Combining CMASS redshift-space distortions and weak lensing to probe gravity

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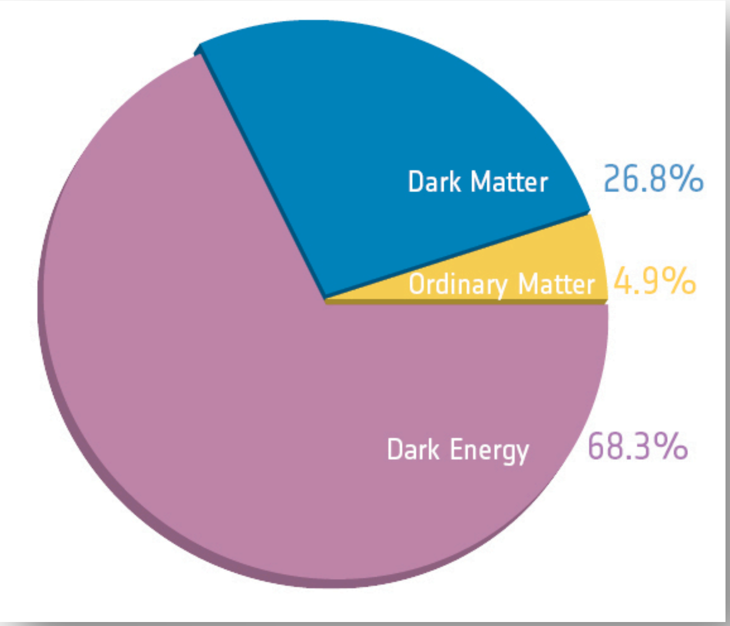
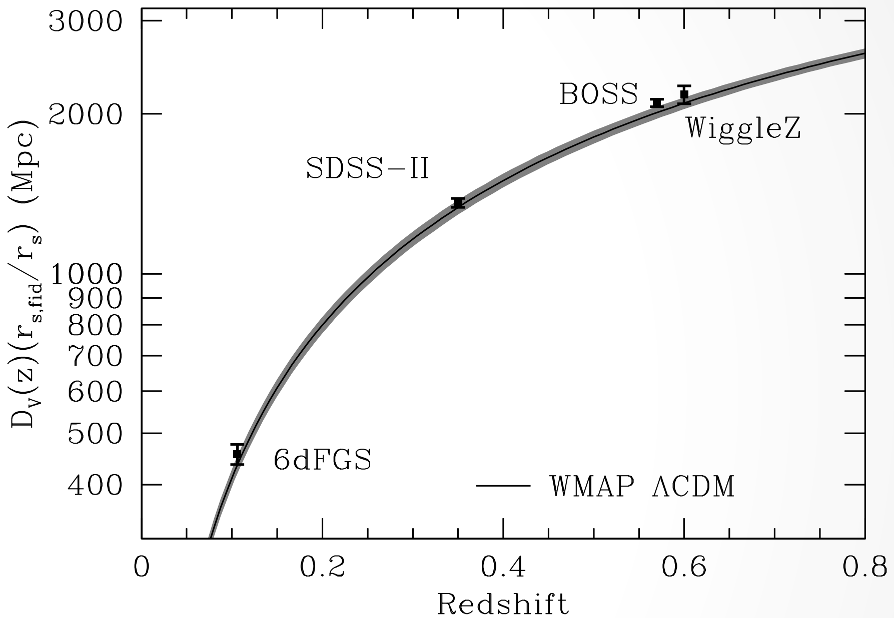
The cosmological model



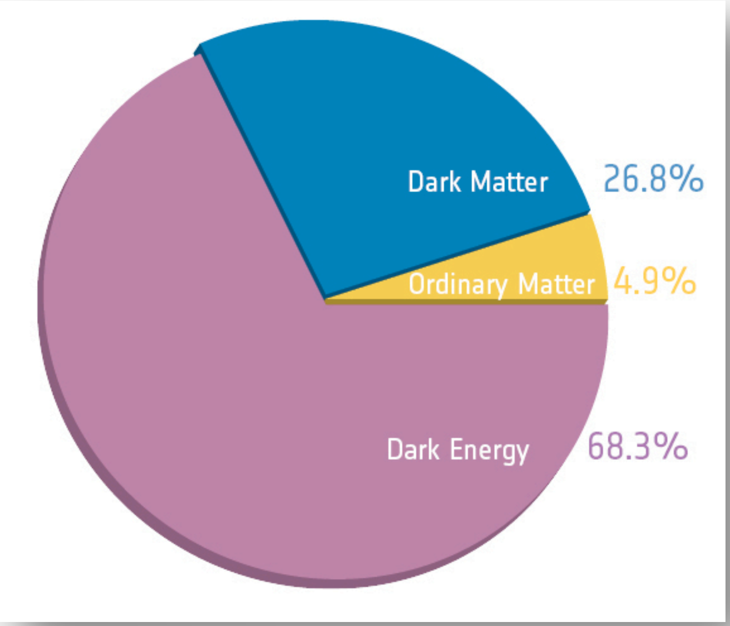
(Planck Collaboration 2013)



(BOSS Collaboration 2012)

- Minimal ΛCDM preferred model (with General Relativity)
- The Universe is dominated by Dark Energy which causes the acceleration of the expansion

The cosmological model



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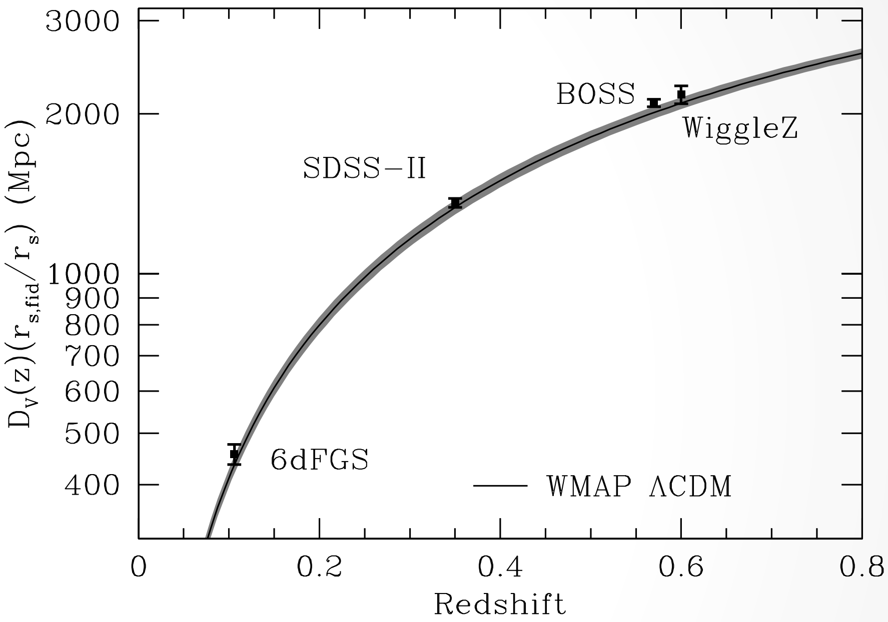


(BOSS Collaboration 2012)

- We know H(z) at <10% level but .... models are degenerate!

