INAF / IASF Milano

Astro-Siesta:

Correlation function and galaxy surveys

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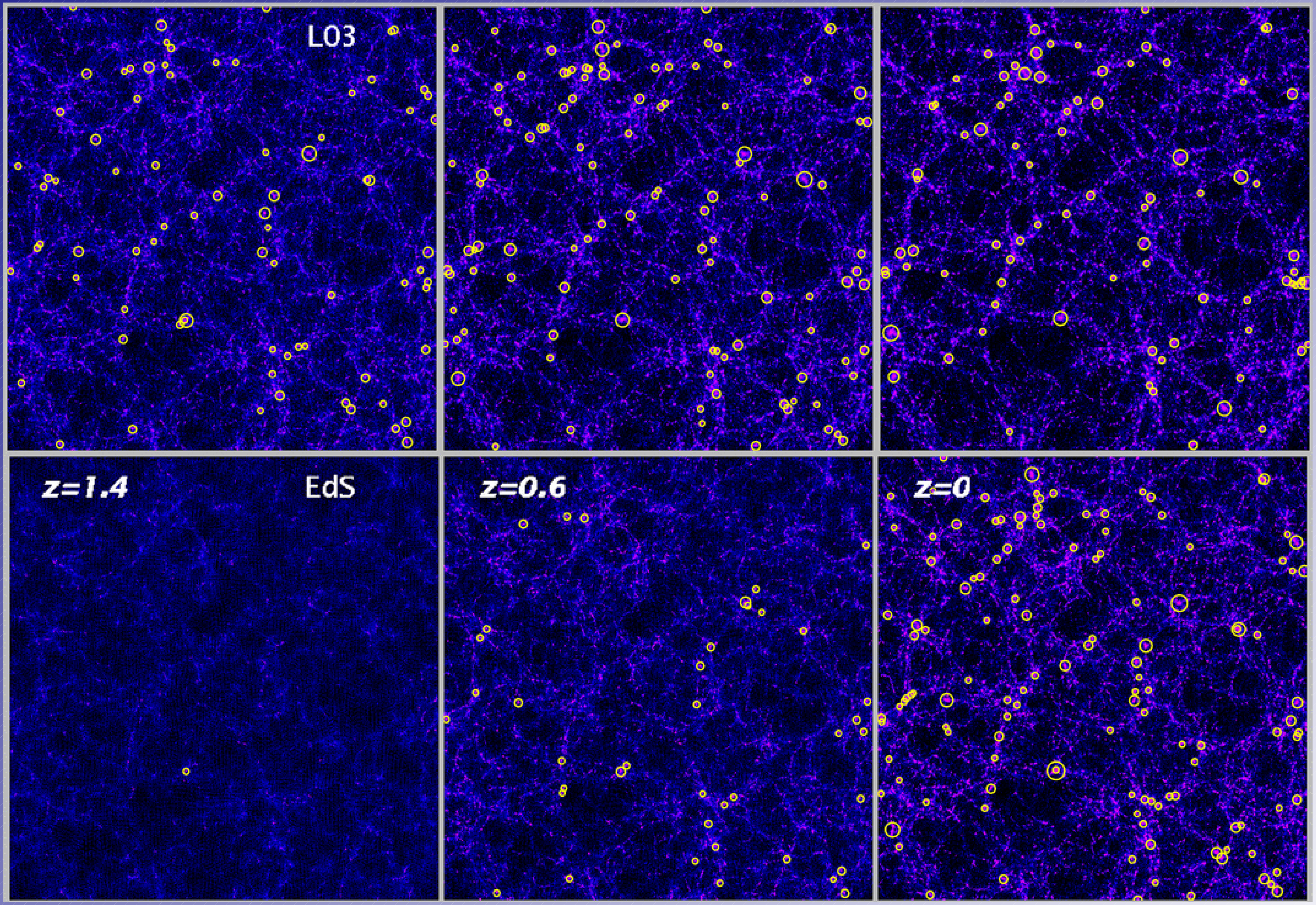
Large scale structure

- Ω_m=0.3
- Ω_Λ=0.7

(concordance cosmology)

