Large scale analysis of the SDSS-III DR8 photometric luminous galaxies angular correlation function

Work in progress

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Correlation function

- galaxy distribution in the survey: $\rho(\vec{x})$

- fluctuations can be described by a density contrast:

$$\delta(\vec{x}) = \frac{\rho(\vec{x}) - \bar{\rho}}{\bar{\rho}}$$

- fluctuations are a random gaussian field: characterized by its moments – 1pt (average), 2pt (variance), 3pt, ...

$$\langle \delta(\vec{x}) \rangle = 0$$

Two-point spatial correlation function

$$\langle \delta(\vec{x}_1)\delta(\vec{x}_2) \rangle = \xi(\vec{x}_1 - \vec{x}_2) = \xi(|\vec{x}_1 - \vec{x}_2|) = \xi(r)$$

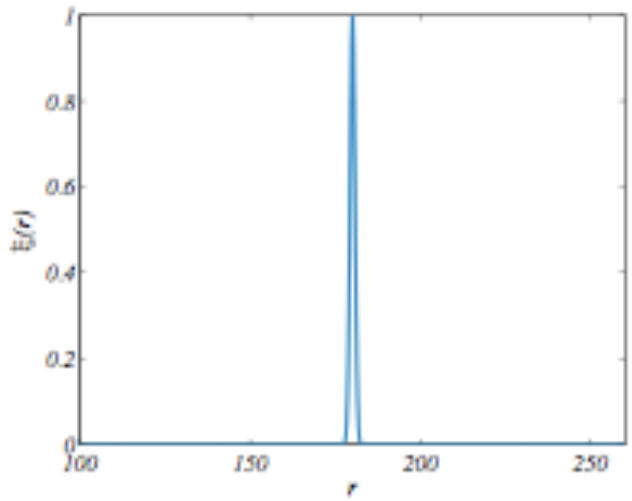
Homogeneity and isotropy

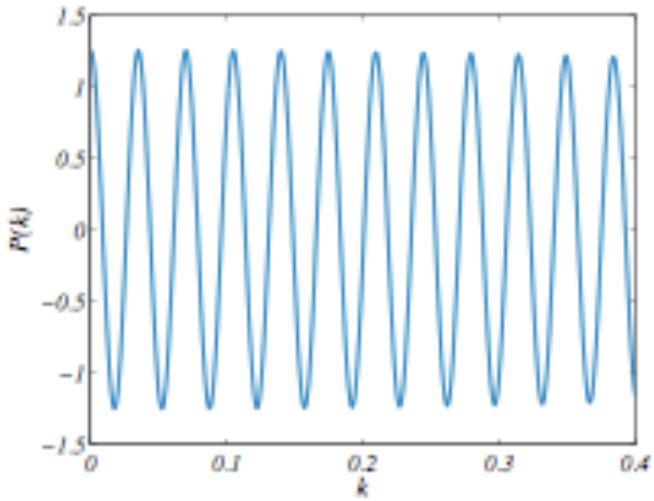
...

- Power spectrum $P(k) = \int d^3 r \xi(r) e^{i\vec{k}.\vec{r}}$

- Sharp peak in correlation results in oscillations in the power spectrum

$$\xi(r) \approx \delta(r - r_*) \qquad P(k) \approx e^{ikr_*}$$





- Preferred scale emerges in galaxy distribution: sound horizon at decoupling.

- Before recombination, baryons and photons were strongly coupled, forming a single fluid with pressure and speed. Dark matter, neutrinos and other forms were decoupled.

