Systematics: Experience from BOSS
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Anderson et al. arXiv:1203.6904

Manera et al. arXiv:1203.6609
Reid et al. arXiv:1203.6641
Ross et al. arXiv:1203.6499
Sanchez et al. arXiv:1203.6616
Tojeiro et al. arXiv:1203.6565

Friday, 20 April 2012
The Matter at Hand
Outline

- BOSS data samples
  - photoz and specz
- Observational systematics
  - Corrections
- $f_{NL}$ measurements
BOSS-trained SDSS DR8 Photozs

- Used over 100,000 BOSS spectra
- Over 1,000,000 photozs over 10,000 sq degrees

SDSS DR9 BOSS Specz ‘CMASS’ Sample

- Targeted 1 million galaxies
- 8600 sq degrees of NGC
- 3100 sq degrees of SGC
- DR9 footprint 3345 sq. deg
- 21% in Southern galactic cap
- 270,000+ redshifts 0.43<z<0.7
- Redshift completeness >98%
- Public July 2012
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$z_{\text{eff}}$=0.57
Observational Systematics

- Object classification
  - Star/galaxy/quasar
  - Use probabilities

- Galactic foregrounds
  - Stars, Galactic Extinction

- Observing conditions
  - Seeing, Sky Background, Airmass

- Photometric offsets, varying dust law?
  - See Schlafly et al. (2011a,b)

- Obtaining redshifts
Stars

- \(3\%\) stellar contamination \(\rightarrow\) \(n_{\text{CMG}}\) should increase with \(n_{\text{star}}\)
- Opposite is observed
- “removing” stellar contamination \(\rightarrow\) huge anti-correlation
- NOT observed in previous SDSS data releases
Stars

- ~3% stellar contamination $\Rightarrow$ $n_{CMG}$ should increase with $n_{\text{star}}$
- Opposite is observed
- “removing” stellar contamination $\Rightarrow$ huge anti-correlation
- NOT observed in previous SDSS data releases
Stars Occult Area

Galaxies around stars $17.5 < i < 19.9$
(23 million stars)
Correcting for Stars
General Solution

- If you can make a map
- 1) Assume intrinsic cross-correlations are 0, subtract measured contribution
- 2) Assume intrinsic no local relationship, weight appropriately
Corrections with Cross-correlations

\[ \delta_g^o = \delta_g^t + \sum_i \epsilon_i \delta_i. \]

\[ w(\theta) = \langle \delta_i \delta_j \Theta_{i,j}(\theta) \rangle \]

Assume true cross-correlation = 0

\[ w_g^t(\theta) = w_g^o(\theta) - \sum_i \epsilon_i^2 w_i(\theta) - \sum_{i,j > i} 2\epsilon_i \epsilon_j w_{i,j}(\theta) \]

\[ w_{g,i}^o = \sum_j \epsilon_j w_{i,j}(\theta) \]
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\[ w_{g,i}^o = \sum_j \epsilon_j w_{i,j}(\theta) \]

\[ A = w_{g,sys}/w_{sys} \]

\[ C = A^2 w_{sys} \sim (w_{g,sys}^2/w_{sys}) \]
Auto-/-cross-correlations

Correction

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For photoz shells:

- **Fit for bias with basic \(\Lambda\)CDM model**
- **With corrections:** \(\chi^2/d.o.f = 0.79, 1.8, 0.99, 1.0\)
- **Without corrections:** \(\chi^2/d.o.f = 0.99, 3.9, 7.0, 6.4\)
• Again went through all potential systematics
• Most important: Correct for presence of stars via weights linear fit to $n_g(n_{\text{star}})$ relationship
• Extensive test on mocks: indicate unbiased and $\sim 10\%$ uncertainty on size of correction
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Clustering Estimators

No corrections
\( \Delta \text{South} \)
\( C_{\text{star,sky}} \)
\(-A_{\text{star}} C_{\text{sky}} \)
Weights

\( \frac{P(k)}{h^{-3}\text{Mpc}^3} \)