What is the origin of the acceleration of the expansion of the Universe: DE or modified gravity?

Why RSD is important?

We need to look at both sides of the story…

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\frac{8\pi G}{c^2} T_{\mu\nu} + \Lambda g_{\mu\nu}$$

?

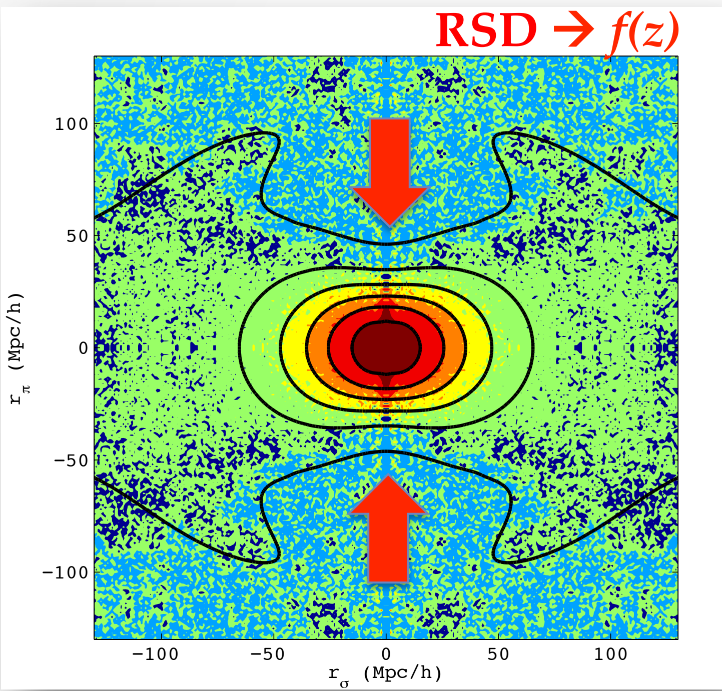
…or modify gravity theory?

Add dark energy

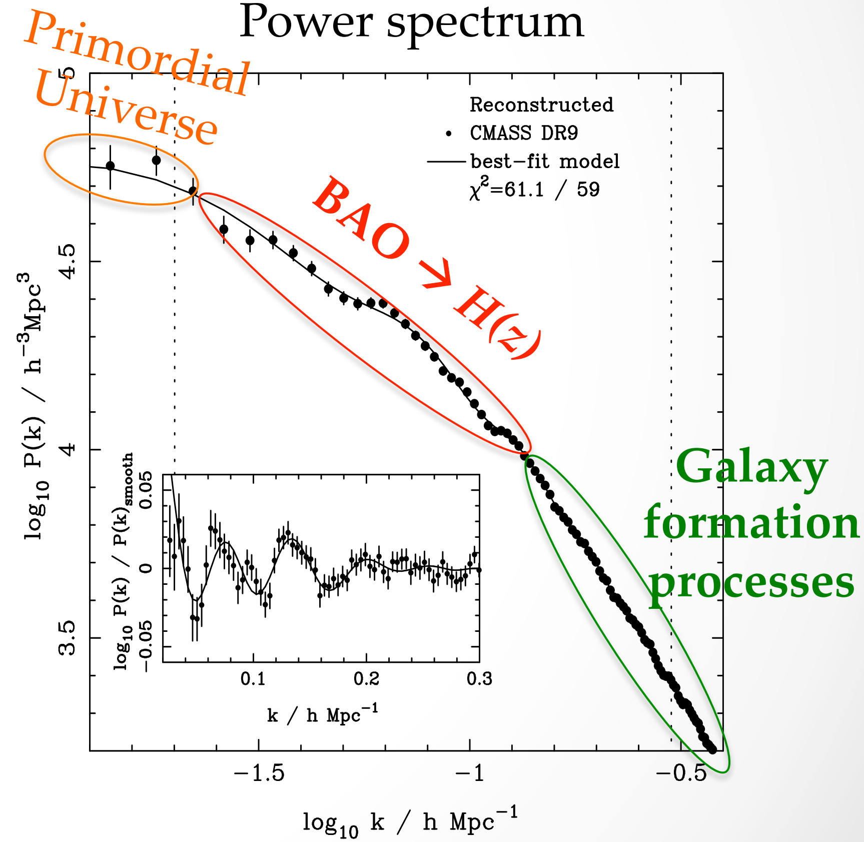
To distinguish these two radically different options
➔ **Probe the dynamics of structure**

