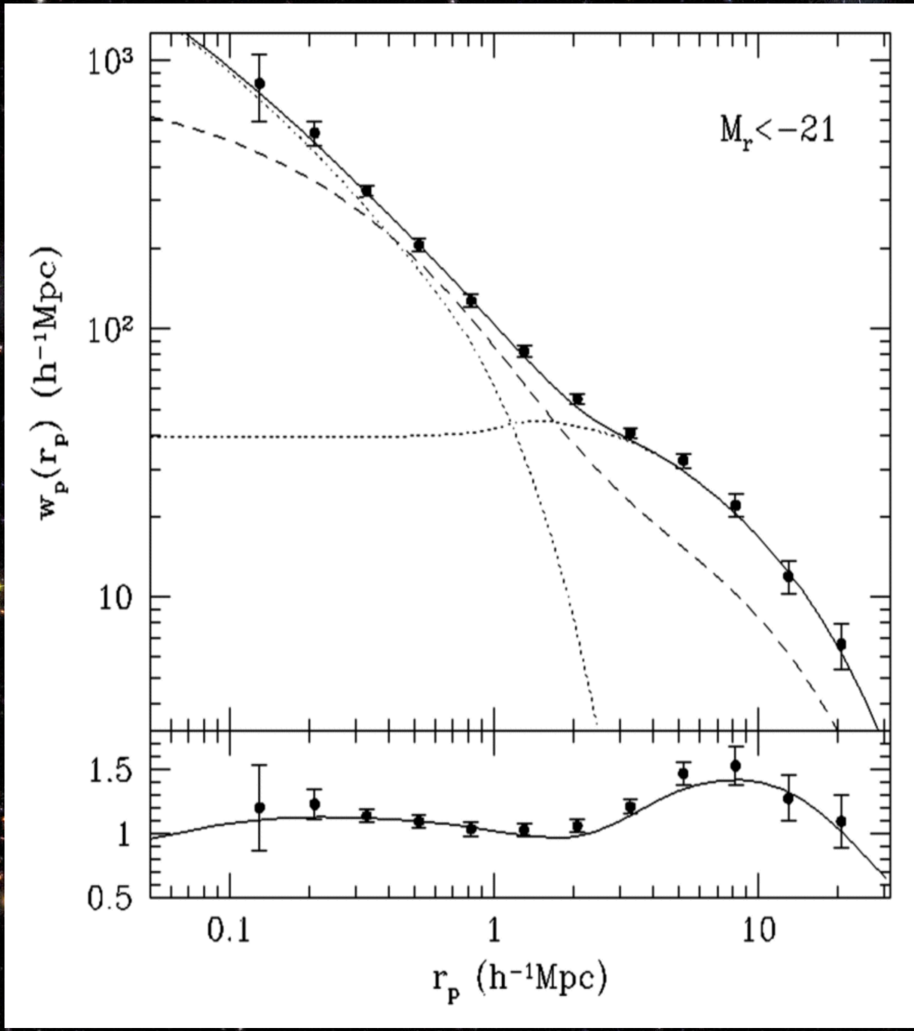


CF detailed shape

information on how galaxies populate DM halos.

- **SDSS now shows this very clearly**
- **interpreted in the framework of the Halo Occupation Distribution model**
  - At small scales CF dominated by galaxy pairs within the same halo
  - At larger scales, dominated by distance between halos

(Zehavi et al. 2003, 2005)



LOCAL UNIVERSE (SDSS)

- **Luminous galaxies more clustered than faint ones,**
- **Different behaviour at different scales:**
  - Small scales: costant amplitude < L*, increasing >L*
  - Large scales: clustering amplitude increases with L
- **massive galaxies more clustered than less massive galaxies**
- **Galaxies redder, large D_{4000}, concentrated, high μ_* more clustered, steeper CF**
  - Larger difference at small scales for low-L low-M
- **A single power Law does not seem enough**