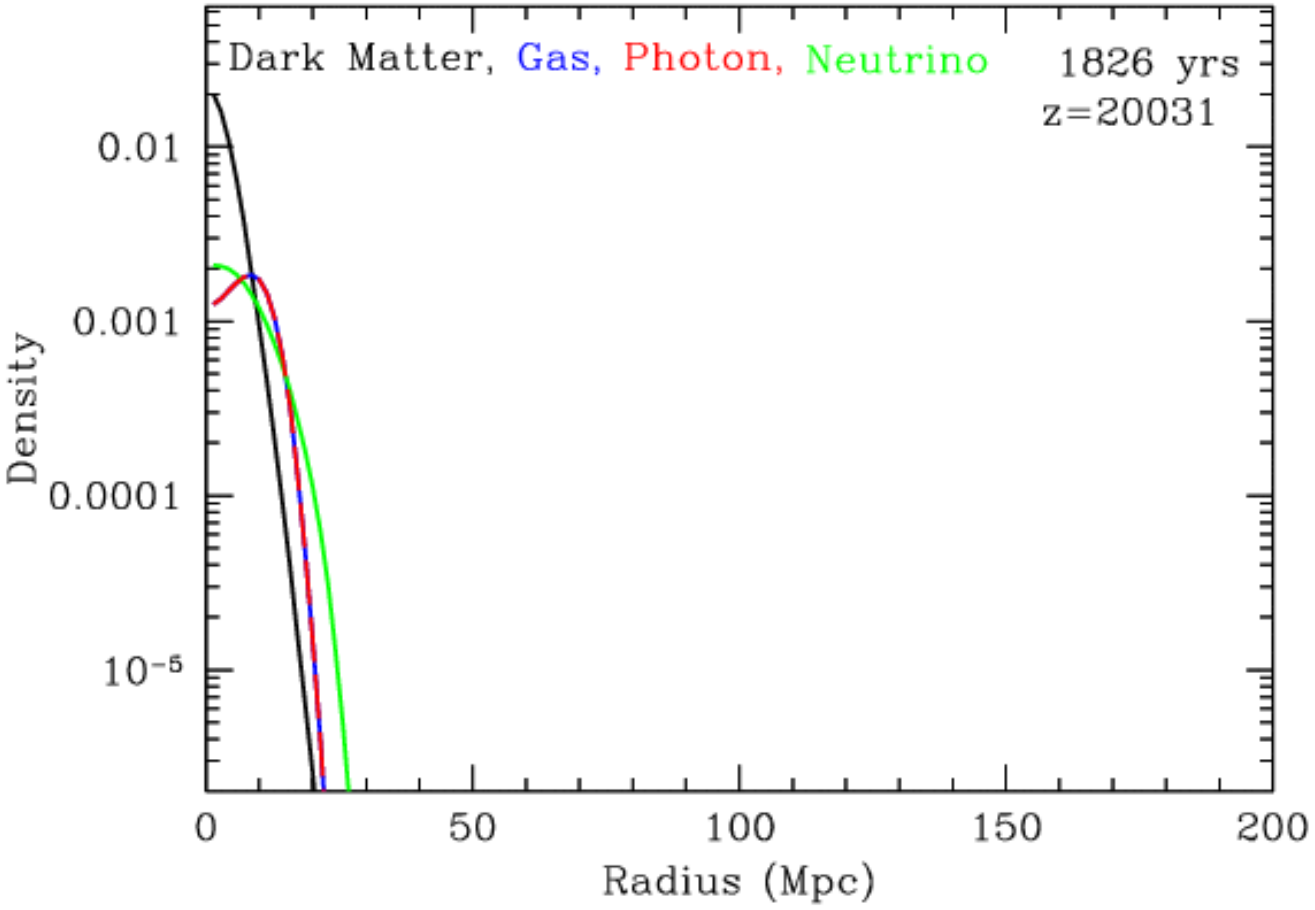
$$c_s^2 = \frac{\partial(p_\gamma + p_b)}{\partial(\rho_\gamma + \rho_b)} \sim \frac{1}{3}$$

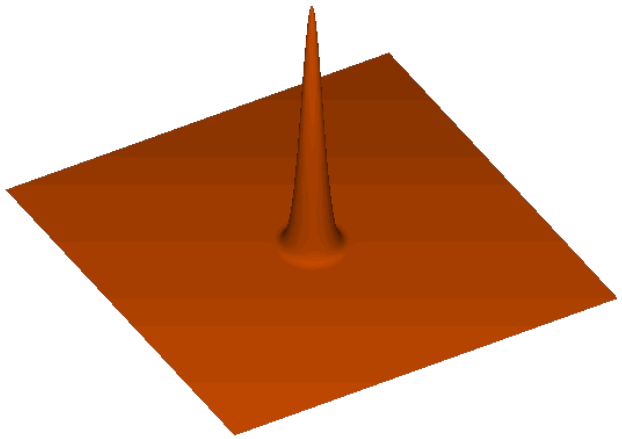
$$r_{BAO} = \int_{z_{rec}}^{\infty} \frac{c_s(z)dz}{H(z)} \approx 150 \text{ Mpc}$$

