

Analysis of the response of void BAO to systematic effects in the SDSS observations using mock datasets

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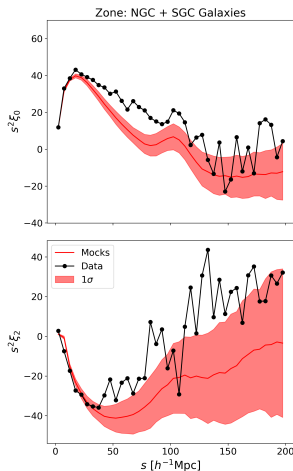
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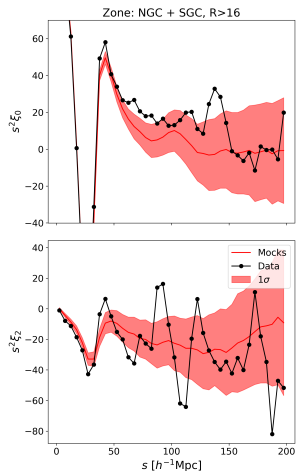
Introduction I

- The use of voids + matter ones $\Rightarrow \sim 10\%$ improvement of error & 20% survey size increase.
- Voids could be less sensitive to systematic effects than matter.
- We want to use mocks to check if there is a difference in the BAO peak shift due to systematical effects between matter tracers and voids.
- Systematics can greatly affect the measurement of the 2PCF in real data.
- Sign of the quadrupole in large-scales.

Introduction II



Galaxy 2PCF from eBOSS ELG sample.



Void 2PCF from eBOSS ELG sample

Voids I

Definition is controversial, we use a **geometrical** one.

Delaunay Triangulation \rightarrow Voids are circumspheres in the simplices with tracers as vertices.

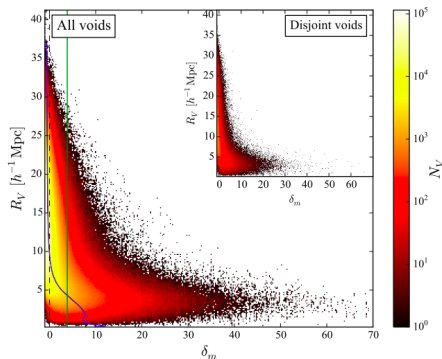
Small voids

- Radius cut: $R_c < 8 h^{-1}\text{Mpc}$
- Located in regions with high δ_{dm}
- Correlated with galaxy sample
- Are actually Dark Matter

Big voids

- Radius cut:
 $R_c > 15.5 h^{-1}\text{Mpc}$
- Located in regions with low δ_{dm}
- Anticorrelated with galaxy sample
- Are actually empty

Voids II



How do we know?

- Large voids are constrained to regions with low matter density.
- Small void population spans a wide range of densities.

Number of voids, N_V , as a function of Dark Matter density, δ_{dm} , and void radius, R_V . Taken from (Zhao et al., 2016)

Data I

We use 1000 **EZ mocks** Zhao and Chuang (2020).

- Displacement field from Zel'dovich
- PDF extraction from n-body simulation
- Halo position assignment

Table: Fiducial cosmology parameters used to produce the EZmocks used in this work.

Parameter	Value
Ω_m	0.307115
Ω_b	0.048206
h	0.6777
σ_8	0.8225
n_s	0.9611

Systematics: Fiber collisions I

- Objects too close in the sky ($r_{cp} < 62''$) can't be seen at the same time due to width of the fiber.
- One is measured by the plate. The other one(s) could still be measured by other plate.
- Define $TSR = \frac{\text{measured targets}}{\text{total number of targets}}$, per sector.
- Compensate this effect with $w_{cp} \approx TSR^{-1}$
 Actually $w_{cp} = \frac{\text{total number of targets}}{\text{measured targets}}$ but defined per **collision group**.

