Effect of Masks on the Shear Power Spectrum

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Introduction:

Measuring the ellipticity of galaxies it is possible to build an estimator of the projected mass power spectrum.

However, the value of this estimator will be affected by the presence of masks and noise. We show a method which takes into account those effects and allows a correct interpretation of the measurements on a real survey.

Effect of masking on power spectrum reconstruction:

The presence of masks in a galaxy survey can be represented through a function F which relates the true and the measured shear signals such as:

$$\gamma_{mes}(\boldsymbol{\theta}) = \gamma_{true}(\boldsymbol{\theta})\mathcal{F}(\boldsymbol{\theta}) \quad (1)$$

F is 1 where is no mask is applied or 0 otherwise. The division of the ellipticity field in E (non rotational) and B (rotational) modes in Fourier space gives:

$$\begin{aligned} \gamma_1(\boldsymbol{k}) &= \gamma_E(\boldsymbol{k})\cos(2\phi_k) - \gamma_B(\boldsymbol{k})\sin(2\phi_k) \\ \gamma_2(\boldsymbol{k}) &= \gamma_E(\boldsymbol{k})\sin(2\phi_k) + \gamma_B(\boldsymbol{k})\sin(2\phi_k) \end{aligned} \quad (2)$$

Assuming the non rotational nature of the shear field one can write the E and B components of the observed shear field as a function of the true shear and the transfer function F

$$\begin{aligned} \gamma_{E,mes}(\boldsymbol{k}) &= \int \frac{d^2\boldsymbol{q}}{(2\pi)^2}\gamma_E(\boldsymbol{q})\tilde{\mathcal{F}}(\boldsymbol{k}-\boldsymbol{q})\cos(2\phi_{kq}) \\ \gamma_{B,mes}(\boldsymbol{k}) &= \int \frac{d^2\boldsymbol{q}}{(2\pi)^2}\gamma_E(\boldsymbol{q})\tilde{\mathcal{F}}(\boldsymbol{k}-\boldsymbol{q})\sin(2\phi_{kq}) \end{aligned} \quad (3)$$

It follows that the expected power spectrum will be:

$$\begin{aligned} <|\tilde{\gamma}_{E,mes}(\mathbf{k})\tilde{\gamma}_{E,mes}(\mathbf{k})|^2> &= \int \frac{d^2\mathbf{q}}{(2\pi)^2}P_\kappa(\mathbf{q})|\tilde{\mathcal{F}}(\mathbf{k}-\mathbf{q})|^2\cos(2\phi_{qk})^2 \\ <|\tilde{\gamma}_{B,mes}(\mathbf{k})\tilde{\gamma}_{B,mes}(\mathbf{k})|^2> &= \int \frac{d^2\mathbf{q}}{(2\pi)^2}P_\kappa(\mathbf{q})|\tilde{\mathcal{F}}(\mathbf{k}-\mathbf{q})|^2\sin(2\phi_{qk})^2 \\ <|\tilde{\gamma}_{E,mes}(\mathbf{k})\tilde{\gamma}_{B,mes}(\mathbf{k})|^2> &= \int \frac{d^2\mathbf{q}}{(2\pi)^2}P_\kappa(\mathbf{q})|\tilde{\mathcal{F}}(\mathbf{k}-\mathbf{q})|^2\cos(2\phi_{qk})\sin(2\phi_{qk}) \end{aligned} \quad (4)$$

Effect of coupling noise-masks:

Eq.(1) can be easily modified to take noise into account.