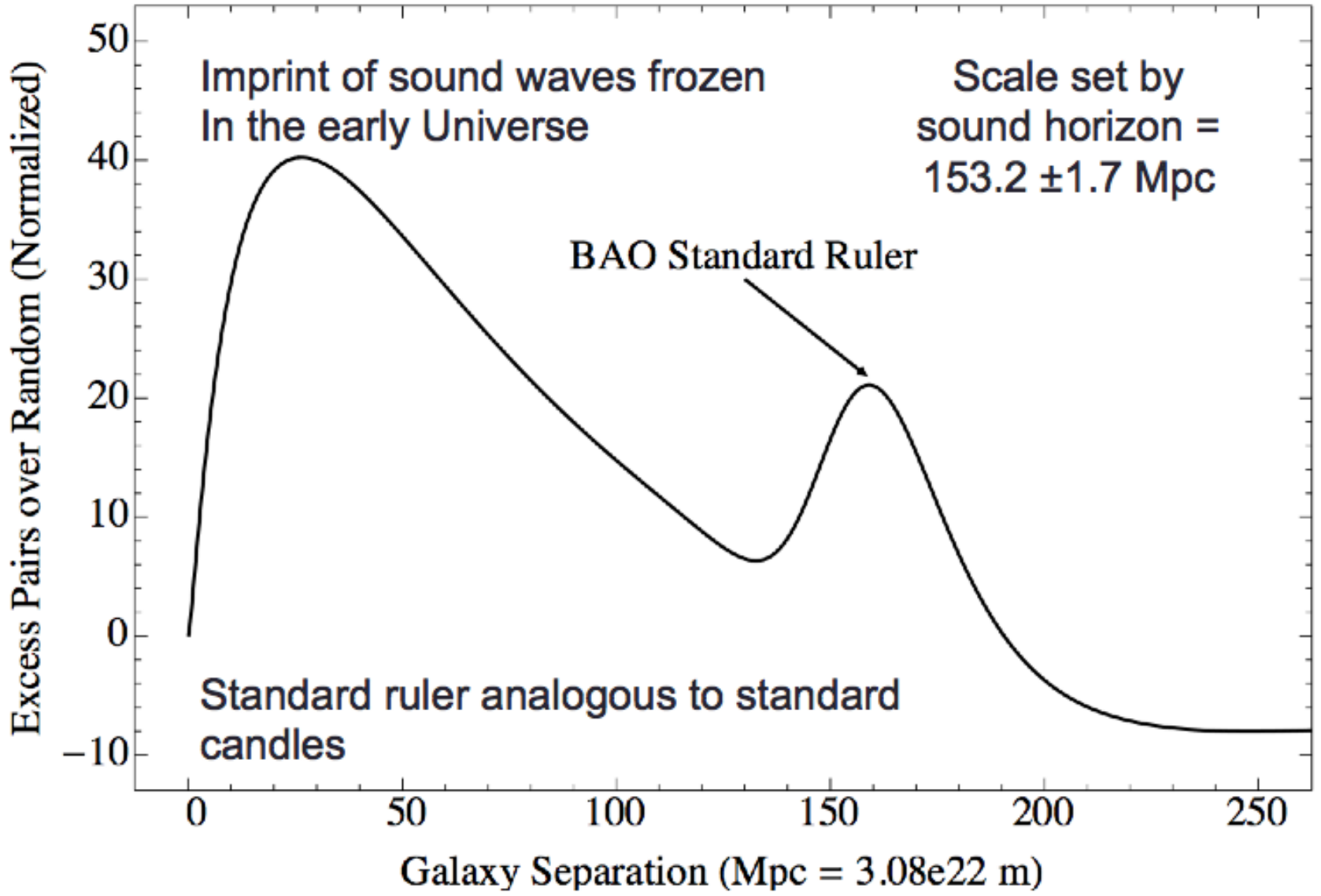
Cosmological parameters

Evolution of one spherical perturbation

Eisenstein



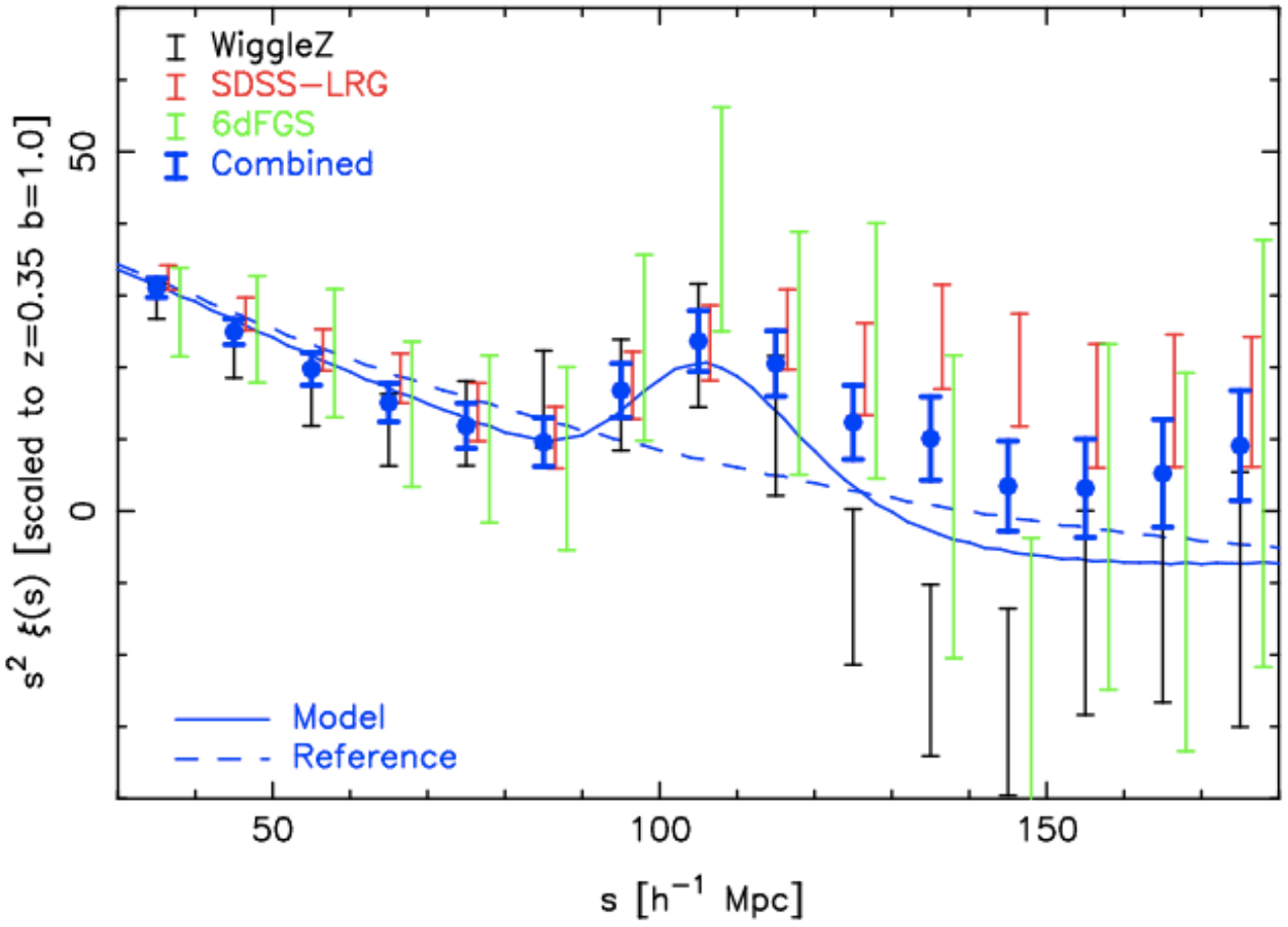



Imprint of sound waves frozen
In the early Universe
Scale set by
sound horizon =
153.2 ±1.7 Mpc
