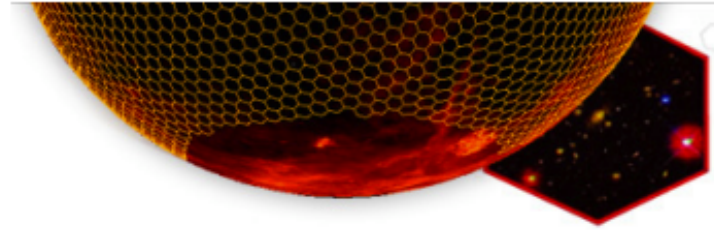
THE DARK ENERGY SURVEY



Measuring Baryon Acoustic Oscillations with the Dark Energy Survey

Ana Isabel Salvador Junco

and

Javier Sánchez López

In collaboration with: D. Alonso, J. García-Bellido, E. Sánchez.

11/08/2014

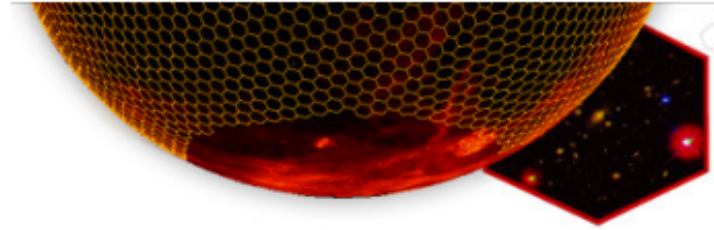
UAM UNIVERSIDAD AUTONOMA DE MADRID

ift Instituto de Física Teórica EXCELENCIA SEVERO OCHOA

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

THE DARK ENERGY SURVEY

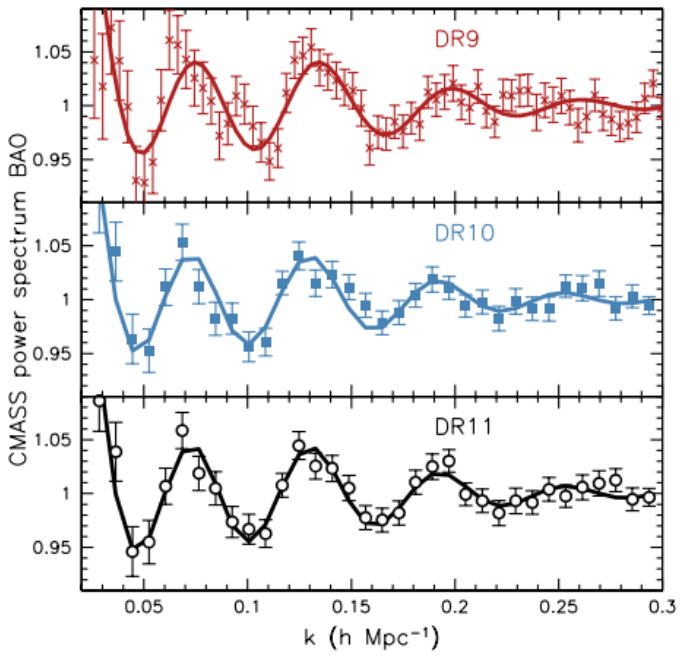
Outline

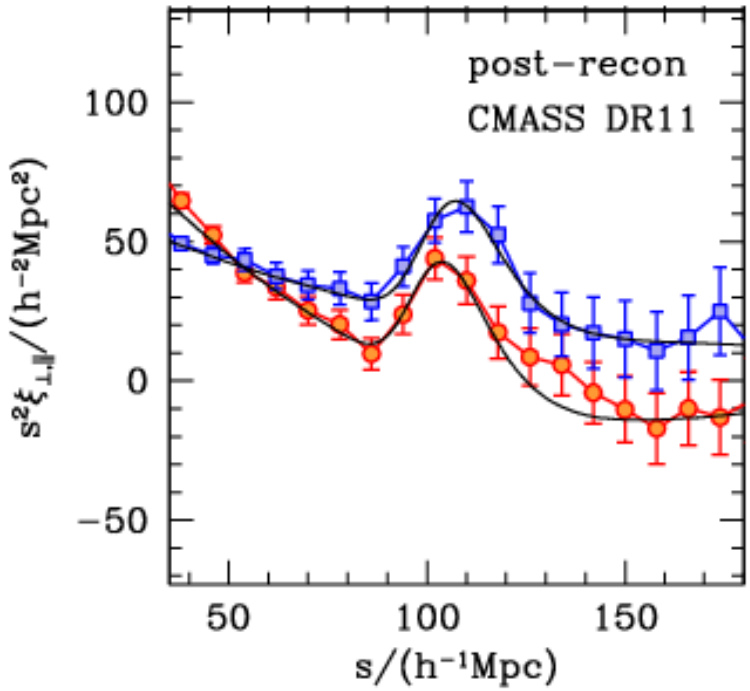


Two-Point Correlation Function

The 2PCF is the Fourier transform of the power spectrum.

$$P(\mathbf{k}) = \int dr^3 \xi(\mathbf{r}) e^{-i\mathbf{kr}}$$





[Anderson et al. 2013(BOSS)]

2PCF

We can estimate the correlation function as:

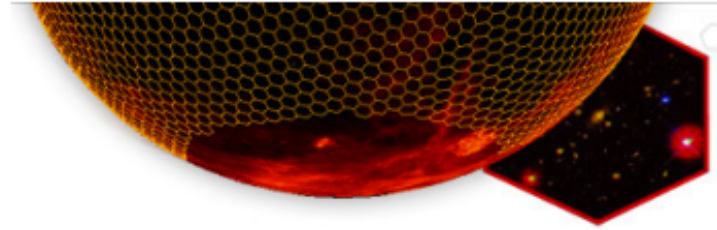
$$1 + \xi(r) = \frac{\#\text{ pairs in the distribution at a distance r}}{\#\text{ pairs expected for a random distribution}}$$

We use Landy & Szalay estimator:

$$\xi_{LS}(r) \equiv \frac{DD(r) - 2DR(r) + RR(r)}{RR(r)}$$

THE DARK ENERGY SURVEY

Observations



From the surveys we have three observable quantities:

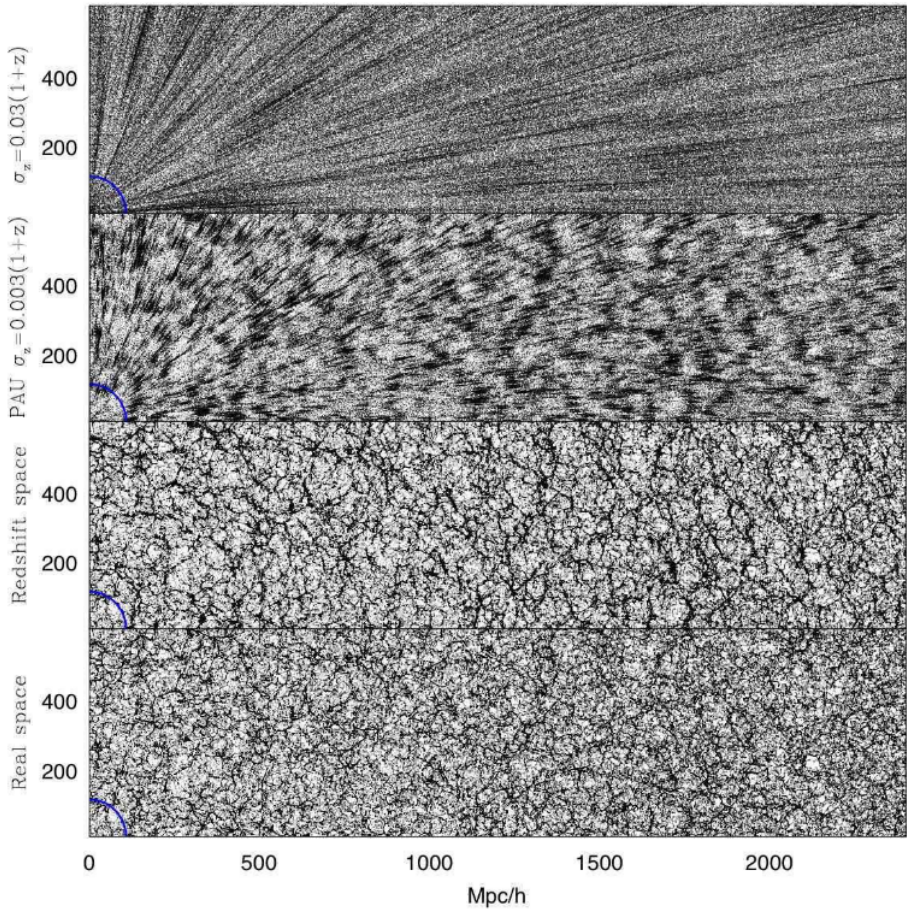
- angular coordinates
  - right ascension (RA, α)
  - declination (dec, δ)
- redshift z.

Two different approaches to measure z:

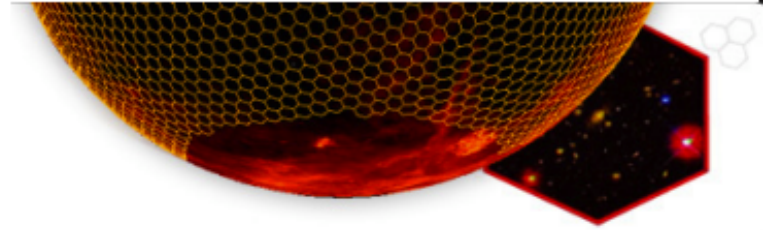
- Spectroscopic redshifts: full spectrum of each galaxy measured. (BOSS)
- Photometric redshifts: the redshift is estimated from photometry in a few broadband filters. (DES)

Photometric redshifts

The big uncertainty in the photo-z only allows a study of the angular statistics of galaxy clustering, $w(\theta)$.

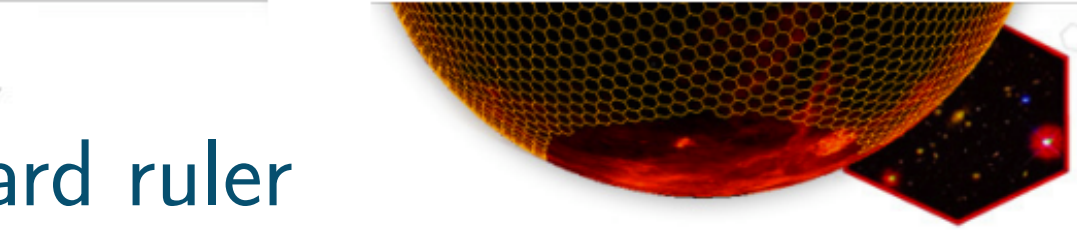


Benitez et al., Measuring BAO in the PAU survey (2009)



THE DARK ENERGY SURVEY

BAO as a standard ruler



Obtain cosmology information:

(I) Calculate the 2PCF or the $P(k)$ from the galaxy distribution for different redshift bins.

(II) Extract the sound horizon scale from the BAO peak of the 2PCF or the wiggles in the $P(k)$ for each redshift bin.

(III) Minimize the χ^2 respect the cosmological parameters:

$$\chi^2 = \sum_{i=1}^{N} \frac{\left(r_{\rm obs}(z_i) - r_s(z_i, \Omega_M, \Omega_\Lambda, w, h, ...)\right)^2}{\sigma^2(z)}$$

BAO as a standard ruler

Obtain cosmology information:

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PLG method

Power Law + Gaussian - Method for photometric surveys based only on observable quantities [Sánchez et al.(2011)]:

(I) Divide the full galaxy sample in redshift bins.

(II) Compute the angular two-point correlation function in each redshift bin.

(III) Parametrize the correlation function:

$$\omega(\theta) = A + B\theta^{-C} + D \exp -\frac{(\theta - \theta_{FIT})^2}{2\sigma^2}$$

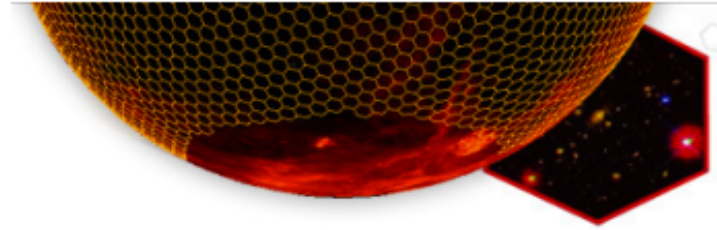
(IV) Correcting the BAO scale (θ_{FIT}) for the projection effect

$$\theta_{BAO} = \alpha\theta_{FIT}$$

(V) Fit cosmological parameters to the evolution of the corrected θ_{BAO} with z.