Cosmology from galaxy spatial distribution

Anisotropic correlation function

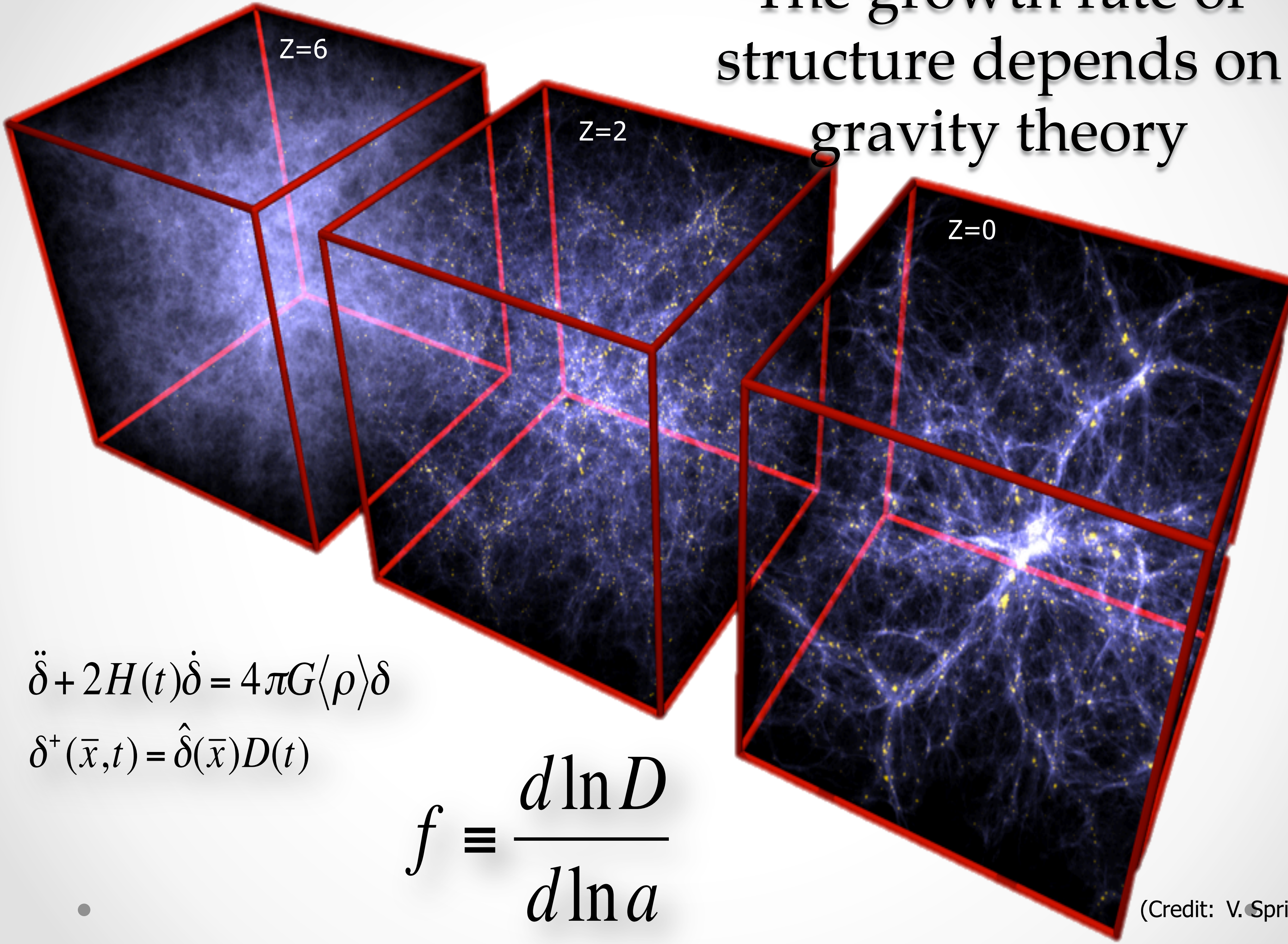


Power spectrum



(Anderson et al. 2012, Reid et al. 2012)

The growth rate of structure depends on gravity theory



(Credit: V. Springel)

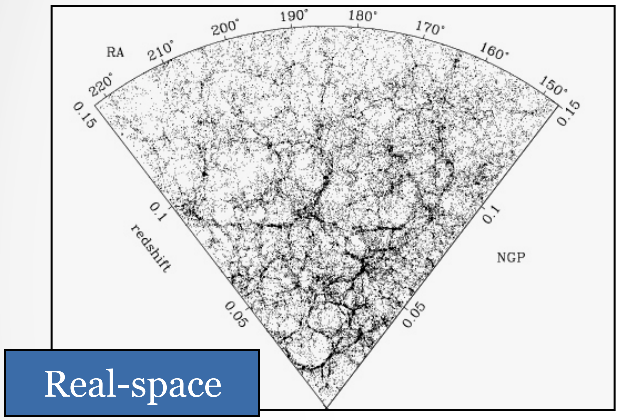
$$\ddot{\delta} + 2H(t)\dot{\delta} = 4\pi G\langle\rho\rangle\delta$$

$$\delta^{+}(\bar{x},t) = \hat{\delta}(\bar{x})D(t)$$

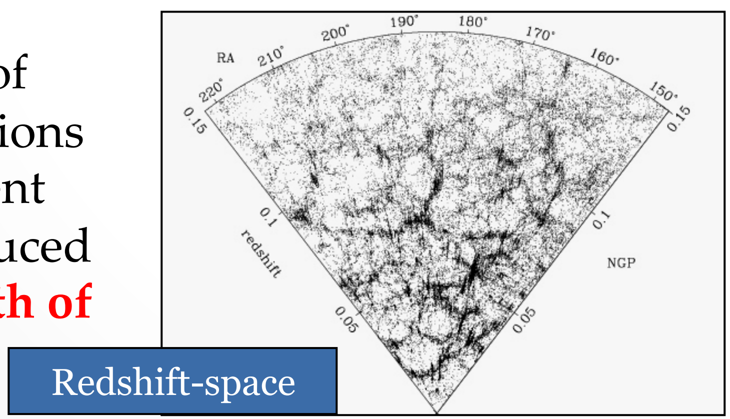
$$f \equiv \frac{d\ln D}{d\ln a}$$

Redshift-space distortions

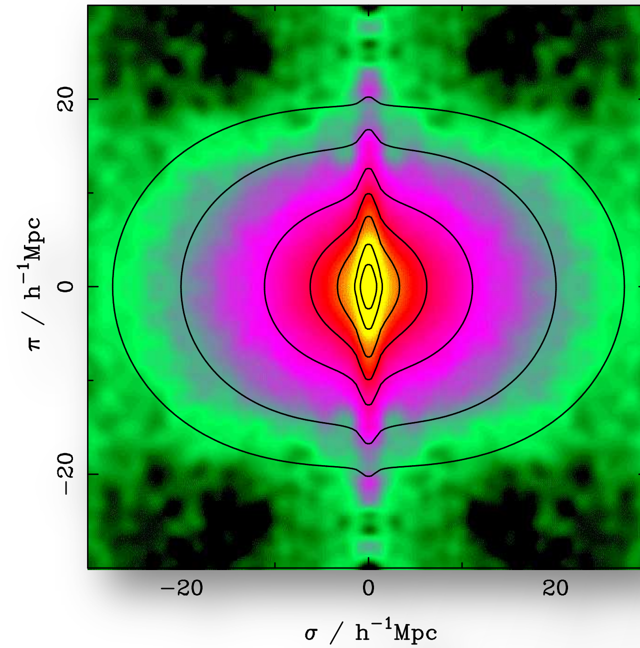
- Galaxy spatial distribution from z-surveys is distorted due to galaxy peculiar motions



The linear component of these distortions maps coherent motions induced by the **growth of structure**



(Peacock et al. 2001)



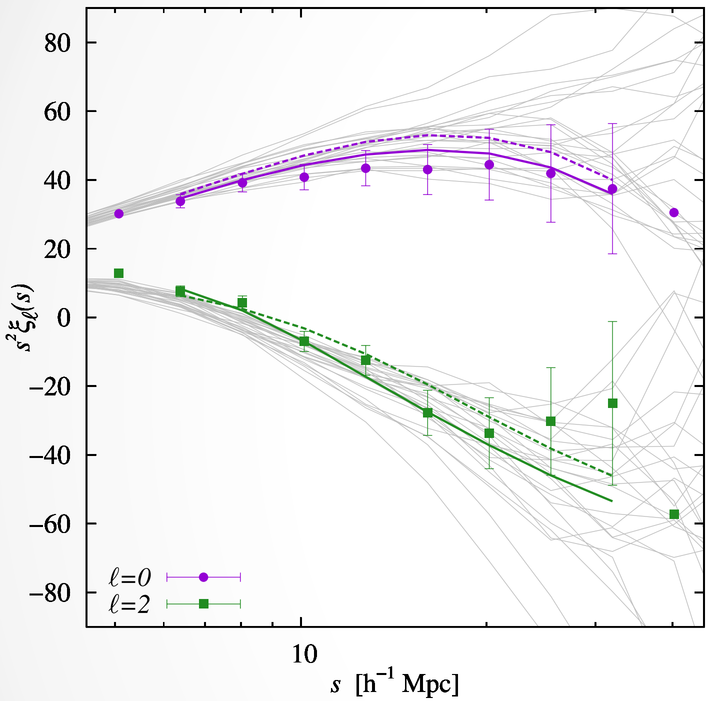
Elongation on small scales:

