This research was supported by NSF Award # 2020275

Delensing CMB B-mode with Galaxy Density Map

Shengzhu(Alex) Wang[a] (mentored by Anton Baleato Lizancos)[a]
Department of Physics, University of California Berkeley, Berkeley, CA 94704[a]

Delsing the CMB B-mode

CMB Lensing

- CMB radiations are generated during the recombination epoch
- In time, the paths of CMB photons are being bent by nearby massive objects through gravitational lensing, leading to CMB anisotropies

CMB Lensed B-mode

- Like any polarized field, CMB can be described in terms of Stokes Parameters as E-mode and B-mode
- Gravitational lensing couples primordial E-modes and B-modes, making the CMB we observe today

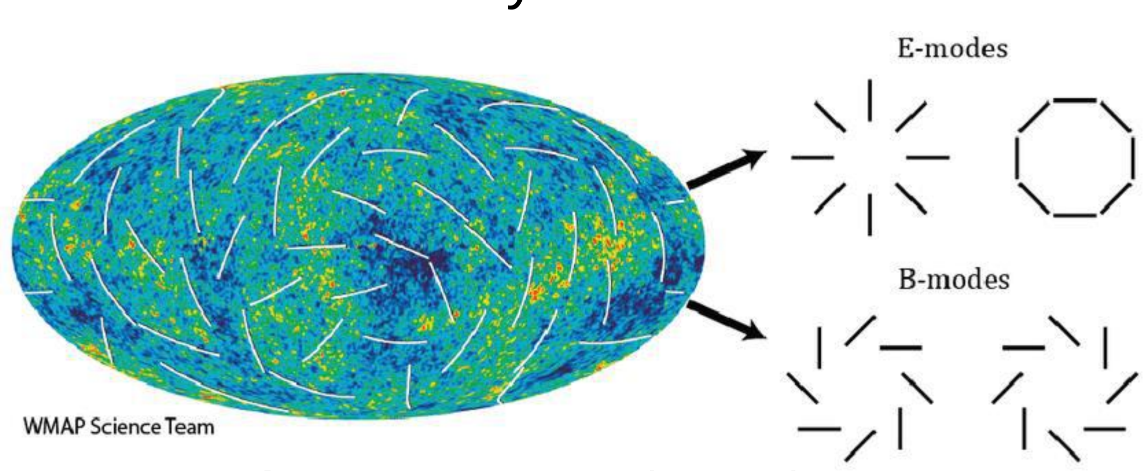

Figure 1: CMB E and B-mode

Delensing the B-mode

- To delens the B-modes, we construct B-mode template which is a convolution of the observed E-mode and lensing potential* ϕ

$$\hat{\tilde{B}}_{lm} = \frac{(-1)^m}{2}\sum_{(lm)_1}\sum_{(lm)_2}\begin{pmatrix} l_1 & l_2 & l \\ m_1 & m_2 & -m \end{pmatrix} W_{l_1 l_2 l}\,\hat{\phi}_{(lm)_1}\hat{E}_{(lm)_2}$$

*the lensing potential captures information about how photons are deflected; the B-mode here is in spherical harmonic space and W is a weighting function

**lensing potential is often transformed into lensing convergence which is -1/2 of the Laplacian of lensing potential

Methodology and Data

Power Spectrum

- Power spectrums capture the smoothness of a map as a function of angular scales

$$C_l \equiv \langle a_{lm} a^*_{lm} \rangle$$

Galaxy Density Maps

- To build the B-mode template, we need a proxy of the lensing potential
- Galaxy Density maps could be a useful proxy as it is closely related to the mass distribution in the universe