The VVDS Project

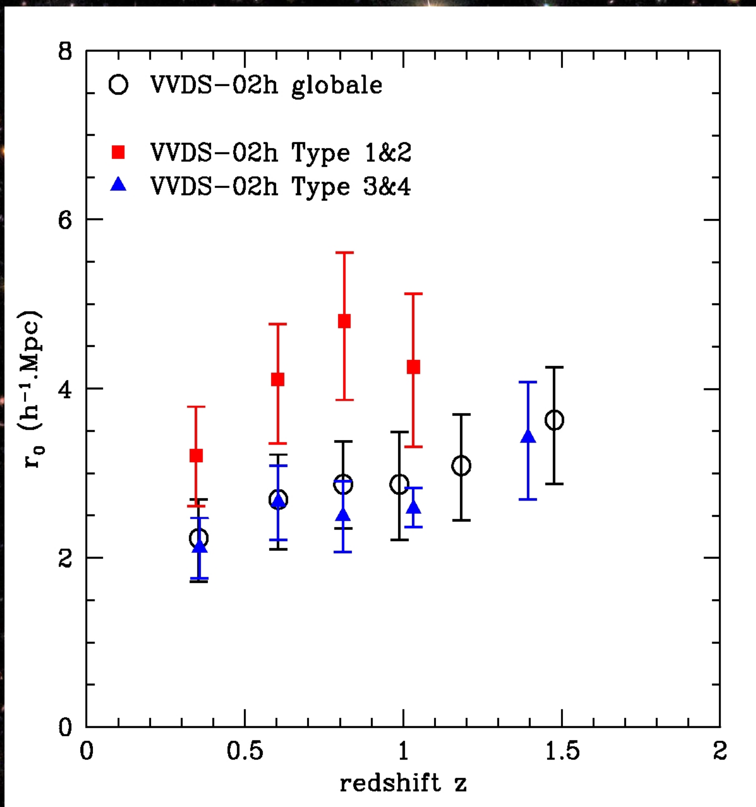
I band magnitude selected

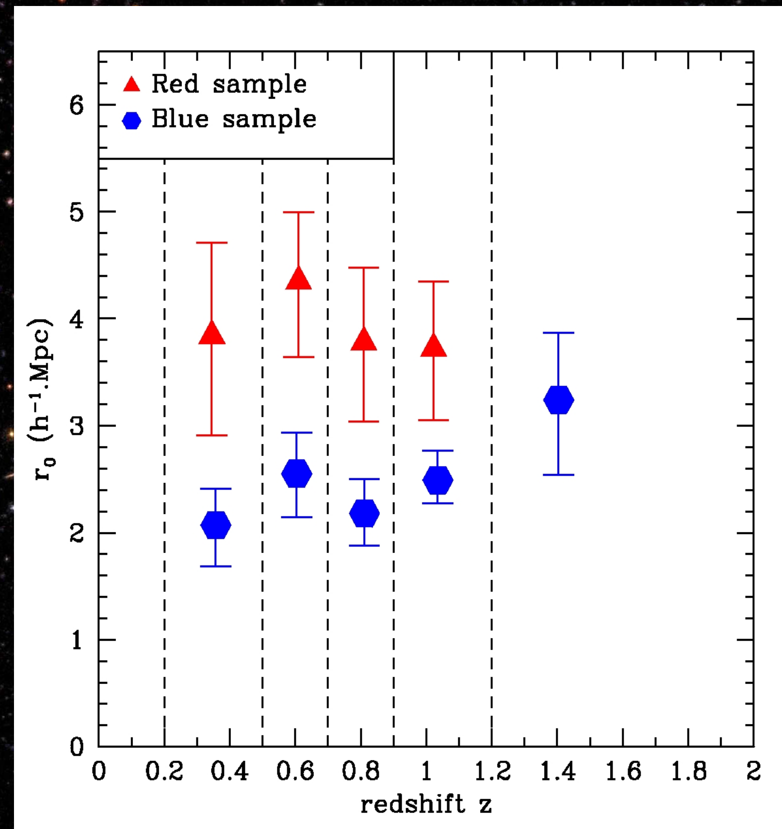
- ULTRA-DEEP: $22.5 \leq I_{AB} \leq 24.75$, 0.25 deg^2
- DEEP: $17.5 \leq I_{AB} \leq 24$, 1.2 deg^2
- WIDE: $17.5 \leq I_{AB} \leq 22.5$, 10$deg^2$

- **Multiλ information, to fit SEDs -> luminosities, spectral types, stellar masses**
  - u*b'g'r'i'z',UBVRI,J,K_s,GALEX,SPITZER,XMM,VLA
- **Large areas, 5 fields, total ~11 deg^2**
  - 0226-04
  - 1000+03 (now the HST-COSMOS field)
  - 1400+05
  - 2217+00
  - CDFS
- **Large numbers, to sample the different populations at the different epochs**
  - >100000 spectra 0<z<5