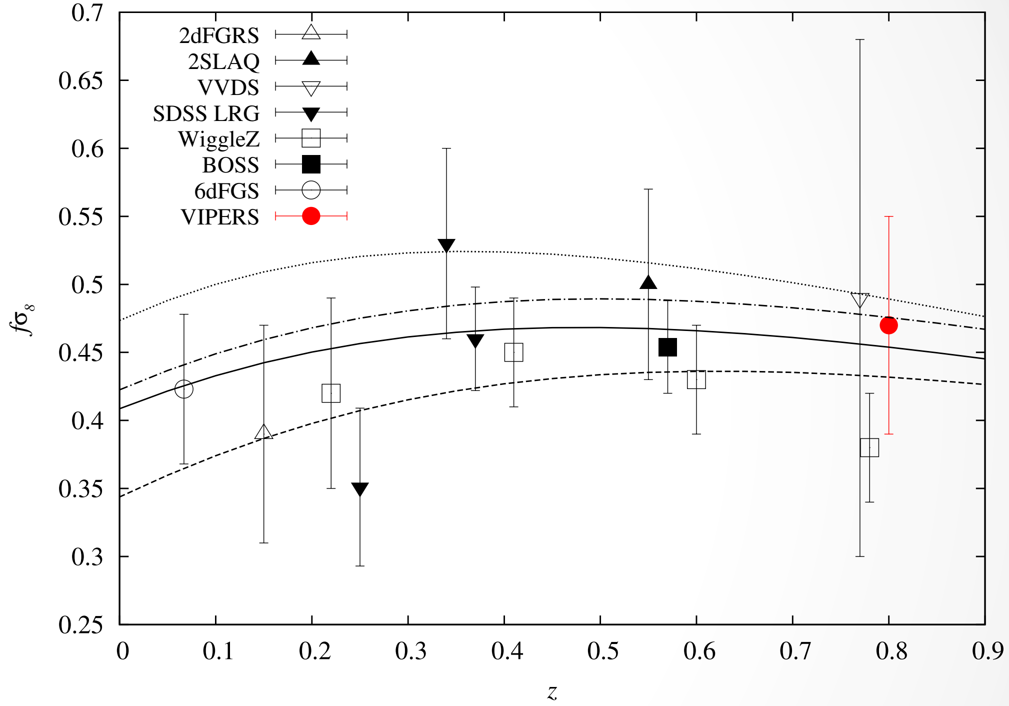
Finger-of-God effect

Squashing on large scales:

« Kaiser » effect

RSD from VIPERS survey

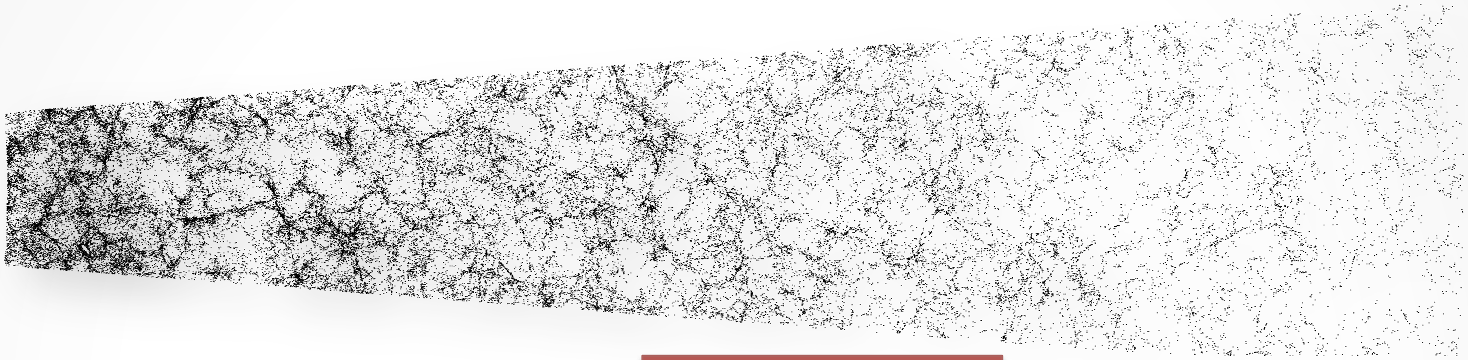




- First measurement of **f_{σ_8} at z=0.8**
- 15% accuracy on f_{σ_8} with the first epoch data of VIPERS
- Measurements in agreement with ΛCDM and Einstein gravity (GR)

(de la Torre et al., 2013)

Simulating surveys



Mock survey

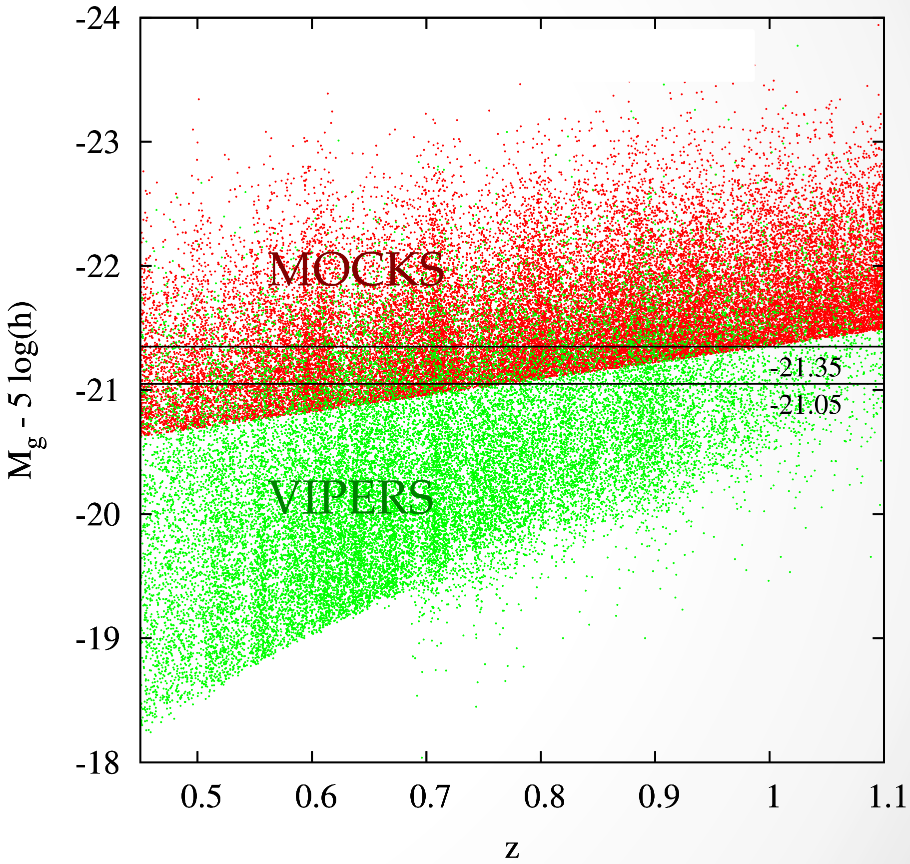
- Mock samples are crucial to test estimators and have realistic error estimates, in particular for cosmological analysis

- VIPERS probes a large volume and a wide range of luminosities/stellar masses: difficult to find N-body DM simulations large enough with sufficient mass resolution to build realisations of the survey

Mass resolution issue

- Galaxy mock resolution limited by DM simulation (halo) mass resolution
- Minimum halo mass too high to include faintest galaxies