BAO Standard Ruler
Standard ruler analogous to standard
candles
Excess Pairs over Random (Normalized)
50
40
30
20
10
0
−10
0
50
100
150
200
250
Galaxy Separation (Mpc = 3.08e22 m)

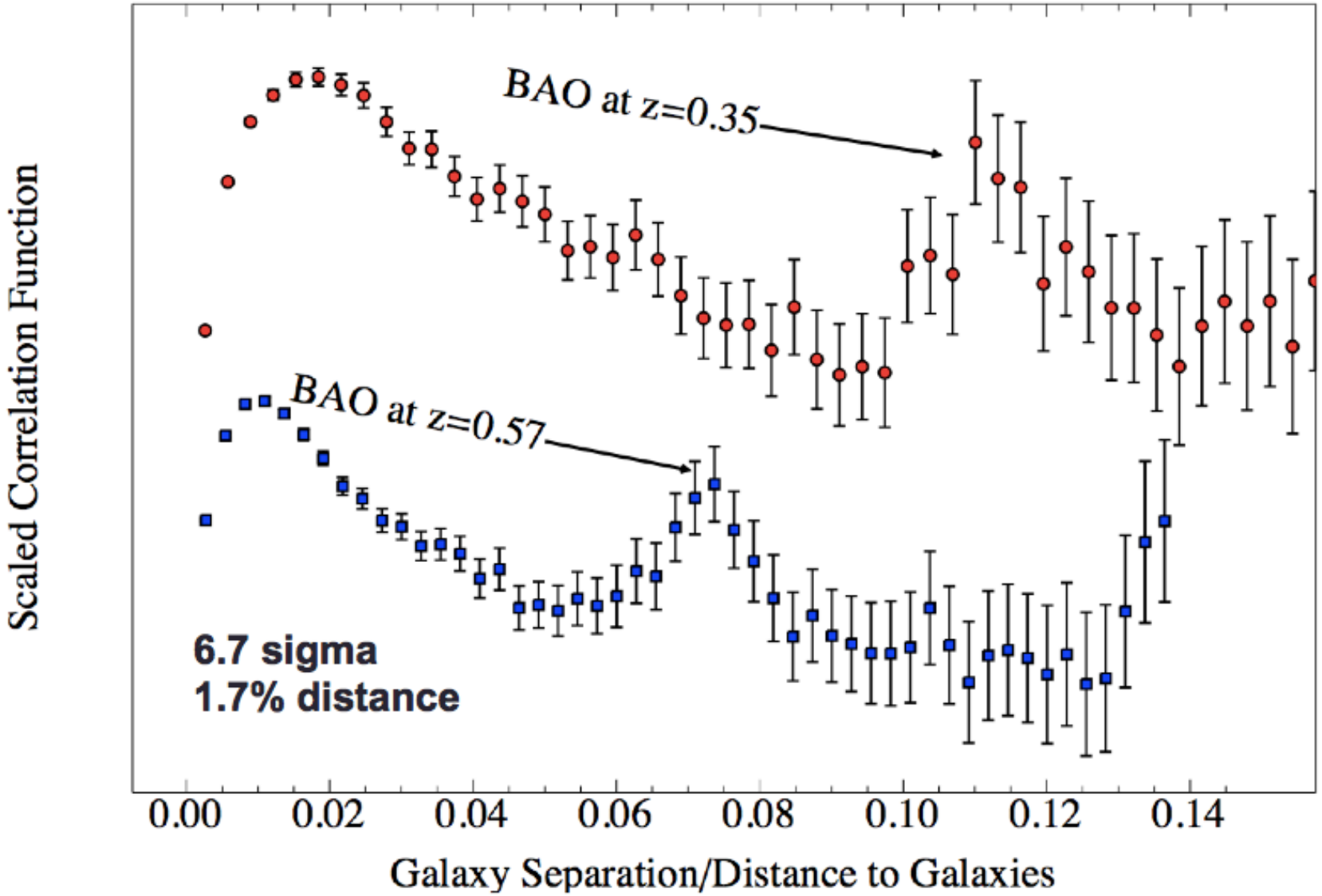
Results from WiggleZ(1108.2635):

