Baryon acoustic oscillations in thin redshift shells from BOSS DR12 and eBOSS DR16 galaxies

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Introduction

Currently, the measurements of H0 from determinations of the late and early universe give rise to the main tension in modern cosmology, which reaches values around 5σ [1]. This creates a place for model-independent analyses, as they can consistently investigate deviations from the standard model, even though this type of approach resulting in weaker constraints on parameters.

This work presents a set of 14 baryon acoustic oscillations (BAO) measurements in thin redshift shells with 3% precision that were obtained by analyzing BOSS DR12 and eBOSS DR16 galaxies in the redshift range $0.32 < z < 0.66$. Thanks to the use of thin shells, the analysis is carried out using just redshifts and angles so that the fiducial model is only introduced when considering the mock catalogs, necessary for the covariance matrix estimation and the pipeline validation. We compare our measurements, with and without supernova data, to the corresponding constraints from Planck 2018, finding good compatibility.

Methodology

The correlation function ξ(s) is related to BAO which defines a characteristic scale of distance. The **projected correlation function w(θ)**, measured in thin redshift shells, is our goal in this work since it does not deal with physical distance (no need to define a fiducial cosmology to analyze the data). we adopt the optimal estimator [2]

$$w(\theta) = \frac{DD(\theta) - 2DR(\theta) + RR(\theta)}{RR} \qquad (1)$$

The data analysis requires an accurate estimation of the covariance between w(θ) and w(θ′).We then use Eq. (1) to compute the angular correlation function for the 1000 mock catalogs and after the covariance matrix:

$$S_{\theta\theta'} = \frac{1}{N-1}\sum_{m=1}^{N}[w_m(\theta) - \bar{w}(\theta)][w_m(\theta') - \bar{w}(\theta')] \qquad (2)$$

Phenomenological Model:

$$w(\theta) = A + B\theta^{\nu} + Ce^{-\frac{(\theta-\theta_{mc})^2}{2\sigma^2}} \qquad (3)$$

The parameter with physical relevance is the center of gaussian function, which marks the biased BAO angular scale. (The parameter space is explored using MCMC method).

Projection Bias:

The w(θ) is calculated assuming all galaxies have the same redshift within each redshift bin. That means radial BAO scale is projected as well, creating a bias in the angular scale measument. This effect depends on the size of the redshift bin chosen. In this work we calculated this dependence to extract the bias from our measured.

Inference Bias:

To estimate how much bias is carried by the expression (3) we use it to recover the angular scale from 1000 Mock catalogs. We found it bias is approximated 3% from measured.

Further Bias:

Further bias, as pointed out by [3], can come from angular scale parametrization and redshift-space distortions, both contributing with biases about 1%.

