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Suppression of the TeV pair-beam plasma instability by a weak intergalactic magnetic field

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We constrain the intermediate-scale intergalactic magnetic field (IGMF) through its suppression of the electrostatic instability for blazar-induced pair beams. IGMF of Femto-Gauss strength is sufficient to significantly deflect the TeV pair beams, which reduces the flux of secondary cascade emission below the observational limits. A similar flux reduction may result from the electrostatic beam-plasma instability, which operates the best at zero IGMF. We study the effect of sub-fG level IGMF on the electrostatic instability of the blazar-induced pair beam. Considering IGMF with correlation lengths smaller than a few kpc, we find that such fields increase the transverse momentum of the pair beam particles, which dramatically reduces the linear growth rate of the electrostatic instability and hence the energy-loss rate of the pair beam. Our results show that the IGMF eliminates the beam-plasma instability as an effective energy-loss agent at a field strength three orders of magnitude below that needed to suppress the secondary cascade emission by magnetic deflection. For intermediate-strength IGMF, we do not know a viable process to explain the observed absence of GeV-scale cascade emission.

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Summary

Context:

- Several gamma-ray observations from distant blazars show a suppressed emission of the inverse Compton scattering cascade of the blazar-induced pair beams at the GeV energy band.
- The first possible explanation is the deflections of the pair beam electrons and positrons by magnetic fields of Femto Gauss strengths in the intergalactic medium.
- The second one is the drain of the pair energy by beam-plasma instabilities resulting in heating up the intergalactic plasma.
- The beam-plasma instabilities of blazar-induced pair beams operate the best at zero intergalactic magnetic fields.

Method:

- We investigate the effect of weak intergalactic magnetic fields with small correlation lengths on the electrostatic beam-plasma instability linear growth rate numerically.
- We find that the weak intergalactic magnetic fields increase the angular distribution of the particles of the pair beam.
- We show that this widening of the pair beam reduces the linear growth rate of the electrostatic instability.
- This reduction of the linear growth rate increases the energy loss time of the beam-plasma instability suppressing the beam-plasma instability.

Results

- The beam-plasma instability suppression occurs at magnetic field strengths three orders of magnitude less than the lower limit of the magnetic fields needed to deflect the secondary cascade emission.
- The intermediate scale intergalactic magnetic fields where he beam-plasma instability nor the intergalactic magnetic field deflection work as an explanation for the observed blazars spectra and so this parameter space region can be excluded if there is no third mechanism that prevents the full electromagnetic cascade emission of the TeV gamma-ray beams from the distance blazars.

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