Reliability of Galaxy Correlation Function Estimation - Application to SDSS DR7

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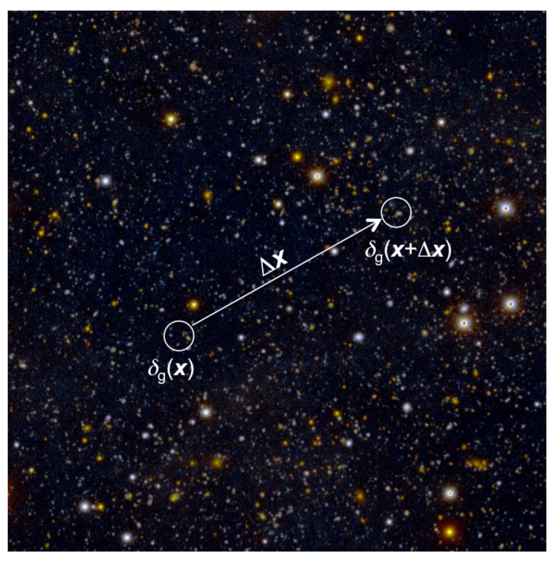
2-Point Correlation Function ξ

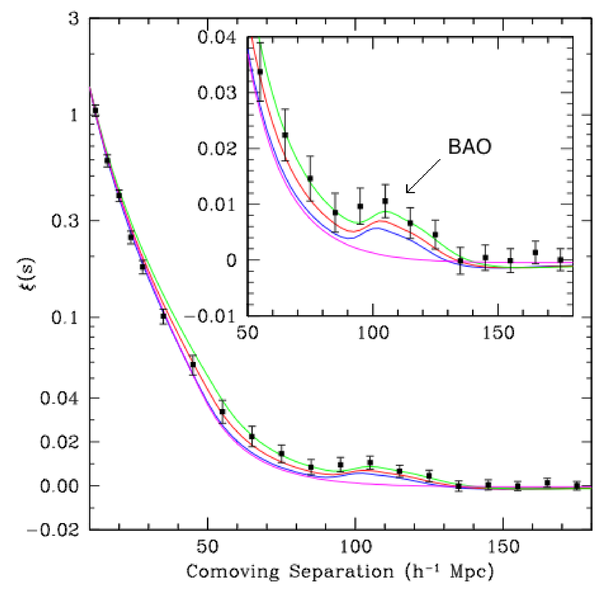
- ξ measures the **clustering** of the distribution (compared to random uncorrelated points)
- Fluctuations: $\delta(\mathbf{x}) = \frac{n(\mathbf{x})-\bar{n}}{\bar{n}}$
- Correlation between 2 points separated by $|\mathbf{\Delta x}| = r$:

$$\xi(r) = <\delta(\mathbf{x})\,\delta(\mathbf{x}+\mathbf{\Delta x})>$$



Deep Lens Survey, Tyson & Wittman

- Predicted matter Correlation function in ΛCDM model, with a dependence on cosmological parameters
- BAO 'bump' around 150 Mpc, relic of acoustic waves in early Universe (position and strength depend on cosmic parameters)



predicted BAO for $\neq$ cosmic parameters (Eisenstein et al., 2005)

Mass - Luminosity relation

- Galaxies form at the peaks of matter density, but the exact relation is not well understood
- Simple model: fluctuations in galaxies are amplified by a **'bias'** b compared to matter fluctuations:

$$\delta_g = b\,\delta_{\text{matter}}$$
$$\xi_g = b^2\,\xi_{\text{matter}}$$

- b depends on the galaxy population and increases with luminosity

Questions

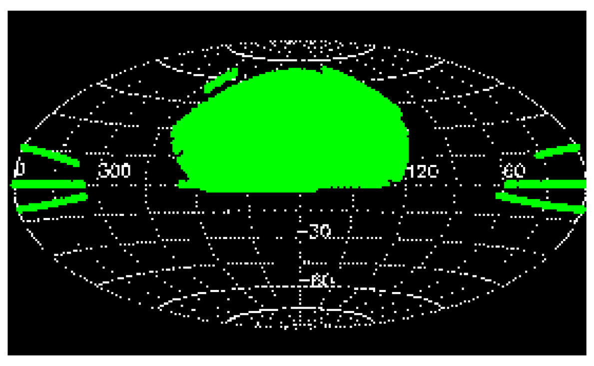
What is the confidence in estimating ξ with current Galaxy Surveys ?