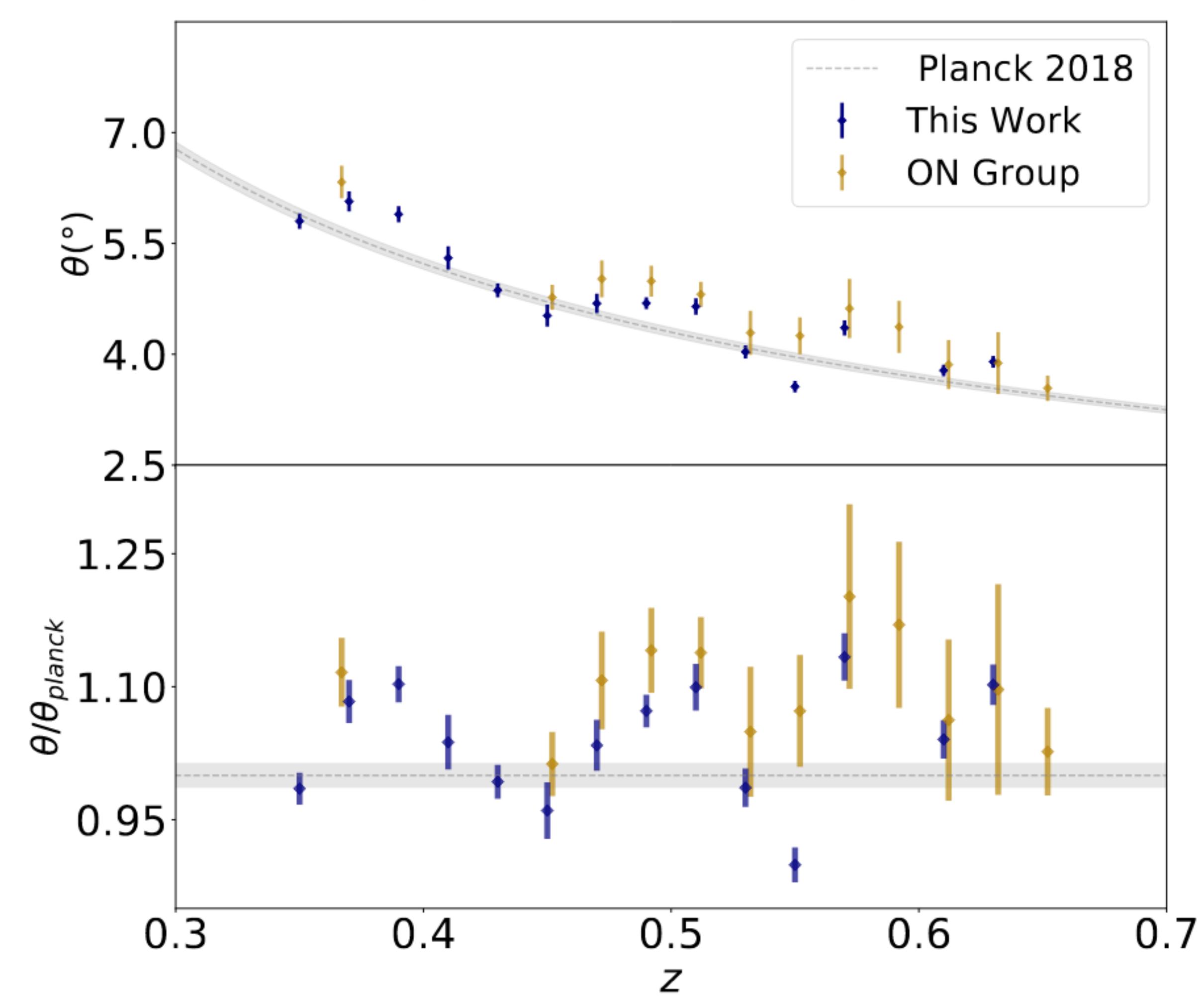
Results

BAO Angular Scale:

Tab. 1: This table summarizes our final BAO measurements from the luminous red galaxies of BOSS DR12 and eBOSS DR16

z	$\theta_{\rm BAO}$	$\sigma_{\rm stat}$	$\sigma_{\rm sys}$	$\sigma_{\rm BAO}$
0.35	5.80	0.063	0.085	0.106
0.37	6.07	0.103	0.089	0.136
0.39	5.89	0.067	0.086	0.109
0.41	5.30	0.137	0.078	0.157
0.43	4.87	0.060	0.071	0.093
0.45	4.52	0.134	0.066	0.150
0.47	4.69	0.111	0.069	0.131
0.49	4.69	0.041	0.069	0.080
0.51	4.65	0.088	0.068	0.112
0.53	4.03	0.067	0.059	0.089
0.55	3.56	0.058	0.052	0.078
0.57	4.36	0.081	0.064	0.103
0.61	3.78	0.056	0.055	0.079
0.63	3.90	0.057	0.057	0.080

Fig. 1: top panel: Redshift evolution of the BAO measurements of Table 1 as compared with the evolution as predicted by the ΛCDM model with the parameters estimated by Planck 2018 [4](Aghanim et al. 2018, Table 2, last column). The gray band corresponds to the 1σ uncertainty on rd*h. Bottom panel: as above, but normalized with respect to the ΛCDM/Planck 2018 expectation.



