The Clustering of the SDSS DR7 Main Galaxy Sample I: A 4 percent Distance Measure at z = 0.15

https://arxiv.org/abs/1409.3242

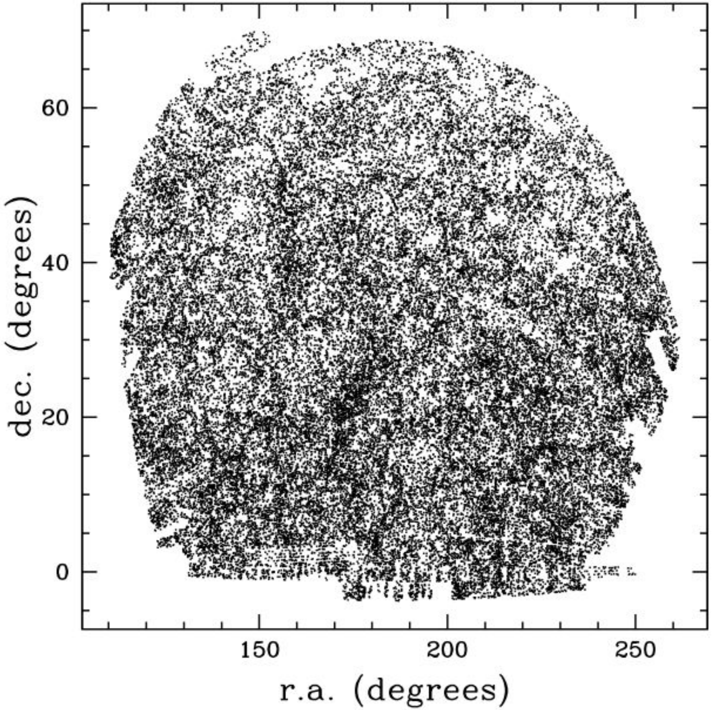
ABSTRACT

- Sample of spectroscopically identified galaxies with $z < 0.2$ from the SDSS - DR7 covering 6813 deg^2
- 1000 mock galaxy catalogs
- Estimate of the gravitational potential to “reconstruct” the linear density fluctuations, enhancing the BAO signal in the measured correlation function and power spectrum
- $D_V (z_{eff} = 0.15) = (664 \pm 25)(r_d / r_{d,fid})$ Mpc : better than 4% distance measurement
- Combining with other BAO measurements provides a 15% improvement in the determination of ω and H_0

INTRODUCTION

- Measurements of the cosmological expansion rate → understand its observed acceleration at low z
- Colour, magnitude and redshift cuts to produce a cosmic-variance limited sample with $z < 0.2$
- Simulate mock galaxy catalogs to test the methods and provide covariance matrices
- Fiducial cosmology based on the best-fit ΛCDM model and consistent with CMB data: $\Omega_m = 0.31$, $\Omega_b = 0.048$, $h = 0.67$, $\sigma_8 = 0.83$, $n_s = 0.96$, and $\Omega_v = 0$

DATA



→ Angular positions of the galaxy sample

- Further cuts based on colour, magnitude, and redshift to produce the MGS catalog
    - Sample of galaxies with $z < 0.2$
    - Reliably simulate the clustering of the galaxies in the sample
    - Minimize the uncertainty of $P(k)$
- Resulting sample contains 63163 galaxies

ANALYSIS

↳Calculating Clustering Statistics

Calculate the correlation function as a function of RSD *s* and the cosine of the angle to the line-of-sight *μ*:

$$\xi(s,\mu) = \frac{DD(s,\mu) - 2DR(s,\mu) + RR(s,\mu)}{RR(s,\mu)}$$

- D: galaxy sample
- R: uniform random sample that simulates the selection function of the galaxies
- DD(s, μ): number of pairs of galaxies with separation *s* and orientation *μ*

ANALYSIS

↳Reconstruction

- Galaxy map to redistribute the galaxies into a spatial configuration that more closely reproduces their positions and removes the effect of RSD
- Reconstructed ξ:

$$\xi(s, \mu) = \frac{DD(s, \mu) - 2DS(s, \mu) + SS(s, \mu)}{RR(s, \mu)}$$

  - S: shifted random field
- P(k) is calculated using the shifted random field.