\( \log_{10} \frac{P(k)}{P(k_{\text{smooth}})} \)

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April 20th, 2012

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f_{NL} from P(k)

- Using P(k)

&Delta;b_{NG}(k) \propto f_{NL} \frac{3(b_{halo} - 1) \Omega_m \delta_c}{k^2 T(k) D(z)} \left( \frac{H_o}{c} \right)^2

- (11 deg of freedom)

- window quite important
$f_{NL}$ from $P(k)$

- Using $P(k)$
  
  \[ \Delta b_{NG}(k) \propto f_{NL} \frac{3(b_{halo} - 1) \Omega_m \delta_c}{k^2 T(k) D(z)} \left( \frac{H_o}{c} \right)^2 \]

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$f_{NL} \text{ from } P(k)$

- Using $P(k)$

$$\Delta b_{NG}(k) \propto f_{NL} \frac{3(b_{halo} - 1)\Omega_m\delta_c}{k^2 T(k) D(z)} \left(\frac{H_0}{c}\right)^2$$

- (11 deg of freedom)

- window quite important
Comparison of Estimators

- photoz doing significantly better than spec
- (spec has 1/3 angular footprint)
Conclusions

• (faint) foreground stars present challenge for all forthcoming surveys

• Systematic effect pretty degenerate with fNL

• ...but utilizing all of the information, robust constraints can be obtained

• (BAO position appear robust to observational systematics)
Model Correlation Functions

- redshift space correlation function (Halofit w/ linear RSD)

- \(w(\theta)\), project over \(n(z)\)

\[
w(\theta) = \int dz_1 \int dz_2 n(z_1)n(z_2) \xi_s(\mu, r_{ev}(\theta, z_1, z_2))
\]

\[
r_{ev}(\theta, z_1, z_2) = \sqrt{\chi^2(z_1) + \chi^2(z_2) - 2\chi(z_1)\chi(z_2)\cos\theta}
\]

\[
\mu = (\chi(z_1) - \chi(z_2))/r_{ev}
\]

Ashley J Ross  LBNL  April 1st, 2011
Redshift Space Distortions (RSD)

- Intrinsic velocities of galaxies imply redshift space is distorted from real-space
- Small scales - finger of God effect
- Large scales - infall onto clusters

Ashley J Ross  
DAMTP  
May 9th, 2011
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Redshift Space Distortions (RSD)
Real/Redshift Space Clustering
Real/Redshift Space Clustering

Redshift Space

Cabré & Gaztañaga (2008)
Redshift Space Clustering

• Large scale distortions can be modeled with linear theory:

\[ P(k, \mu) = (1 + f \mu^2)^2 P(k) \]
\[ \mu = \cos(\theta); f = \frac{\text{dln}(D)}{\text{dln}(a)} \sim \Omega_{\text{matter}}^{\gamma} \]

• GR predicts \( \gamma = 0.557 \)
Redshift Space Clustering

Large scale distortions can be modeled with linear theory:

\[ \gamma = 0.557 \]

\[ P(k, \mu) = \frac{1 + f\mu}{2} P(k) \]

\[ \mu = \cos(\theta) \]

\[ f = \frac{d \ln(D)}{d \ln(a)} \sim \Omega_\gamma \]

Blake et al. (2010)
\[ \sigma_{8,\text{mass}}(z) = \sigma_{8,\text{mass}}(0) D(z) \]

\[ f(z) = \frac{d \ln(D)}{d \ln(a)} \]

- Black line: \( w = -1 \)
- Red line: \( w = -1.2 \)
- Blue line: \( w = -0.8 \)
RSD with Photozs?

• Projections for Dark Energy Survey

Ross et al. 2011
Measure $f\sigma_8$ with DES?

