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X-ray polarimetric features of Gamma-ray Bursts across varied redshifts and hints for Axion-Like-Particles

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The study of polarimetric features during the prompt phase of Gamma-ray Bursts (GRBs) has been essential for elucidating the debated emission mechanisms and gaining insight into the inner structure of GRBs. However, the potential impact of photon-Axion-Like-Particles (ALPs) mixing in extragalactic magnetic fields, leading to significant modifications in the initial polarization, has been overlooked in discussions concerning prompt phase constraints. In this article, we first examine the statistical characteristics of linear polarization degree (Π_L) in GRBs, utilizing data from updated polarimetric missions focusing on sub-MeV emissions. Our analysis, conducted with a restricted sample of GRBs spanning various redshifts, reveals a diverse distribution of Π_L, which currently shows no correlation with spectral parameters or properties of candidate host galaxies. Furthermore, we explore alternations to the initial Π_L due to photon-ALP mixing within a domain-like structure of the intergalactic magnetic field ($\mathbf{B}_{\rm IGM}$), considering various parameter sets associated with ALPs and $\mathbf{B}_{\rm IGM}$. With the existence of ALPs with mass m_a
$lesssim 10^{-14}$ eV and photon-ALP coupling constant $g_{a\gamma}\simeq 0.5\times10^{-11}$ GeV^{-1}, we show that for GRBs with redshifts above approximately 1, fully linearly polarized photons may experience a polarization reduction of up to 20%, whereas for unpolarized photons, the mixing can increase polarization by up to ~40%. To ensure that the effect of mixing is small enough to be negligible, there is a strong constraint on the mixing term $\Delta_{a\gamma}$ should be less than $1.5\times10^{-4}{\rm Mpc}^{-1}$. Currently, the number of GRBs with both sub-MeV polarization measurements and redshift confirmation remains very limited. Harf of the GRBs with available polarization data have a Π_L of less than 30\%. Certification of redshift for this subset of GRBs would aid in further constraining the parameter space of low-mass ALPs or providing an independent means to determine the upper limit on $\mathbf{B}_{\rm IGM}$

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