ANALYSIS

↳Measuring BAO Positions

- Measurements of the dilation factor α can be related to physical distances via:

$$\alpha = \frac{D_V(z)\, r_d^{fid}}{D_V^{fid}(z)\, r_d}$$

$$D_V(z) = \left[cz\,(1+z)^2 D_A^2(z)\, H^{-1}(z)\right]^{1/3}$$

$$D_z^{fid}(z) = 638.95\ \mathrm{Mpc}$$

$$\mathrm{r}_d^{fid} = 148.69\ \mathrm{Mpc}$$

- r_d: sound horizon at the baryon drag epoch
- $D_A(z)$: angular diameter distance
- $H(z)$: Hubble parameter

ANALYSIS

↳Covariance

$$\tilde{C}(X_i, Y_j) = \frac{1}{N_{mocks} - 1} \sum_{m=1}^{N_{mocks}} (X_{i,m} - \overline{X}_i)(Y_{i,m} - \overline{Y}_i)$$

→ Estimated covariance between statistic X in measurement bin ***i*** and statistic Y in measurement bin ***j***

(m: different realisation of the sample)

$$C^{-1} = \frac{N_{mocks} - N_{bins} - 2}{N_{mocks} - 1} \tilde{C}^{-1}$$

→ $N_{mocks} = 1000$; N_{bins} will change depending on the test performed

MOCK SAMPLES

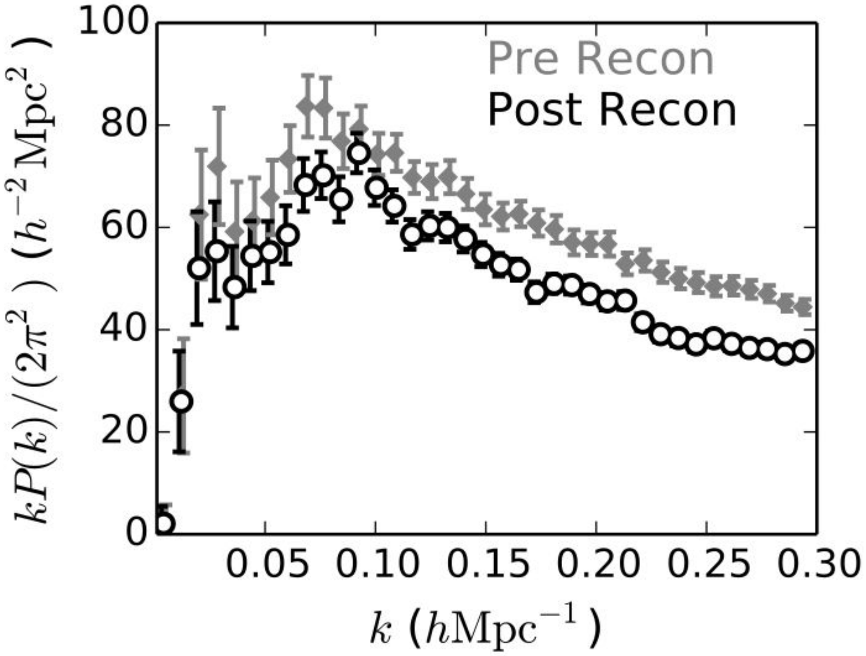
↳Testing BAO measurements on mocks

1. Fit the mean of the mock samples using the covariance matrix:
   - Pre-reconstruction: $P(k) \rightarrow \alpha = 0.998 \pm 0.080$; $\xi(s) \rightarrow \alpha = 1.005 \pm 0.095$
   - Post-reconstruction: $P(k) \rightarrow \alpha = 0.998 \pm 0.044$; $\xi(s) \rightarrow \alpha = 0.998 \pm 0.048$
2. Combine results across bin centres:
   - $P(k)$: 5 bins centres; correlation between 0.98 and 0.99
   - $\xi(s)$: 4 bins centres; correlation between 0.91 and 0.95

   → combined $P(k)$ and $\xi(s)$: 0.97
3. BAO measurements to constrain cosmological parameters: use the full likelihood distribution