Ross et al. 2011

assuming

$\Delta z = \sigma_z = 0.03(1+z)$
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Redshift Space Distortions (RSD)

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CfA2 First 8 Slices
8.5 ≤ δ < 42.5
< m_g < 16.5
Redshift Space Distortions (RSD)

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Redshift Space Distortions (RSD)

- Intrinsic velocities of galaxies imply redshift space is distorted from real-space.
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Redshift Space Clustering

\[ P(k, \mu) = (1 + \beta \mu^2)^2 P(k) \]

\[ \mu = \cos \theta; \quad \beta = f/b; \quad f = \frac{\text{dln}(D)}{\text{dln}(a)} \sim \Omega_m(z)^{0.557} \]
$\sigma_{8,\text{mass}}(z) = \sigma_{8,\text{mass}}(0)D(z)$

$f(z) = \frac{d\ln(D)}{d\ln(a)}$

- $w = -1$
- $w = -1.2$
- $w = -0.8$
Optimal Galaxy Sample?

Bias, redshift error, and median redshift are important factors

- Assumes 10 million galaxies per $\Delta z = 0.066 (1+z)$
- $1/8^{th}$ sky cover

$\bar{z} = 0.5$

$\sigma_z = 0.05(1+z)$

$b = 1.5$

$b = 1.2$

$b=1, \sigma_z=0.03(1+z), \bar{z}=1$
Combined Constraints

Constant offset from $\Lambda CDM$

$$\Delta (f(z)\sigma_8(z)) = \frac{1}{\sqrt{\sum_{i,j} C_{i,j}^{-1}}}$$

DES should be able to detect 10% deviation in $f(z)$ from $\Lambda CDM$
Combining 2nd and 3rd-order clustering

- Produces tighter cosmological constraints
- $\bar{\omega}_N$ easy to calculate with photometric data
- Reminder:

\[
\bar{\omega}_N(\theta) = \langle \delta^N \rangle_c \quad s_N(\theta) = \frac{\bar{\omega}_N}{\bar{\omega}_2 - 1}
\]
Measuring $\sigma_8$

- $\sigma_8$: rms mass fluctuation at $8 \, h^{-1} \, \text{Mpc}$
- $\langle \delta^2_{DM} \rangle \propto \sigma_8^2$ so $b_1 \propto 1/\sigma_8$
- This makes it nuisance parameter for 2-point measurements
- Adding $s_3$:
  - Measure $s_3$ for galaxies, determine $c_2(\sigma_8)$
  - Turn $\delta_g$ to $\delta_{DM}$ with assumed $b_1$ and $b_2$, measure corrected $\mathcal{W}_2$, match to model $\mathcal{W}_{2,DM}$, yields separate $c_2(\sigma_8)$
SDSS LRG Catalog

- SDSS DR5 LRGs with MegaZ-LRG color cuts (Collister et al. 2007) and ANNz for photozs and star/galaxy separation
- Over 1.6 million LRGs with $0.4 < z < 0.7$ and median redshift of 0.52
- Split into three distinct redshift ranges with median redshifts of 0.47, 0.53, and 0.61
LRG Results

- Measured $\sigma_8 = 0.78 \pm 0.08$, $0.80 \pm 0.09$, and $0.80 \pm 0.09$
- Combine for $\sigma_8 = 0.79 \pm 0.05$
- Find $b_1 = 1.47 \pm 0.09$, $1.65 \pm 0.09$, $1.80 \pm 0.10$
- $c_2 = 0.09 \pm 0.04$, $0.09 \pm 0.05$, $0.09 \pm 0.03$
LRG Results

Ross et al. (2008)

$0.5 < z < 0.57$

$0.4 < z < 0.5$

$0.57 < z < 0.7$

$0.5 < z < 0.57$

\[ \sigma \]

\[ S3 \]

\[ \sigma \]

\[ S3 \]

\[ \sigma \]

\[ S3 \]

\[ corrected \]

\[ \sigma \]

\[ S3 \]

\[ \sigma \]

\[ S3 \]

\[ \sigma \]

\[ S3 \]
Testing on Millennium Simulation

- $M_r < -23$ and $B - R > 1.4$
  from Blaizot et al. (2005)
- Found $\sigma_8 = 0.898 \pm 0.062$
- (Input is $\sigma_8 = 0.9$)