~50000 spectra today

VVDS: clustering up to z=1.5





- **Are galaxies more clustered at high redshift?**

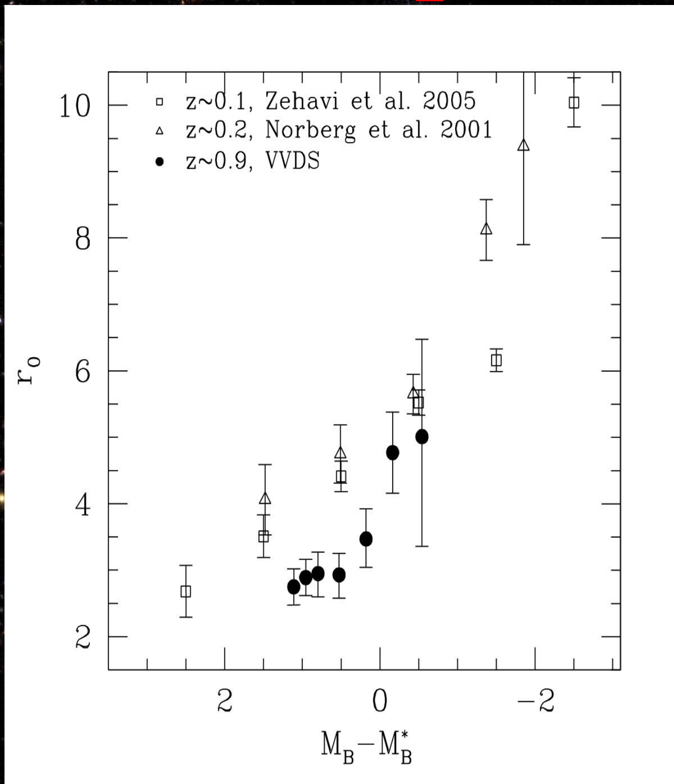
LeFèvre & VVDS Team, 2005, A&A

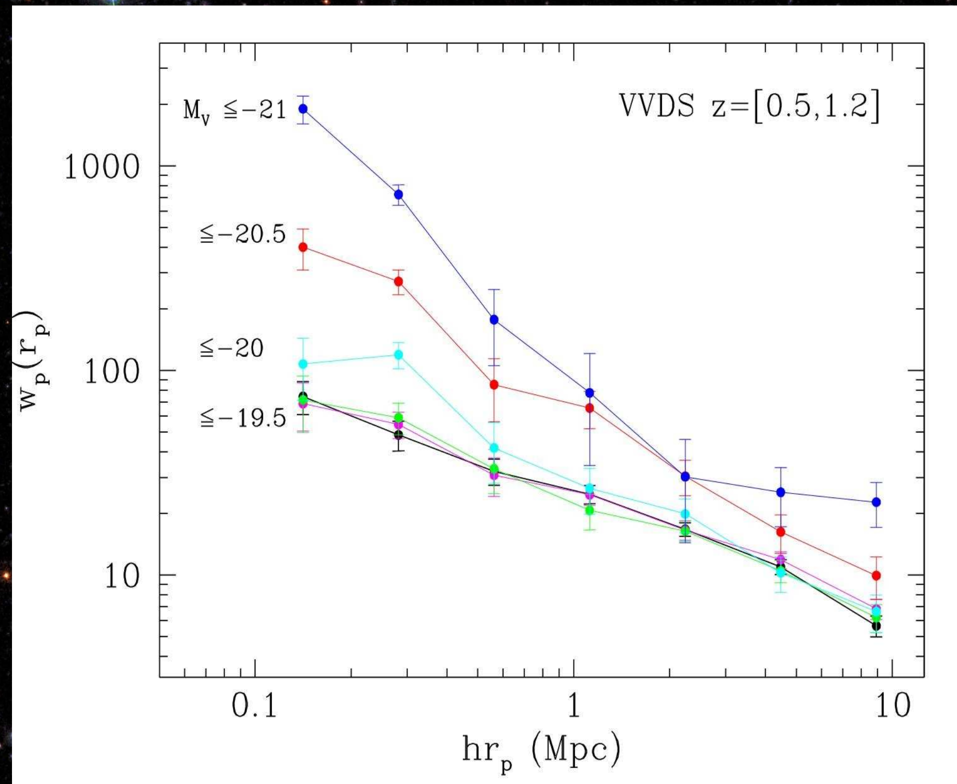
- **Early type** galaxies are more clustered than **late type** ones