Systematics: Redshift Failures I

- Errors in the spectroscopic pipeline \Rightarrow $SSR < 1$.
- Two sources of error: Observational conditions & Position of fiber
- This is corrected by the weight

$$w_{noz} \equiv (SSR_{\text{obs}} SSR_{\text{pos}})^{-1}.$$

Systematics: Angular Photometric I

- Represented as HEALPIX maps containing different photometric parameters, p_i .
- Parameters are combined as

$$y^k = \epsilon + \sum_i c_i p_i^k$$

where the model weights, c_i are optimized (per chunk) such that $n_{\text{dat},k} \approx n_{\text{ran},k} y^k$, where k indicates the pixels.

- The photometric weights designed to partially correct for these effects are defined as

$$w_{\text{systot}} = (y^k)^{-1}.$$

Systematics: Normalization I

- Completeness weights are defined as:

$$w_{\text{comp}} = w_{\text{systot}} w_{\text{cp}} w_{\text{noz}}.$$

- Some normalization is done (on w_{systot} before w_{comp} and on w_{noz} after).
- Invalid objects are set $w_{\text{cp}}, w_{\text{noz}} = 0$.
- Only elements with $\text{SSR} \geq 0$, $z \in (0.6, 1.1)$ and completeness $> 50\%$ are selected.
- The dependence on $n(z)$ is corrected by

$$w_{\text{FKP}} \equiv \frac{1}{1 + n(z)P_0}; \quad P_0 = 4000 h^{-3} \text{Mpc}^3.$$

Systematics: Application I

- We compute $w_{\text{comp}}^{\text{ALLSYST}} = w_{\text{systot}} w_{\text{cp}} w_{\text{noz}} w_{\text{FKP}}$ and the effective number of tracers in each chunk

$$n_{\text{eff}} = \sum_{i=1}^{N_{\text{chunk}}} w_{\text{comp},i}^{\text{ALLSYST}},$$

where N_{chunk} is the number of tracers in the chunk considered.

- We then compute

$$w_{\text{comp}}^{\text{PARTIAL}} = w_{\text{FKP}} \prod_{s \in S'} w_s,$$

Systematics: Application II

where $\mathcal{S}' \subseteq \mathcal{S}$ is the subset of systematic effects to be considered and $\mathcal{S} = \{\text{systot}, \text{noz}, \text{cp}\}$. In this case we compute the new effective number of tracers

$$n'_{\text{eff}} = \sum_{i=1}^{N_{\text{chunk}}} w_{\text{comp},i}^{\text{PARTIAL}}.$$

- Objects in the catalog with $w_{\text{comp}}^{\text{PARTIAL}} = 0$ or $\text{veto} = 0$ (such as objects outside the survey area or masked by bright stars) are removed.
- We then normalize the completeness weights in each chunk by the corresponding $n_{\text{eff}}/n'_{\text{eff}}$ to keep the original effective number of tracers.

Catalog generation I

- Export catalogs with

RA, DEC, z , $w_{cp}w_{FKP}$, w_{cp} , w_{FKP} , $n(z)$

- Use DIVE to extract void catalogs with (we use $\Omega_m = 0.31$)

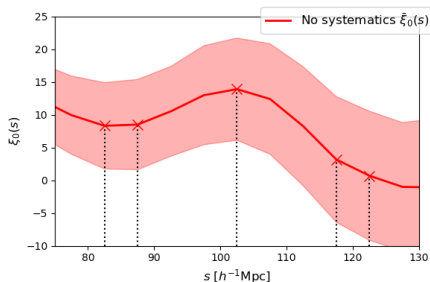
RA, DEC, z , R

- Mask void catalogs
- Create void randoms
 - Combine 100 void mocks
 - Divide into z bins
 - divide each bin in R bins
- Split “vertically” into RA, DEC | z , R .
- Shuffle one of the two halves.
- Recombine halves and all bins.
- Randomly choose 2700 000 with $R > R_c (= 15.5 h^{-1} \text{Mpc})$

