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Suppressing astrophysical backgrounds for gamma->ALP searches in extreme blazar spectra

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Most of the existing works on extragalactic TeV gamma-ray propagation account for only adiabatic losses and primary gamma-ray absorption due to pair production on extragalactic background light (EBL) photons, i.e. assuming the "absorption-only model"(AOM). However, the observable spectra of some active galactic nuclei (AGN) reveal a tentative excess in photon counts with respect to the AOM in the optically thick region of the spectrum (where the optical depth of pair production on EBL photons \tau>1) [1-3]. This apparent excess could be due to an exotic process, namely, oscillations of primary gamma-rays into axion-like particles (gamma⟶ALP) in magnetic fields and back into gamma-rays relatively near to the observer [4-5].

In the framework of the AOM, the shape of the intrinsic spectrum of an extragalactic gamma-ray source could be reconstructed by compensating for the attenuation and redshift. Some blazars, called "extreme TeV blazars"(ETBs), have such reconstructed intrinsic spectral energy distributions (SEDs) peaking at an energy E>1 TeV. ETBs are very promising sources for the gamma⟶ALP oscillation search. However, compared to "classical"blazars such as Mkn 501 and Mkn 421, ETBs, as a rule, reveal weak and slow variability in the high energy (HE, E >100 MeV) range. Therefore, it is possible that a part of observable emission of these sources was produced not inside the source, but as a result of electromagnetic (EM) cascade development in the intergalactic medium. This intergalactic cascade process could, in principle, create a dangerous source of background for gamma⟶ALP oscillation search, especially if these cascades were initiated by ultra high energy cosmic rays (UHE CR). A part of interactions of these primary CR occurs relatively near to the observer, and thus cascade gamma-rays experience a lesser degree of absorption on EBL photons than the primary gamma-rays from the same source.

In the present work we demonstrate that the background from CR-initiated intergalactic EM cascades could be greatly suppressed as follows. During their propagation from the source to the observer, primary CR are deflected to appreciable angles (~0.1-1 degree) in filaments of the large scale structure. This effect broadens the observable angular distribution significantly and leads to an effective cutoff in the observable point-like spectrum (i.e. the spectrum collected inside the point spread function of the observing instrument). We have performed detailed simulations of integralactic UHECR propagation using the publicly-available code CRPropa3 [6] and, profiting by a hybrid approach developed by us in [7], calculated the observable spectrum and the angular distribution of gamma-rays. We show that the observable spectrum is similar to the so-called universal spectrum of the intergalactic EM cascade model. This study could significantly facilitate future gamma⟶ALP oscillation searches in the optically thick region of blazar spectra with existing and future gamma-ray instruments such as Fermi-LAT, H.E.S.S., MAGIC, VERITAS, CTA, HAWC, and LHAASO.

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