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

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Introduction

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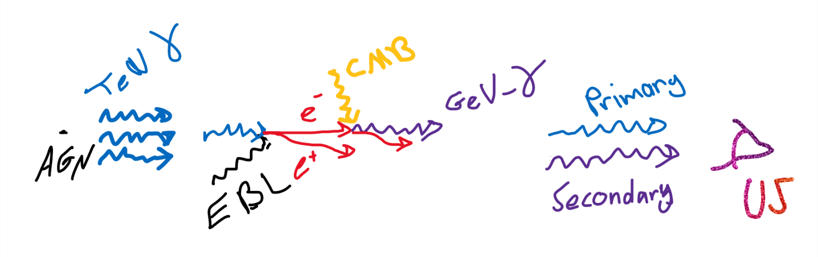
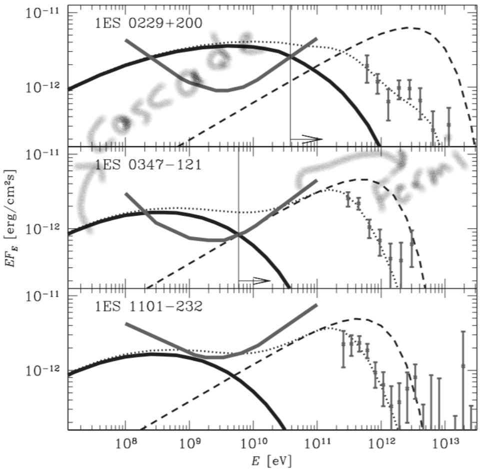
- Blazars are AGN's with a jet oriented along the line of sight.
- Some population of blazars (BL Lacs, in particular) shows an intense emission γ-ray at TeV energies.
- Along with the primary TeV emmision we expected to detect an electromagnetic cascade in the GeV energy band due to the attenuation in the IGM:



The electromagnetic cascade is missing in the observations

- Some of the observed blazars arriving energy fluxes in the GeV band are under the predicted flux from the full electromagnetic cascade.

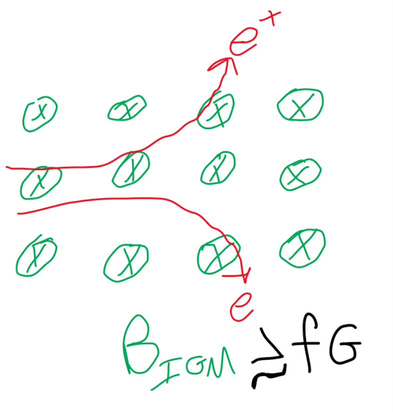
Fig. 1. A comparison of models of cascade emission from TeV blazars (thick solid black curves) with Fermi upper limits (gray curves) and HESS data (gray data points). Thin dashed curves show the primary (unabsorbed) source spectra. Dotted curves show the overall (cascade plus direct) spectra after propagation through the EBL. Vertical lines with arrows show the energies below which the cascade emission should be suppressed. HESS data points (with SEM error bars) are taken from (*23*, *36*, *37*).



Neronov and Vovk (2010)

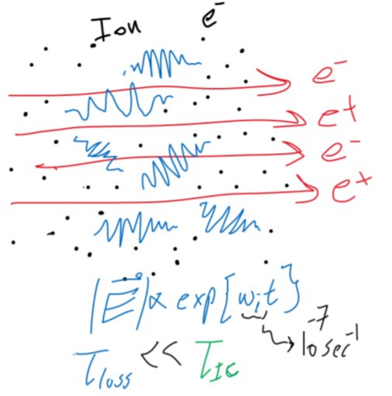
Two possible explanations

Deflection by the IGM magnetic field



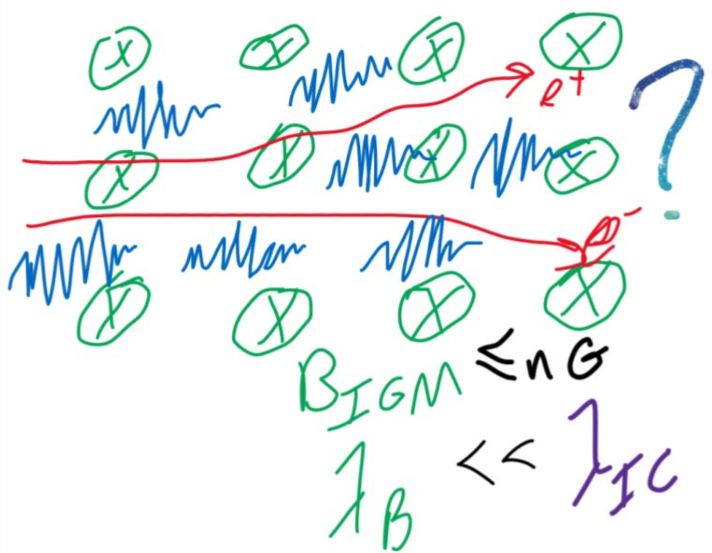
Neronov and Vovk (2010)
Taylor et al. (2011)

Energy loss due to the Beam-plasma instabilities



Broderick et al. (2012)
Brejzman and Ryutov (1974)

What is the effect of weak intergalactic magnetic fields on the plasma instability?