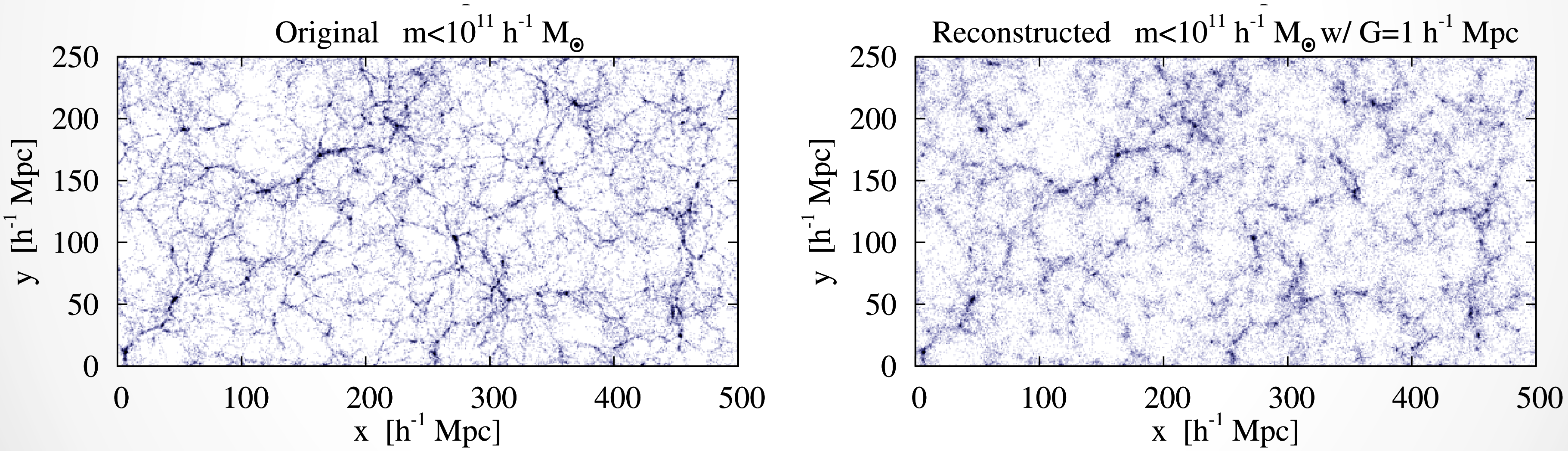
How to solve this issue?



Beat resolution limit in simulations

- Novel method based on reconstructing the density field from original haloes and sample it using constraints from the conditional halo mass function:

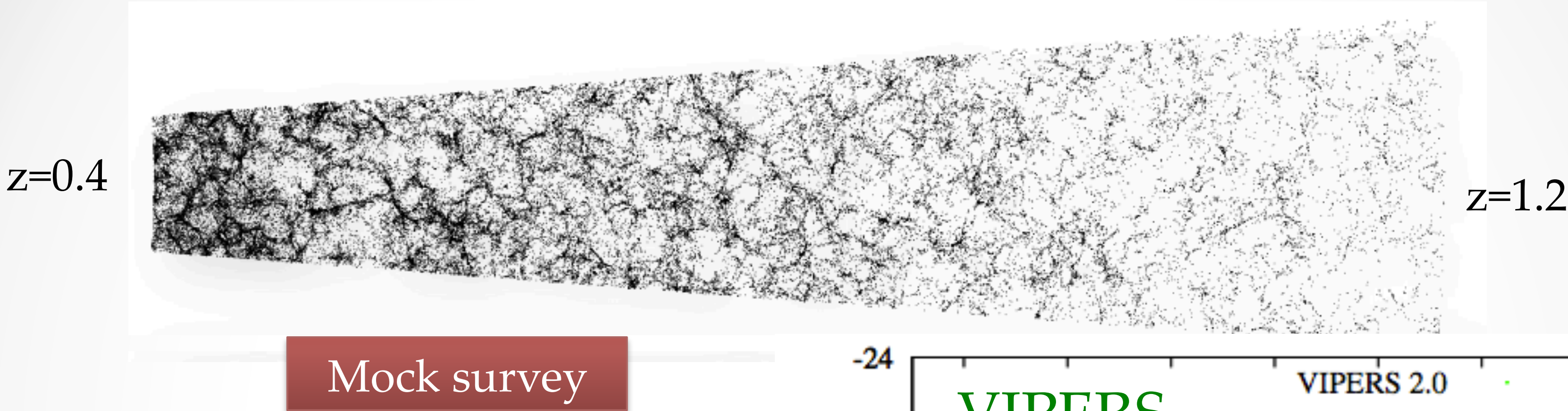
$$n(m|\delta_h) \propto n(m)(1+\delta_h)^{b(m)/b_0}$$

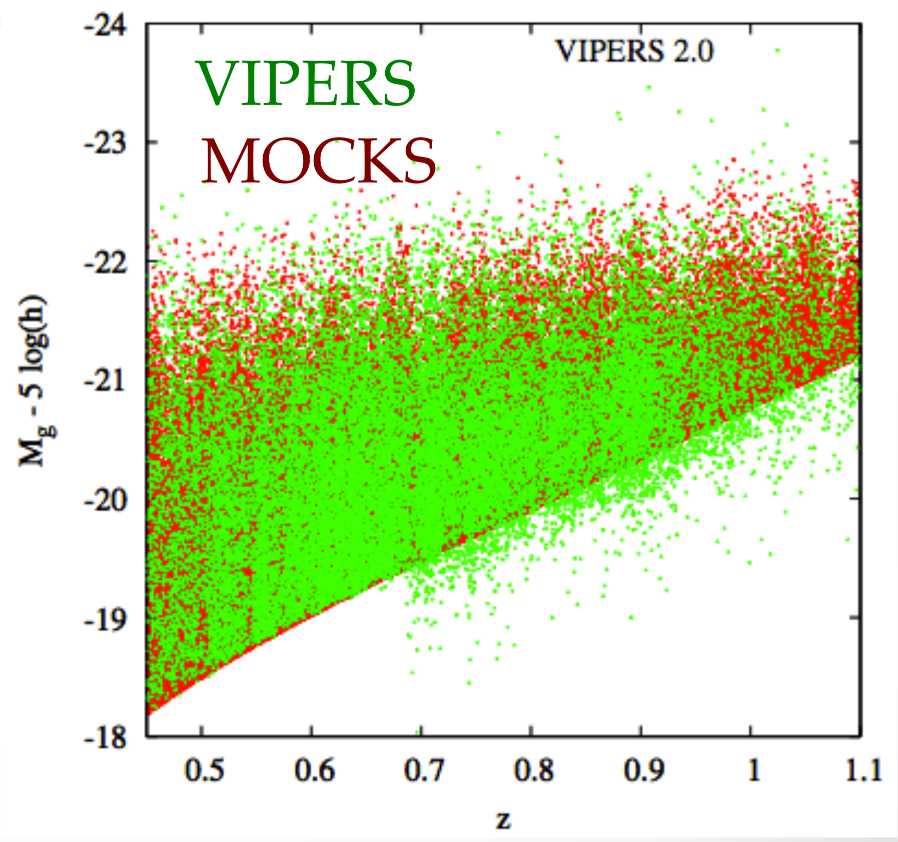


- This allows to reconstruct simulated haloes and galaxies as faint observed in VIPERS volumes

(de la Torre & Peacock, 2013)