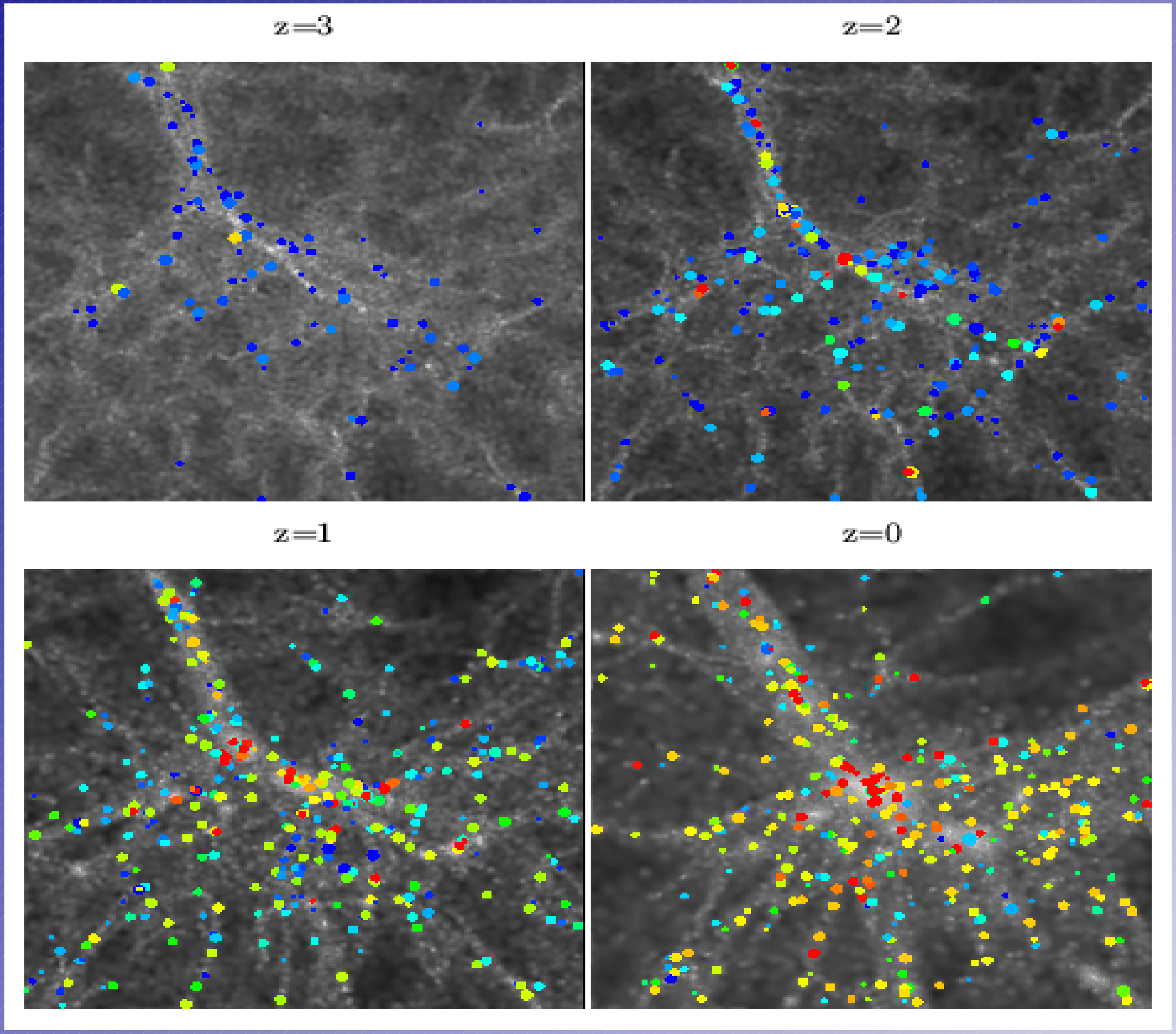


- Ω_m=1
- Ω_Λ=0

(Einstein-de Sitter)

Both are normalized to observed clustering at z = 0

Large scale structure



Large scale structures evolve with z ...

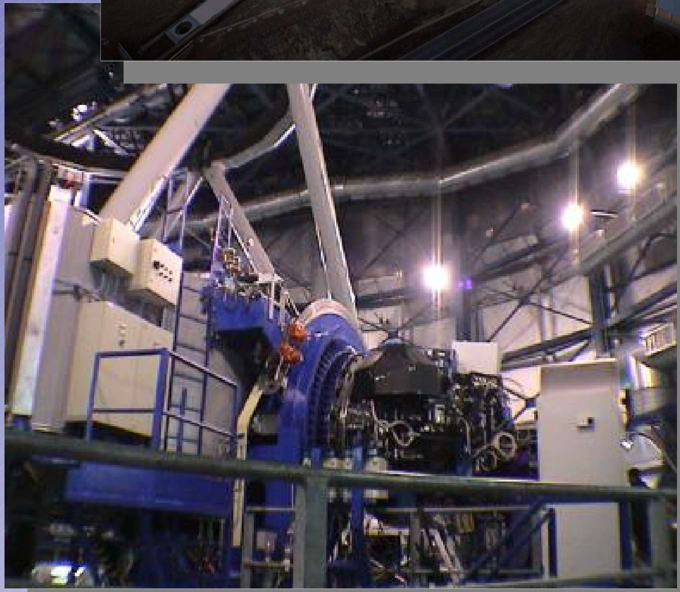
... but galaxies evolve at the same time!

The VVDS Project

- Instruments: VIMOS spectrograph at VLT, Chile (complemented by data from CFHT, Hawai'i)

- Bands: UBVRI+ugriz(CFHTLS),JK(ESO+UKIDSS)

- Magnitude selection in I band:
  - WIDE: *$17.5 \leq I_{AB} \leq 22.5$, ~6.5deg²*
  - DEEP: *$17.5 \leq I_{AB} \leq 24.0$, ~1.2 deg²*
  - ULTRA-DEEP: *$22.5 \leq I_{AB} \leq 24.7$, ~0.19 deg²*

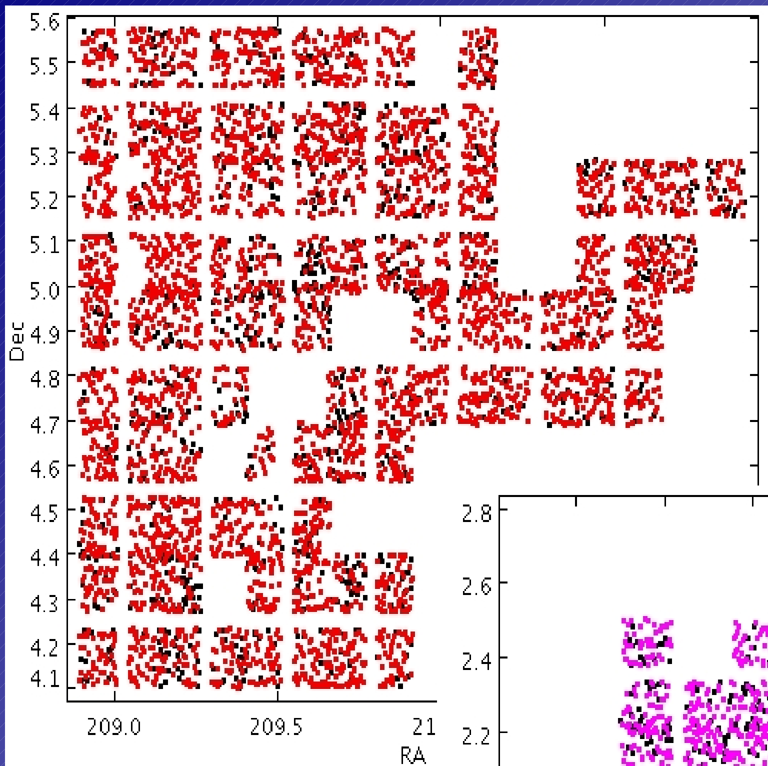


- Large area, 4 separate fields, total ~6.5 deg²:
  - *0226-04 (F02) [VVDS-DEEP]*
  - *1000+03 (F10)*
  - *1400+05 (F14)*
  - *2217+00 (F22)*