(N = 158,741 galaxies in the redshift range 0.2 < z < 1.0)

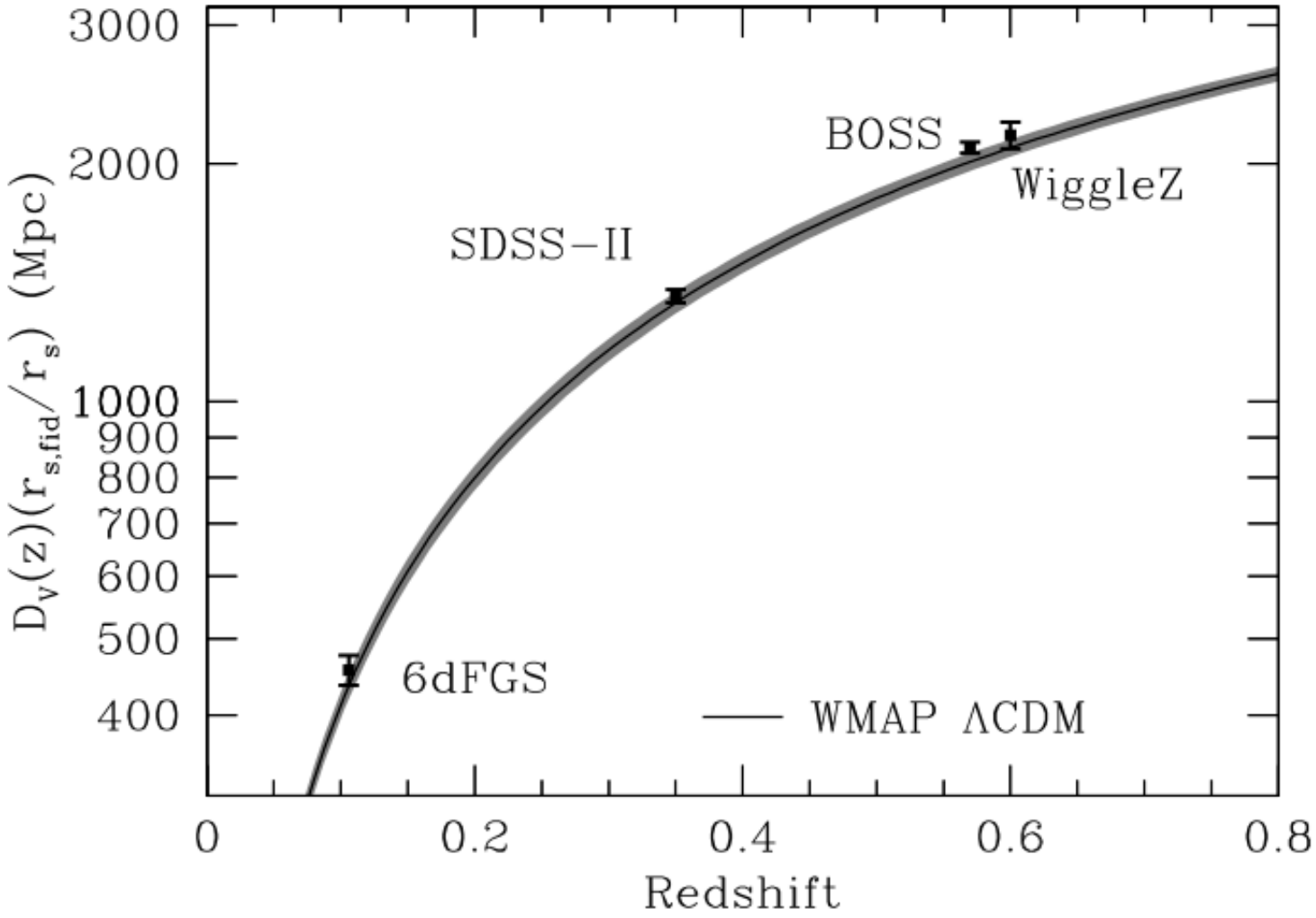
4.9σ significance



SDSS-II and SDSS-III (BOSS): 6.7σ detection



BAO Hubble diagram

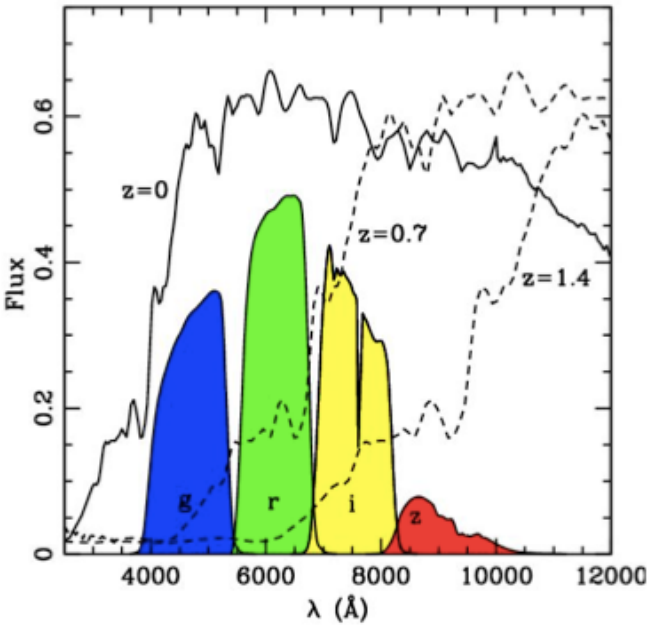


These results were obtained using spectroscopic redshifts. However, surveys such as DES will use photometric redshifts (cheaper, larger volumes but less accurate).

E.g., DES will survey

~ 300 million galaxies

z up to 1.4



In this work we use the CMASS Luminous Galaxies photometric catalogue from SDSS-III 8th data release:

~500,000 galaxies with $0.45<z<0.65$

Angular correlation function

- Photo-z measurements are not very precise
- We divide the observed volume into 4 bins of redshift and project the spatial correlation function in an angular correlation function in that particular bin:

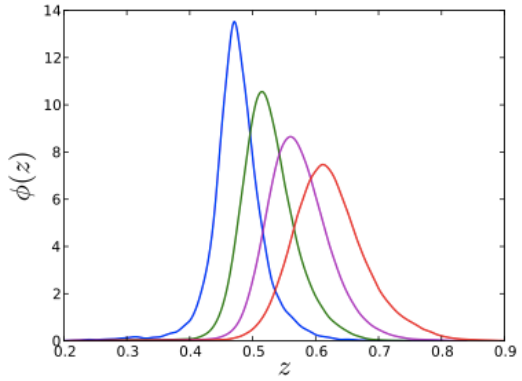
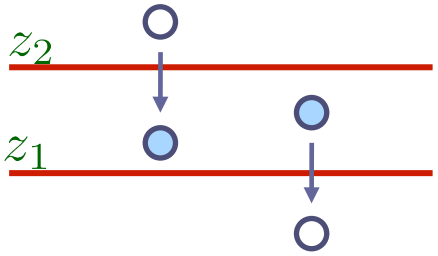


Figure 1. Selection functions for the set of redshift shells applied in the cosmological analysis.



Reshift shell	N_{gal}	σ_{phot}
$0.45 \leqslant z_p \leqslant 0.50$	154531	0.043
$0.50 \leqslant z_p \leqslant 0.55$	198132	0.044
$0.55 \leqslant z_p \leqslant 0.60$	190603	0.052
$0.60 \leqslant z_p \leqslant 0.65$	121181	0.063

$$\delta_i(\hat{n}) = \int \phi_i(z)\delta(\vec{r}, z)$$

selection function for bin i

$$\omega(\theta) = \langle \delta(\hat{n})\delta(\hat{n}+\hat{\theta})\rangle = \int dz_1 \phi_1(z_1) \int dz_2 \phi_2(z_2) \overbrace{\langle \delta(\vec{r}_1, z_1)\delta(\vec{r}_2, z_2)\rangle}^{\xi(r(z_1, z_2, \theta))}$$

Estimated ACF

ACF measured for $1^0 < \theta < 8^0$ in 35 angular bins, corresponding to $25 < r < 200\ h^{-1}$ Mpc

