D.E.S reconstructed lensing potential template and application to delensing and cross correlation

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Goal: test if, at least on a small patch of the sky 500 deg^2 LSS survey like D.E.S or DESI can improve the reconstruction of the lensing potential that lenses the CMB photons. This would be crucial to build a template of the B-mode signal coming from the lensing of the primordial E-mode. This will be at multipoles higher than 200 the main contaminants of the primordial B-mode.
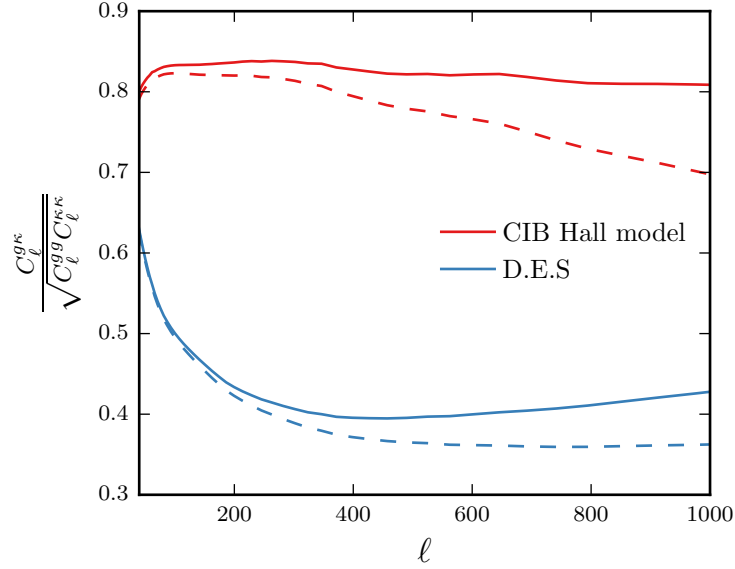
I.   THEORY

FIG. 1: Correlation factor between galaxies survey and CMB lensing potential.

As for the temperature, the intensity map of photons on the sky, also the Q and U mode decomposition of their polarization is modified by lensing as:

$$Q(\hat{\mathbf{n}}) = Q_{\text{unlensed}}(\hat{\mathbf{n}} + \mathbf{d}); \quad U(\hat{\mathbf{n}}) = U_{\text{unlensed}}(\hat{\mathbf{n}} + \mathbf{d}) \tag{1}$$

where $\mathbf{d}$ is the deflection angle directly related to the lensing potential ϕ.

As a first approximation, the B mode resulting from the lensing of primordial E mode by a convergence field κ is:

$$B^{\text{lens}}(\mathbf{l}) = \int \frac{d^2 \mathbf{l}'}{(2\pi)^2} W(\mathbf{l}, \mathbf{l}') E(\mathbf{l}') \kappa(\mathbf{l} - \mathbf{l}') \tag{2}$$

where

$$W(\mathbf{l}, \mathbf{l}') = \frac{2\mathbf{l}' \cdot (\mathbf{l} - \mathbf{l}')}{|\mathbf{l} - \mathbf{l}'|^2} \sin(2\varphi_{\mathbf{l}, \mathbf{l}'}), \tag{3}$$

As usual we define the power spectrum as:

$$\langle B^{\text{lens}}(\mathbf{l}) \, B^{\text{lens}^*}(\tilde{\mathbf{l}}) \rangle \equiv (2\pi)^2 \delta^D(\mathbf{l} - \tilde{\mathbf{l}}) C_l^{BB,\text{lens}} \tag{4}$$
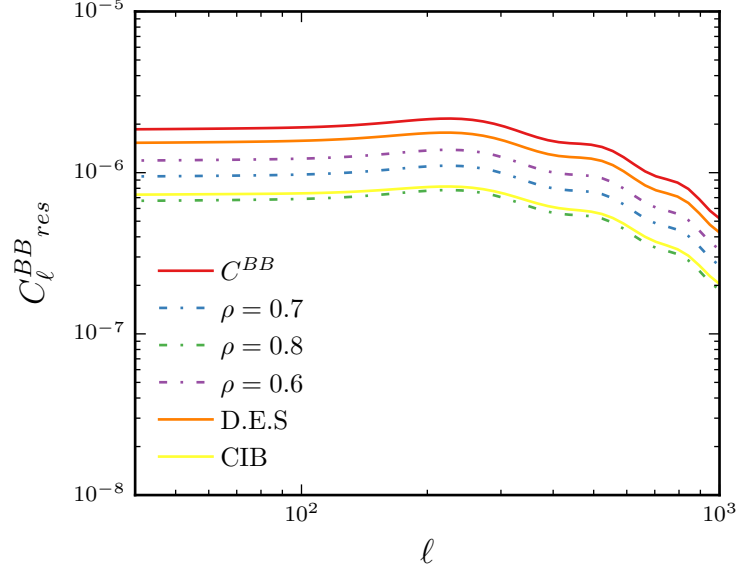
FIG. 2: Residual lensing B modes power spectrum using different large scale structure.
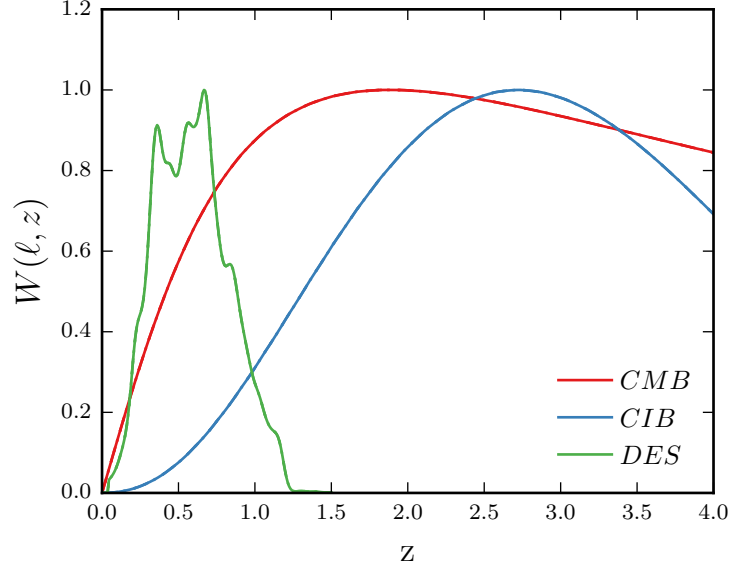