Cosmological Analysis:

We've used our new BAO measurements to constrain the flat ΛCDM model, whose prediction for θBAO is given by:

$$\theta_{\rm BAO}(z) = \frac{r_d}{(1+z)d_A(z)}$$

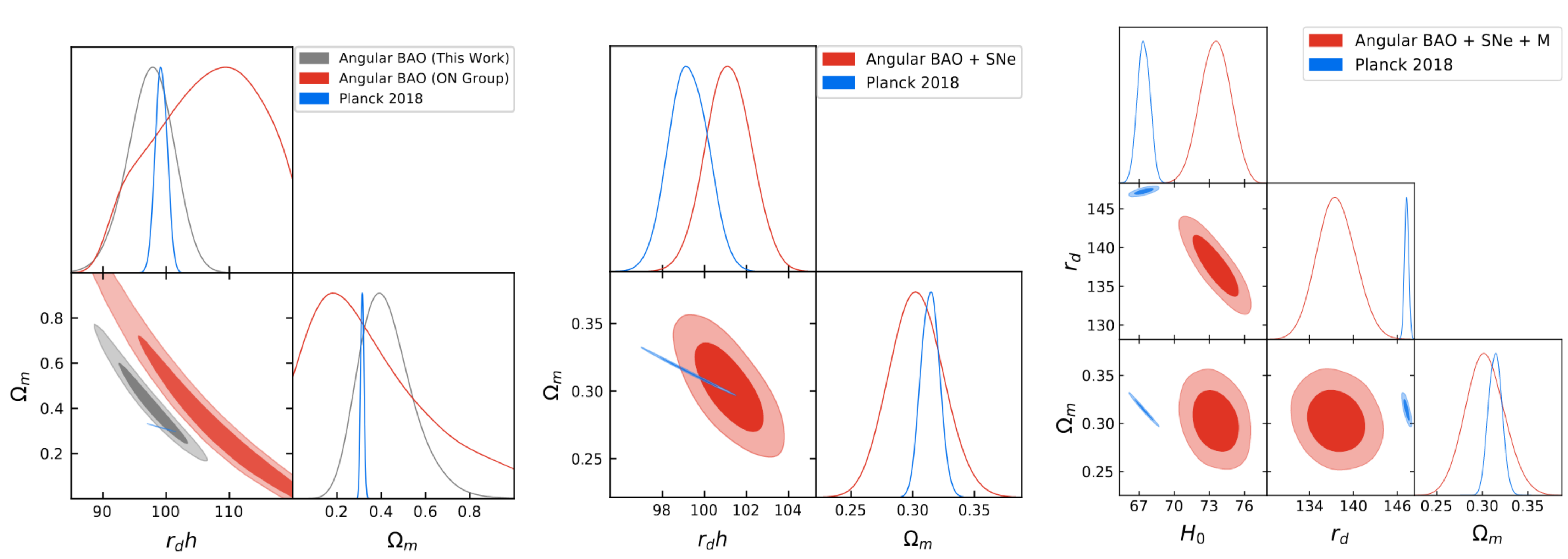


Fig. 2: Left panel: Cosmological Analysis made using only BAO data. Middle panel: Cosmological analysis combining the BAO data and the Suernovae data [5]. RIght panel: Cosmological analysis using the BAO and supernova data plus a gaussian prior (we call SH0ES prior) over the supernova's absolute magnitude (such prior can be used to recover the result for H0 local measured by SH0ES team [6]).

Analysis	$r_d h$ [Mpc]		Tension
Planck 2018	99.23 ± 0.94		-
Angular BAO	97.5 ± 3.6		0.5σ
Angular BAO+SNe	101.2 ± 1.1		1.3σ
	r_d [Mpc]	H_0 $\left[\frac{\rm Km/s}{\rm Mpc}\right]$	Tension
Planck 2018	147.21 ± 0.23	67.66 ± 0.42	-
Angular BAO+SNe+M	137.6 ± 2.6	73.5 ± 1.3	4.5σ

Tab. 2: We find good compatibility with Planck 2018, also when combining these angular BAO measurements with supernova data. Once we add the SH0ES prior on M we find a strong 4.5σ tension in the rd-H0 plane with respect to Planck 2018.

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