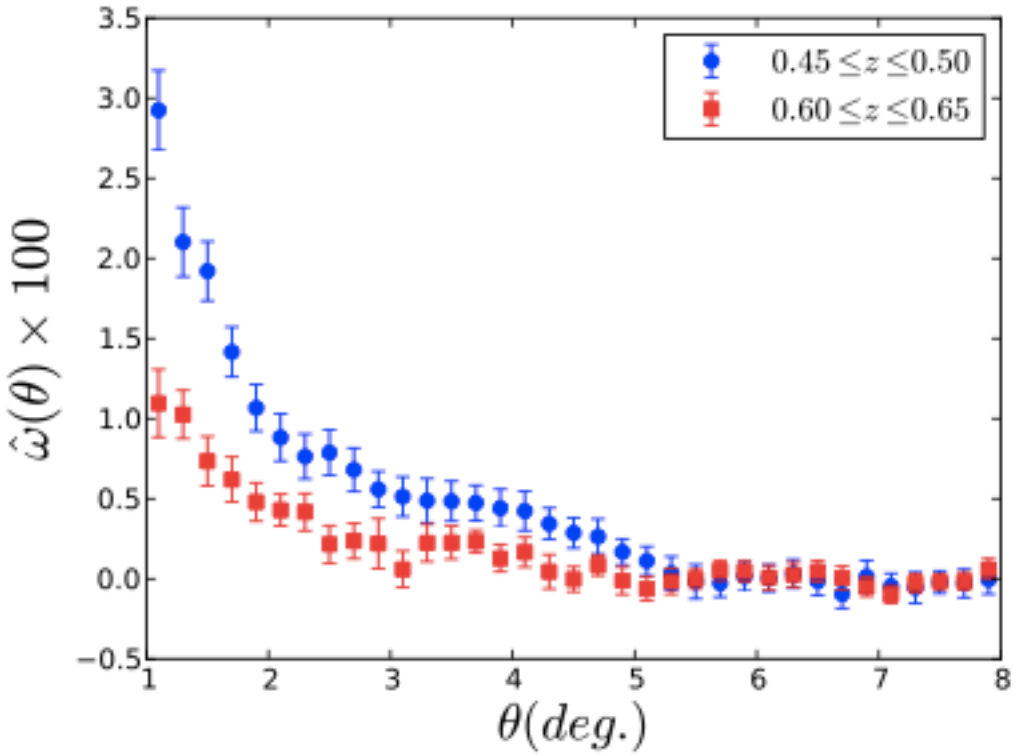


Figure 2. Estimated ACF for the first and last redshift shells. The error bars are estimated via jack-knife.

Three analysis

. Cosmological parameters from the full shape of the ACF

. Cosmological parameters from a power-law + gaussian fit (PLG)

. Parameters from redshift-space distortion (RSD)

Theoretical ACF

Theoretical modelling of ACF includes:

. Primordial power spectrum (n_s and σ_8)
. Transfer matrix (CAMB)
. Growth function
. Bias
. Selection function
. Redshift space distortion
. Non-linear effects

$$\omega(\theta) = \int dz_1 f(z_1) \int dz_2 f(z_2) \xi_{nl}^{(s)}(\theta, z_1, z_2)$$

Redshift distortion

nonlinearity

$$f(z) = b(z)\phi(z)D(z)$$

bias

Selection function

Growth function

Estimating cosmological parameters from ACF

Follow methodology of Sobreira et al (2012).

Define usual chi2 and likelihood

theoretical covariance matrix

$$\chi^2 = \sum_{i,j=1}^{N_z} \sum_{n,m=1}^{N_a} \left(\omega^i_{\rm th}(\theta_n, p) - \omega^i_{\rm obs}(\theta_n)\right) \left[\mathrm{Cov(p)}^{(i,j)}_{(n,m)}\right]^{-1} \left(\omega^j_{\rm th}(\theta_m, p) - \omega^j_{\rm obs}(\theta_m)\right)$$

parameters

$$\mathcal{L} \propto \frac{1}{\sqrt{\det\ \mathrm{Cov}(p)}} e^{-\chi^2(p)/2}$$

Estimating cosmological parameters from ACF

Use CosmoMC to estimate a subset of cosmological parameters:
Ω_m , $f_b = \Omega_b/\Omega_m$, b and σ_8 (keeping other parameters at WMAP7 values)

$\sigma_8 = 0.76 +/- 0.11$ but highly degenerate with bias
(assumed to be constant in each shell)

Preliminary results

- When analyzing all shells together, with the full covariance matrix, the best-fit values were: $\Omega_m = 0.276 \pm 0.022$ and $f_b = 0.211 \pm 0.026$ in good agreement with WMAP7 results.