Meneux & VVDS Team, 2006, A&A

- **Red** galaxies are more clustered than **blue** ones

Dependence on luminosity

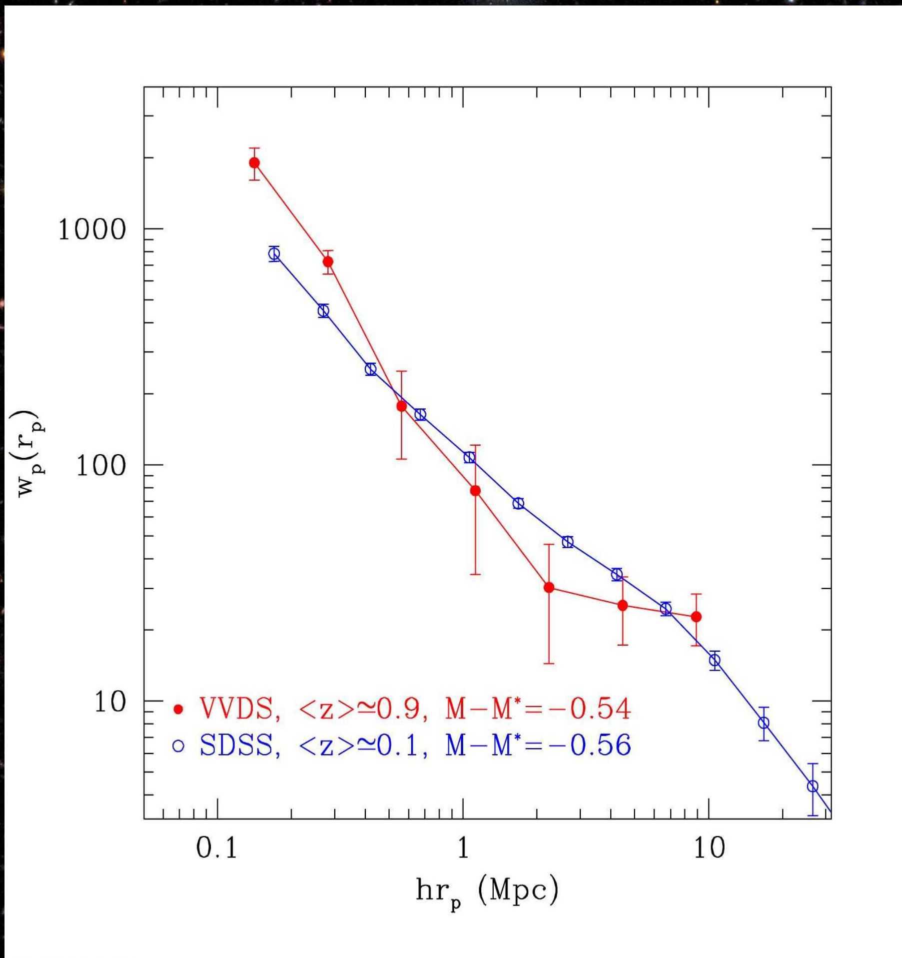




- For $M_B < M_B^*$ clustering length has a low constant value
- At $M_B > M_B^*$ it increases approaching local Universe values
- steepening at $M_B > M_B^* + 0.5$, luminosity dependent

Pollo & VVDS Team, 2006, A&A, in press (astro-ph/0512429)

