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First constraints on axion-like particles from Galactic sub-PeV gamma rays

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Experimental refinements and technical innovations in the field of extensive air shower telescopes have enabled measurements of Galactic cosmic-ray interactions in the sub-PeV (100 TeV to 1 PeV) range, providing new avenues for the search for new physics and dark matter. For the first time, we exploit sub-PeV (10 TeV – 1 PeV) observations of Galactic diffuse gamma rays by Tibet ASγ and HAWC to search for an axion-like-particle (ALP) induced gamma-ray signal directly linked to the origin of the IceCube extragalactic high-energy neutrino flux. Indeed, the production of high-energy neutrinos in extra-galactic sources implies the concomitant production of gamma rays at comparable energies. Within the magnetic field of the neutrino emitting sources, gamma rays may efficiently convert into ALPs and escape their host galaxy unattenuated, propagate through intergalactic space, and re-convert into gamma rays in the magnetic field of the Milky Way. Such a scenario creates an all-sky diffuse high-energy gamma-ray signal in the sub-PeV range. Accounting for the guaranteed Galactic astrophysical gamma-ray contributions from cosmic-ray interactions with gas and radiation as well as from sub-threshold sources, we set competitive upper limits on the photon-ALP coupling constant $g_{a\gamma\gamma}$. We find $g_{a\gamma\gamma} < 2.3 \times 10^{-11}$ GeV^{-1} for ALP masses $m_a \leq 2 \times 10^{-7}$ eV at a 95\% confidence level, progressively closing the mass gap towards ADMX limits.

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