VIPERS galaxy lightcones





- Simulation (halo) mass resolution is extended and now allows building realistic VIPERS mocks down to i<22.5

On-going project

- Combine VIPERS/BOSS 3D clustering and lensing measurements in CFHTLS/STRIPE82 fields and use estimator such as (*Zhang 2007*):

$$E_G \equiv \frac{\nabla^2(\psi-\phi)}{3H_0^2 a^{-1}\beta\delta} = \frac{1}{\beta}\frac{\Upsilon_{gm}}{\Upsilon_{gg}} \propto \frac{b}{f}\frac{\Omega_{M_0}}{b} \approx \frac{\Omega_{M_0}}{f}$$

in order to measure RSD with higher accuracy and break bias degeneracy and related uncertainties with lensing

- On the observational side, Reyes et al define E_G as

$$E_G(R) = \frac{1}{\beta}\frac{\Upsilon_{gm}(R)}{\Upsilon_{gg}(R)}$$

where Υ_{gm} depends on gg-lensing and Υ_{gg} depends on projected w

- We propose to perform a combined fit RSD + Lensing to account for the degeneracies between β, Υ_{gg}, galaxy bias and Ω_m

BOSS/CFHTLS/STRIPE82 overlap

CMASS Z>0.43 | LOWZ Z<0.43

Surface (deg)^2	Galaxies	Galaxies weighted	Random	Random weighted	Galaxies	Galaxies weighted	Random	Random weighted
W1 63.8	4067	870.6	218183	43230.4	2352	300.6	133731	16357.3
W3 44.2	3142	620.2	146970	28779.4	1596	218.0	77258	10307.6
W4 23.3	1760	394.1	91498	18135.7	957	120.9	55676	6811.5
stripe82 10	14288	2878.8	678653	134593.6	8610	1086.6	410079	50081.9

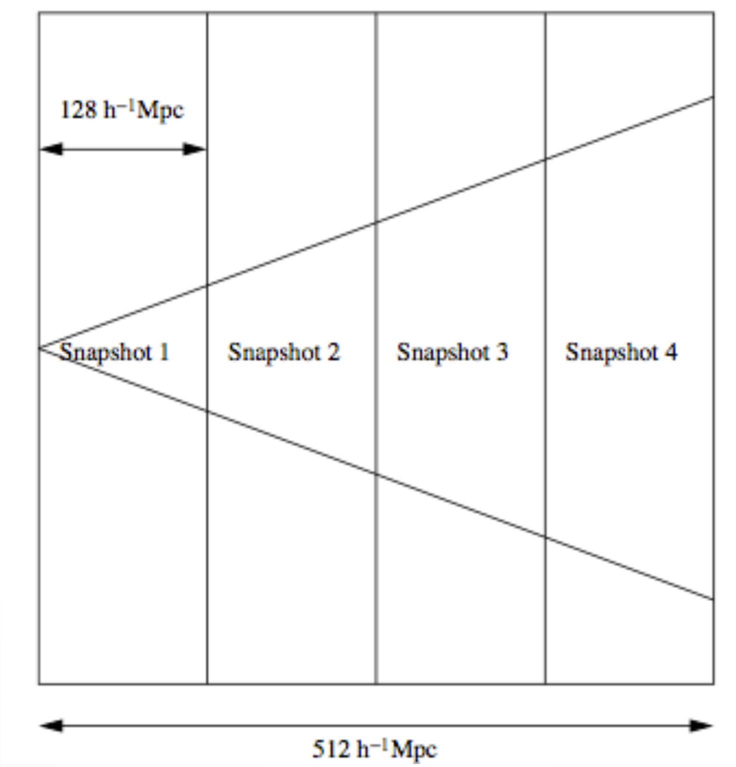
For VIPERS/CFHTLS → 100% overlap → ~100000 spec-z galaxies

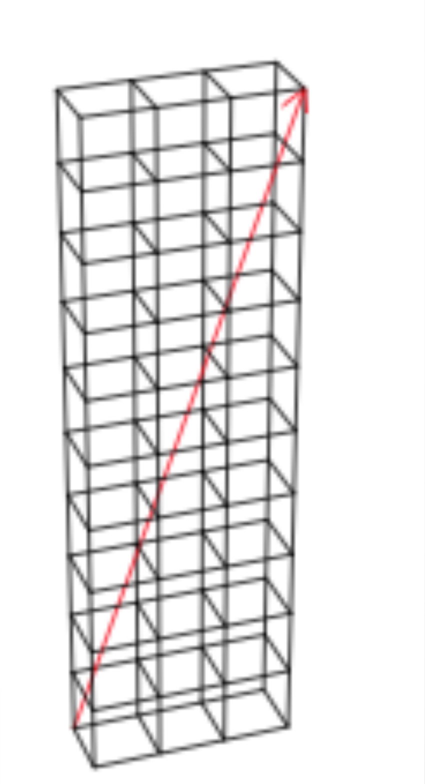
Big Multidark

- Sim. DM-only with Planck cosmology ($\Omega_m = 0.31$)
- 2.5 Gpc/h periodic box and 3840^3 particles
- 80 snapshots from z = 10 to z = 0 (69 below z = 1)
- Mass range of halos 4.7×10^{11} to 6×10^{15} Msun/h
- Force resolution 10 kpc/h (lowz) and 30 kpc/h (highz)
- Halo catalogs extracted with BDM

Lensing simulation tools

- GLAMER (Metcalf et al. 2013, Petkova et al. 2013)
  - Based on density maps
  - Flat sky