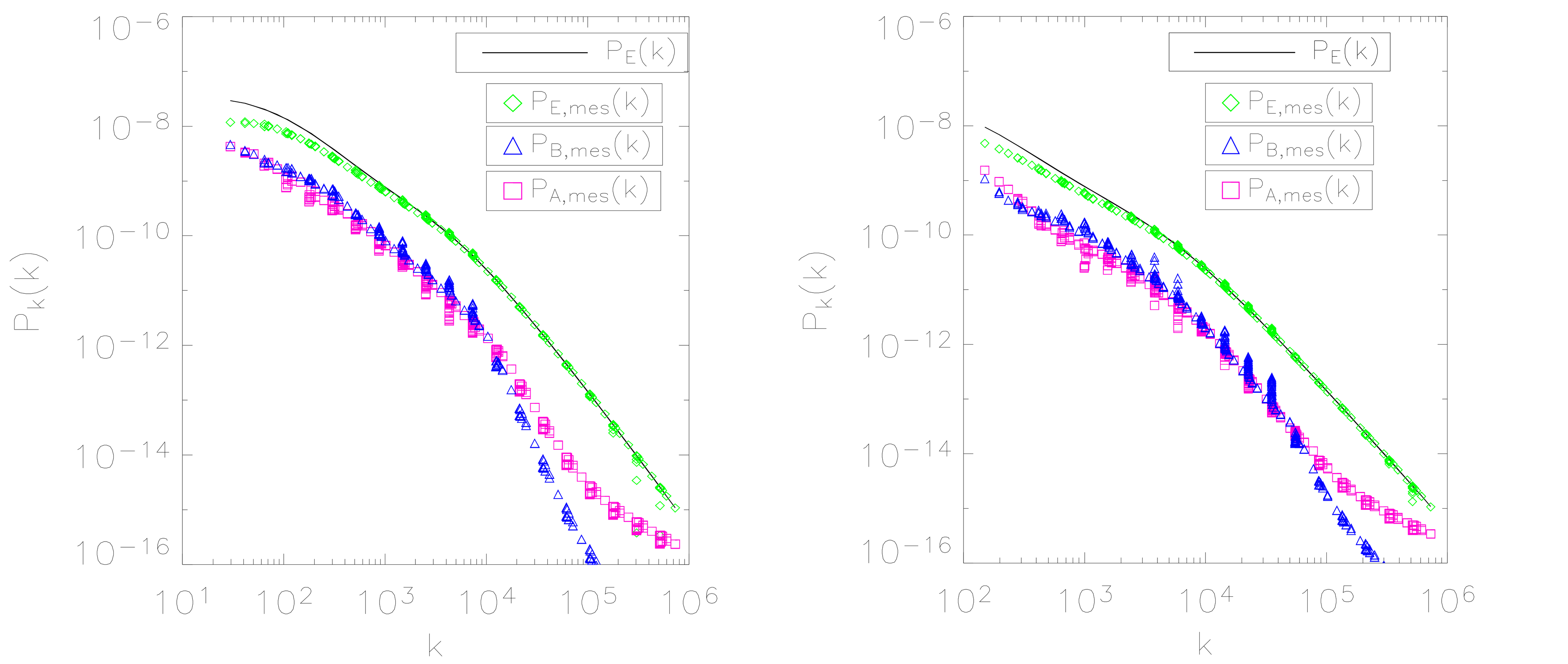
$$\gamma_{mes}(\boldsymbol{\theta}) = (\gamma_{true}(\boldsymbol{\theta}) + \epsilon(\boldsymbol{\theta}))\mathcal{F}(\boldsymbol{\theta}) \quad (5)$$

This equation is general, and different models of noise can be assumed.
In this work we will show the results in the case of a white noise coming from the intrinsic ellipticity of galaxies. In this case the measured power spectrum (4) will be modified as follows:

$$\begin{aligned} P^{noise}_{E,mes}(\mathbf{k}) &= P_{E,mes}(\mathbf{k}) + \sigma_\epsilon^2\int\frac{d\mathbf{q}}{(2\pi)^2}|\tilde{\mathcal{F}}(\mathbf{k}-\mathbf{q})|^2\cos(\phi_{kq})^2 \\ P^{noise}_{B,mes}(\mathbf{k}) &= P_{B,mes}(\mathbf{k}) + \sigma_\epsilon^2\int\frac{d\mathbf{q}}{(2\pi)^2}|\tilde{\mathcal{F}}(\mathbf{k}-\mathbf{q})|^2\sin(\phi_{kq})^2 \\ P^{noise}_{A,mes}(\mathbf{k}) &= P_{A,mes}(\mathbf{k}) + \sigma_\epsilon^2\int\frac{d\mathbf{q}}{(2\pi)^2}|\tilde{\mathcal{F}}(\mathbf{k}-\mathbf{q})|^2\cos(\phi_{kq})\sin(\phi_{kq}) \end{aligned} \quad (6)$$

Results:

The effect of masking and noise has been tested using 2 different types of masks, used for the CFHTLS-Deep (1 deg²) and for VIRMOS-Descart (2.8 * 1.9 deg²).



