Contribution ID: **287** Type: **Talk**

Towards more robust models of extragalactic gamma-ray propagation

Friday 31 August 2018 14:34 (17 minutes)

Emission of distant (redshift z>0.1) extragalactic sources in the GeV-TeV energy range may be significantly transformed during the propagation between the source and the observer. So far, the only robust result in this area was the firm establishment of the existence of the \gamma\gamma\rightarrow e^{+}e^{-} pair production process. During the last 8 years, there were many other claims that were ultimately rejected or remain unconfirmed. Namely, 1) the strength and structure of the extragalactic magnetic field (EGMF) is still virtually unknown, 2) the anomalies indicating the presence of \gamma\rightarrow axion-like particle (ALP) oscillation in magnetic fields are still not confirmed 3) for some sources such as extreme TeV blazars, the shape of the primary spectrum is still not well constrained.

We argue that many difficulties in this area of research have a methodical origin. We illustrate these difficulties in the framework of intergalactic cascade models that include secondary (cascade) gamma-rays produced in electromagnetic (EM) cascades initiated by primary gamma-rays or protons. For instance, we argue that the recent claim of astro-ph/1804.08035 that the EGMF strength is constrained to be above 0.3 pG for the case of stable sources is driven mainly by the assumptions made by the authors (namely, that "accounting for the cascade contribution does not change the best-fit spectrum of the central point source in the entire Fermi-LAT energy band by more than 5 \sigma"). As well, recent works aimed at the discovery of the \gamma\rightarrow ALP process, besides other methodical difficulties, do not consider a possible source of background from intergalactic electromagnetic cascades.

We apply intergalactic cascade models to the case of extreme TeV blazar observations with atmospheric Cherenkov telescopes (ACTs) and the Fermi-LAT telescope. We show that the development of intergalactic EM cascades may, in principle, represent a dangerous source of astrophysical background for \gamma\rightarrow ALP searches. On the other hand, intergalactic EM cascades from primary protons and nuclei do not modify the effective opacity of the Universe significantly. We discuss how to falsify these "electromagnetic"and "hadronic"intergalactic cascade models with contemporary and future gamma-ray observations, thus allowing to suppress the background for the \gamma \rightarrow ALP process searches with ACTs and Fermi LAT. We also argue that while measuring weak EGMF (~1 fG or less on the spatial scale of 1 Mpc) with weakly variable sources, ACTs such as the Cherenkov Telescope Array (CTA) should be supplemented by space-based telescopes such as Fermi LAT. We argue that these results are robust with respect to many systematic effects. Some details of our calculation methods are available in [T.A. Dzhatdoev et al., A&A, 603, A59 (2017)].

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Session Classification: Gamma Rays

Track Classification: Gamma-rays