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Extragalactic photon–axion-like particle oscillations up to 1000 TeV

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Axion-like particles (ALPs) are very light, neutral, pseudo-scalar bosons which are supposed to interact with two photons. They can give rise to very interesting astrophysical effects taking place in the very-high energy band and above ($10\,\mathrm{GeV} - 1000\,\mathrm{TeV}$) when an external magnetic field is present. So far, the extragalactic magnetic field $B_{\rm ext}$ has been generally modeled as a domain-like network with 'sharp edges': all domains have the same size $L_{\rm dom}$ and $B_{\rm ext}$ has the same strength, but the direction of $B_{\rm ext}$ changes randomly and abruptly from one domain to the next. While this model has repeatedly been used so far, it is a mathematical idealization wherein the components of $B_{\rm ext}$ are discontinuous across the edges. Still, it gives correct results under the unstated assumption that the photon-ALP oscillation length $l_{\rm osc}$ is much larger than $L_{\rm dom}$. However, for the new generation of γ-ray observatories like CTA, HAWC, GAMMA-400, LHAASO and TAIGA-HiSCORE things are different: photon dispersion on the CMB implies $l_{\rm osc} < L_{\rm dom}$, which occurs just above the TeV scale. In such a situation the above model breaks down and must be replaced by one in which $B_{\rm ext}$ is continuous across the edges. We describe such a new model and apply it to a sample of mock blazars at different z and at energy E up to $1000\,\mathrm{TeV}$. We analyze the propagation of the photon-ALP beam generated as pure photons at the jet base of a BL Lac, we study the photon-ALP oscillations during its path up to us while crossing the BL Lac magnetic field, the extragalactic magnetic field which we describe by means of our new model and the Milky Way magnetic field.

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