THE DARK ENERGY SURVEY

PLG method



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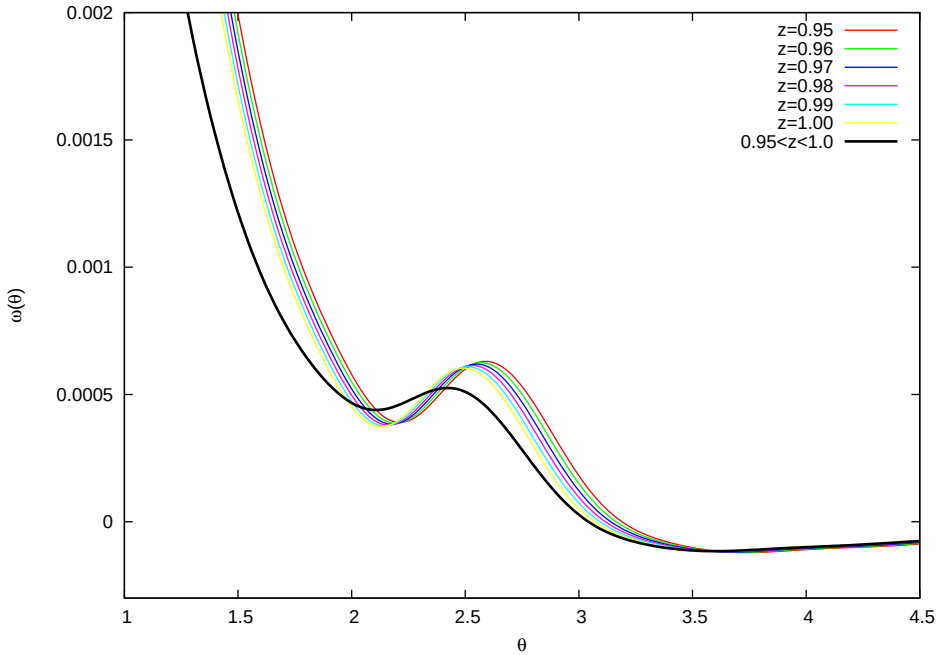
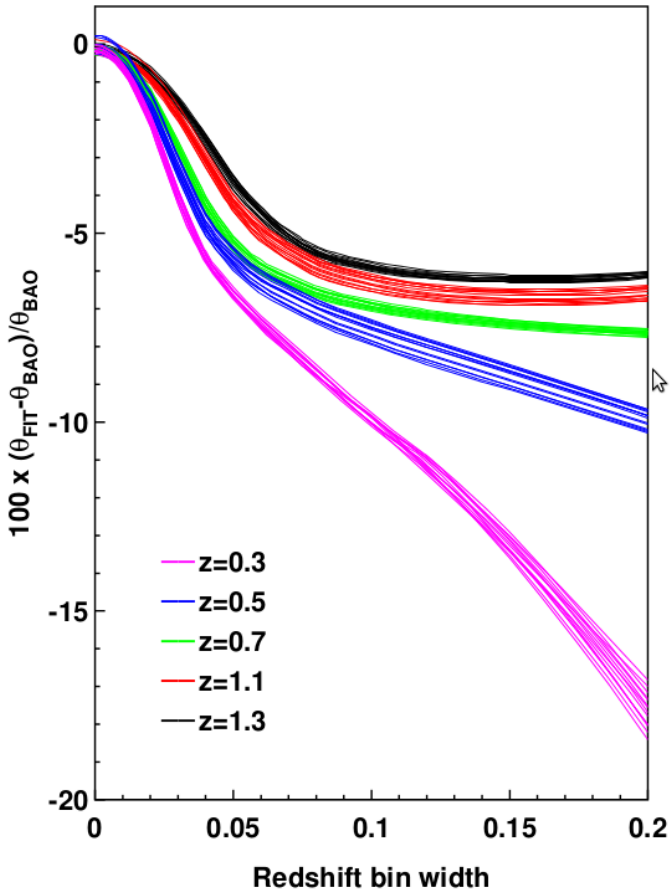
Projection effect





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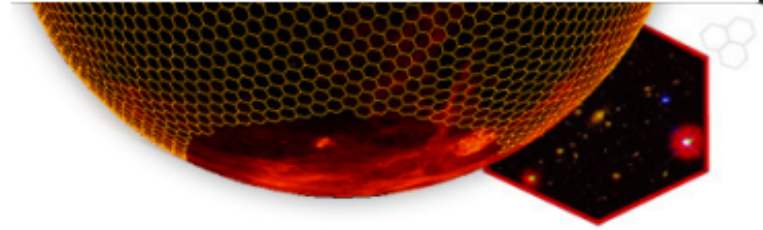
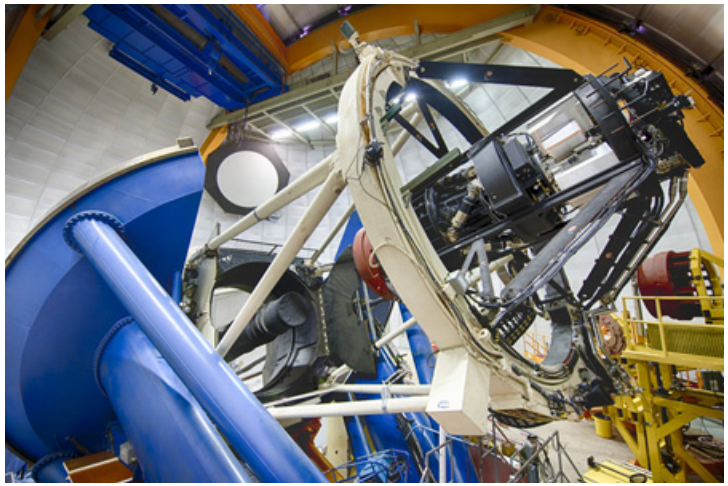
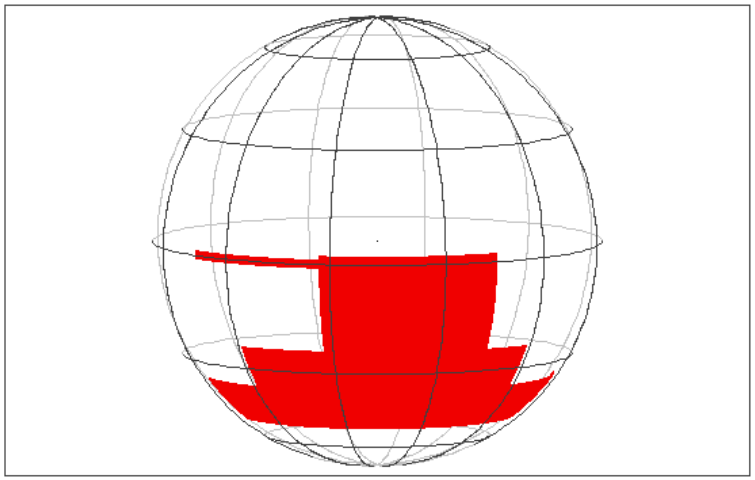


