Spherical Harmonics Analysis of the SDSS Galaxies

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Abstract

Velocity of galaxies will be an important information on the validity of the general relativity. Although the redshift distortion of galaxy power spectrum could provide this information in the form of velocity power spectrum, normal methods of measuring the power spectrum are strongly affected by wide angle shape of survey geometry. In this poster, we present a measurement of the velocity power spectrum from the SDSS galaxy catalogue using the spherical harmonics expansion, which can naturally take account of the survey geometry and the inhomogeneity of the redshift distorted density fluctuations.

1. Galaxy Peculiar Velocity as Information

✔Contamination and noise

- Annoying contamination to distant measurement.
- "Redshift distortion"

✔No, it contains information

- Kaiser 1987
- Deepening the understanding of its effect on statistics (such as the power spectrum or two-point correlation function),
- "β" detects growth of structure.

$$\beta \equiv \frac{d\log D/d\log a}{b}$$

✔Yes, it has very important information!

- e.g., Taruya et al 2010
- Response to potentials is different from that of density fluctuation.
- Possible detector of deviation from GR!

2. Power Spectrum in Redshift Space?

$$\langle\delta(\boldsymbol{k})\delta^*(\boldsymbol{k'})\rangle \equiv (2\pi)^3\delta^K_{\boldsymbol{k},\boldsymbol{k'}}P(\boldsymbol{k})$$

Random field is homogeneous

✔Real Space

- Isotropic & homogeneous

✔Distant Observer Approximation

- Anisotropic & homogeneous
- We can define power spectrum. The power spectrum will be anisotropic.

✔*Real* Redshift Space

- Isotropic & inhomogeneous
- We CANNOT define power spectrum.

We need something different to measure the "redshift-space power spectrum"!

3. Expansion with Spherical Harmonics and Spherical Bessel

Model Description

Decompose spherical harmonics coefficients to the density and velocity fluctuations

$$D^m_{ln} = \sum_{l'n'm'}(\Phi^{mm'}_{ll'nn'}\delta^{m'}_{l'n'} + V^{mm'}_{ll'nn'}\theta^{m'}_{l'n'})$$

Take m-mean to reduce the number of modes

$$\mathcal{P}_{ln} = \frac{1}{2l+1}\sum_m |D^m_{ln}|^2$$

Derive covariance matrix (the most costly part!)

$$\mathrm{Cov}[\mathcal{P}_{l_0n_0}, \mathcal{P}_{l_1n_1}] = 2\frac{1}{2l_0+1}\frac{1}{2l_1+1}\sum_{m_0}\sum_{m_1}\left|\sum_2\{\Phi_{02}\Phi^*_{12}P_{\rm gg}(k_2) + \Phi_{02}V^*_{12}P_{\rm gv}(k_2) + V_{02}\Phi^*_{12}P_{\rm gv}(k_2) + V_{02}V^*_{12}P_{\rm vv}(k_2)\}\right|^2$$

$$\mathcal{L} \propto (\hat{\mathcal{P}}_{ln} - \mathcal{P}_{ln,model})^T C^{-1}(\hat{\mathcal{P}}_{ln} - \mathcal{P}_{ln,model})$$

Data Procedure

$$\hat{\mathcal{P}}_{ln} = \frac{1}{2l+1}\sum_{m=-l}^{l}|\hat{D}^m_{ln}|^2 - \mathcal{P}^{\rm shot}_{ln}$$

Take m-mean and subtract the shot-noise term

$$\hat{D}^m_{ln} = c_{ln}\sum_i w(r_i,\theta_i,\phi_i)j_l(k_{ln}r_i)Y^{m*}_l(\theta_i,\phi_i) - \bar{D}^m_{ln}$$

Expand galaxy distribution with the spherical harmonics and the spherical Bessel function

4. Pros and Cons

✔Pros

- Natural definition of the line-of-sight.
- Precise treatment of the angular and radial selection function.
- Straight decomposition of the velocity component.