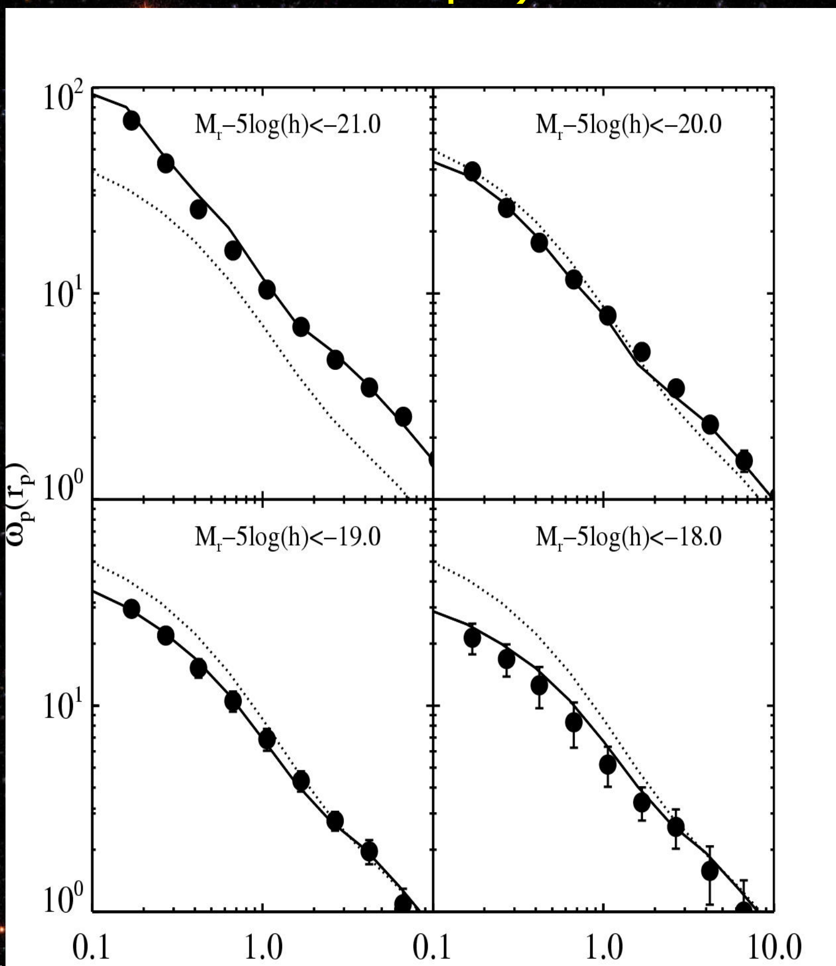
$w_p(r_p)$ steepening at z~0.9



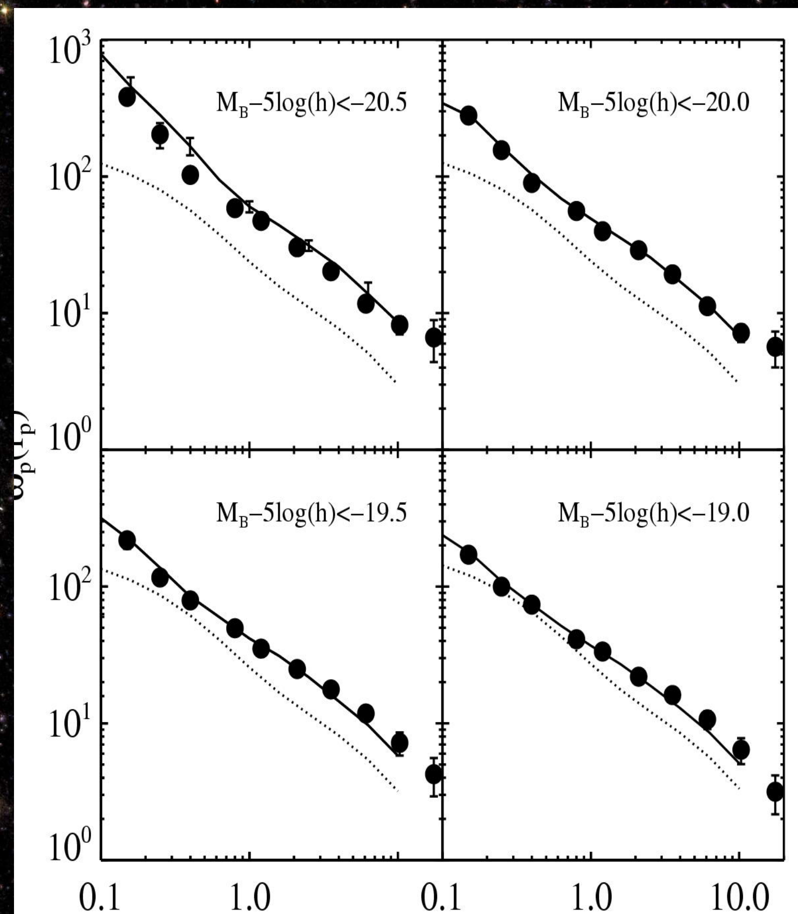
- **Luminous galaxies are clustered in a more "peaked" way at z=1 than they are today**
- **interpreted in the framework of the Halo Occupation Distribution model**
  - At small scales CF dominated by galaxy pairs within the same halo
  - At larger scales, dominated by distance between halos