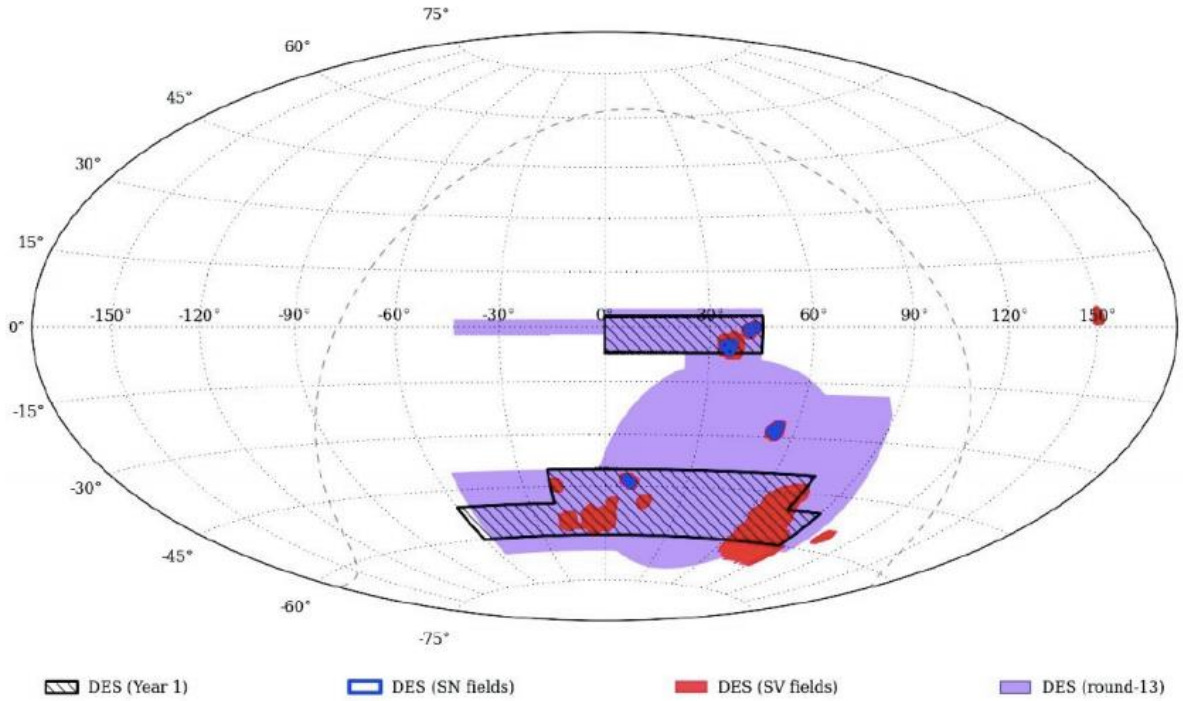
DES





- It combines four probes of Dark Energy:
  - Type Ia Supernovae (SN)
  - Baryon Acoustic Oscillations (BAO)
  - Galaxy clusters (GC)
  - Weak Gravitational Lensing (WL)

DES Science Verification



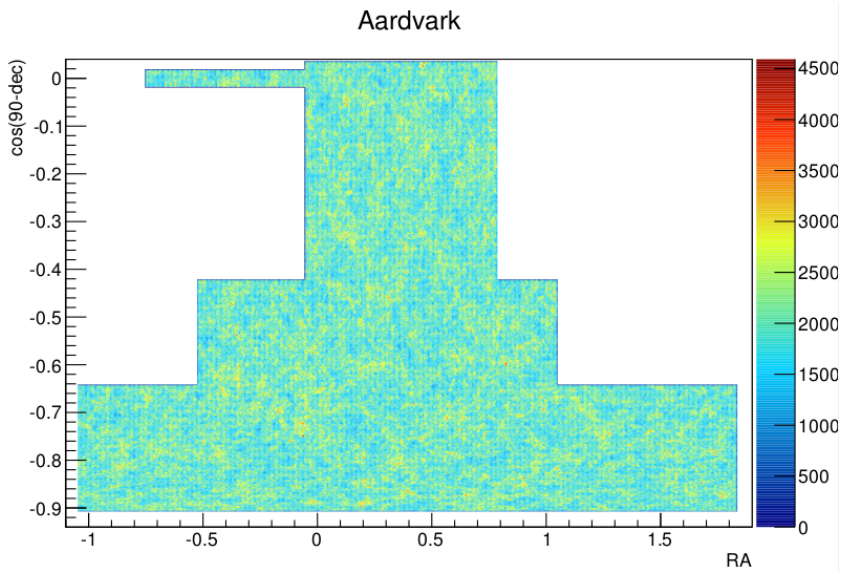
- Galaxy clusters - arXiv:1405.4285
- Photometric redshift analysis - arXiv:1406.4407

Simulations

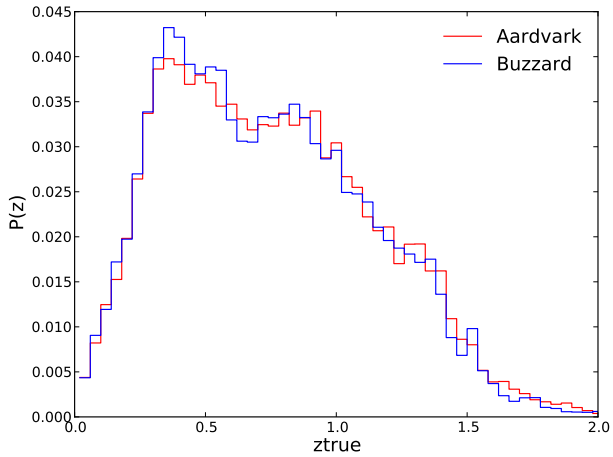
*w*CDM simulations by Stanford group led by Risa Wechsler provided to DES collaborators blindly (unknown underlying cosmological parameters).

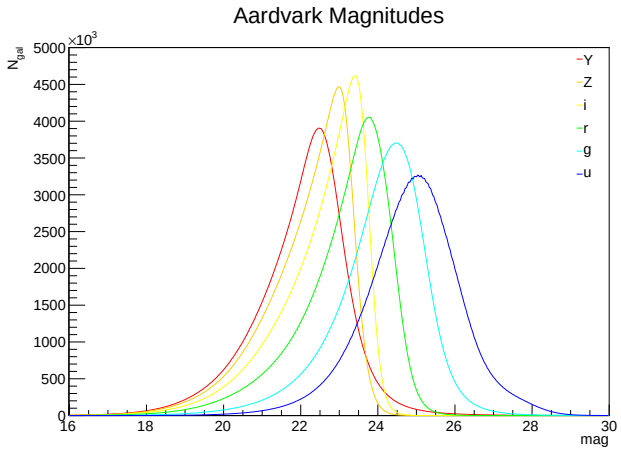
Aardvark and Buzzard:

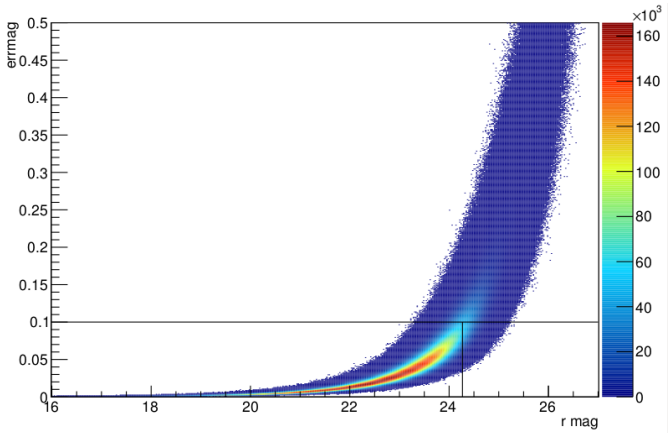
- 10313 sq. degrees (quarter of sky).
- 1.36 billion galaxies to the DES 5-sigma limit.