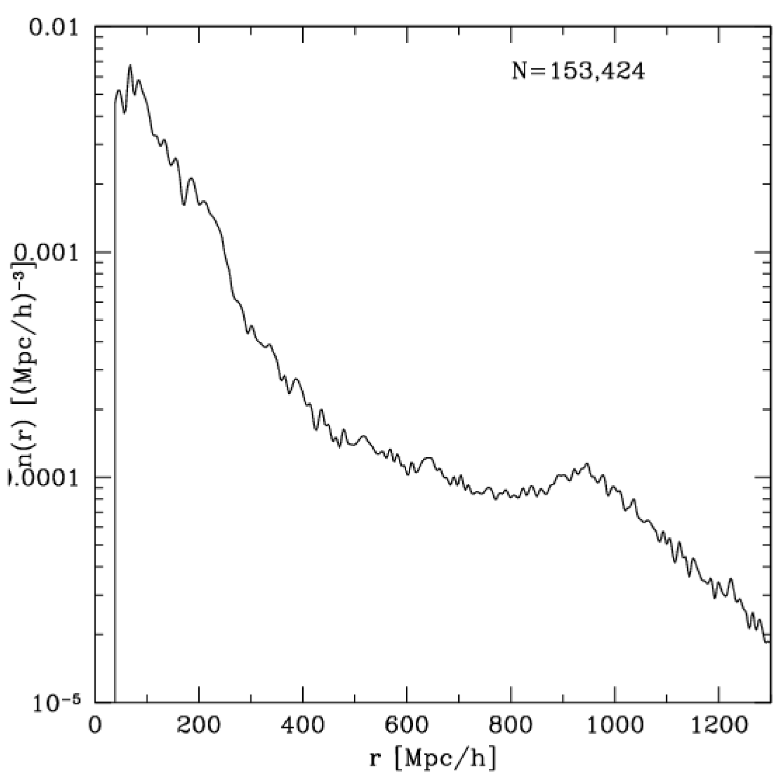
✔Cons

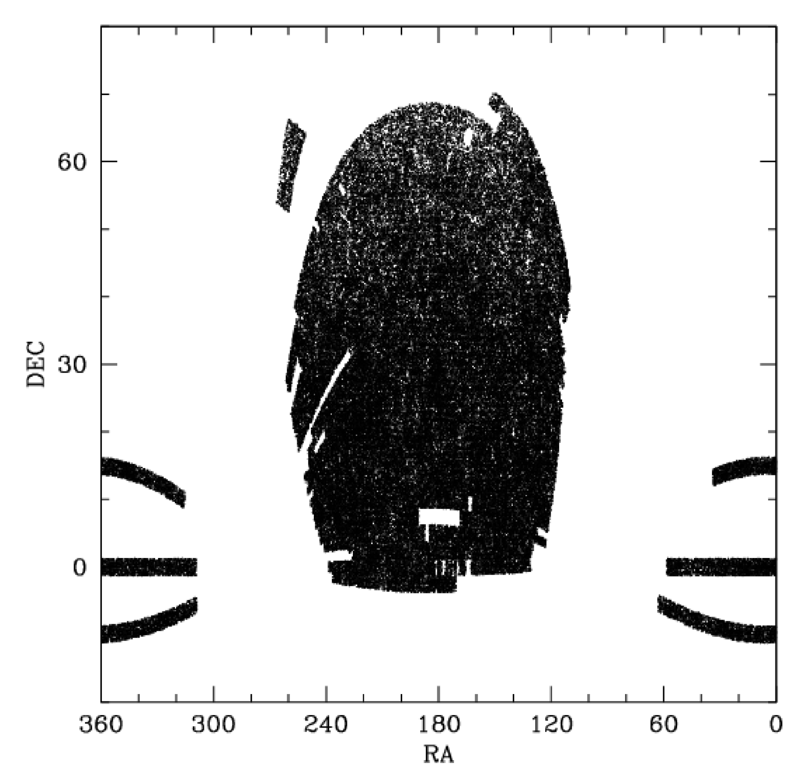
- FFT-like fast method is not known.
- Transformation from spherical harmonics modes to Fourier modes requires some modeling or approximation.