Is it precise enough to recover the BAO feature or constrain cosmological parameters ?

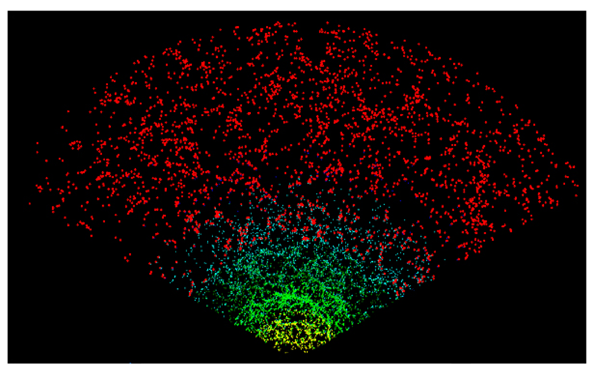
SDSS DR7 Survey

Sloan Digital Sky Survey, 8 years program with 2.5m telescope at Apache point:

- Mapped 7500 square degree of the sky
- Spectrum for 930 000 galaxies (largest galaxy survey up to date)
- 1 magnitude-limited samples of galaxies (Main), up to $D \approx 600\,h^{-1}$Mpc
- 1 approximately volume-limited of luminous red galaxies (LRG), up to $D \approx 1150\,h^{-1}$Mpc



