What is the best way to measure BAOs?

We use 50 very large volume N-body simulations to investigate the BAO signature in the two-point correlation function. We find that the correlation function is less affected by scale dependent effects than the power spectrum. We show that a model for the correlation function proposed by Crocce & Scoccimarro, based on renormalised perturbation theory (RPT), gives an essentially unbiased measurement of $w_{\rm DE}$. This means that information from the large scale shape of the correlation function, can be used to provide robust constraints on cosmological parameters, providing a better constraint than the more conservative approach required when using the power spectrum (i.e. which requires long wavelength shape information to be discarded).

A complete model of the large scale shape of $\xi(r)$ must take into account the effects of the non-linear growth of fluctuations, the scale dependence of the bias factor and redshift-space distortions. In order to assess the impact of these effects on the correlation function, we used an ensemble of 50 very large volume N-body simulations, the `L-BASICC II` [1,3]. We measured the correlation function of the dark matter and of different halo samples in both real and redshift-space in each of the realizations in the ensemble. The results are shown in Figure 1.

Based on RPT, [2] proposed a model to describe the effect of the mode coupling on $\xi(r)$ near to the acoustic scale. We tested this ansatz by comparing the results from our simulations against the non-linear correlation function given by

$$\xi_{\rm nl}(r) = \xi_{\rm lin}(r) \otimes \tilde{G}(r) + A_{\rm mc}\, \xi'_{\rm lin}\xi^{(1)}_{\rm lin}(r), \qquad (1)$$

where $\xi'_{\rm lin} = {\rm d}\,\xi_{\rm lin}/{\rm d}\,r$ and $\xi^{(1)}_{\rm lin}(r) \equiv \hat{r}\cdot\nabla^{-1}\xi_{\rm lin}(r)$. The function $\tilde{G}(r)$ is the Fourier transform of

$$G(k) \equiv \exp\left[-(k/\sqrt{2}k_\star)^2\right]. \qquad (2)$$

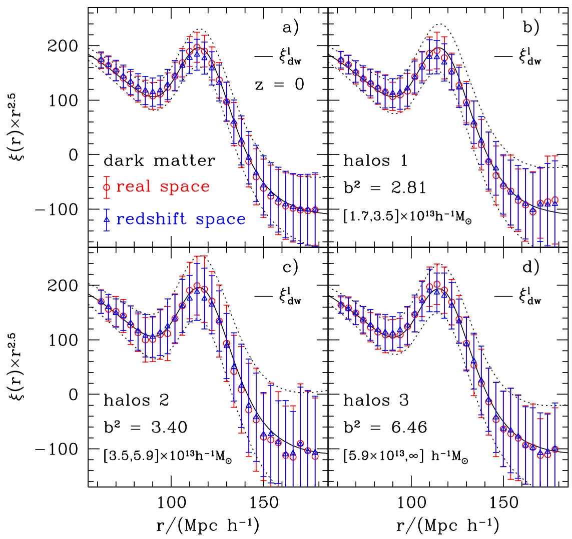

Figure 1. Mean correlation functions at $z = 0$ from our ensemble of simulations in real-space (circles) and redshift-space (triangles) for dark matter (panel (a)) and halos in samples 1, 2 and 3 (panels (b), (c) and (d)). The error bars show the variance from the estimates in the different realizations. To highlight the acoustic peak we show $\xi(r)\times r^{2.5}$. The results in redshift space are divided by the Kaiser (1987) boost factor. The results for the halo correlation functions were scaled by the bias factors shown in the annotations in each panel. The solid lines show the fits to the simulation data with the model of Eq.(1). The dotted lines show the estimates of the variance for each sample.

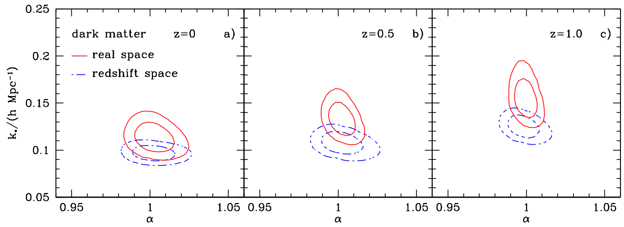

Figure 2. Constraints on α and $k_\star$ obtained using the mean real-space (solid lines) and redshift-space (dashed lines) dark matter correlation functions from the ensemble of simulations at redshift $z = 0$, 0.5 and 1 (panels (a), (b) and (c) respectively)

We assume that the values of all cosmological parameters are known, apart from $w_{\rm DE}$. In this case, the effect of a variation in $w_{\rm DE}$ can be represented by a rescaling of the distances by a 'stretch' factor $\alpha = \frac{r_{\rm true}}{r_{\rm app}}$.

We analyse the constraints on α using the model of Eq.(1), treating $k_\star$ and $A_{\rm mc}$ as free parameters. The results are shown in Fig. 2. The constraints of $k_\star = 0.115 \pm 0.009$ at $z = 0$ can be compared with the predictions of RPT [2] which gives $k_\star = 0.117\,h\,{\rm Mpc}^{-1}$.

To address the question of which two-point statistic is the more powerful for extracting the BAO, we repeated the power spectrum analysis carried out by [1]. These constraints are summarised in Table 1.

This test shows that the full large-scale shape of the correlation function can provide tighter constraints on $w_{\rm DE}$ than ones in which the scale of the acoustic oscillations is extracted from the power spectrum.

		Constraints on α	
Sample id	z	Fits to $\xi(r)$	Fits to $P(k)$
DM	0.0	1.003 ± 0.008	1.006 ± 0.008
	0.5	1.002 ± 0.005	1.002 ± 0.007
	1.0	1.000 ± 0.003	1.000 ± 0.006
Halos 1	0.0	1.002 ± 0.013	0.997 ± 0.019
	0.5	0.999 ± 0.012	1.004 ± 0.019
	1.0	1.003 ± 0.015	0.992 ± 0.020
Halos 2	0.0	1.004 ± 0.011	1.009 ± 0.020
	0.5	1.010 ± 0.016	0.972 ± 0.020
	1.0	1.009 ± 0.022	0.994 ± 0.027
Halos 3	0.0	1.003 ± 0.015	1.002 ± 0.015
	0.5	0.997 ± 0.018	1.009 ± 0.015
	1.0	1.010 ± 0.027	1.008 ± 0.023

Table 1. Comparison of the constraints on the stretch factor α obtained using the model of Eq.(1) for the correlation functions and by applying the fitting procedure of [1] to the real-space power spectra of the dark matter and the different halo samples. The first column gives the label of the sample. The second column gives the redshift output. Columns 4 and 5 give the obtained constraints on α.

[1] Angulo R., Baugh C.M., Frenk C.S., Lacey C.G., 2008, MNRAS, 383, 755
[2] Crocce M., Scoccimarro R., 2008, PRD, 77, 023533
[3] Sánchez A.G., Baugh C.M., Angulo R., MNRAS in press, arXiv:0804.0233

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