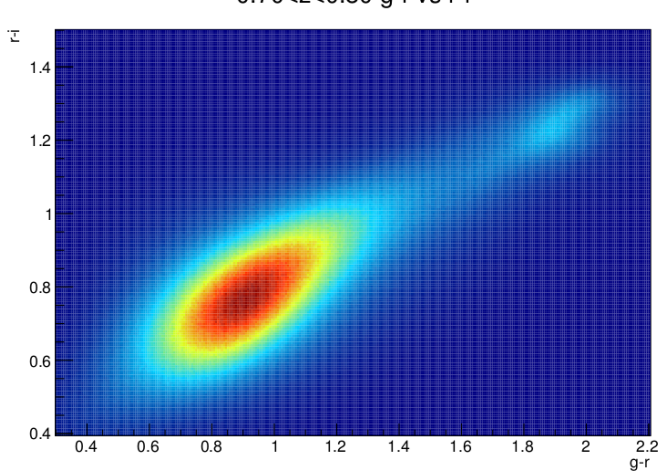


Data checks


Aardvark
Buzzard
P(z)
ztrue


Aardvark Magnitudes
N_gal
mag
Y
Z
i
r
g
u


errmag
r mag


0.70<z<0.80 g-r vs r-i
r-i
g-r

Select Redshift bins

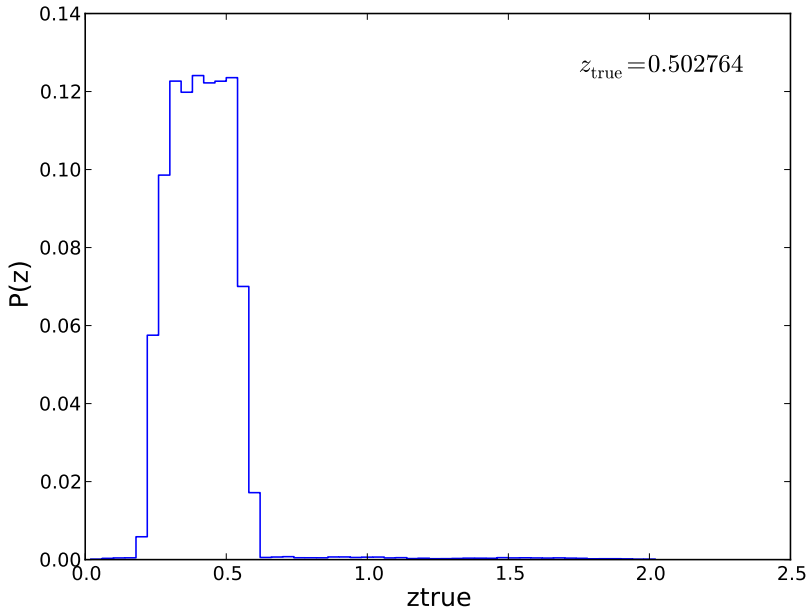


Photo-z of one galaxy

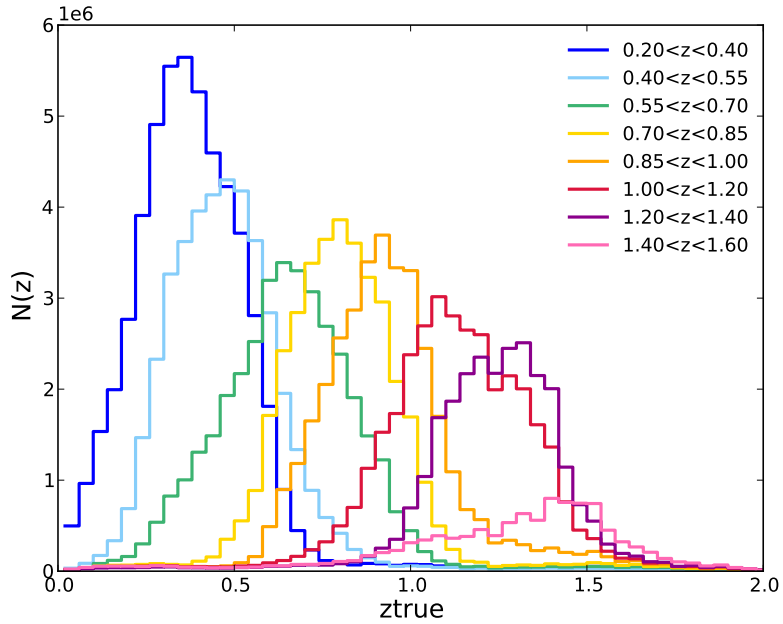
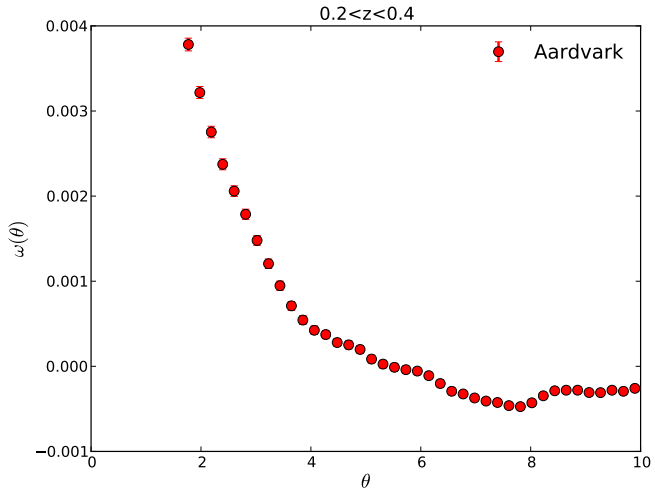
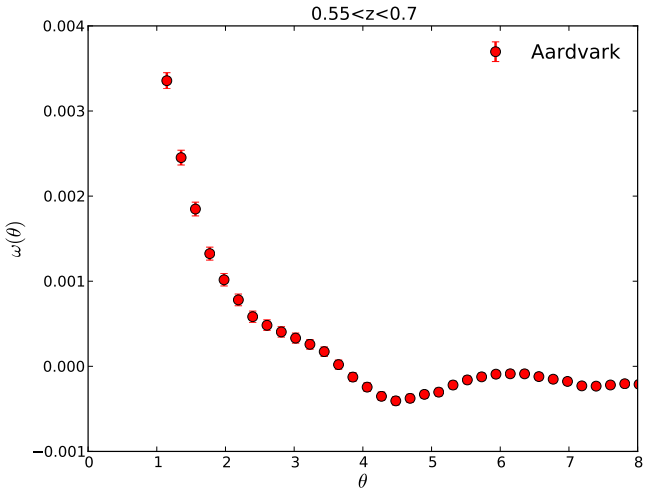
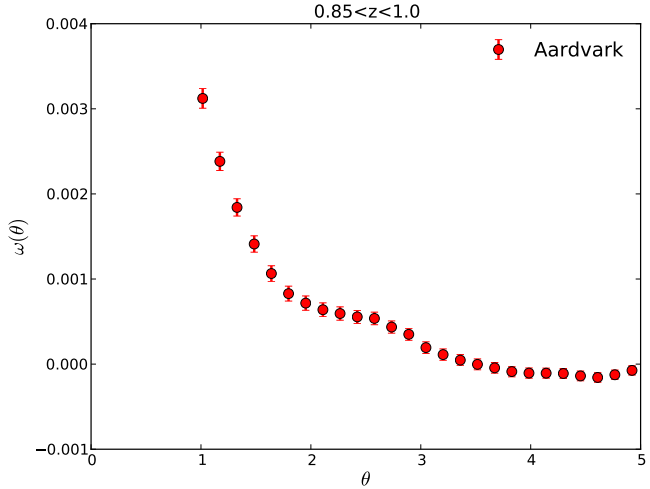


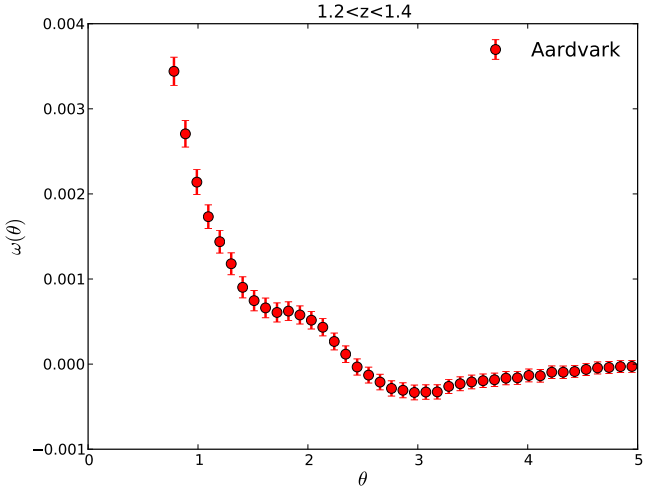
Photo-z distributions in the selected redshift bins.