Guzzo & VVDS team, 2007, in preparation

Similar behaviour observed in DEEP2 survey → statistical models from Conroy, Wechsler & Kravtsov (astro-ph/0512234) seem to reproduce well the observed behaviour with simple recipe (by matching halo «primordial» masses in a Λ-CDM simulation to observed luminosity function of sample)

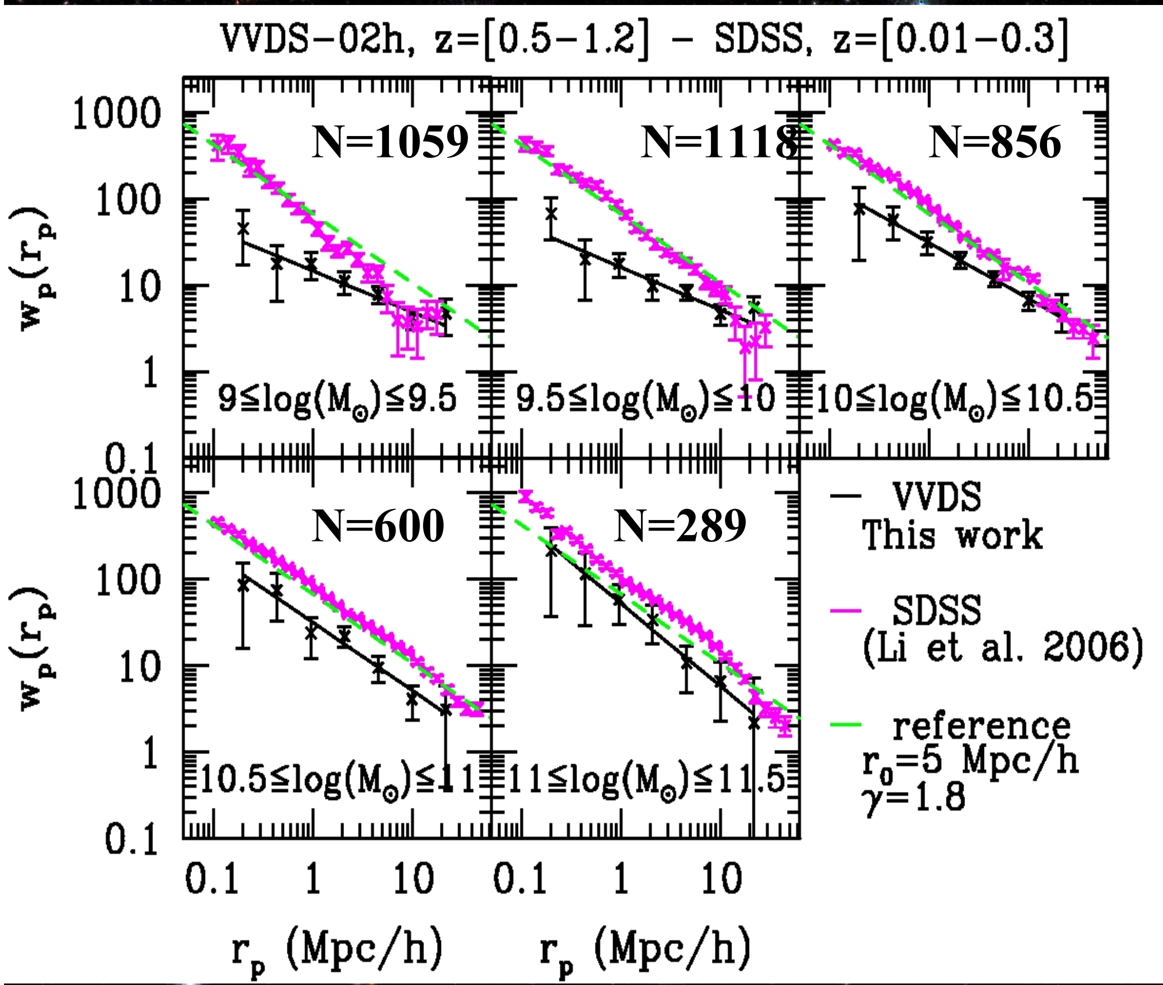


SDSS



DEEP2

CF vs. Stellar Mass



- low mass galaxies are less clustered than high mass ones
- Clustering evolution different for low and high mass galaxies
- low numbers in the highest mass bins, enlarge the volume (at the expense of depth)