Weak Intergalactic Magnetic Fields effect on the Linear Growth Rate of Electrostatic Instability

Weak Intergalactic Magnetic Fields effect on the Linear Growth Rate of Electrostatic Instability

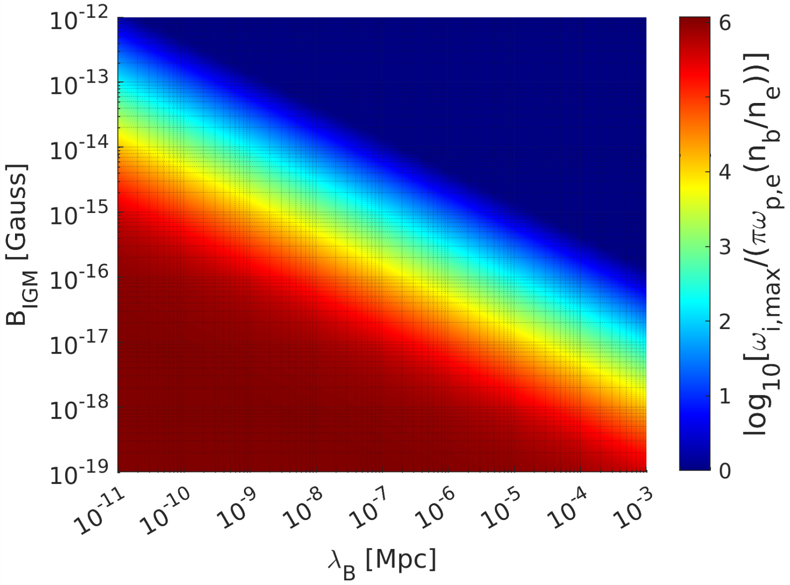
- The linear growth rate depends significantly on the pair beam distribution.
- The intergalactic magnetic fields cause stochastic deflections of the electrons and positrons increasing the angular distribution function of the pair beam as a Gaussian with the angler spread

$$\Delta\theta = \frac{m_e c}{p}\left[1 + \sqrt{\frac{2}{3}\lambda_{IC}\lambda_B}\,\frac{e B_{IGM}}{m_e c}\right]$$

$$\lambda_B = pc \quad \approx \quad 10^{-6}\left[1 + B_{IGM}/10^{-18}[G]\right]$$

$$\omega_i \propto \frac{1}{(\Delta\theta)^2}$$

Maximum linear growth rate with IGMF



Plasma instability limit

Energy loss time of the beam-plasma instability

- We consider the energy loss time in Vafin et al. (2018) that is about one order of magnitude less than the IC energy loss time at redshift 0.2:

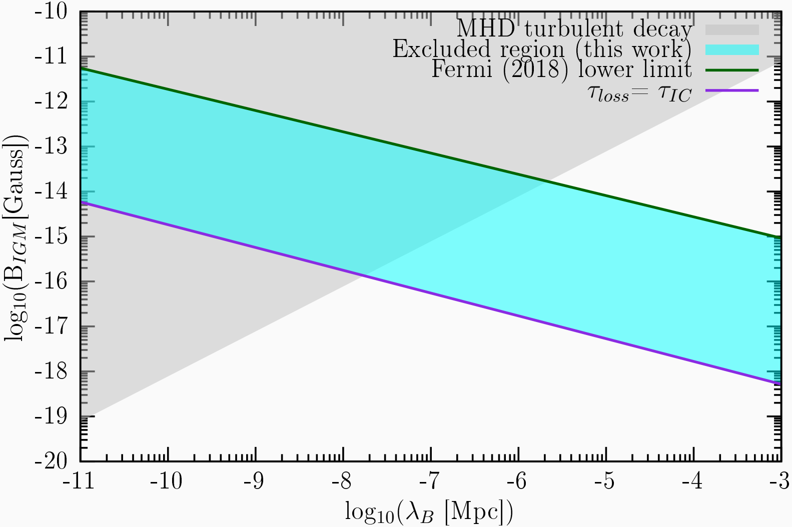
$$\frac{\tau_{\text{loss}}}{\tau_{\text{IC}}} = 0.026, \tag{1}$$

- The energy loss time of the beam-plasma instability is inversely proportional to the maximum linear growth rate (Vafin et al., 2018; Miniati and Elyiv, 2013)

$$\tau_{\text{loss}} \propto \omega_{i,\text{max}}^{-1}. \tag{2}$$

- The weak intergalactic magnetic field increases the energy loss time of the beam-plasma instability suppressing it after a certain limit.

Plasma instability limit compared to the time delay limit



Summary

Summary

- Weak intergalactic magnetic field slow down the linear electrostatic instability.
- This suppression is effective for fields a factor of a thousand weaker than those needed for magnetic deflection of the cascade emission.
- Non-observation of the cascade emission hence exclude IGM magnetic field of intermediate strength (10^{-15} G on parsec scale).

References

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