Radius cut I

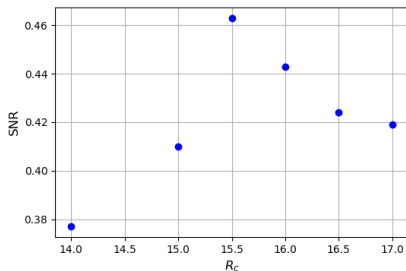
Analyze signal-to-noise ratio ($\text{SNR} \equiv \frac{\langle S \rangle}{\sigma_S}$) for 100 void mocks with different R_c . Use definition of signal, S , as in Liang, Zhao, Chuang, Kitaura, and Tao (2016).

$$S = \xi_0(s^{\text{BAO}}) - \frac{\xi_0(s_1^{\text{dl}}) + \xi_0(s_2^{\text{dl}}) + \xi_0(s_1^{\text{dr}}) + \xi_0(s_2^{\text{dr}})}{4} \quad (1)$$



$s_1^{\text{dl}} = 82.5$, $s_2^{\text{dl}} = 87.5$, $s_1^{\text{BAO}} = 102.5$,
 $s_1^{\text{dr}} = 117.5$ and $s_2^{\text{dr}} = 122.5 \, h^{-1}\text{Mpc}$
 respectively from left to right.

Radius cut II



SNR vs low radius cut R_c . Upper cut is always set to $50 h^{-1}\text{Mpc}$. Maximum SNR is obtained for $R_c = 15.5 h^{-1}\text{Mpc}$.

The BAO model I

We use the model in Zhao et al. (2018):

$$\xi_t(s) = \int \frac{k^2 dk}{2\pi^2} \frac{\sin ks}{ks} P_t(k) \exp(-k^2 a^2), \quad a = 1 h^{-1} \text{Mpc} \quad (2)$$

$$P_t(k) = \left\{ [P_{\text{lin}}(k) - P_{\text{nw}}(k)] \exp\left(\frac{-\Sigma_{\text{nl}}^2 k^2}{2}\right) + P_{\text{nw}}(k) \right\} \frac{P_{\text{t,nw}}(k)}{P_{\text{lin,nw}}(k)}, \quad (3)$$

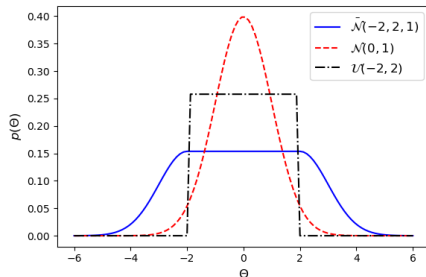
$$\xi_{\text{model}}(s) \equiv B^2 \xi_t(\alpha s) + A(s), \quad A(s) = \frac{a_1}{s^2} + \frac{a_2}{s} + a_3 \quad (4)$$

	Galaxies	Voids
$\frac{P_{\text{t,nw}}(k)}{P_{\text{lin,nw}}(k)}$	1	$1 + ck^2$

Parameter fitting I

Bayesian inference for parameter Θ :

$$\begin{aligned}
 p(\Theta|X) &= \frac{p(X|\Theta)p(\Theta)}{p(X)} \\
 &= \frac{\mathcal{L}(X|\Theta)p(\Theta)}{\mathcal{Z}},
 \end{aligned} \tag{5}$$



Examples of the different kinds of priors used in the fitting.

Parameter fitting II

Voids

$$p(\Sigma_{\text{nl}}) = \mathcal{U}(0, 20) \quad (6)$$

$$p(B) = \mathcal{N}(2, 0.15) \quad (7)$$

$$p(\alpha) = \mathcal{U}(0.8, 0.12) \quad (8)$$

$$p(c) = \tilde{\mathcal{N}}(-500, 1000, 100) \quad (9)$$

Galaxies

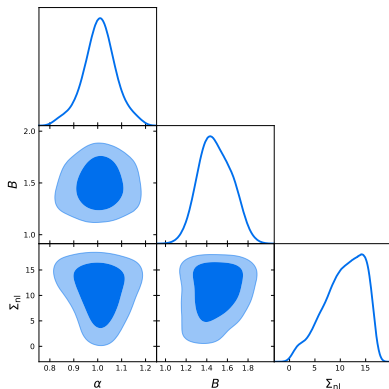
$$p(\Sigma_{\text{nl}}) = \mathcal{U}(5, 17) \quad (10)$$

