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Magnetic fields in the early universe

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Abstract

The Planck satellite mission has set an upper limit of about $4{:}4\cdot10^{-9}$ G for the strength of stochastic primordial magnetic fields. Two recent estimates of lower limits for the stochastic primordial magnetic fields are reviewed.

The first estimate pioneered by Neronov and Vovk (2010) is based on GeV-TeV γ-ray observations of distant blazars by air-Cherenkov telescopes and the FERMI satellite. The generated $e^{\pm}$ pair beams from double photon collisions with the extragalactic background light have been expected to initiate a full electromagnetic cascade as in vacuum. However, as the cascaded GeV inverse Compton scattered gamma-rays have not been detected, the existence of small irregular intergalactic magnetic fields, scattering the produced pairs, has been predicted. However, the generated initial pair beams are subject to rapid electrostatic and electromagnetic kinetic plasma instabilities (Broderick et al. 2012, Schlickeiser et al. 2012) in the unmagnetized fully-ionized intergalactic Medium, so that less kinetic initial pair energy for the cascade emission is available, explaining the non-detected GeV γ-rays.

The second estimate calculates the magnetic (and electric) equilibrium wavenumber spectrum of aperiodic collective fluctuations in the thermal isotropic electron-proton intergalactic plasma using the generalized Kirchhoff laws, accounting self-consistently for the simultaneous competition of spontaneous emission and absorption processes. By integrating the wavenumber spectrum over all wavenumber values provides for the total magnetic field strength in the IGM $|\delta B| = \sqrt{(\delta B)^2} \simeq 10^{-17}$ with maximum length scales ≤ 10^{15} cm. This guaranteed magnetic field in the form of randomly distributed aperiodic fluctuations, produced by the spontaneous emission of the isotropic thermal IGM plasma, sets a robust lower limit on stochastic primordial magnetic fields, and serves as seed field for amplification by later possible plasma instabilities from anisotropic plasma particle distribution functions, MHD instabilities and/or the MHD dynamo process.