5. Data | SDSS LRG

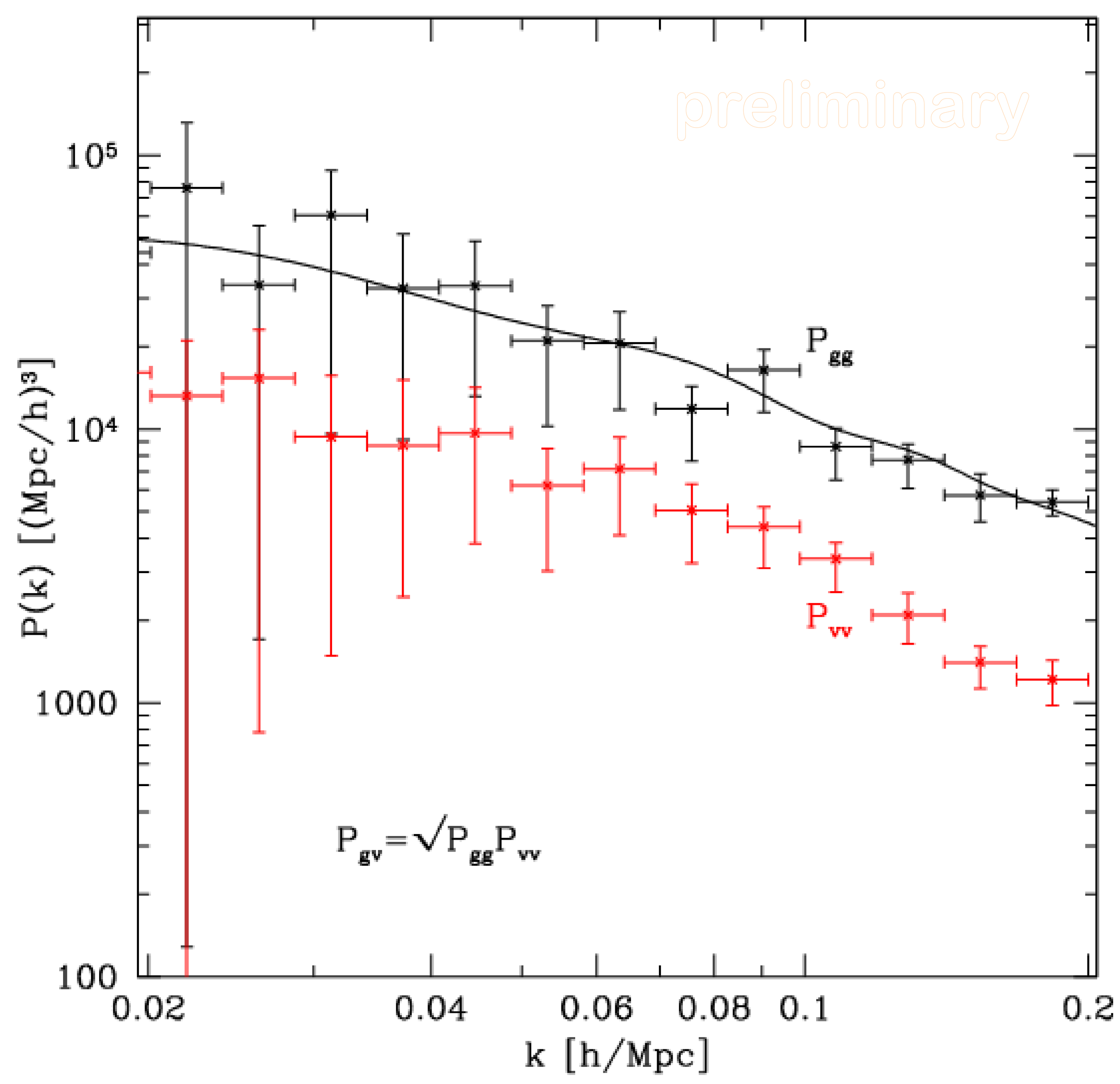
✔"One-halo" LRG

- Reid+ 2010
- Finger-of-god effect is expected to be suppressed.
- #sample ~ 150,000





6. Result



✔We have succeeded measuring Pvv

- l_max=40 (with l_max for convolution of 100)
- Error bars are scaled for l_max=220

✔Next work...

- Perform l_max=220 measurement.
- Measure Pvv as a function of galaxy properties to see whether velocity bias exists or not.
- Forecast for near future survey projects.