$$p(B) = \tilde{\mathcal{N}}(1.4, 1.6, 0.12) \quad (11)$$

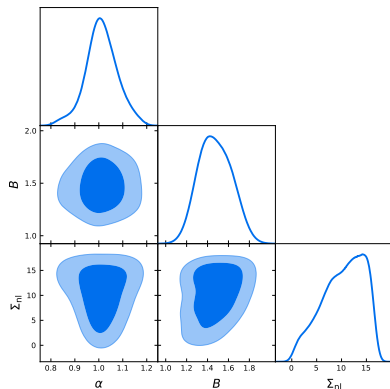
$$p(\alpha) = \mathcal{U}(0.8, 0.12) \quad (12)$$

Results: Mean 2PCF Galaxies I

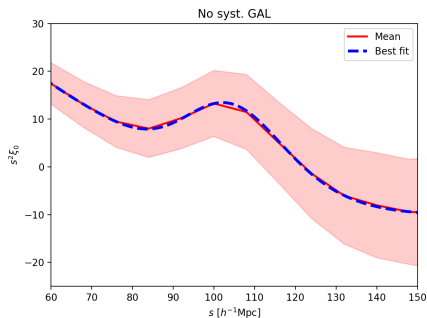
No systematics



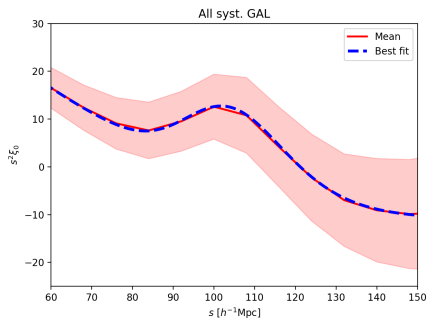
All systematics



Results: Mean 2PCF Galaxies II



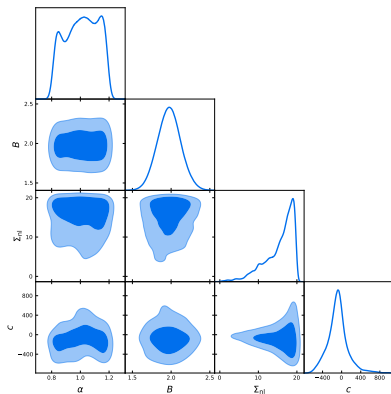
$$\chi^2_{\text{best}}/\text{dof} = 0.04$$



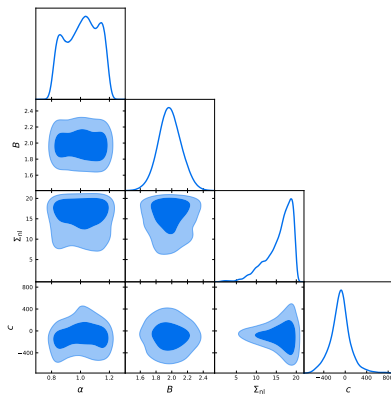
$$\chi^2_{\text{best}}/\text{dof} = 0.06$$

