

宇宙地球フロンティア実地研修 報告書

Report for Onsite Training in Earth-Space Frontier Science

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Modern cosmology predicts that inflation not only explains the flatness and homogeneity of universe, but also generates **primordial gravitational waves (PGWs)**, whose detection remains a major challenge. The most promising approach is to search for the **B-mode** (curl pattern) in the CMB polarization, which is uniquely sensitive to PGWs and, by constraining tensor-to-scale ratio, $r>0.002$, could rule out many single-field inflation models with characteristic potential scales larger than the Planck scale. However, a key difficulty is contamination from **gravitational lensing**, which deflects CMB photons and converts part of the E mode into a **lensing-induced B mode** at the last scattering surface, due to the gravitational potential of the large-scale structure. This signal dominates over the expected primordial component at target sensitivity of LiteBIRD ($r=0.001$), making **delensing**, the removal of lensing effects, crucial for PGW detection.

To reconstruct the lensing potential, we combine CMB maps with large-scale structure tracers—such as galaxies and the cosmic infrared background (CIB)—in a **multi-tracer delensing** framework. Earlier approaches often neglected optimization when the lensing B-mode template exhibited strong spatial inhomogeneity, since a direct treatment would require handling its full pixel-space covariance, which is computationally prohibitive. To address this, we developed a **pixel-weighted delensing** technique that assigns inverse-variance weights to each pixel, achieving an optimal balance between cosmic variance and noise.

During the reporting period, I collaborated with Prof. Toshiya Namikawa at the Department of Applied Mathematics and Theoretical Physics, University of Cambridge (DAMTP) on a project focused on estimating r using the **Hamimeche & Lewis (2008) likelihood (HL likelihood)**. Our research aimed to compare the tightness of constraints on r with and without **pixel-weighted delensing**. We prepared several lensed B-mode templates for each realization, including options with and without delensing and with or without weighting. Our analysis demonstrated that **delensing with weighting** provided the tightest constraints on r , improving the precision of the estimate by approximately **30%** compared to other methods, indicating that delensing with optimal weighting significantly improves the precision of the estimate.



Figure 1 The office in DAMTP.