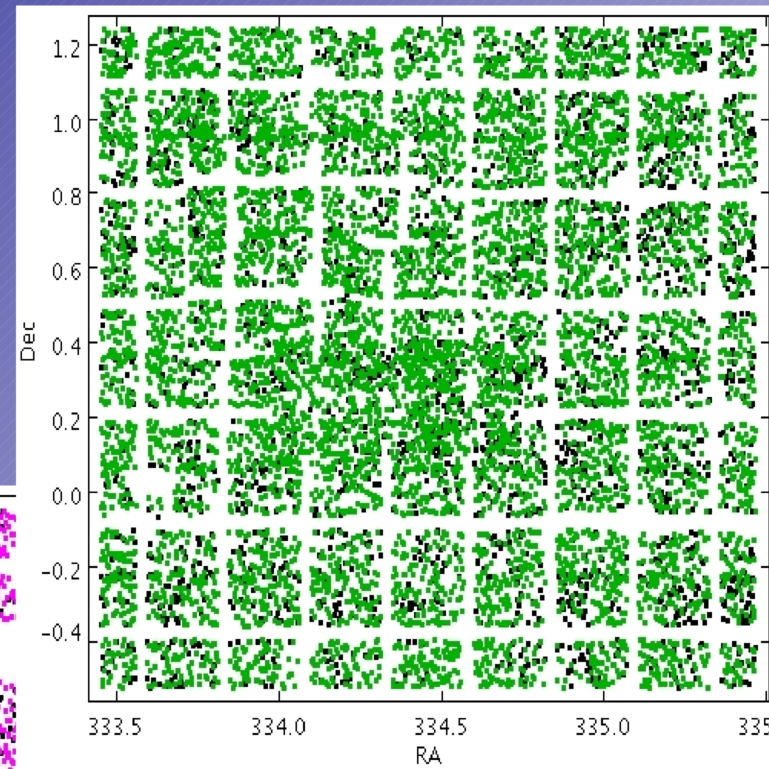
~ 35,000 spectra (26,000 galaxies) today (Garilli et al, 2008)

VVDS

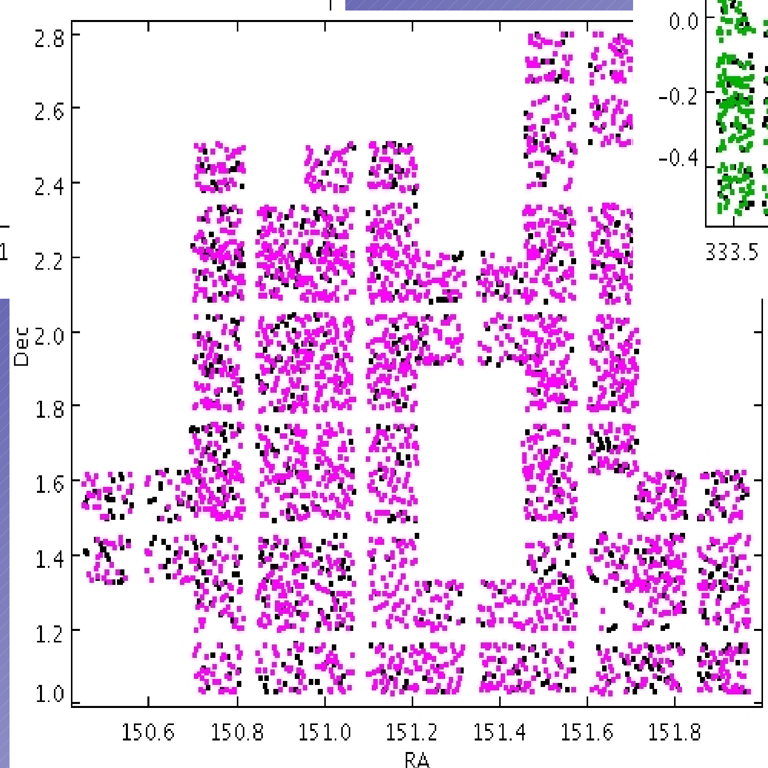
The VVDS data



F14: 4,547 galaxies with secure redshift (confidence >75%)



F22: 8,150 galaxies with secure redshift (confidence >75%)



F10: 3,285 galaxieswith secure redshift (confidence >75%)

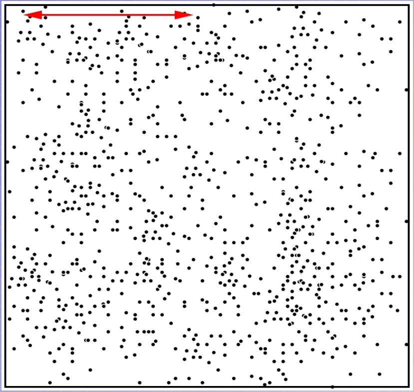
The 2-points correlation functions

Definition: excess probablility (with respect to a random distribution) of finding a pair of galaxies with a given spatial separation *r* (Pebbles, 1980).

For a random distribution: $\delta P = r_0^2\, \delta V_1\, \delta V_2$ **, for a clustered distribution:** $\delta P = r_0^2\, \xi[1+(r_{12})]\, \delta V_1\, \delta V_2$

From previous studies: (in the range 1-30 h^{-1} **Mpc) it is well described by a single power law:**

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

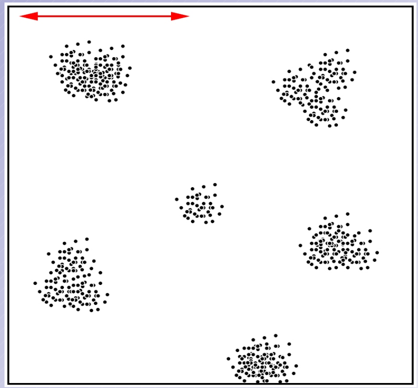


small r_0

2 free parameters:
r_0 ***(correlation length) = indication of the strenght of correlation***
γ ***(slope of the correlation function) = indication of scale dependence***

Correlation lenght:

- ***Greater r0 means galaxies more clustered***
- ***Smaller r0 means galaxies less clustered***