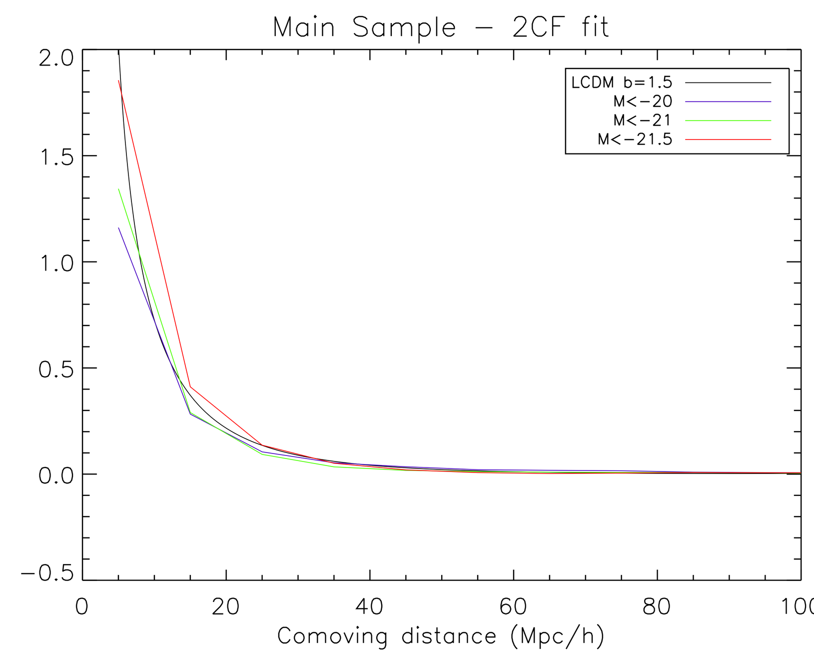
SDSS spectroscopic sky coverage

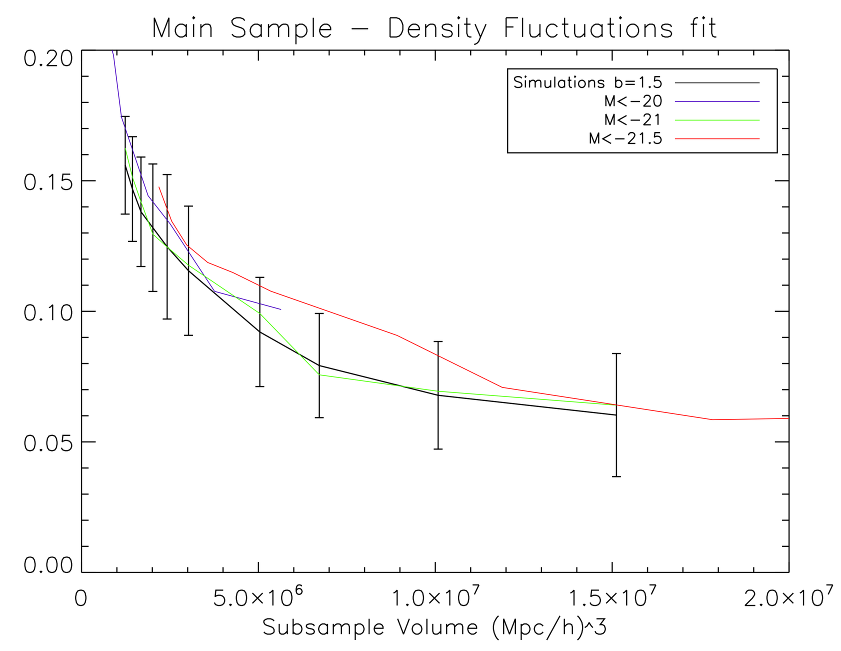


SDSS main sample (yellow, cyan, green) and luminous red galaxies (red)

Lognormal Simulations (Coles and Jones, 1991)

- ΛCDM Correlation function & same properties as data samples (density, volume, bias b)
- Simulation is fast and gives matter density $\rho > 0$ without ad hoc adjustments
- 2 different methods for adjusting the mass-luminosity bias b:
  - -adjust b to fit ξ estimated on the data
  - -adjust b to fit **density fluctuations** $\sigma(V)$ (fluctuations in the number of galaxies when dividing sample in several subvolumes)
- We find $b \approx 1.5$ for Main and $b \approx 2.5$ for LRG





Method of analysis

We use 40 lognormal simulations for each sample (Main $M < -21$ & LRG).

For Main & LRG we get ξ estimators **mean** and **variance** (gives 1σ confidence for ξ estimation).

Comparison of $\neq$ estimators of ξ

- Estimators of ξ based on histograms of pairs:

($DD(r)$=data-data, $DR(r)$=data-random, $RR(r)$=random-random)

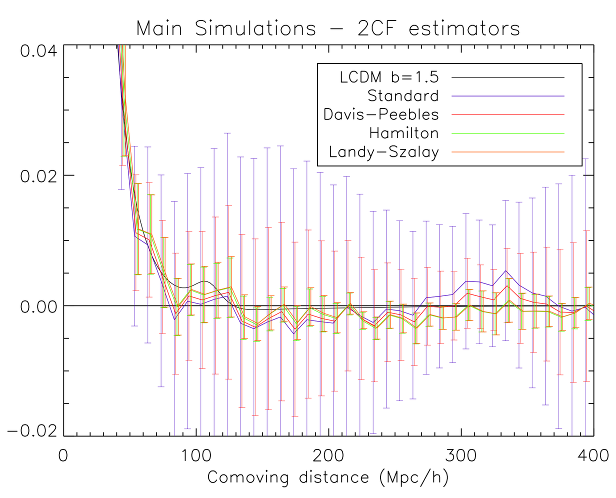
Standard $\hat{\xi}_S = \frac{N_{RR}}{N_{DD}}\frac{DD(r)}{RR(r)} - 1$

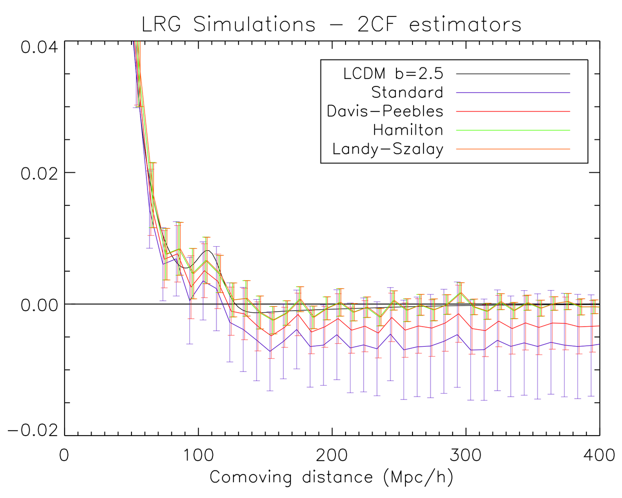
Davis-Peebles $\hat{\xi}_{DP} = \frac{N_{DR}}{N_{DD}}\frac{DD(r)}{DR(r)} - 1$

Hamilton $\hat{\xi}_{HAM} = \frac{N_{DR}^2}{N_{DD}N_{RR}}\frac{DD(r)RR(r)}{DR(r)^2} - 1$

Landy-Szalay $\hat{\xi}_{LS} = \frac{N_{RR}}{N_{DD}}\frac{DD(r)}{RR(r)} - 2\frac{N_{RR}}{N_{DR}}\frac{DR(r)}{RR(r)} + 1$