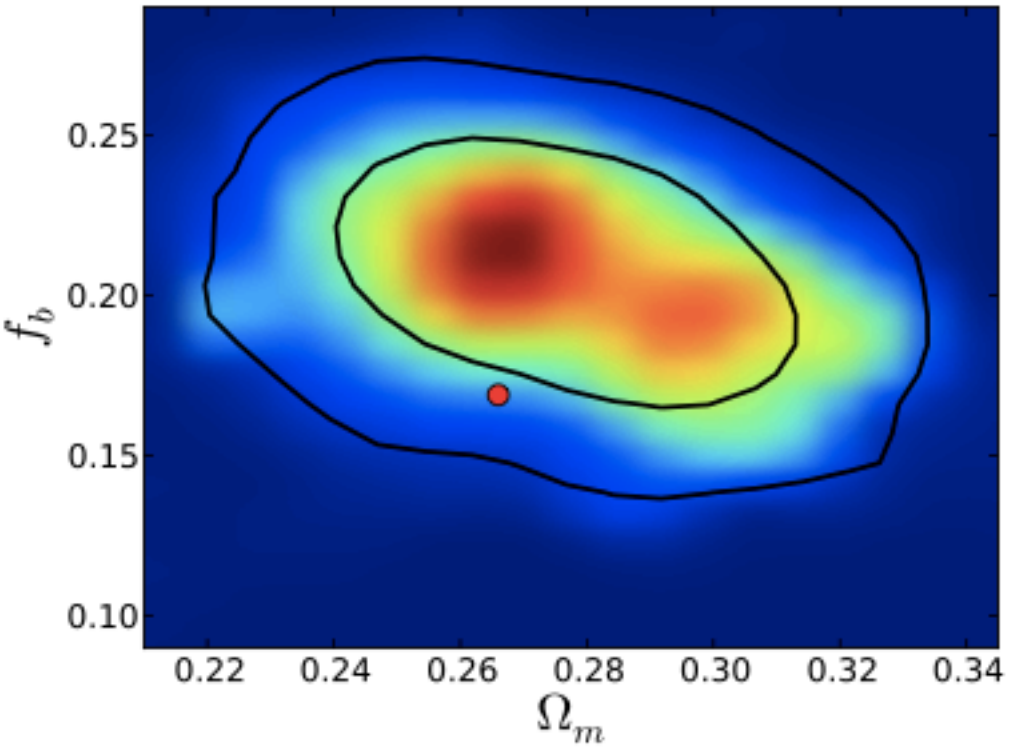


Figure 8. The probability distribution function for Ω_m and f_b combining the four redshift shells when marginalizing over σ_8 and four bias parameters. 1σ and 2σ are displayed. The red dot is the WAMP7 best-fit values for the same parameters.

Preliminary results

Using another MCMC code with the same methodology and data (see poster of Chavez and Lima):

PARAMETER	68% LIMITS
Ω_m	$0.28^{+0.03}_{-0.04}$
f_b	$0.20^{+0.04}_{-0.03}$
b_{00}	$1.13^{+0.21}_{-0.28}$
b_{01}	$2.11^{+0.31}_{-0.51}$
b_{02}	$2.35^{+0.26}_{-0.52}$
b_{03}	$2.17^{+0.36}_{-0.54}$
σ_8	$0.74^{+0.12}_{-0.23}$

Consistent with CosmoMC results.

Parameter estimation from PLG

Methodology developed in Carnero et al (2012):

$$\omega(\theta) = A + B\theta^{\gamma} + Ce^{\frac{-(\theta-\theta_{plg})^2}{2\sigma}}$$

related to BAO peak

6 free parameters

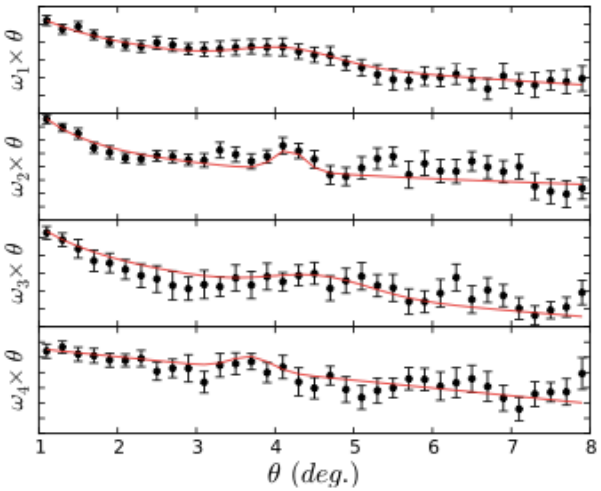


Figure 5. PLG fit (red line) to the four ACF (black dots) simultaneously using the full covariance matrix with correlations between redshift shells. We do not display the ACF values for clarity. The redshift shells are arranged from top to bottom with increasing redshift.

$\Omega_m = 0.22 \pm 0.03,\ w = -1.05 \pm 0.13$

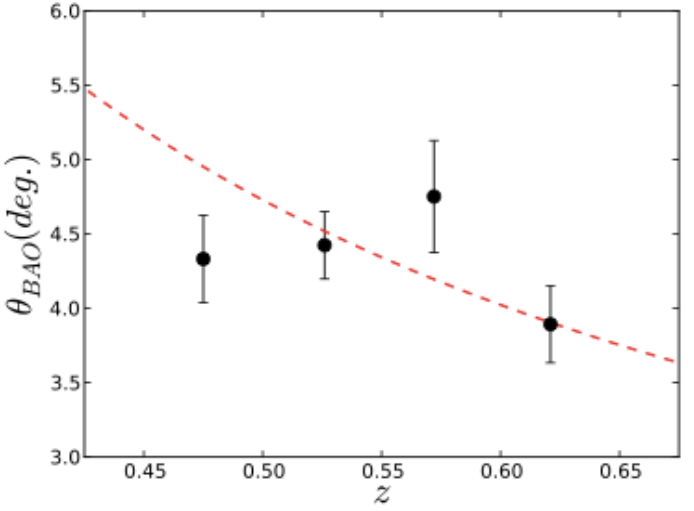


Figure 6. θ_{BAO} as a function of z for the CMASS catalog. The dashed line is given by the best fit cosmology, see text.

RSD

. Use MCMC to constrain parameters directly related to RSD

$$b(z)\sigma_8(z) = b\sigma_8 D(z)\,,$$

and

$$f(z) = d\ln D/d\ln a$$

$$f(z)\sigma_8(z) = f\sigma_8 D(z)\,.$$

assuming b(z) and f(z) constant in each redshift bin.

Conclusions

. Presented first results on extracting cosmological parameters from a photometric survey using full shape of the angular correlation function.

. Results are in good agreement with more precise spectroscopic surveys and WMAP

. Ready to use this methodology in DES data!

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