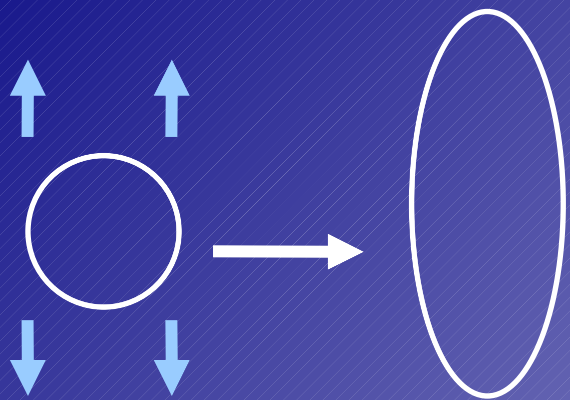


large r_0

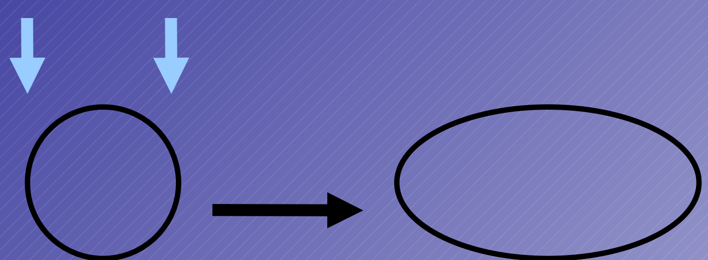
Slope:

- ***Greater γ means more marked difference between clustering at different scales***
- ***Smaller γ means less marked difference between clustering at different scales***

Distorsions in redshift space

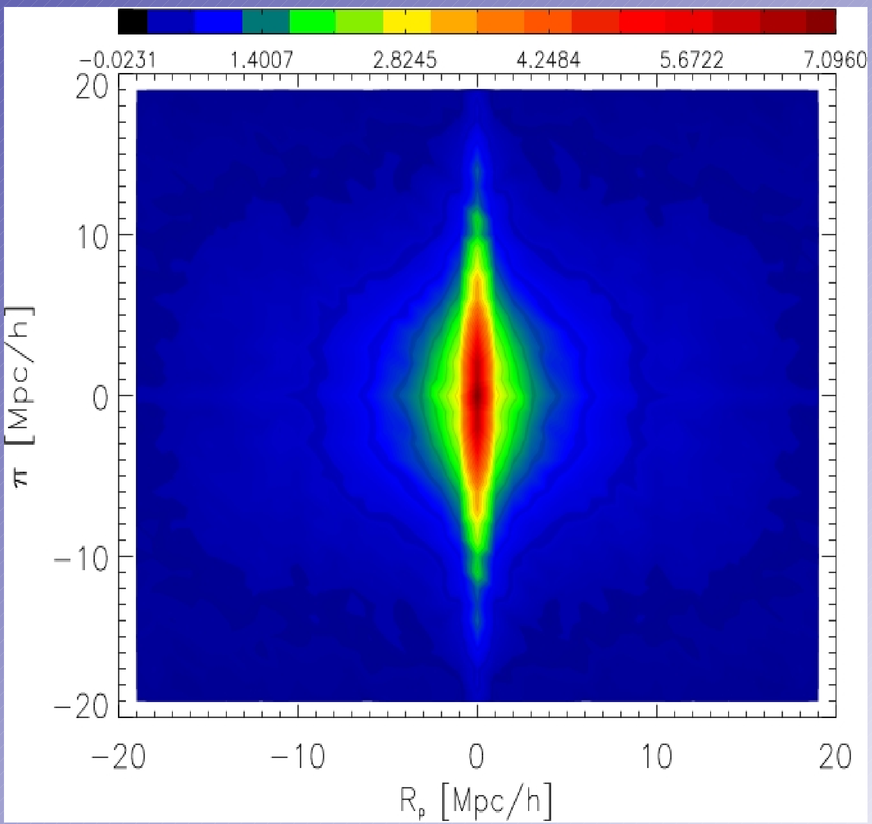


On small scale: elongation along the line of sight *(Finger-of-God effect)* = due to peculiar velocities of galaxies in clusters



On large scale : flattening along the line of sight *(Kaiser effect)* = due to coherent motions of galaxies falling towards clusters

Redshift distortions can be separated from true spatial correlation by computing *ξ(r_p, π)* along and transversally to the line of sight. This way, only one variable (*π*) is affected by redshift distortions.



ξ(r_p, π) **for the mean of 10 mock catalogs (*0.3<z<0.5*) Colour-coded level describe the degree of correlation as a function of *r_p* and *π*. Actual measurements are replicated over 4 quadrants**

Projected correlation function

We can recover real-space correlation function by projecting *ξ(r_p, π)* along the line of sight.

This way we integrate out the line-of-sight effects and we obtain a quantity *wp(r_p)* that is independent of redshift space distortions (Davis & Peebles, 1983).

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

If we now assume the power-law model $\xi(r)=(r/r_0)^{-\gamma}$, the integral can be computed analytically, given as a results:

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

where Γ in Euler's Gamma function.

Simulating the observations

To tackle the problem of the correlation function, we also use simulations.

Why do we need them?

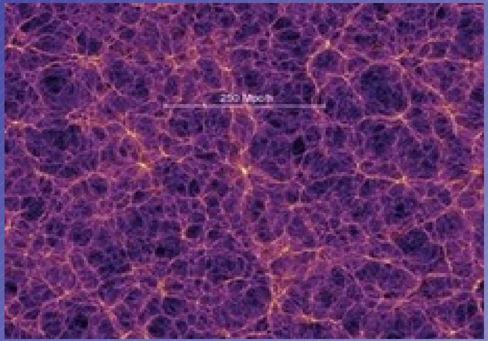
- To provide errorbars for the correlation function on the real data set
- To identify and quantify the effects of the observational strategy

Simulation used: Millennium Run (10^{10} total particles), carried out at Max Plank Society's Supercomputing Center, Garching bei München, Germany. Concordance cosmology was used ($h=1.0$, $\Omega_\Lambda=0.7$, $\Omega_m=0.3$)

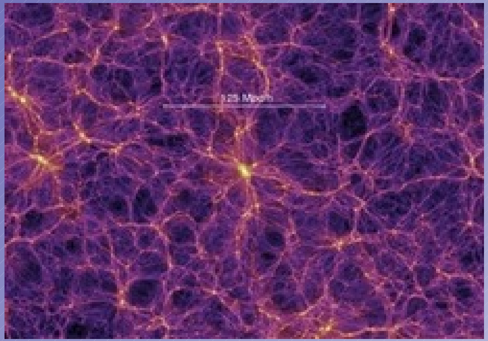
We created a total of 100 mock catalogs. They are built using mathematical algorithms that mimic various effects of the obervational strategy of the VVDS-WIDE.