FIG. 3: Comparison of the different kernels used in this analysis. This allow to understand Redshift distribution of D.E.S galaxies (I suspect this is the benchmark, anyway taken from Giannantionio et al.).

From this we get that the power spectrum:

$$C_l^{BB,\text{lens}} = \int \frac{d^2 \mathbf{l}'}{(2\pi)^2} W^2(\mathbf{l}, \mathbf{l}') C_{l'}^{EE} C_{|\mathbf{l}-\mathbf{l}'|}^{\kappa\kappa}. \tag{5}$$

Now the full B-mode power spectrum measured on the sky is

$$C_l^{BB,\text{full}} = C_l^{BB,r} + C_l^{BB,\text{lens}} + N_l^{BB}. \tag{6}$$

Now, if we have an LSS measurements I that traces the lensing potential responsible for the lensing of

the CMB we can build a template of the true lensing B mode on the sky with a weighted convolution:

$$\hat{B}^{\text{lens}}(\mathbf{l}) = \int \frac{d^2\mathbf{l}'}{(2\pi)^2} W(\mathbf{l},\mathbf{l}')f(\mathbf{l},\mathbf{l}')E^N(\mathbf{l}')I(\mathbf{l}-\mathbf{l}') \tag{7}$$

where $f(\mathbf{l},\mathbf{l}')$ is a weight that must be determined.

The residual lensing b mode will be

$$B^{\text{res}}(\mathbf{l}) = B^{\text{lens}}(\mathbf{l}) - \hat{B}^{\text{lens}}(\mathbf{l}) = \int \frac{d^2\mathbf{l}'}{(2\pi)^2} W(\mathbf{l},\mathbf{l}') \times$$
$$\left(E(\mathbf{l}')\kappa(\mathbf{l}-\mathbf{l}') - f(\mathbf{l},\mathbf{l}')E^N(\mathbf{l}')I(\mathbf{l}-\mathbf{l}') \right) \tag{8}$$

and its power spectrum

$$C_l^{BB,\text{res}} = \int \frac{d^2\mathbf{l}'}{(2\pi)^2} W^2(\mathbf{l},\mathbf{l}')[C_{l'}^{EE}C_{|\mathbf{l}-\mathbf{l}'|}^{\kappa\kappa}$$
$$- (f(\mathbf{l},\mathbf{l}') + f^*(\mathbf{l},\mathbf{l}'))C_{l'}^{EE}C_{|\mathbf{l}-\mathbf{l}'|}^{\kappa I}$$
$$+ f^*(\mathbf{l},\mathbf{l}')f(\mathbf{l},\mathbf{l}')(C_{l'}^{EE} + N_{l'}^{EE})C_{|\mathbf{l}-\mathbf{l}'|}^{II}] \tag{9}$$

We can now easily choose $f(\mathbf{l},\mathbf{l}')$ so that the residual lensing B mode power is minimized. We find:

$$f(\mathbf{l},\mathbf{l}') = \left(\frac{C_{l'}^{EE}}{C_{l'}^{EE} + N_{l'}^{EE}} \right) \frac{C_{|\mathbf{l}-\mathbf{l}'|}^{\kappa I}}{C_{|\mathbf{l}-\mathbf{l}'|}^{II}} \tag{10}$$

Notice that the first term consists in the usual inverse variance filter applied to the measured E-mode and the second minimize the difference between the reconstructed ϕ and the CMB lensing potential.

We finally have that the residual power is:

$$C_l^{BB,\text{res}} = \int \frac{d^2\mathbf{l}'}{(2\pi)^2} W^2(\mathbf{l},\mathbf{l}')C_{l'}^{EE}C_{|\mathbf{l}-\mathbf{l}'|}^{\kappa\kappa} \tag{11}$$
$$\times \left[1 - \left(\frac{C_{l'}^{EE}}{C_{l'}^{EE} + N_{l'}^{EE}} \right) \rho_{|\mathbf{l}-\mathbf{l}'|}^2 \right]$$

with

$$\rho_l = \frac{C_l^{\kappa I}}{\sqrt{C_l^{\kappa\kappa}C_l^{II}}}. \tag{12}$$

The bigger ρ_l is for a LSS field the more it is correlated with the lensing potential acting on the CMB photons. An higher correlation allows for a better reconstruction of the ϕ^{CMB} and, as a consequence, of B^{lens}.

II. DATA

D.E.S, Planck CIB, DESI? [1–12]

III. FORECAST

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