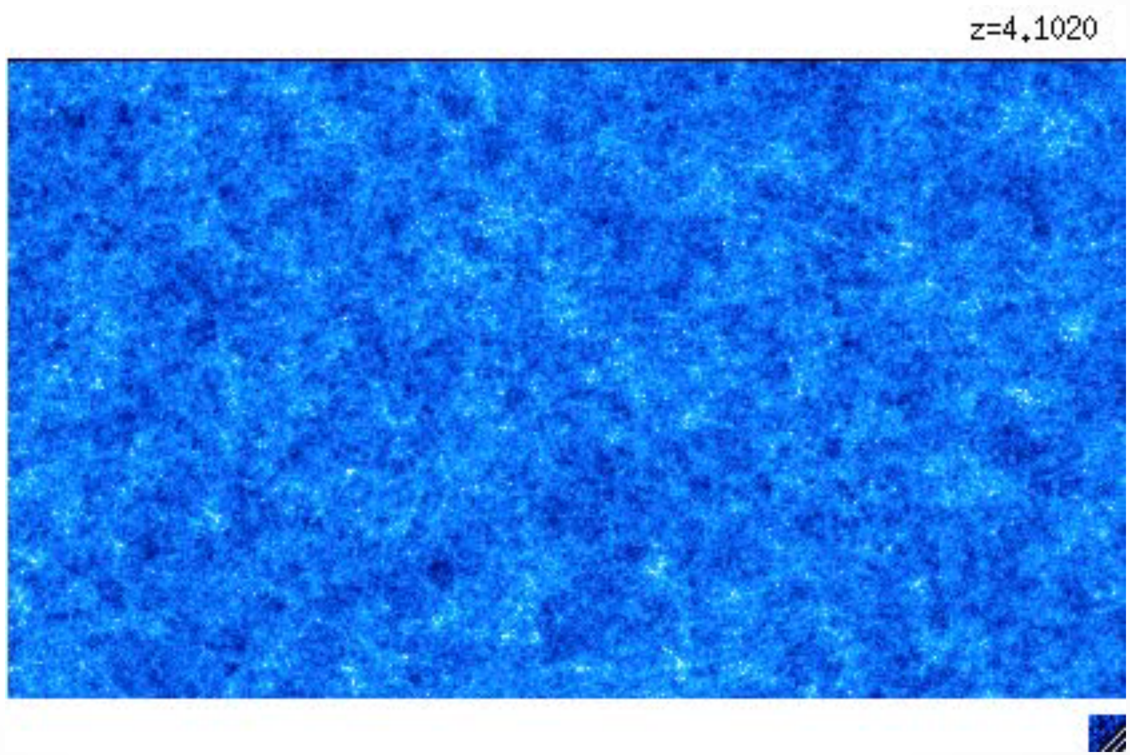




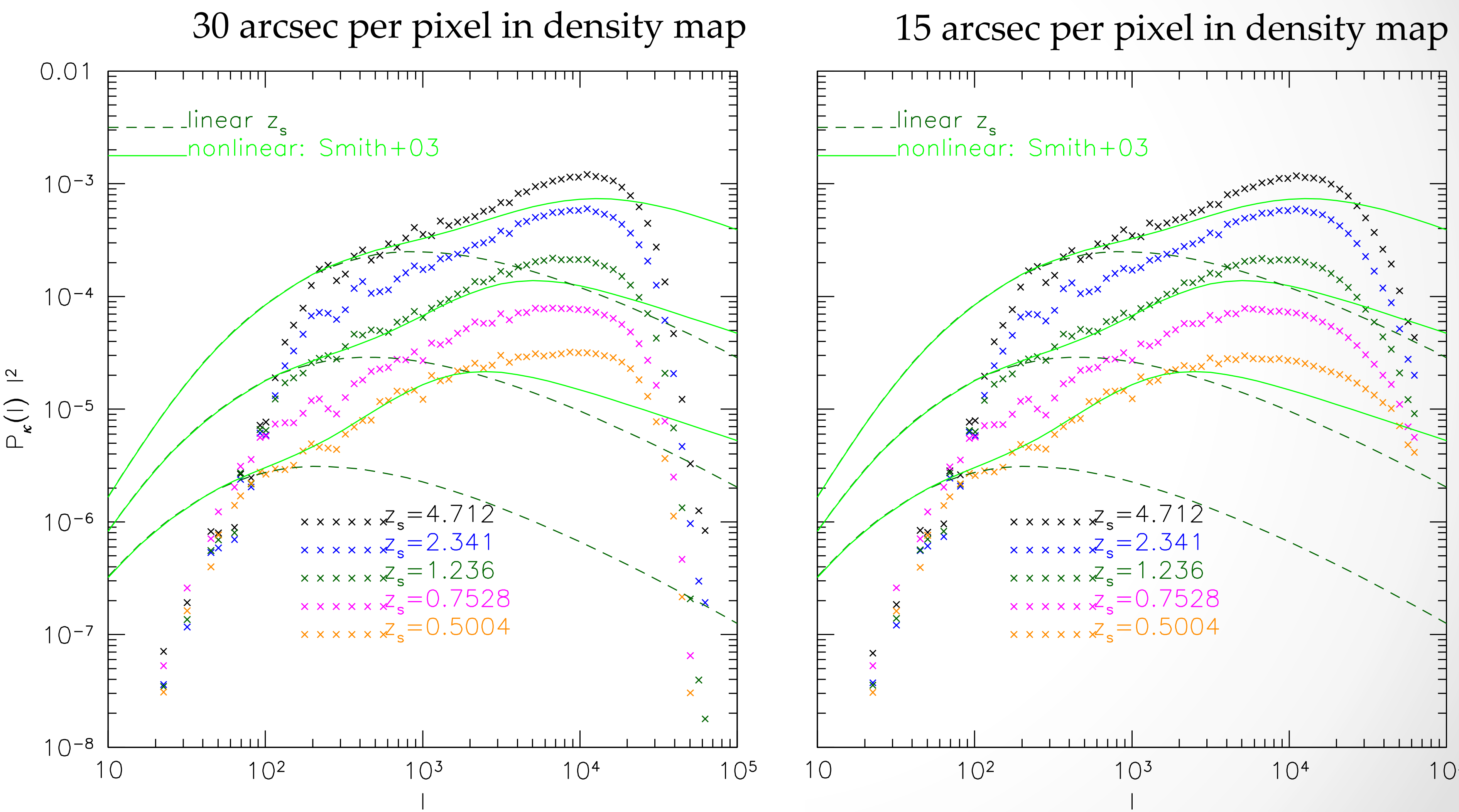
VIPERS-like density planes

7 degrees

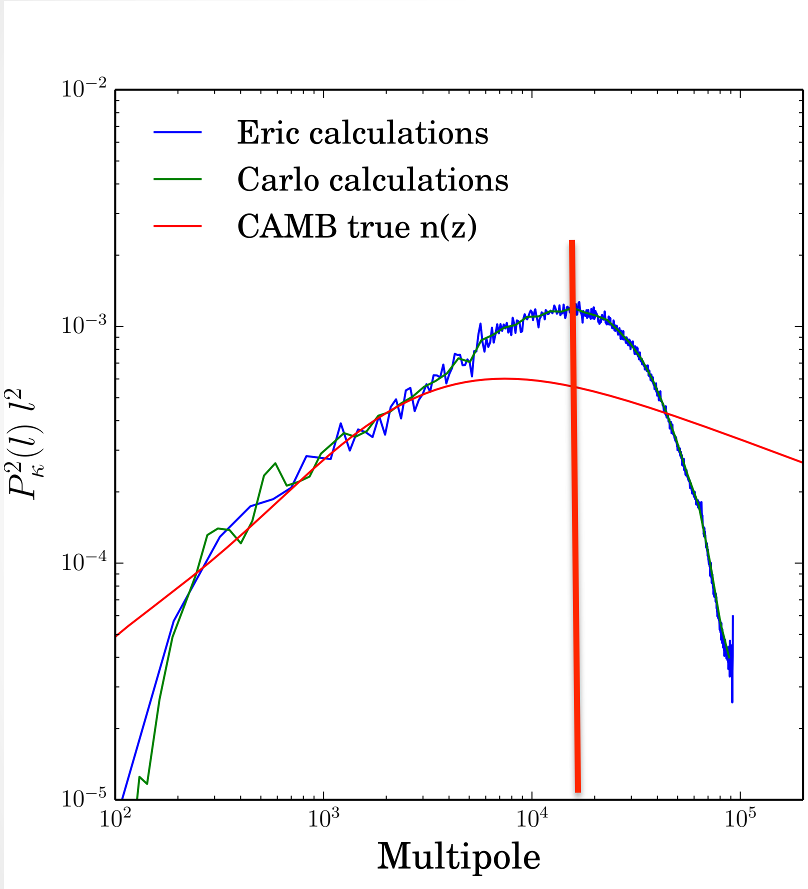
4 degrees



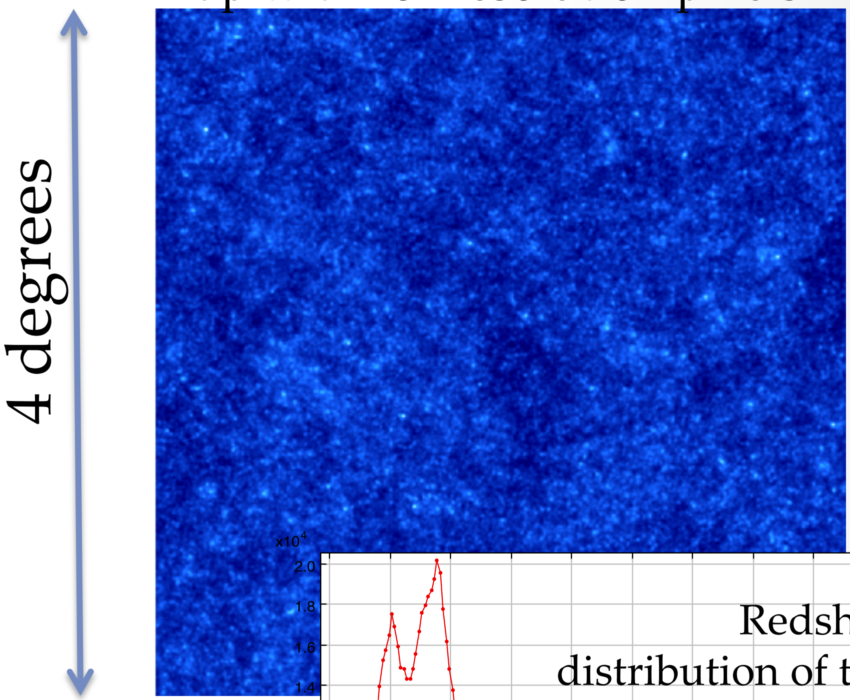
Lensing power spectrum

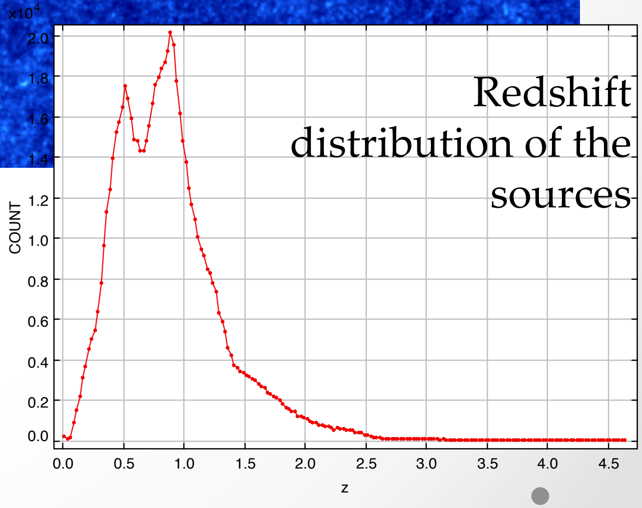


Comparing Power spectrum calculations



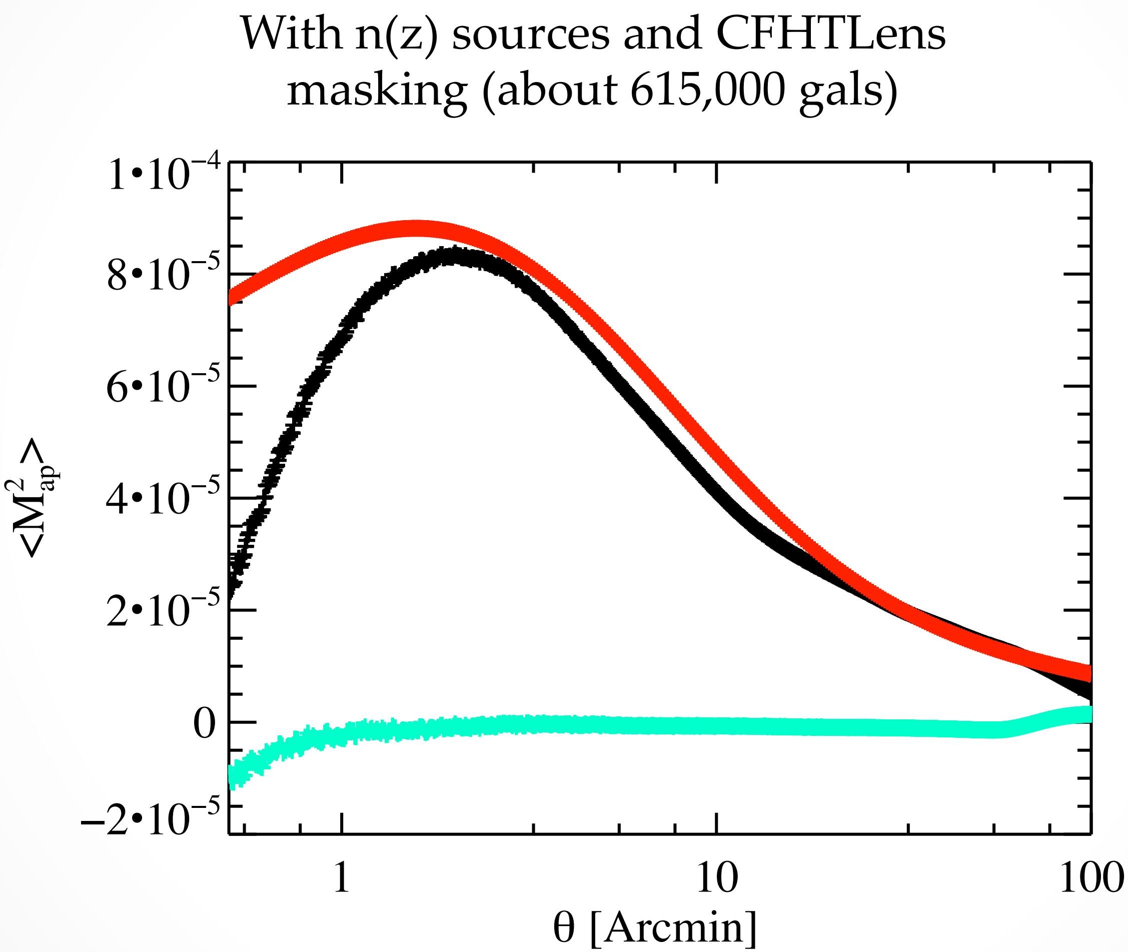
GLAMER projected convergence map with 15" resolution pixels





Redshift distribution of the sources

Mass aperture E/B mode decomposition



Conclusion

- Done:
  - 1 lensing lightcone of 7x4deg2 has been produced
  - The overlap between the lensing and spectroscopy fields is done
- In Progress:
  - 54 lensing lightcones of 8.5x1.8 deg2 are being computed
  - 54 galaxy mocks with VIPERS properties are being computed
  - The lensing estimator is done and tested on toy models
  - The final testing the cross correlation lensing and BigMD halos positions
- Todo:
  - Calculations of the covariance matrices with the mocks
  - Final coding of the estimators and the fit procedure