► Number of galaxies per mock catalog (in the selected ranges of z and I_{AB}): ~105,000

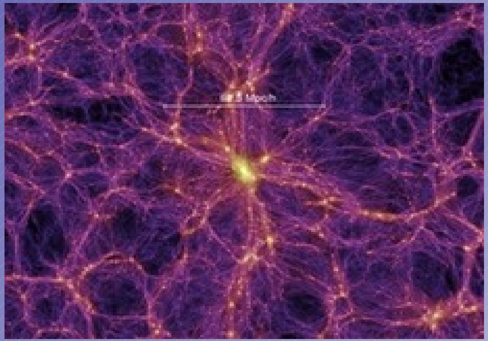
► Number of galaxies per observed mock catalog (with secure redshift): ~12,000



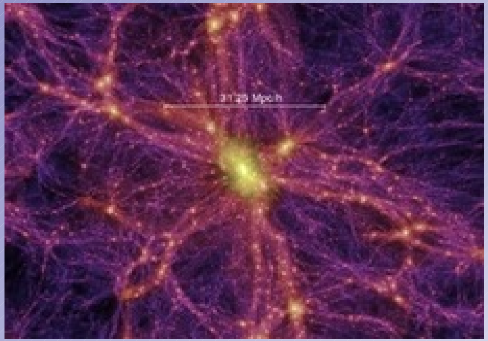
250 Mpc/h



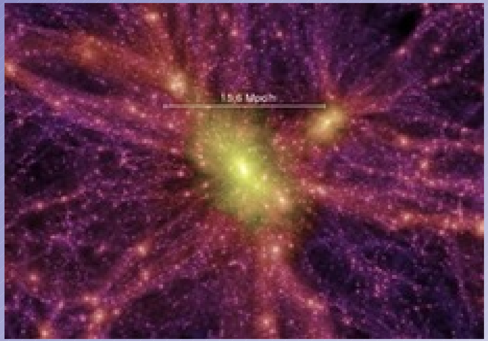
125 Mpc/h



62.5 Mpc/h



31.25 Mpc/h



15.6 Mpc/h

3.9 Mpc/h

Identification of observational biases

A number of factors, both in the parent phot. catalog and in the way spectroscopic observations are carried out contribute to create biases that effect the estimate of galaxy clustering.

We identificated 5 biases and their effects:

- ***Photometric mask***

  it take into consideration holes in the photometric catalog, due to defects of the photometric observation as saturate area and stray light – NEGLIGIBLE

- ***Stellar contribution***

  simulated catalogs lack stars. We add a proportion of stars that depends on magnitude and galactic latitude of the field – NEGLIGIBLE

- ***Redshift uncertaintly***

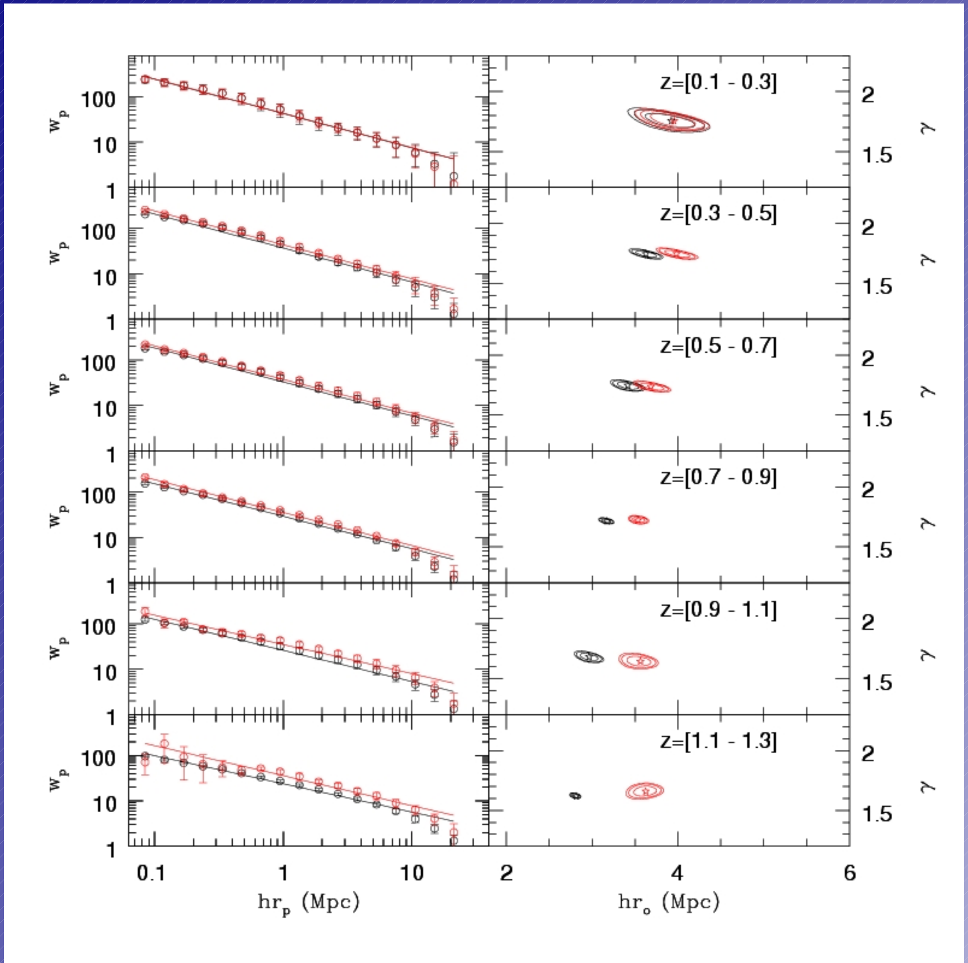
  it takes into consideration errors in *z* measurements, that depend on spectral resolution of the istrument – NEGLIGIBLE