RESULTS

↳Distance Scale Measurement

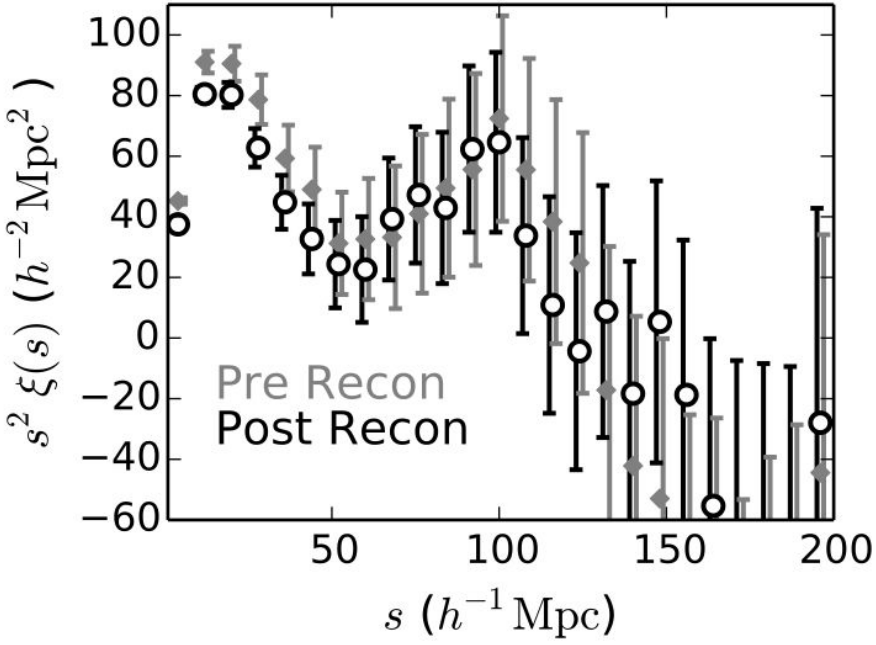


→ Measured power spectrum P(k)

- Reconstruction induces a decrease in the clustering amplitude due to the removal of large-scale RSD and improves the uncertainty

RESULTS

↳Distance Scale Measurement



→ Measured correlation function ξ(s)

- Reconstruction sharpens the BAO feature and improves the uncertainty

RESULTS

↳Distance Scale Measurement

- Detections of the BAO signal for the reconstructed data using both P(k) and ξ(s)
- Combine these data to obtain the consensus measurement of $\alpha = 1.041 \pm 0.037$ by taking the mean of the combined P(k) and ξ(s) $\Delta\chi^2$
- Measured BAO positions are consistent with those observed in the pre-reconstruction clustering measurements
- Robustness checks reveal no potential systematic effect that would bias ξ(s) and P(k)

COSMOLOGICAL INTERPRETATION

↳BAO Distance Ladder and Cosmological Constraints

- BAO distance measurements are consistent with each other and with the ΛCDM prediction
- Combine 6dFGS ($z = 0.11$) and BOSS ($z = 0.32$ and $z = 0.57$) with MGS ($z = 0.15$) to obtain cosmological constraints
- Volume of MGS overlaps slightly with 6dFGS but the covariance is negligible:
  - 6dFGS footprint has less than 3 percent overlap with MGS
  - Redshift distributions are significantly different
- Footprint of MGS overlaps with the footprint of the BOSS sample and is also negligible:
  - Volume overlap is 3 percent and the correlation is less than 0.03

CONCLUSION

- Reconstruction improves the precision of the BAO measurement and provides robust detection
- Measurements are combined to obtain the distance value $D_V(z_{eff} = 0.15) = (664 \pm 25)(r_d / r_{d,fid})$ Mpc
- The distance scale measurement can be combined with other BAO distance scale measurements to improve the precision of cosmological constraints
  - Decreases the derived value of H_0 when combining CMB (Planck) and BAO data
  - Increases the tension between direct H_0 measurements and CMB+BAO derived constraints
  - For dark energy constraints, improves the precision on the equation of state of dark energy by 15 per cent, to $\omega_0 = -1.010 \pm -0.081$