Towards the angular clustering of ALHAMBRA Luminous Red Galaxies

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Abstract

The cosmological theory makes clear cut prediction for the clustering properties of matter in our Universe. It is customary to assume that galaxies are biased samplers of the density field. Theory predicts that matter fluctuations are Gaussian distributed, completely determined by second order moments like the correlation function $\xi(x)$ or the power spectrum $P(k)$. Here we study two different methods to estimate the power spectrum of any generic distribution of galaxies with a window function, that will be applied to the ALHAMBRA survey in the near future.

1-Introduction

We model the galaxy overdensity on the plane, or galaxy density contrast, as

$$\delta_g(\mathbf{x}) = \frac{n_g(\mathbf{x}) - \langle n_g \rangle}{\langle n_g \rangle} = b\delta_m(\mathbf{x}),$$

where $\delta_m(\mathbf{x})$ is the total mass density contrast, b the bias factor and $\langle n_g \rangle$ is the average of the galaxy density. The standard cosmological theory predicts $\delta_m(\mathbf{x})$ to be a Gaussian variable, completely determined by the second order moment, the correlation function $\xi(\mathbf{x})$, and its Fourier transform, the power spectrum $P(\mathbf{k})$:

$$\xi(\mathbf{x}) = \langle \delta(\mathbf{y})\delta(\mathbf{x}+\mathbf{y}) \rangle = \int \frac{d\mathbf{k}}{(2\pi)^2} e^{-i\mathbf{k}\cdot\mathbf{x}} P(\mathbf{k}).$$

3-Method I

In order to correct for the mask we follow the approach of Hivon *et al.*. The observed power spectrum $\langle \tilde{P}(k_1) \rangle$ results from the integration of:

$$\langle \tilde{P}(k_1) \rangle = \int \frac{k_2 dk_2}{(2\pi)^2} M(k_1,k_2) \langle P(k_2) \rangle = C(k_1,k_2)\langle P(k_2) \rangle,$$

where the Coupling-Kernel matrix is given by:

$$M(k_1,k_2) = 2\pi \int k_3 dk_3 W(k_3) J(k_1,k_2,k_3).$$

The $W(k_3)$ function is the radial average of the squared Fourier transform of the mask function:

$$W(k_3) = \frac{1}{2\pi} \int d\theta w(\mathbf{k}) w(\mathbf{k})^*,$$

where the window function is

$$w(\mathbf{r}) = \int \frac{d\mathbf{k}}{(2\pi)^2} w(\mathbf{k}) \exp 2i\pi\mathbf{k}\cdot\mathbf{r},$$

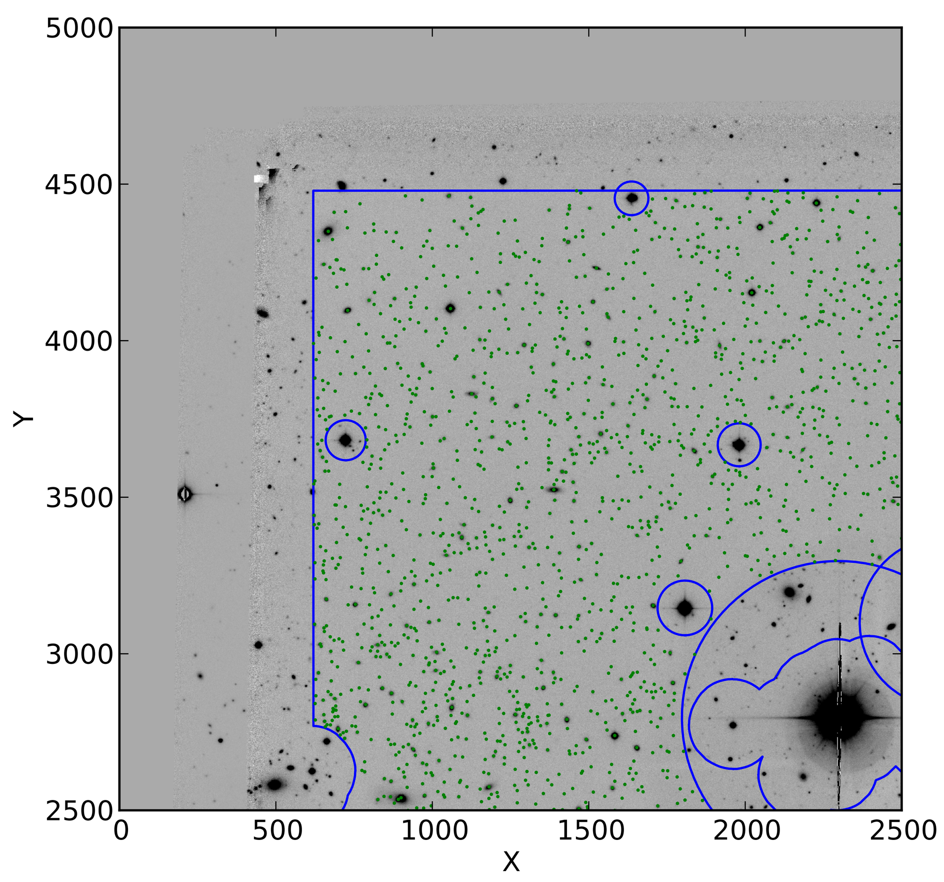
and the $J(k_1,k_2,k_3)$ is defined as follows:

$$J(k_1,k_2,k_3) = \frac{2}{\pi} \frac{1}{\sqrt{2k_1^2k_2^2 + 2k_1^2k_3^2 + 2k_2^2k_3^2 - k_1^4 - k_2^4 - k_3^4}}.$$

The $\langle P(k_2) \rangle$ can be estimated via: $\langle P(k_2) \rangle = C(k_1,k_2)^{-1} \langle \tilde{P}(k_1) \rangle$

5-Future application to ALHAMBRA survey

These two methods will be applied to the Luminous Red Galaxies of the ALHAMBRA survey, which covers an 4. degrees sky area and has a complex window function as shown in Figure 3, with the mask limits in blue and the objects included in the catalog and inside the mask, in green, (Arnalte *et al.*)



2-Power Spectrum estimation

A partial sky coverage translates into a window function that biases the power spectrum estimation. If we denote $W(\mathbf{x})$ as the window function, then the measured galaxy overdensity reads:

$$\tilde{\delta}(\mathbf{x}) = \delta(\mathbf{x})W(\mathbf{x}), \quad \tilde{\delta(\mathbf{k})} = \int d\mathbf{x} e^{-i\mathbf{k}\cdot\mathbf{x}} \tilde{\delta}(\mathbf{x}),$$

$$\tilde{\delta}(\mathbf{k}) = \int \frac{d\mathbf{k}'}{(2\pi)^2} W(\mathbf{k}-\mathbf{k}')\delta(\mathbf{k}'), \quad \tilde{P}(\mathbf{k}) = \int \frac{d\mathbf{k}'}{(2\pi)^2} P(\mathbf{k}) \mid W(\mathbf{k}-\mathbf{k}') \mid^2.$$

Here $\tilde{P}(\mathbf{k})$ denotes the observed power spectrum and $W(\mathbf{k})$ the Fourier transform of the window function.

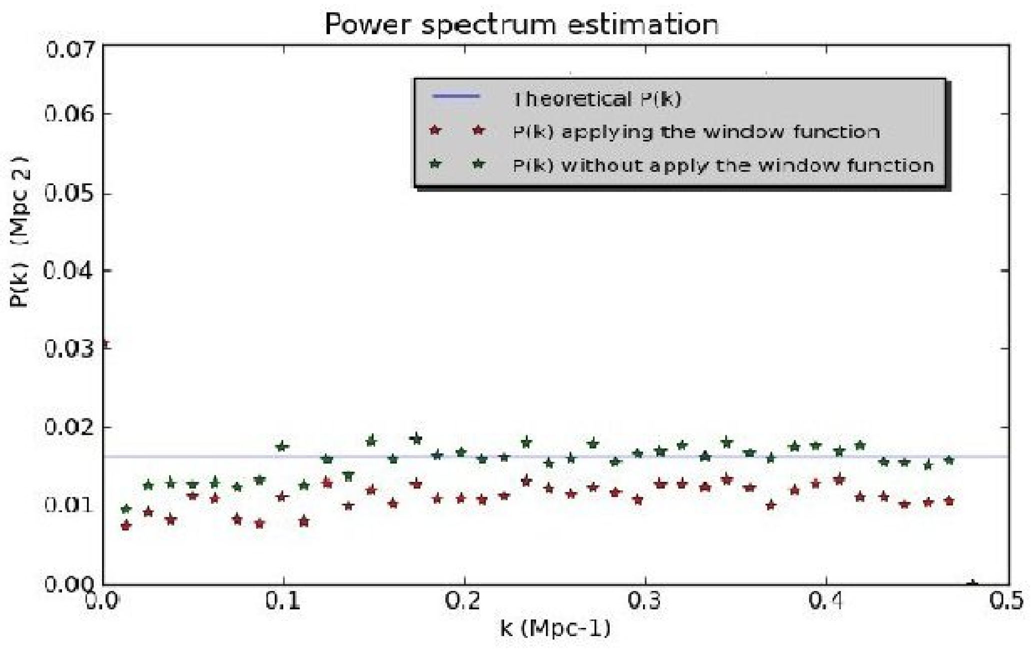


Figure 1: *Power spectrum estimation of a random sample of galaxies in a patch before (green stars) and after (red stars) applying a mask. The theory prediction is displayed by the horizontal line ($\frac{1}{\langle n_g \rangle}$).*

