Optimising primordial non-Gaussianity measurements from galaxy surveys
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Outline

- Overview: extended BOSS survey (eBOSS)
- Constraining primordial non-Gaussianity with LSS
- Redshift weighting techniques
- Accounting for systematics effects
eBOSS: First results

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147,000 quasars from the extended Baryon Oscillation Spectroscopic Survey (eBOSS)

Good agreement with Planck LCDM
Primordial Non-Gaussianity

Simple form: Local type

\[ \Phi(x) = \phi(x) + f_{NL}^{loc}(\phi^2(x) - \langle \phi^2(x) \rangle) \]

Induces scale dependent halo bias due to “mode coupling”

e.g. de Putter
Primordial non-Gaussianity from LSS

Scale dependent halo bias

\[ b_{\text{total}} = b + \Delta b \]

\[ \Delta b(k) \propto \frac{f_{NL}}{k^2} \]

Very sensitive at large scales

e.g. Dalal et. al 2008, Slosar et. al 2008
Constraints from LSS

Current, e.g.:

Ross et al. (2012): SDSS DR9 BOSS data

\[-45 < f_{NL}^{\text{local}} < 195\]

Giannantonio et al. (2014): Correlations between CMB lensing and large-scale structure

\[f_{NL} = 12 \pm 21(1\sigma)\]

Upcoming, e.g.:

DESI, Euclid: error on fNL ~ few

Further improvement with SPHEREx: error on fNL~1
Optimising LSS analysis

**Idea:** No binning in redshift

Apply redshift weights

Redshift weighted power spectrum

$z_1, z_2, z_3, z_4, z_5, z_6, \ldots$
Redshift Weighting

**Idea:** No binning in redshift

**Motivation:**
- Fisher predictions ~20% better than actual results
- Reduce edge effects due to binning
- Decrease computational effort for large data sets
- Splitting the survey volume decreases S/N at large scales at which non-Gaussianity has the biggest impact
FKP weights


\[ w_{\text{FKP}}(z) = \frac{1}{1 + n(z)P_0} \]

Inverse variance weight

Balances shot noise and cosmic variance

Improves signal to noise of 2-point statistics
“Sweet Spot”: Theory vs. Statistics

FKP: Balance comic variance and shot noise

Weights optimally balance statistical uncertainty and underlying redshift evolution of the theory
Redshift weights for BAO

- Redshift weights improve BAO constraints
- Redshift weights do NOT bias the results
Minimise Fisher information

\[ F_{ij} \equiv \left\langle \frac{\partial^2 \mathcal{L}}{\partial \theta_i \partial \theta_j} \right\rangle \quad \mathcal{L} \text{ -- Likelihood} \]

\[ \theta_i, \theta_j \text{ -- parameters} \]

Redshift weights:

\[ \mathbf{w}^T = C^{-1} \mu_{i, \cdot} \]

Depends on the tracer

More total weight is given to galaxies at high redshifts

\[ b = 0.84/D(z) \]

\[ b = 0.53 + 0.29(1 + z)^2 \]
Redshift weighted power spectrum

\[ P_{l,w}(k) \equiv \frac{1}{N_i} \int dW(z) w_{l,i}(z) P_l(k, z) \]

Feldman, Kaiser & Peacock:
\[ dW \equiv C^{-1} = \left( \frac{\bar{n}}{\bar{n}P + 1} \right)^2 dV \]

Normalisation:
\[ N_i = \int w_i \, dW \]

Forecasts

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“Sweet Spot”: Theory vs. Statistics

Statistical noise on the weighted power spectrum is larger

But: It is more sensitive to $f_{NL}$, i.e. more capable to constrain PNG

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Measurement improvement

30-40% improvement for eBOSS

Depends on
- Redshift range
- Bias evolution

+ Improved constraints
+ Computationally more feasible for large data sets

- Weights are model dependent
- Loss of generality

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Problem: Systematics

Systematic effects are strongly impacting large scales

not accounting for systematics

with systematic treatment
eBOSS systematics: ‘Attack approach’

Systematics can have scale dependent effects on large scales.

linear fit ~ 1/w
Summary

- First eBOSS results are out!
- Non-Gaussianity can be constrained using the scale dependent halo bias
- Redshift weighting technique: Apply weights to take the underlying theory into consideration
- Systematic effects need to be studied carefully for fNL measurements

Thank you!
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Non-Gaussianity measurement from eBOSS

Redshift space distortion measurement from eBOSS using redshift weights (Rossana Ruggeri et. al)

Accessing systematic effects using mode projection (Benedict Kalus et. al)