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Cosmic Last Scattering Surface as an Axion Dark Matter Detector

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We derive the isotropic birefringence (all-sky rotation of linear polarization) of the cosmic microwave background (CMB) sourced by axion-like particles (ALPs) or 'axion'dark matter. We find distinct birefringence signals for oscillating ultra-light axions at recombination as well as from local dark matter. Using *Planck* upper limits while incorporating allowed axion fractions of dark matter, we find strong constraints on the axion-photon coupling which can improve over CAST limits by up to 5 and 2 orders, respectively for recombination and local dark matter axions.
Forecast constraints (*SO, CMB-S4, CMB-HD & PICO*) can tighten coupling constraints further by 1-2 orders, extending to higher axion mass.

The recent hints of a detection (at ~3σ) of isotropic CMB birefringence from a re-analysis of *Planck* and *WMAP* data are considered, in light of our new axion dark matter signals. We point out regions of interest in the parameter space for ultra-light axion dark matter which could explain this detection of isotropic cosmic birefringence, if confirmed.
CMB birefringence constraints scale only weakly with ALP fraction of dark matter. They are also unaffected by uncertainties common to other astrophysical ALP probes: strength and spectrum of magnetic fields, overdensity of ALPs in structures or objects and the source's intrinsic polarization orientation.

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