2PCF - Aardvark

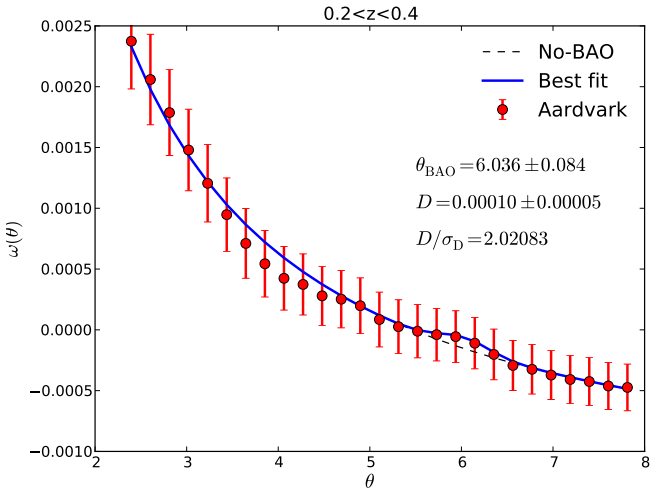


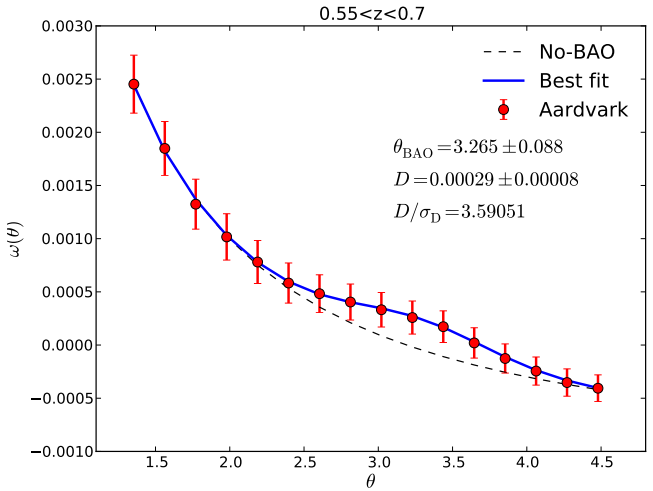


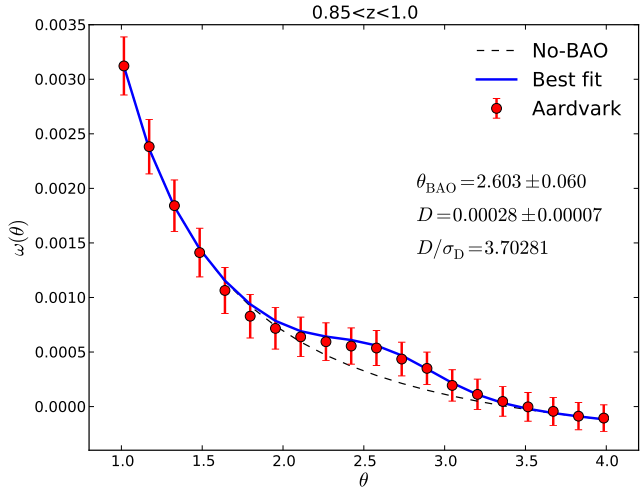


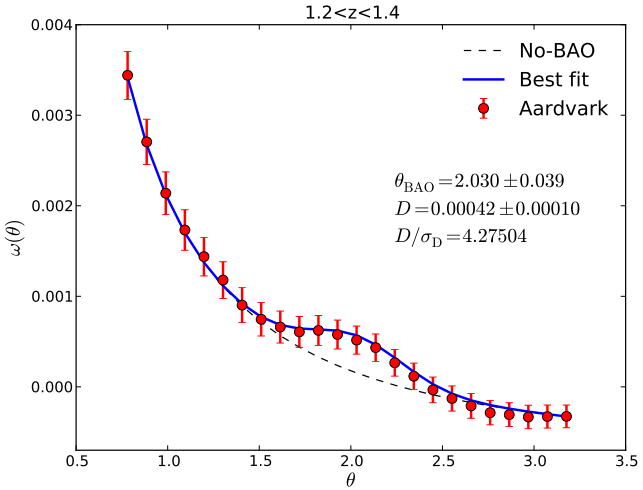


Fit 2PCF - Aardvark