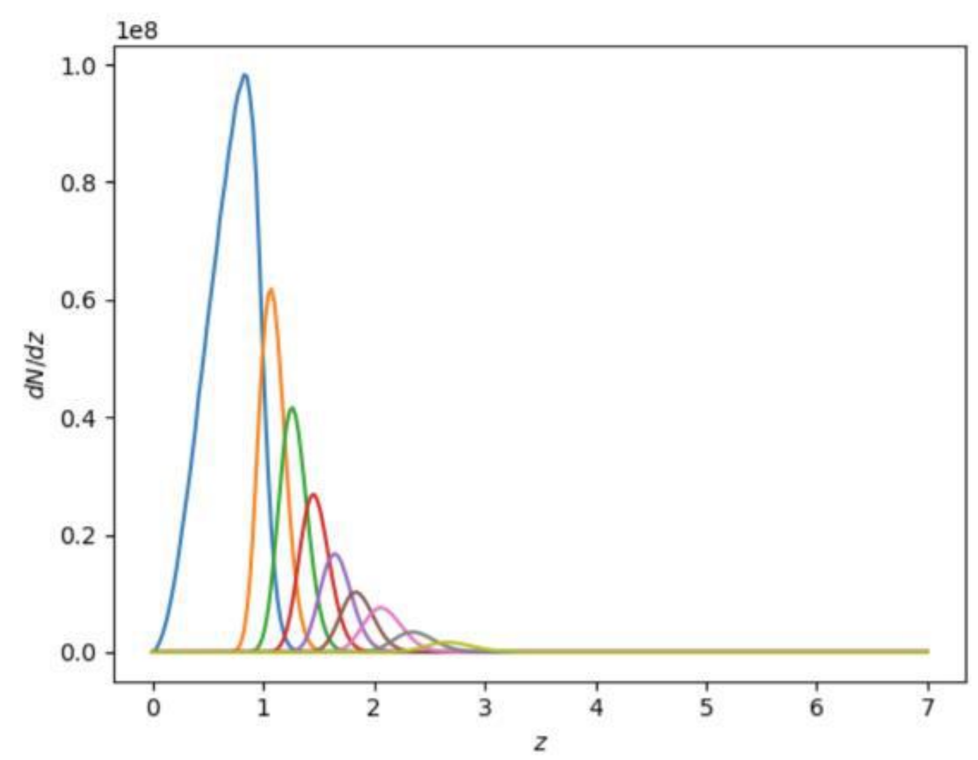

Figure 2: simulated galaxy counts as a function of redshifts in different bins. Generated by Jose Bernal

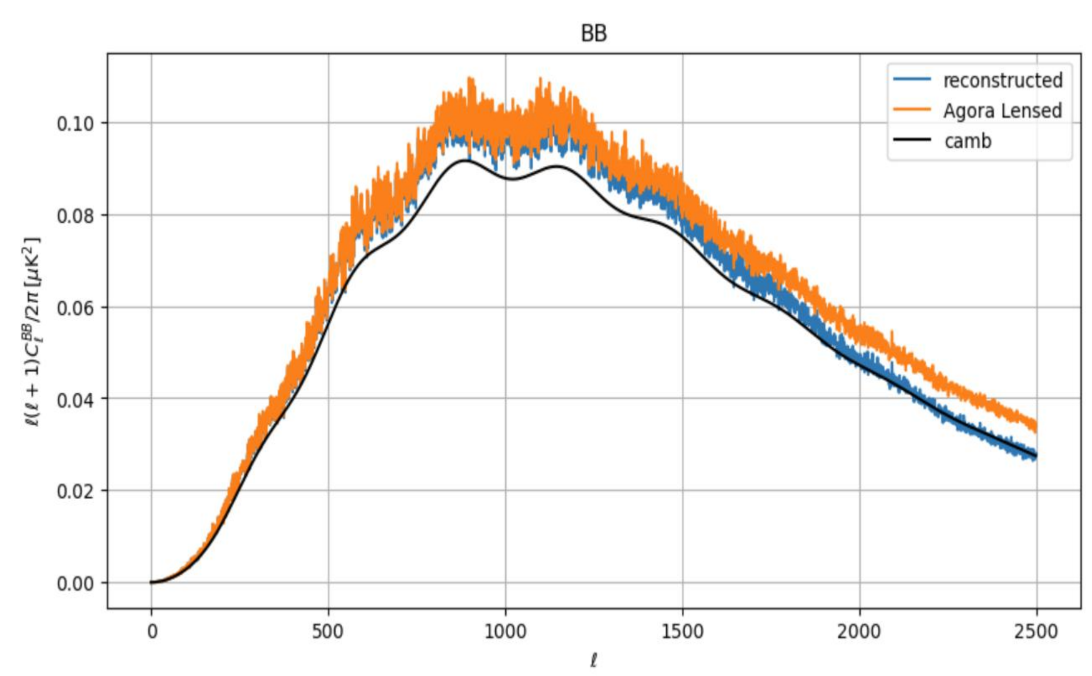

Figure 3: simulated and reconstructed B-mode template. The lensing convergence here is from Agora N-body simulation

Galaxy Bias and Shot Noise

- The galaxy clustering is not a perfect representation of the underlying mass, this bias is the galaxy bias: $b(z)$
- This also introduces a shot noise for auto-spectrum

$$N_l^{ab} = \delta_K^{ab}\, f_{\rm sky}\,\frac{4\pi}{N_a}$$

Linear Galaxy Bias

- The linear galaxy bias model assumes that the galaxy clustering and the underlying mass distribution are only different by some constant
- This model works well only for large angular scales
- To see where this linear bias model breaks, we compare an analytical solution of the galaxy power spectrum to simulated data