4-Method II

The Coupling matrix can be alternatively expressed as the angle average of the squared window function inside an annuli of different radii and constitutes an independent estimator of the power spectrum, which can be computed in any space of n-dimensions:

$$\tilde{P}(k_1) = \frac{1}{(2\pi)^2} \int k_2 dk_2 P(\mathbf{k_2}) \frac{1}{2\pi} \int d\theta_1 d\theta_2 \mid W(\mathbf{k_2}-\mathbf{k_1}) \mid^2 =$$

$$= \sum_{k_2} C(k_1,k_2)P(k_2).$$

The $P(k_2)$ can be then estimated by inverting the coupling matrix $C(k_1,k_2)$.

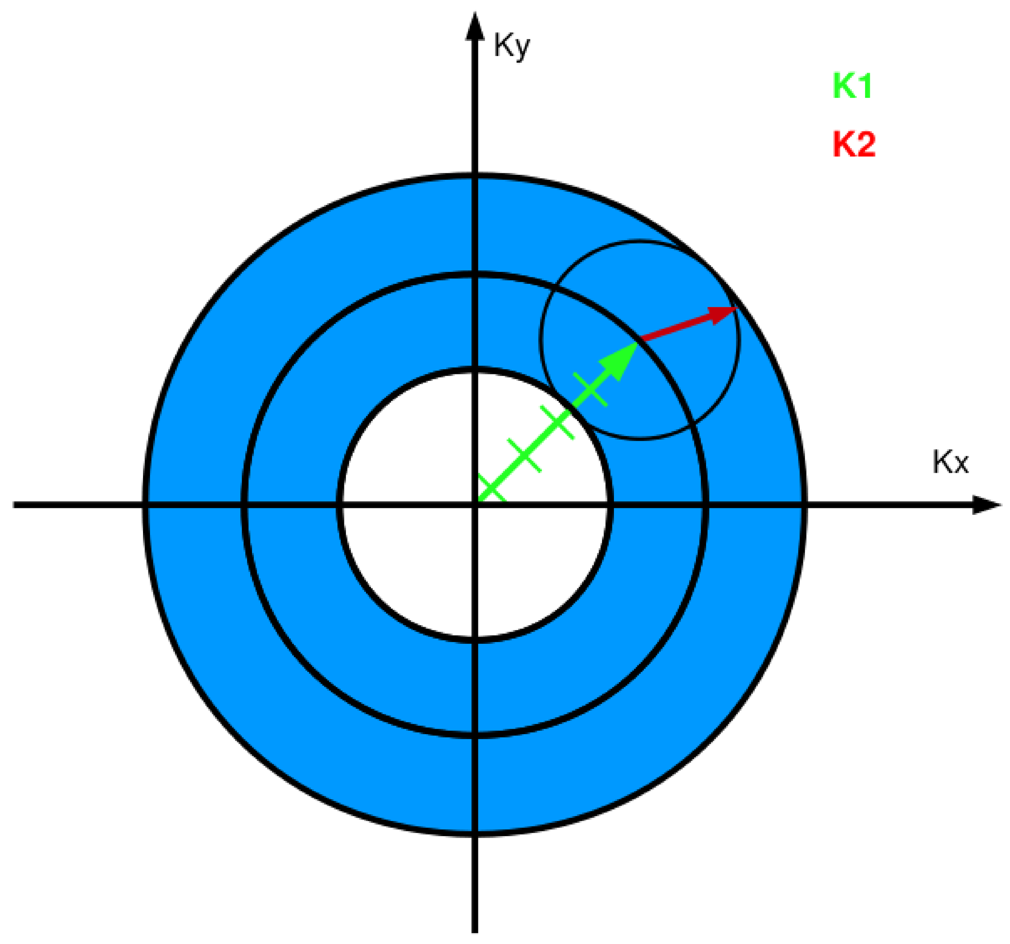


Figure 2: *The coupling matrix can be trivially computed from the integral of $\mid W(\mathbf{k}) \mid^2$ in different annuli in the Fourier space(the blue region in the plot).*

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References

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Hivon, E. *et al.*, 2002, ApJ 567,2.