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Author(s): Aditya Rotti, Kevin Huffenberger

Title: `Real-space computation of $E$/$B$-mode maps I: Formalism, Compact Kernel`

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Referee report

This paper establishes a framework for real-space computation of the E/B maps. The method is important for CMB data analysis and is potentially advantageous in terms of foreground isolation. The analogy to electromagnetism under the notion of Green's function is insightful. The paper is well organized and is clearly written. And I expect that this paper will be suitable for publication. However, I have a number of concerns I'd like the authors to address before I make that recommendation for publication in Journal of Cosmology and Astroparticle Physics.

The real space formalism looks very helpful, but it is unclear what a mask can do to the E/B mixing. The E/B leakage due to masking is inevitable as Ref. [31] argued, but it is not discussed. Also, some brief comparison with the conventional approaches in the literature, such as the pure estimator (astro-ph/0511629), could be added to explain why such a real space approach is necessarily required and why it is more advantageous.

At the end of paragraph 5 in the introduction, it says "... for minimizing foreground contamination...". Similar to the question above, it looks like the main motivation is the foreground isolation but it is not discussed.

Maybe this is still related to the first question. The authors derived the radiation and convolution kernels that are shown in Figs. 3 and 4. It is still unclear to me what the E/B power spectra look like from this real-space computation. For example, the authors can make a quick simulation on a small patch or the full-sky to easily validate that the E/B power spectra are correctly recovered from this real space computation.

What is the time complexity of the real space transformation? Eq. (3.26) seems to indicate it is actually $\mathcal{O}(N_{pix}^2)$ which is not as efficient as the conventional approaches. If possible, the authors could briefly discuss it.

Please find below all other comments (most are minor) for the authors to consider.

–It looks like the real part (E) and imaginary part (B) can be easily calculated from Eq. (3.8). It is unclear why the purifying procedure – Eq. (3.25) is needed. The authors should explain it at the beginning of section 3.4. Also, the maps $\bar{P}_E$ and $\bar{P}_B$ in Eqs. (3.17) and (3.18) should be explicitly written down using E and B modes like Eq. (2.8).

–In the first row of Fig. 3, why is the color/pattern of the third plot so different from the rest? Is there any numerical issue with the pole? Why is necessary to show the location of the North Pole in Fig. 3?

–Section 3.5 fails to explain what the non-locality is, why it matters, especially how that is connected to the E/B separation problem. Also, what is the implication of the band limit dependence for E/B separation problem? Is there any first-principle calculation of the value ℓ_0 that is purely phenomenological in the text?

–Given the oscillatory feature in Fig. 6, is there any technical difficulty for getting a good convergence for the real space transformation when the radiation/convolution kernels are sampled at discrete pixels? Is there any convergence criterion?

–For any subplot shown in Fig.6, is the pixel size ($\Delta\Omega$) a fixed value or varying at different ℓ_{max}? Can the authors clarify this? It seems to indicate that the resulting E/B power spectra will depend on the ℓ_{max} even for the same Q/U maps. Or simply, how would the ℓ_{max} be chosen for a given experiment if the transformation kernel is dependent of ℓ_{max}?

–With a high value of ℓ_{max}, it looks like only the neighboring pixels are important for the kernels. What is the ratio of $\beta_0/\sqrt{\Delta\Omega}$ at different ℓ_{max}? As Fig. 7 indicates, is the portion $\theta > 3\beta_0$ just neglected to speed up the computation? If true, how big is the error?

–In Fig. 7, the authors need to discuss a few aspects for the chosen example of the modified radial function, including what motivates this form, how this is done for the real-space maps and how it is reconstructed. A fractional error is seen from the input (red) and reconstructed (dashed black) so there might be a leakage from the E modes into B modes. Ideally the reconstruction at any ℓ_{max} should work, for example $\ell_{max} = 768$, not just limited to 1536. Can the authors verify this?

–It is unclear what motivates the discussion of section 4 on page 19. The authors should add some introductory text at the beginning of section 4 to connect it to the previous sections.

–A few definitions are missing: $\bar{P}_E$ and $\bar{P}_B$ in Eqs. (3.17) and (3.18), ${}_{+2}X_{E/B}$ in Eq. (3.26), ${}_M f$ in Eq. (3.5c), N_{pix} and N_{alm} in Eq. (2.9).

–Fig. 5 seems to be redundant because Fig. 6 shows the same content although in log scale. The authors should mention the difference between the two.

–Figs 6 and 7 are not legible.