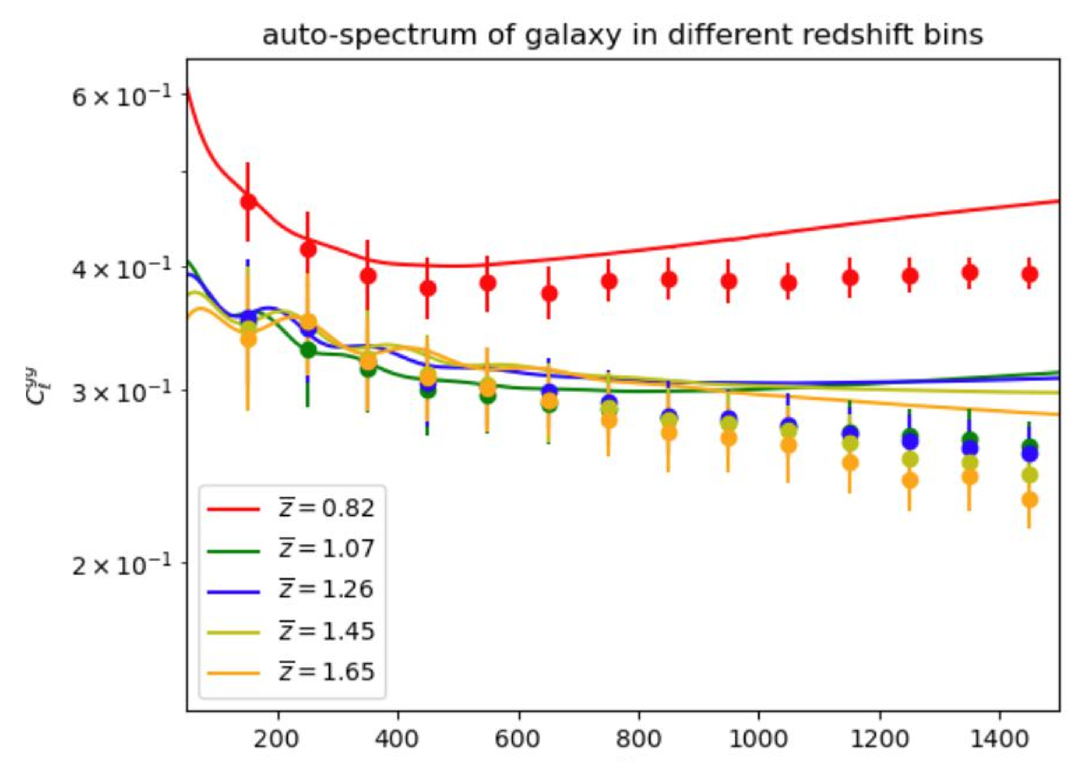

Figure 4: auto-power spectrum of galaxy density in different redshift bins

Results and Discussion

Fitting the Galaxy Bias and Shot Noise

- We fit our simulated data to analytical solutions assuming linear bias to see how linear bias model causes predicted power spectrums to deviate

