

A Joint Search for Circular Polarization and Kinematic Dipole Anisotropies in the Stochastic Gravitational-Wave Background

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Certain early-Universe scenarios predict a stochastic gravitational-wave background (SGWB) with nonzero circular polarization, making its detection a potentially powerful probe of parity-violating physics and the physics of the primordial Universe. In addition to polarization, the SGWB may exhibit anisotropies. A particularly well-motivated contribution is the kinematic dipole induced by the observer's motion relative to the cosmic rest frame.

In this work, we develop a unified Bayesian analysis framework to jointly investigate circular polarization and kinematic-dipole anisotropies in the SGWB. We model the cross-correlated detector response in terms of the circular-polarization parameter Π , the spectral index α , the SGWB energy-density amplitude Ω_{ref} , and the spherical-harmonic dipole components Ω_{lm}^D that encode directional anisotropy. The pipeline is first validated through injection–recovery tests using simulated data for third-generation detector networks consisting of Cosmic Explorer and Einstein Telescope. We further assess the projected sensitivity of these future detector networks. We then apply this framework to the LIGO/Virgo O1–O3 cross-spectral dataset. Finding no significant evidence for an SGWB signal, we derive constraints on the parameters related to dipole anisotropies and circular polarization. These results establish a framework for simultaneously probing circular polarization and Doppler-induced kinematic dipole anisotropies in the SGWB, and highlight the potential of next-generation gravitational-wave observatories to place substantially stronger constraints on parity-violating and anisotropic cosmological backgrounds.

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