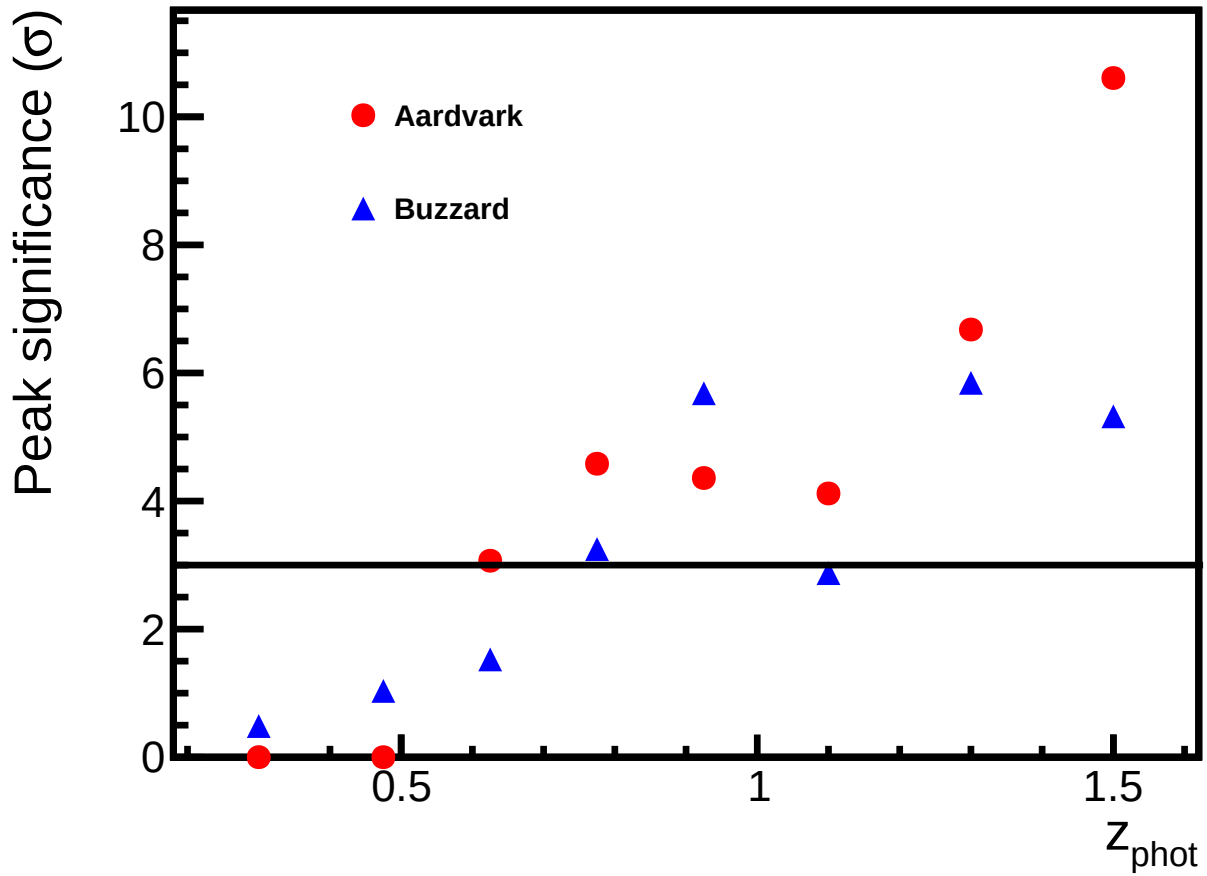




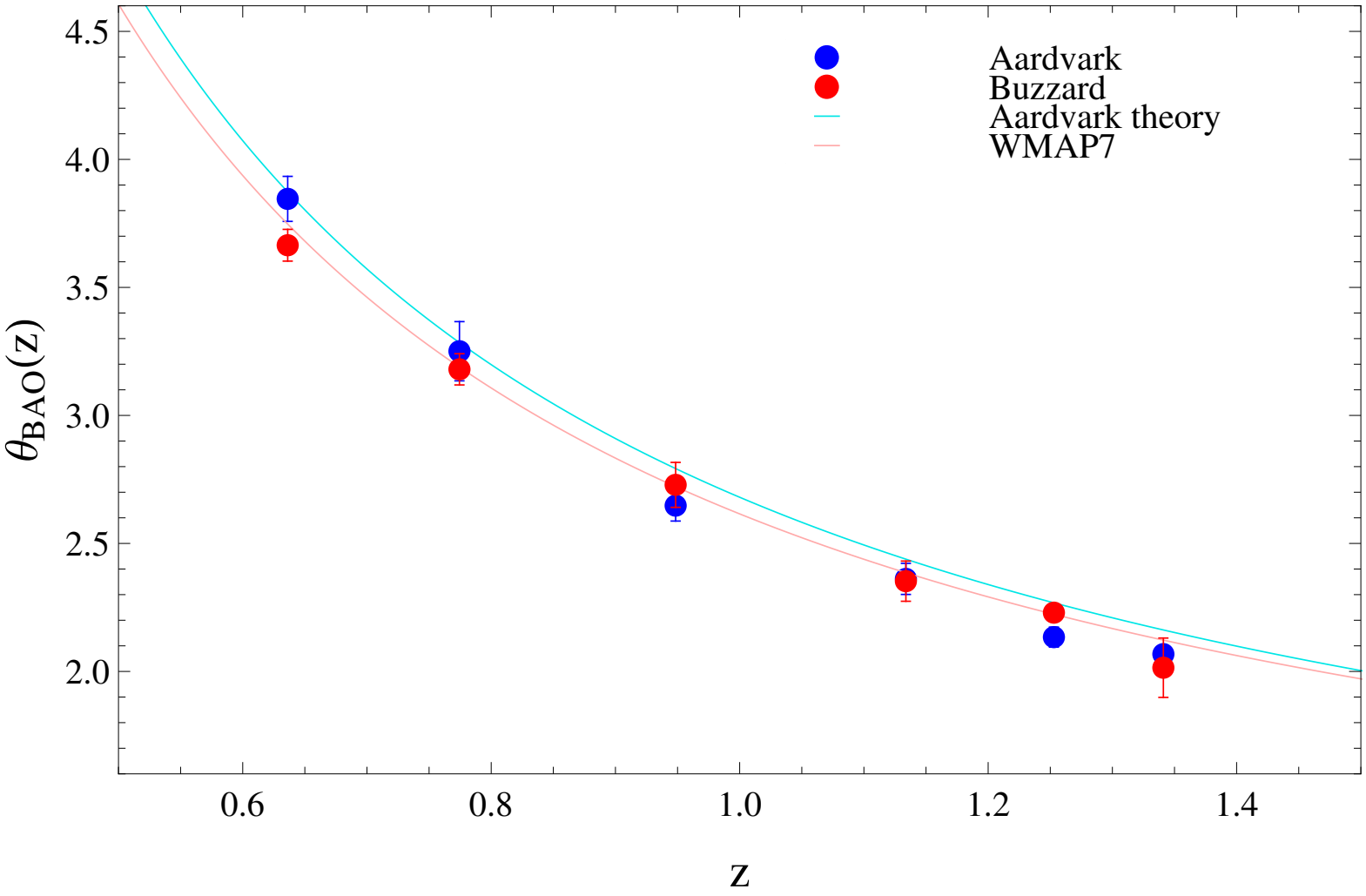


Statistical significance

The statistical significance of the detection is given by the ratio D/σ_D where D is the amplitude of the Gaussian.