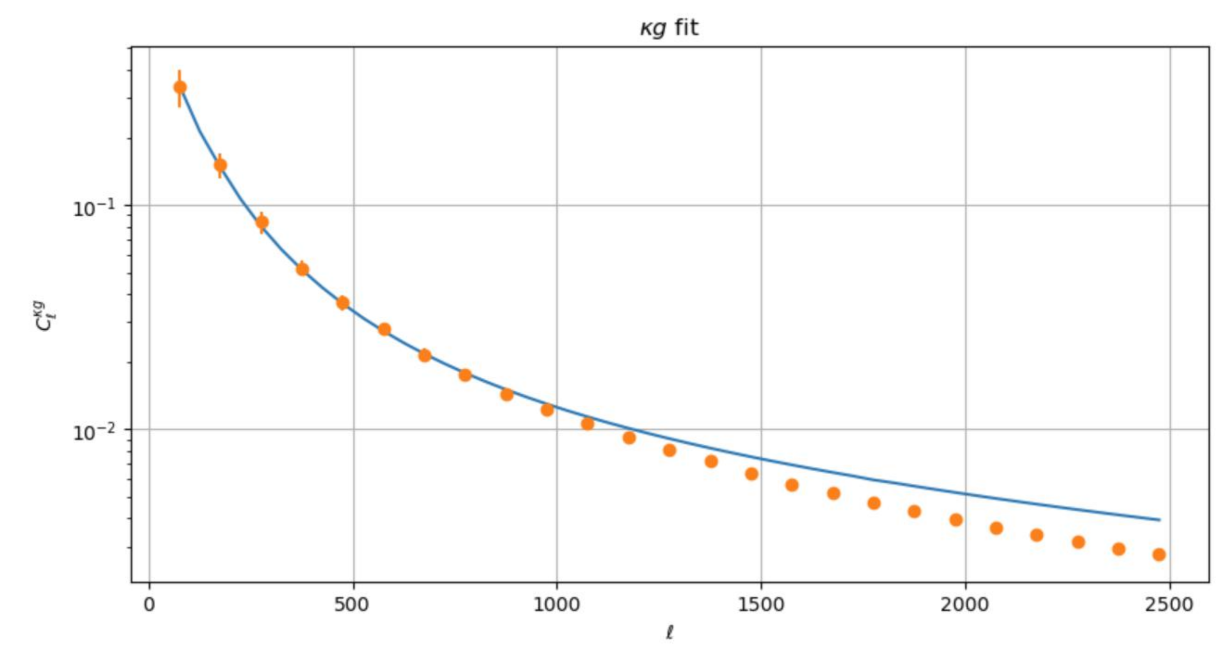

Figure 5: fit to analytical solution assuming linear bias model of the lensing convergence** and the galaxy density cross-spectrum

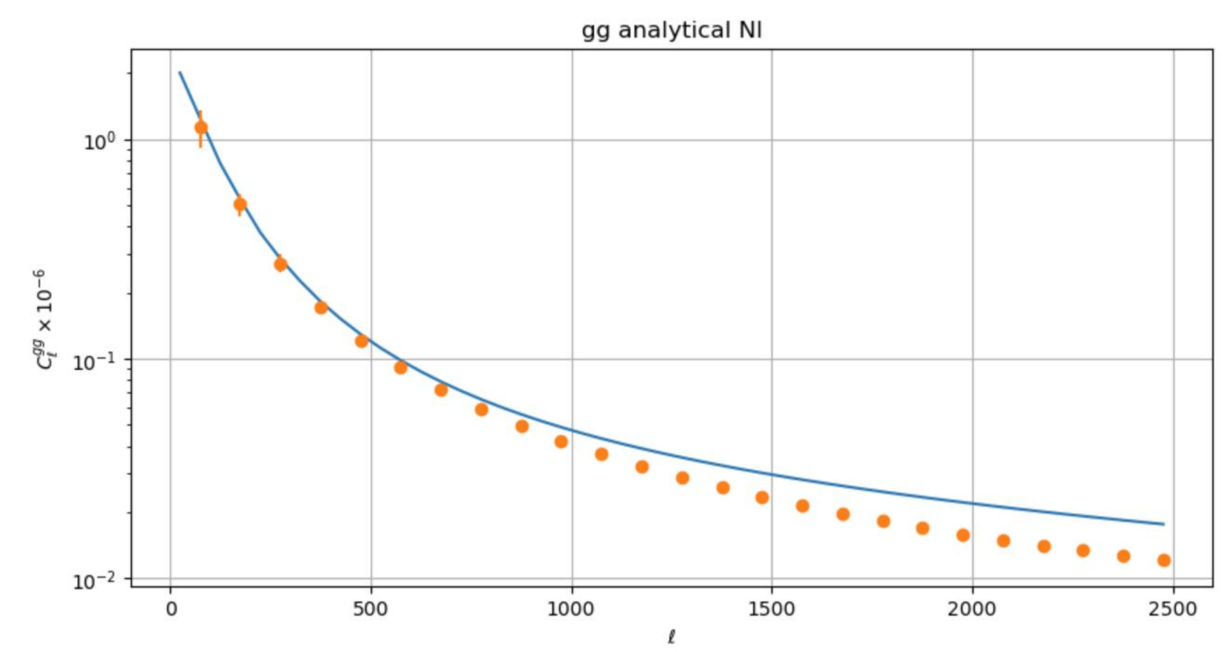

Figure 6: fit to analytical solution assuming linear bias model and analytical shot noise of the galaxy density auto-spectrum

- We wish to explore how this deviation affects the efficiency of template delensing

References

1. Yu B, Hill JC, Sherwin BD (2017) Multitracer CMB delensing maps from Planck and Wise Data. Physical Review D. doi: 10.1103/physrevd.96.123511
2. Lizancos BA, Challinor A Polishing the lenses: Refined modelling of gravitational lensing and Delensing of the cosmic microwave background. Dissertation
3. Paech K, Hamaus N, Hoyle B, et al (2017) Cross-correlation of galaxies and galaxy clusters in the sloan digital sky survey and the importance of non-Poissonian Shot Noise. Monthly Notices of the Royal Astronomical Society 470:2566–2577. doi: 10.1093/mnras/stx1354
4. Namikawa T, Yamauchi D, Sherwin B, Nagata R (2016) Delensing Cosmic microwave background B modes with the Square Kilometre Array Radio Continuum Survey. Physical Review D. doi: 10.1103/physrevd.93.043527