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## Simultaneous determination of miscalibrated polarization angles and cosmic birefringence from Planck PR4

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We present a new implementation of the methodology proposed in Minami et al. (2019) for the simultaneous determination of cosmic birefringence and the miscalibration of polarization angles based on a fast and analytical maximum likelihood solution iterative algorithm. Following the hint of the  $2.4\sigma$  cosmic birefringence signal of  $\beta = 0.35^\circ \pm 0.14^\circ$  found by Minami & Komatsu (2020) in Planck 2018 polarization data (PR3), we apply this methodology to continue the search for the signature of parity-violating physics in the Cosmic Microwave Background using data from Planck PR4 (NPIPE reprocessing). For nearly full-sky data, we initially confirm the previously reported value with a smaller statistical uncertainty. We also find that the values of  $\beta$  decrease as the Galactic mask is enlarged, which can be interpreted as the effect of polarized foreground emission. Acknowledging that the miscalibration of polarization angles is not the only instrumental systematic that can create spurious TB and EB correlations, a detailed study of NPIPE's end-to-end simulations is conducted to evaluate the possible impact of systematics like cross-polarization effects or temperature-to-polarization leakage. This study demonstrates that the  $\beta$  measurements are not significantly affected by any of the known systematics, reinforcing the hypothesis that the decline on  $\beta$  as the Galactic mask is enlarged is driven by the foreground EB correlation. Finally, two independent ways to model the foreground EB contribution and mitigate its impact on  $\beta$  are proposed. Although the good agreement between the two models is encouraging, we do not assign cosmological significance to the measured value of  $\beta$  until we improve our knowledge of the foreground polarization.

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