Meneux & VVDS team, 2006, in preparation

<z>~0.9

- Red/early galaxies more clustered than blue/late galaxies
- bright galaxies cluster more strongly than faint ones
- high mass galaxies cluster more strongly than low mass ones
- Clustering evolution stronger for low luminous galaxies
- Clustering evolution different for high mass/low mass galaxies

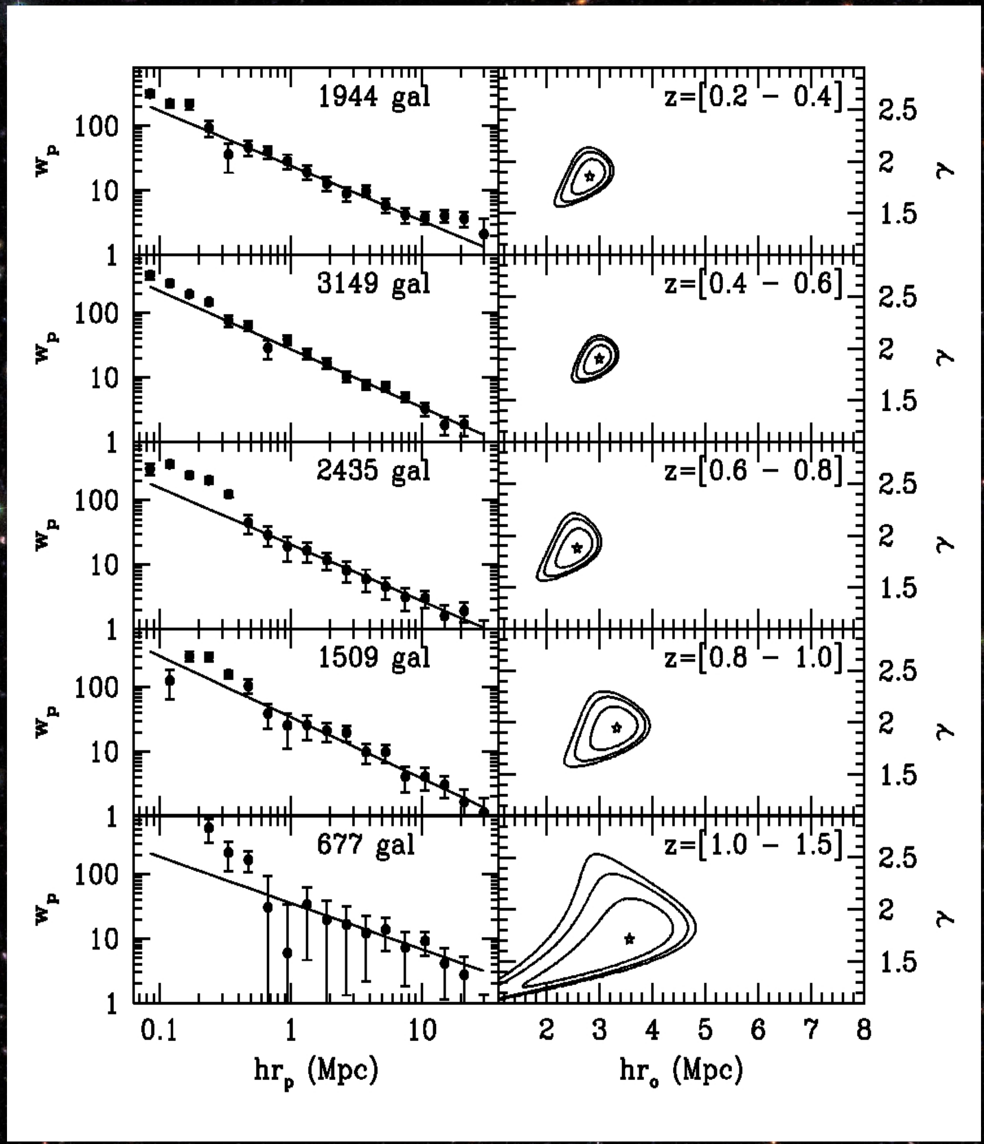
CF in the VVDS-Wide

Preliminary results:

Hint for a change of slope at low scales, starting at z~0.7

NEED further investigation

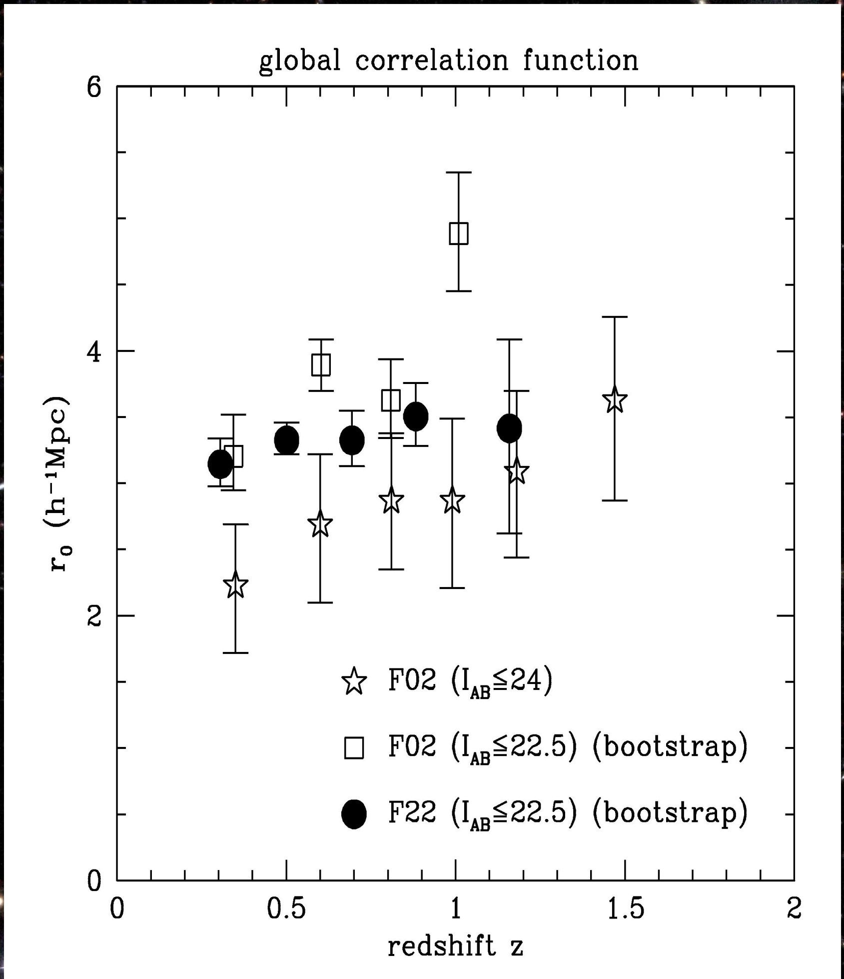
Would make sense in a Halo Occupation Model framework



CF in the VVDS-Wide

- r_0 is flatter with respect to the VVDS-Deep sample, no change in z:
  - lower flux limit, larger volume sampled
  - in the VVDS-Wide, luminous galaxies dominate at all redshifts

- Comparison with VVDS-Deep cut at the same flux limit:
  - similar behaviour
  - cosmic variance?



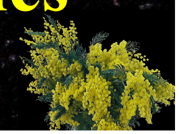
zCosmos 10k sample

	zCosmos	Deep	Wide
Limiting mag	22.5	24	22.5
<z>	0.6	0.9	0.6
sampling	~30%	35%	20%
Area	1	0.7	4
# galaxies	~10000	~10000	~13000
Log(M)>10	~50%	25%	50%

- Better measurement of spectral features
- ACS images (morphology)
- vs. Deep: better statistics on high luminous/high massive galaxies
- vs. Wide: more uniform coverage

Summary

- VVDS-DEEP, DEEP2 accumulating several new measurements on the properties of galaxy clustering at z~1, with increasing statistical precision and minimizing systematic errors due to cosmic variance
  - Red/early galaxies more clustered than blue/late galaxies
  - bright galaxies cluster more strongly than faint ones
  - Clustering evolution stronger for low luminous galaxies
  - high mass galaxies cluster more strongly than low mass ones
  - Clustering evolution different for high mass/low mass galaxies
- VVDS-Wide, zCosmos better tracing of evolution of clustering properties for luminous, massive galaxies



Cosmological scenario

- Hierarchical model
- Biased distribution of galaxies