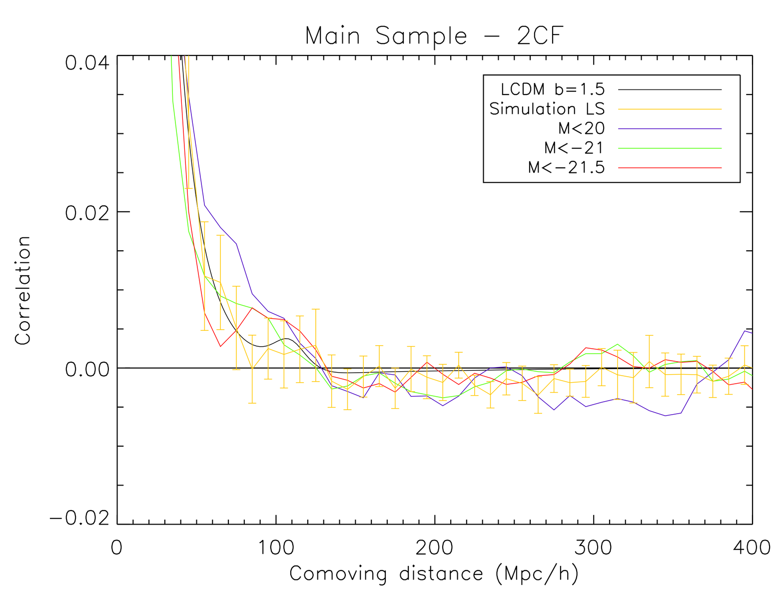
- Result: Hamilton and Landy-Szalay are almost equivalent and much superior to the 2 others (much less variance, mean closer to real ξ)



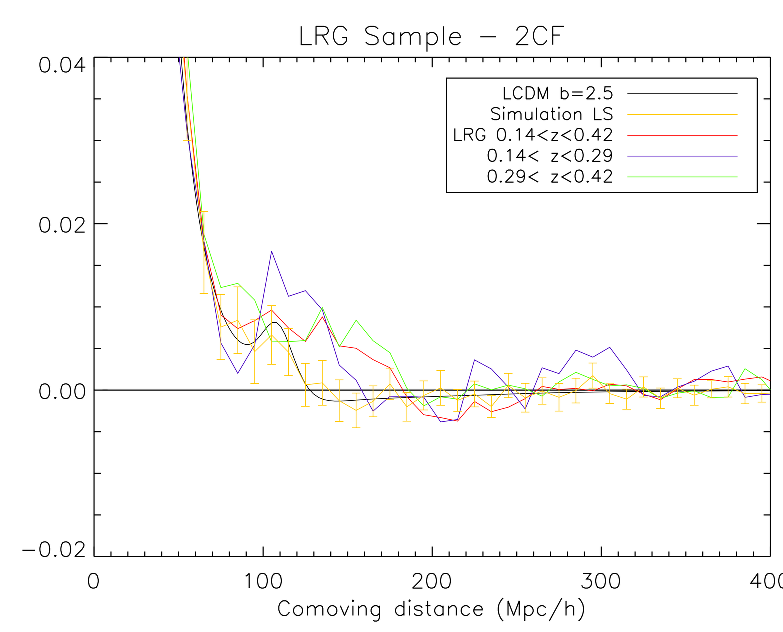


Detectability of the BAO (Landy-Szalay estimator)

- On Main sample $M < -21$, BAO detection is not reliable (around $110\,h^{-1}$Mpc , 0 is in the 1σ range of ξ).
- Clear signal only on the largest Main sample $M < -21.5$



- On the LRG sample the detection is reliable. On simulations a 'bump' is visible for most realizations.
- However the 'bump' in the data seems too wide, at more than 2σ of theoretical ξ between 120 and 180 h^{-1}Mpc (already found in different analysis and not explained by any systematic effect).
- Dividing the sample in 2 ($0.14 < z < 0.29$ and $0.29 < z < 0.42$), we find that the widening of the peak increases with distance.



References

[1] P. Coles and B. Jones. A lognormal model for the cosmological mass distribution. *Mon. Not. R. Astron. Soc.*, 248 :1-13, 1991.

[2] D. J. Eisenstein et al. Detection of the baryon acoustic peak in the large-scale correlation function of SDSS luminous red galaxies. *Astrophysical Journal*, 633 :560-574, nov 2005.

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