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Constraints on the extragalactic magnetic field and the nature of multi-TeV gamma-rays from the brightest of all time GRB 221009A

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GRB 221009A, a relatively nearby (redshift z = 0.1505) and exceptionally bright gamma-ray burst, has been detected with the LHAASO-KM2A instrument up to the energy of \approx 13 TeV. The unprecedented fluence of TeV gamma-rays from GRB 221009A allows to set constraints on the strength B of the extragalactic magnetic field (EGMF), excluding the values of B < 10^{-18} G [Dzhatdoev et al., MNRAS Lett., 527, L95 (2024)].

Contrary to some previous studies, we show that the intrinsic (intergalactic absorption-corrected) gamma-ray spectrum of GRB 221009A reveals a surprising cutoff or a break above the energy of several TeV. The nature of the multi-TeV gamma-rays is not clear due to a possible strong influence of the Klein-Nishina effect, severely limiting the observable gamma-ray intensity at the energy in excess of several TeV. A significant part of \approx 10 TeV gamma-rays from GRB 221009A could have been produced by an unconventional mechanism. We consider one possible unconventional scenario described below.

Gamma-ray bursts are typically situated in star-forming regions. Therefore, the "near"(<100 pc) environment of GRBs is often occupied by a significant amount of gas (typical column density \sim 10^{21}–10^{23} 1/cm^{2}). Furthermore, GRBs are capable of accelerating protons and/or nuclei up to the energy of at least 1 PeV/nucleon in the fireball's rest frame. The protons/nuclei accelerated during the GRB prompt phase could interact with dense photon fields producing neutrons. These neutrons escape from the magnetic fields of the fireball freely and interact with the interstellar matter of the star-forming region, eventually resulting in an observable flux of multi-TeV gamma-rays. We show that for certain values of relevant parameters the intensity of these gamma-rays could contribute significantly to the observable spectrum at E > 10TeV.

The presented results are relevant for cosmology (constraints on the EGMF strength) as well as for new physics searches (e.g. gamma-ray — axion-like particle oscillation search and constraints to the effects of Lorentz invariance violation). Finally, we briefly discuss the relevance of the presented findings to the models of gamma-ray production in GRBs and to intergalactic gamma-ray propagation models.

Internet talk

Maybe

Is this an abstract from experimental collaboration?

No

Name of experiment and experimental site

N/A

Is the speaker for that presentation defined?

Yes

Details

N/A

Author: DZHATDOEV, Timur

Presenter: DZHATDOEV, Timur

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