Plot 1: On the left : measured power spectrum of the convergence for a VIRMOS–like mask, compared with the theoretical power spectrum (WMAP-1 year values). B and "ambiguous" A component are also showed. The noise is assumed uncorrelated and characterized by a dispersion of 0.4 On the right: same results for a CFHTLS-Deep-like mask.

Both results are similar. The amplitude of the measured spectrum is smaller than the theoretical spectrum. This effect varies with the scales and is more significant (~10%) for small k, i.e. large scales.
The dispersion of the measures at given mode k is due to the symmetry break given by the masks.
Using the following relation:

$$\Delta P^\kappa(k) = \sqrt{\frac{2}{(2k+1)f_{sky}}}\left(P^\kappa(k) + \frac{\sigma_\epsilon^2}{n}\right) \quad (7)$$

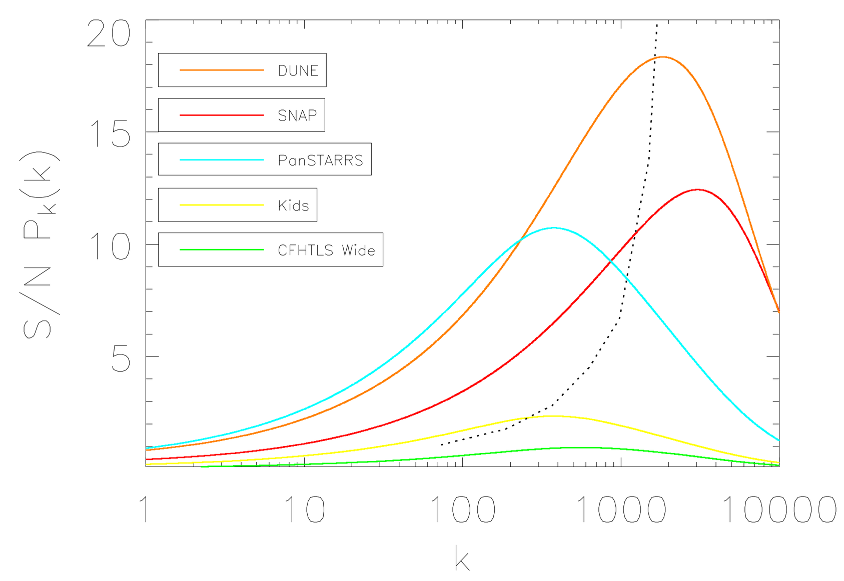
which allows, for a given survey to quantify the cosmic and noise variance for each mode k, we can investigate for which surveys the contamination becomes important.
In fact one can roughly consider that the mask effects can be neglected until:

$$P^\kappa/\Delta P^\kappa(k) < P^\kappa/(P^\kappa - P^\kappa_{mes})(k) \quad (8)$$

Plot (2) shows the amplitude of the first term of (8) for different surveys whose characteristics are shown in the table 1.

	f_{sky}	σ_ϵ	n
CFHTLS Wide	0.004	0.44	14
KIDS	0.036	0.44	10
PanSTARRS	0.75	0.44	10
SNAP	0.12	0.3	80
DUNE	0.48	0.3	35

Table 1. Characteristics of different surveys, i.e. fraction of sky, intrinsic ellipticity dispersion and galaxy number density / arcmin, for which the power spectrum S/N ratio is shown in plot (2).



Plot 2: S/N ratio as a function of k for the surveys of Table 1, compared with the deviations of the expected E signal caused by the presence of masks and noise (green dotted line). The contribution of masks and noise can be neglected for CFHTLS-Wide-like survey, but it becomes important already for a KIDS-like survey

Conclusion:

This method represents an alternative way to rebuild the spectrum of the convergence via FFT taking into account the effects of masking and noise.
It can be used also to correct the second order statistics measured directly via FFT and not through 2pcf.
This kind of approach could be especially useful if extended to the third order statistics for which the computation of the correlation functions is costly.

Bibliography:

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