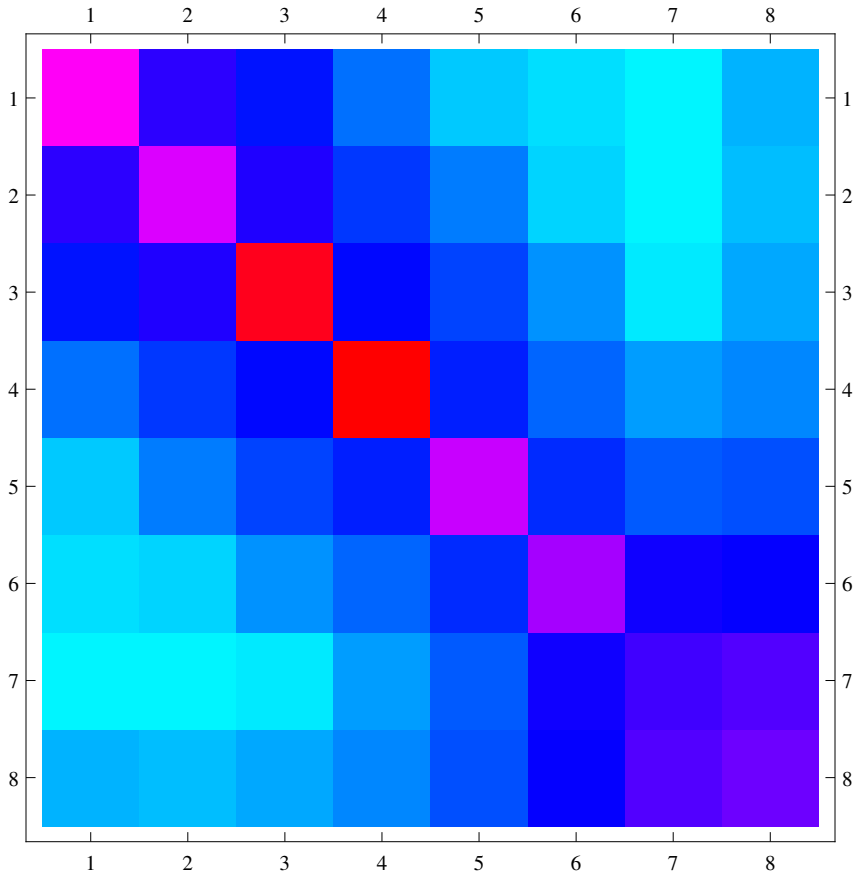
Evolution of θ_{BAO} with z



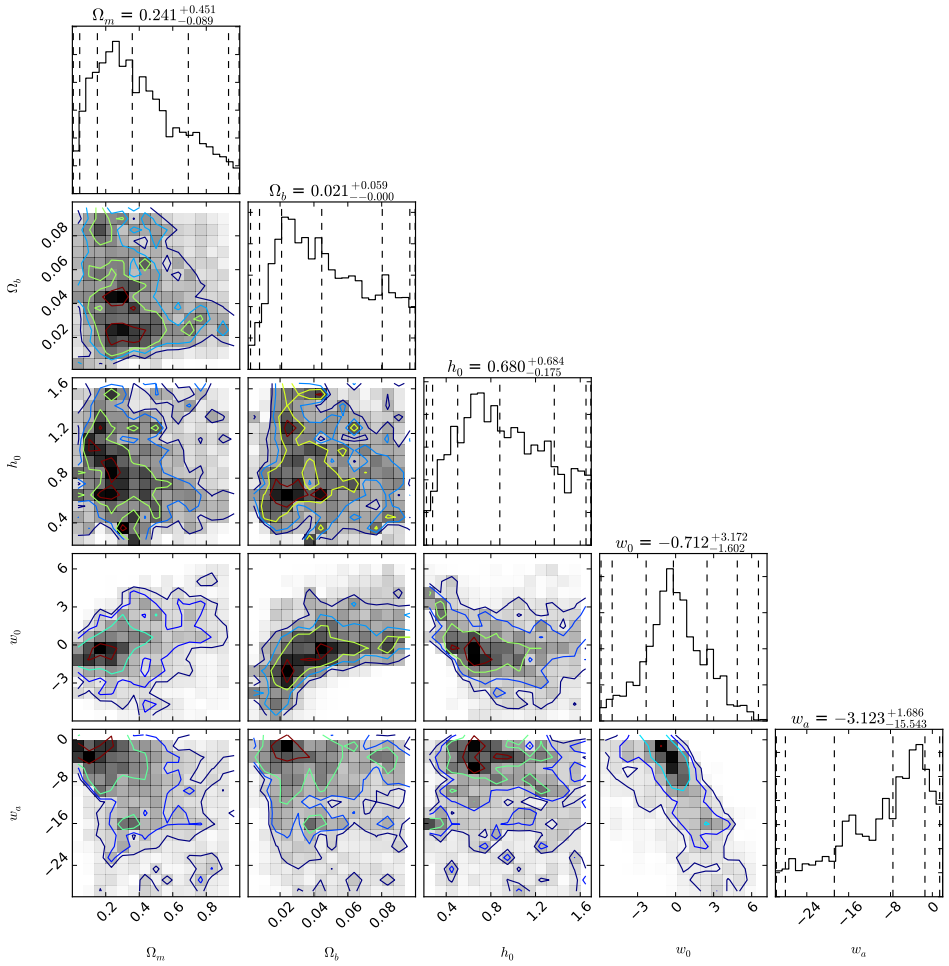
Covariance Matrix

Different redshift bins are not independent.

The correlation matrix for Aardvark is:



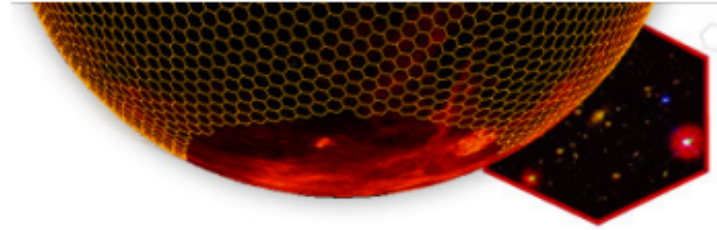
Cosmology - Aardvark



Ω_m	$0.241^{+0.451}_{-0.089}$	0.23
Ω_b	$0.021^{+0.059}_{-0.050}$	0.042
h_0	$0.680^{+0.684}_{-0.17}$	0.72
w_0	$-0.712^{+3.172}_{-1.602}$	-1
w_a	$-3.123^{+1.686}_{-15.543}$	0

We used MCMC code cosmoSIS. Credit: Joe Zuntz.

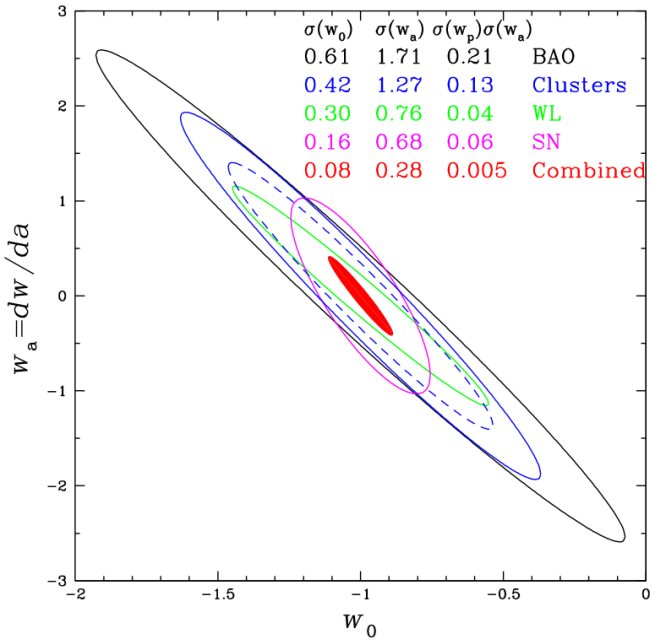
Conclusions



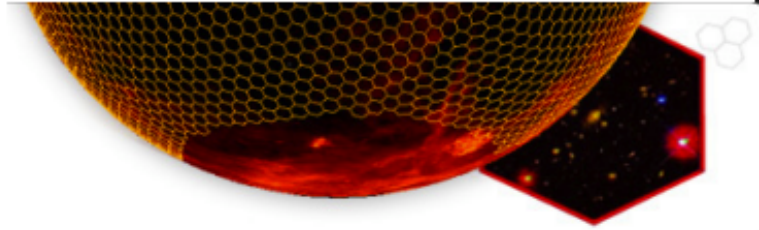
- Using the PLG method we have been able to recover the underlying cosmological parameters of one of the simulations using the position of the BAO peak only.
- We proved that this analysis method of BAO works for a scenario similar to the final DES data.
- We obtained the correct underlying cosmological parameters within 1-sigma.

Future work

- Apply the PLG method to DES data.
- The ΛCDM model is described by a group of parameters highly correlated, we will break degeneracies and improve the precision using other probes such as weak lensing, supernovae and cluster counts.



[Weller et al. 2006]



THANK YOU FOR YOUR ATTENTION