- ***Magnitude selection*** *(see hereinafter)*

- ***Target selection*** *(see hereinafter)*

Identification of observational biases

Magnitude selection



$w_p(r_p)$ [mock catalogs] in 6 z-bins
Complete: black - mag selected: red

Comparison between

- $w_p(r_p)$ complete spectroscopic catalogs
- $w_p(r_p)$ catalogs selected at I_{AB}<22.5

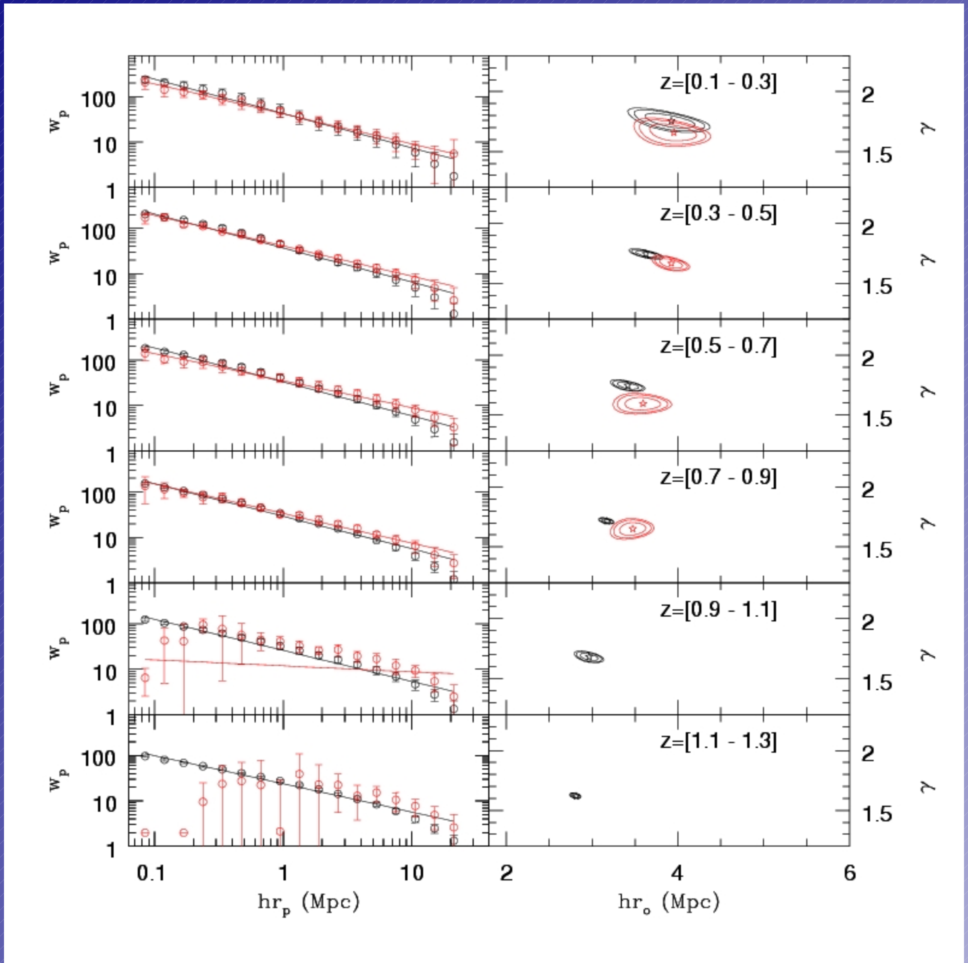
Effects:

- ***r_0(cut) > r_0(true)***
- ***|r_0(cut) – r_0(true)| increase*** **with z**
- ***lower the cut, greater the difference***

This effect is expected: the magnitude cut expunge less luminous galaxies at higher z, leaving more and more luminous galaxies in the catalog.
More luminous galaxies are known to be more clustered (also in local universe, i.e. SDSS)

Identification of observational biases

Target selection



$w_p(r_p)$ **[mock catalogs] in 6 z-bins**
Complete: black - target selected: red

Due to pointing geometry (quadrants) and specific inhomogeneities introduced by the slit positioning code and mask preparation software (Bottini et al., 2005).

Comparison between

- **$w_p(r_p)$ complete spectroscopic catalogs**
- **$w_p(r_p)$ target selected catalogs**

Effects:

▶ ***complicated***

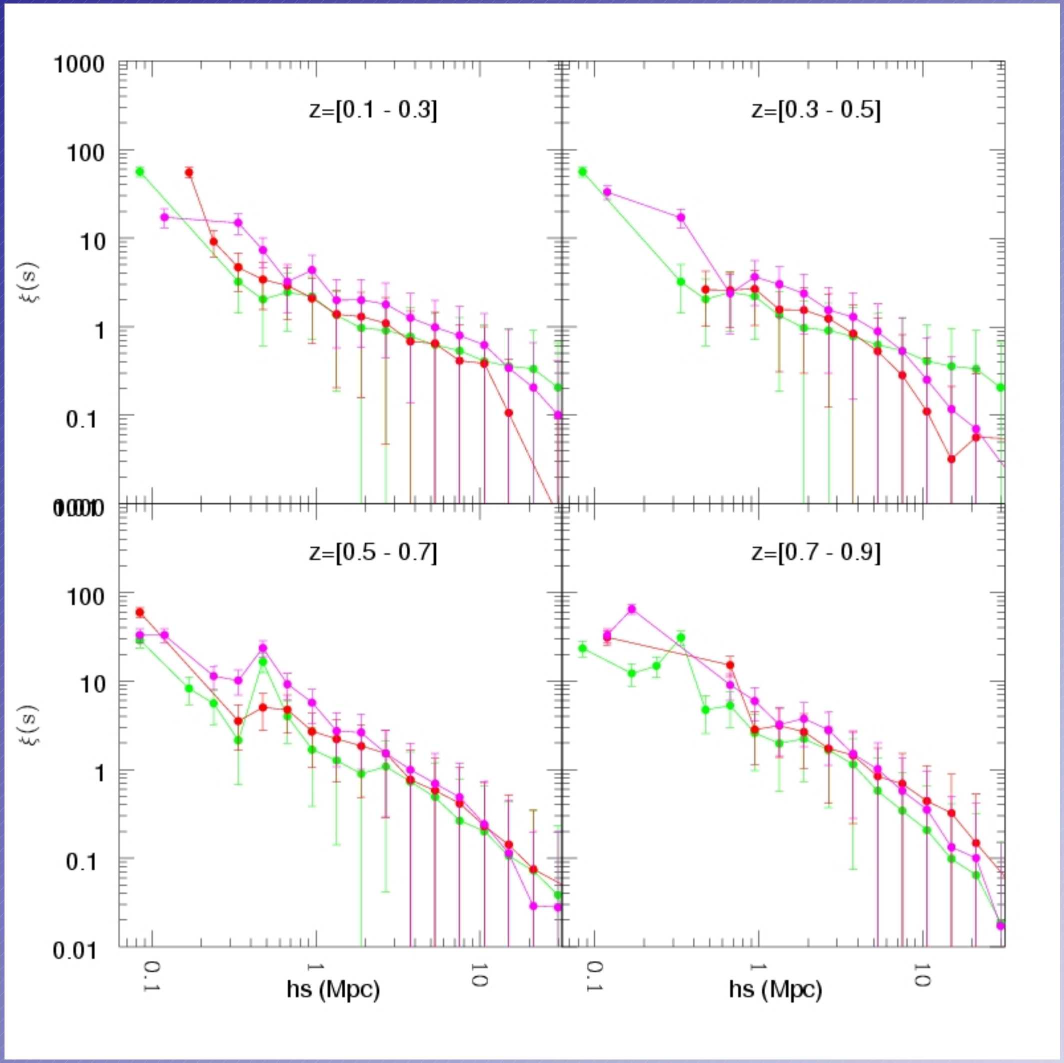
▶ ***no correlation function above z=1***

Local scale effect below 1-2 Mpc.

Slit positioning introduce a bias against close angular pairs and hinder successful recovery of correlation function for z>1.

Correlation function (F22-F14-F10)

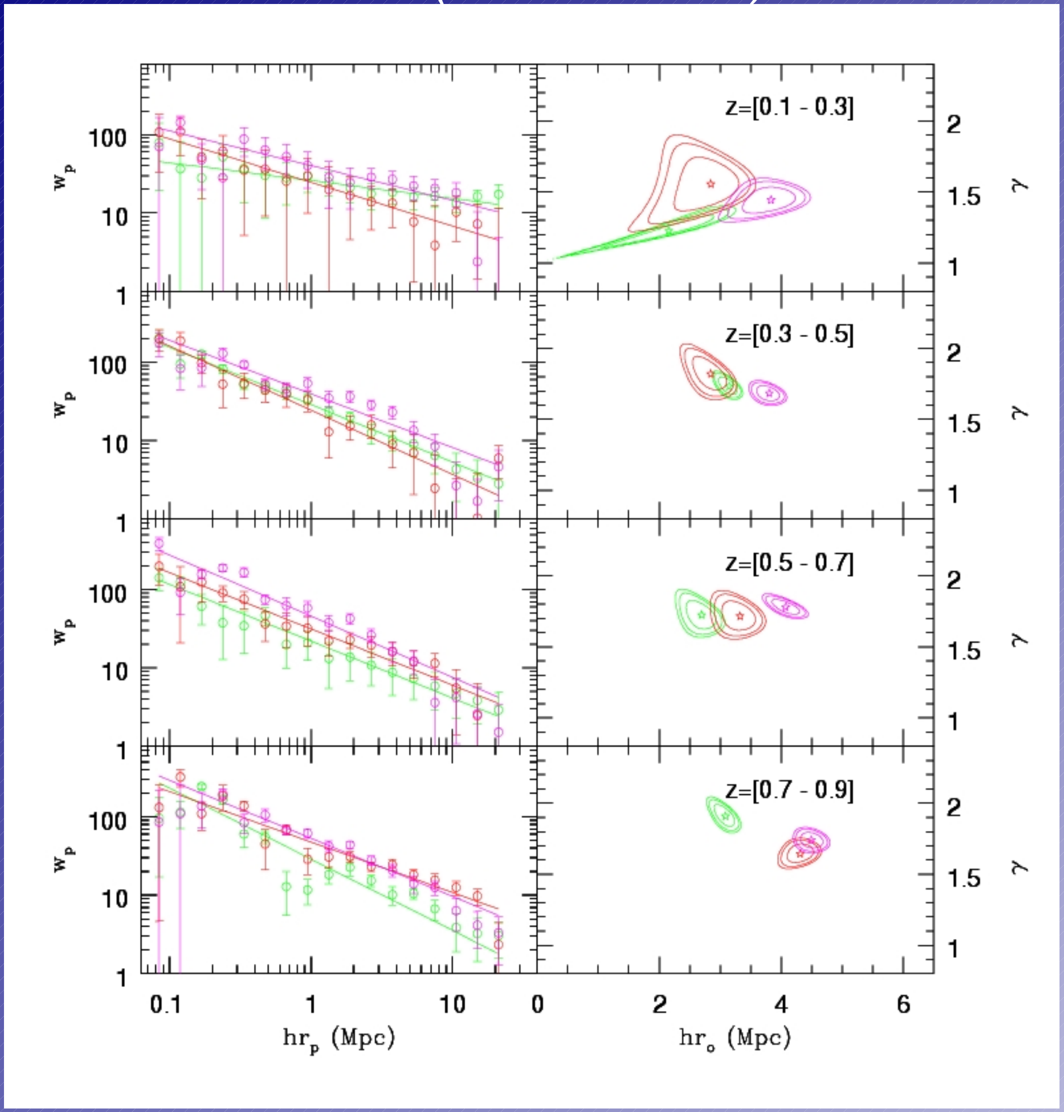
Secure redshift (confidence >75%)