Results: Mean 2PCF Voids I

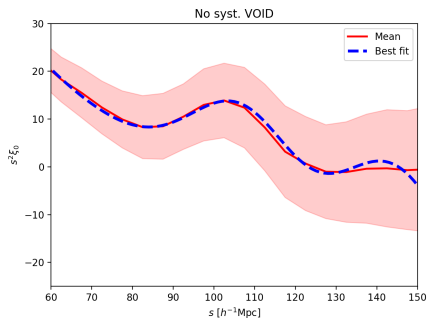
No systematics



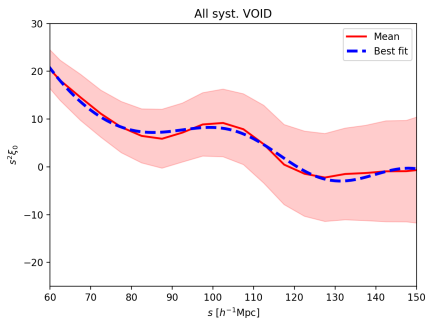
All systematics



Results: Mean 2PCF Voids II



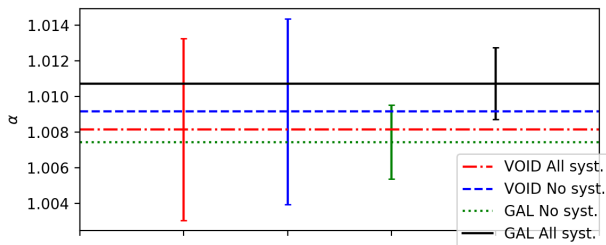
$$\chi^2_{\text{best}}/\text{dof} = 0.36$$



$$\chi^2_{\text{best}}/\text{dof} = 0.42$$

Results: Mean2PCF Comparison I

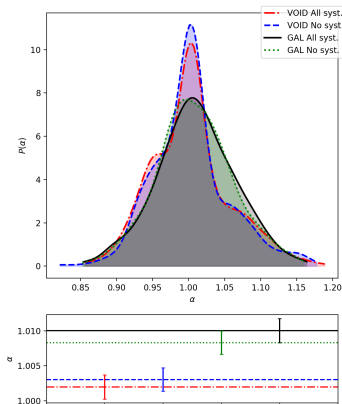
$$\alpha_{\text{all}} - \alpha_{\text{none}} \quad \begin{array}{cc} \text{Galaxies} & \text{Voids} \\ (3.34 \pm 2.89) \times 10^{-3} & (-9.9 \pm 72.9) \times 10^{-4} \end{array}$$



Fit results for the dilation parameter α when using the mean of the mocks.

Results: Individual 2PCF I

$$\alpha_{\text{all}} - \alpha_{\text{none}} \quad \begin{array}{cc} \text{Galaxies} & \text{Voids} \\ (1.89 \pm 2.39) \times 10^{-3} & (-1.07 \pm 2.39) \times 10^{-3} \end{array}$$



Fit results for the α parameter from fitting each of the mocks individually. Top panel shows the distributions obtained. Bottom panel shows the mean values and the (scaled) standard deviation as error.

Conclusions I

- The fit to the mean 2PCF shows a smaller shift due to systematics in the void case.
- The posteriors $p(\alpha|X)$ in the void case have large widths that make it difficult to be confident in the conclusion above.
- The individual fits show smaller uncertainty in the void measurement and still show the difference in the peak shift.
- Priors can be tweaked to get a better $p(\alpha|X)$ for voids but reduced χ^2 is already close to 1.
- Dataset is noisy as shown by the low SNR
- The analysis should be repeated with other tracers with better SNR (e.g. LRG)

References I

- Liang, Y., Zhao, C., Chuang, C.-H., Kitaura, F.-S., & Tao, C. (2016). Measuring baryon acoustic oscillations from the clustering of voids. *Monthly Notices of the Royal Astronomical Society*, 459(4), 4020–4028. doi:10.1093/mnras/stw884
- Zhao, C. & Chuang, C.-h. (2020). The SDSS-IV Extended Baryon Oscillation Spectroscopic Survey : mock catalogues for the eBOSS final Data Release. *in preparation*, 10(December 2019), 1–10.
- Zhao, C., Chuang, C.-h., Kitaura, F.-s., Liang, Y., Pellejero-Ibanez, M., Tao, C., ... Yepes, G. (2018). Improving baryon acoustic oscillation measurement with the combination of cosmic voids and galaxies. 19(February), 1–19. arXiv: 1802.03990. Retrieved from <http://arxiv.org/abs/1802.03990>

References II

Zhao, C., Tao, C., Liang, Y., Kitaura, F.-S., & Chuang, C.-H. (2016). DIVE in the cosmic web: voids with Delaunay triangulation from discrete matter tracer distributions. *Monthly Notices of the Royal Astronomical Society*, 459(3), 2670–2680.
[doi:10.1093/mnras/stw660](https://doi.org/10.1093/mnras/stw660)