The BigBOSS Dark Energy Figure of Merit

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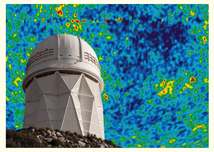


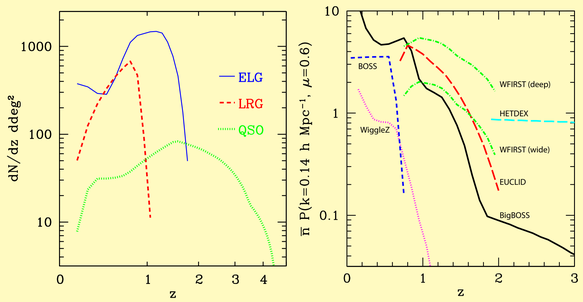
Abstract

BigBOSS will make a redshift-space map of 14000 sq. deg. of sky using galaxies out to $z \sim 1.6$ (covering ~ 50 cubic h^{-1}Gpc of volume) and quasars beyond that, producing baryon acoustic oscillation (BAO) distance measurements out to $z \sim 3.5$ (with the $z \gtrsim 2$ measurement dominated by the Lyman-α forest). These measurements will improve the Dark Energy Figure of Merit (FoM) by a factor ~ 3 beyond Stage III experiments, comparable to any planned BAO experiment (including those in space). A further factor of ~ 2 or more in FoM can be gained using the galaxy power spectrum beyond BAO, e.g., including redshift-space distortions and the Alcock-Paczynski test. We describe these projections and comparisons with other experiments.

Number densities and biases

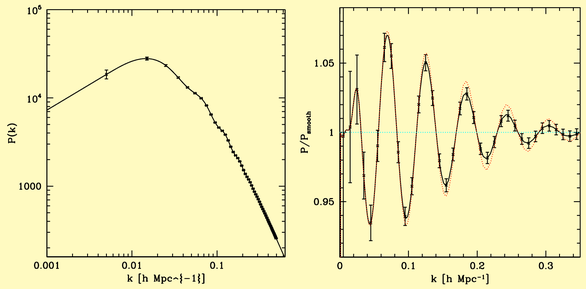
In addition to volume, the key numbers determining the constraining power of a large-scale structure (LSS) survey are the bias and number density of the LSS tracers.

The following figure shows (on the left) the number density of the three BigBOSS LSS tracers, Emission Line Galaxies (ELGs), Luminous Red Galaxies (LRGs), and Quasars (QSOs). On the right we show the typical signal power to noise power ratio for these tracers, $\bar{n}P$, assuming biases $b_{ELG}(z)D(z) = 0.84$, $b_{LRG}(z)D(z) = 1.7$, and $b_{QSO}(z)D(z) = 1.2$ (where $D(z)$ is the linear growth factor normalized to 1 at the present time). Several other existing or planned experiments are plotted for comparison.



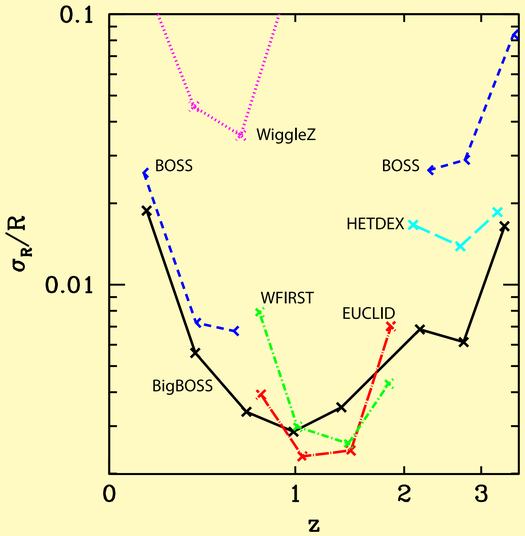
Power spectrum errors

BigBOSS will achieve very small errors on the power spectrum. The left panel here shows these errors plotted with the total power while the right has been divided by broadband power to isolate BAO – the scale of these wiggles is the standard ruler we will use to constrain Dark Energy. This example is for galaxies in the redshift range $0.5 < z < 0.9$.



BAO Distance Errors

We plot the projected BAO distance errors for different experiments using the error on the dilation factor R – the error on a proportional rescaling of both $H(z)$ and $D_A(z)$. The radial and transverse errors generally behave similarly so we use R here for compactness – we use H and D_A errors and their correlations for FoMs.



DETF Figures of Merit from BAO

With the equation of state of Dark Energy parameterized as $\frac{p(z)}{\rho(z)} \equiv w(z) = w_0 + w_a(1-a)$ (for a cosmological constant, $w = -1$), the Dark Energy Task Force Figure of Merit is defined to be proportional to the inverse of the area within the expected contours of constraint on w_0 and w_a. The Figure of Merit Science Working Group (Albrecht et al. 2009) further defined a set of "Stage III" experiments that we will use as baseline constraints, along with the Planck CMB satellite (WLIII for weak lensing, SNIII for supernovae – for BAOIII we use estimates of WiggleZ and HETDEX constraining power)

	no BOSS	BOSS	BigBOSS
no Lyman-α	0	11	125
+BAO III	12	34	132
+SNIII	27	49	163
+WLIII	43	83	201
with Ly-α		23	150
+BAO III		39	155
+SNIII		56	186
+WLIII		89	232

We see that BigBOSS represents a substantial improvement over Stage III. Furthermore, BigBOSS is roughly equivalent as a BAO experiment to the planned space mission EUCLID (or, similarly, WFIRST).

	BigBOSS	+BB LyaF	EUCLID
P+SIII	201	232	223

(Of course, EUCLID can also do weak lensing, which is not included here.)

Broadband Power FoMs

BAO constraints are only the most conservative possible way to use a redshift survey. There is much additional information in the full power spectrum, including redshift-space distortions and geometric distortions (Alcock-Paczynski effect). Depending on the maximum k to which nonlinearity can be effectively modeled, the achieved FoM can be much improved over BAO alone.

	P+III+BigBOSS
BigBOSS galaxy BAO	201
+Ly-α BAO	232
+gal P($k_{\rm max} = 0.15h{\rm Mpc}^{-1}$)	491
+gal P($k_{\rm max} = 0.30h{\rm Mpc}^{-1}$)	721

Discussion

- BigBOSS will make BAO measurements comparable to any planned experiment, including from space.
- BigBOSS will improve the DETF FoM by a factor of ~ 3 over Stage III using BAO alone, and a factor ~ 8 or more using broadband information.
- Additionally (not shown), BigBOSS will measure the modified gravity parameter γ to a factor ~ 4 better than Stage III (i.e., a factor ~ 16 in inverse variance FoM)
- BigBOSS will probe (also not shown) the spectrum and Gaussianity of the inflationary perturbation spectrum and curvature, beyond what can be done with Planck.

References

For further details and references, see Schlegel et al. (2011), arXiv:1106.1706.

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