ξ*(s)* for real data in 4 z-bins
F22: green – F14: red – F10: magenta

Projected corr. function (F22-F14-F10)

Secure redshift (confidence >75%)



***$W_p(r_p)$* for real data in 4 z-bins with best fit parameters**
F22: green – F14: red – F10: magenta

F22

<z>	*r_0*	*gamma*	*chi^2*
0.2	2.155	1.228	2.801
0.4	3.145	1.732	9.935
0.6	2.695	1.724	5.597
0.8	3.085	1.908	92.764

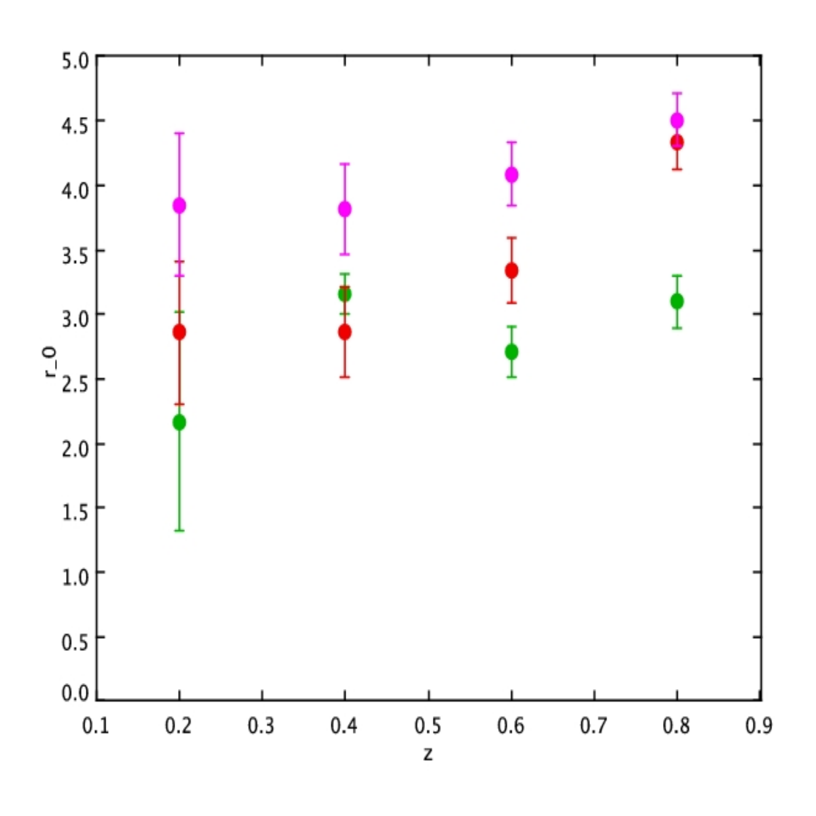
F14

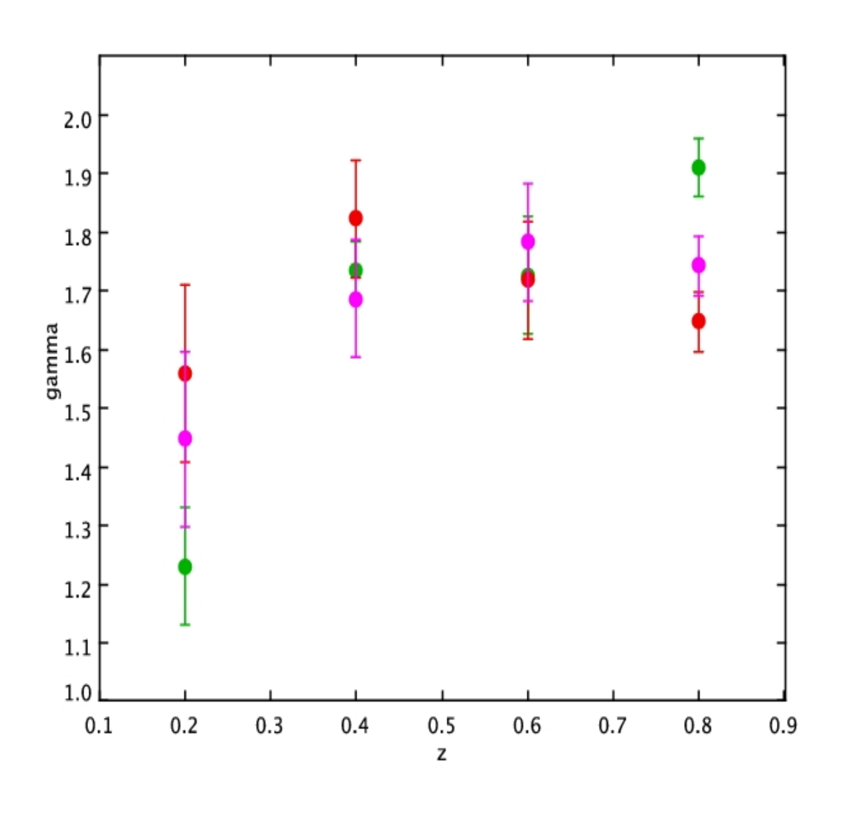
<z>	*r_0*	*gamma*	*chi^2*
0.2	2.845	1.556	1.738
0.4	2.845	1.820	8.617
0.6	3.325	1.716	11.776
0.8	4.315	1.644	23.993

F10

<z>	*r_0*	*gamma*	*chi^2*
0.2	3.835	1.444	13.470
0.4	3.805	1.684	37.166
0.6	4.075	1.780	41.721
0.8	4.495	1.740	21.230

CF Parameters (F22-F14-F10)





Findings

► ***Clustering evolution:*** **no clear evolution**

hints of r_0 increase with z
step in γ between z=0.2 and z=0.4

► ***Cosmic variance:*** **different correlation lenght in different fields (effect > *3σ*)**

question: effects of cosmological parameters?

Thank you…

Pierdomenico Memeo