Multimessenger Constraints on Intergalactic Magnetic Fields from Flaring Objects

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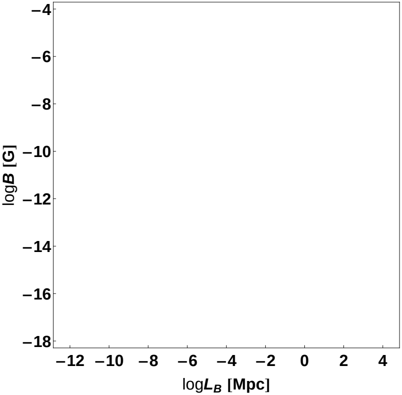
IGMF - Standard Constraints [Neronov and Semikoz, 2009]



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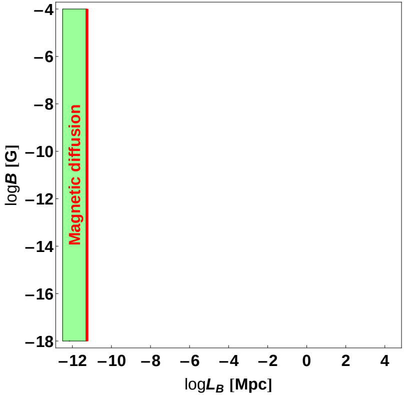

Resistive decay removes short correlation lengths

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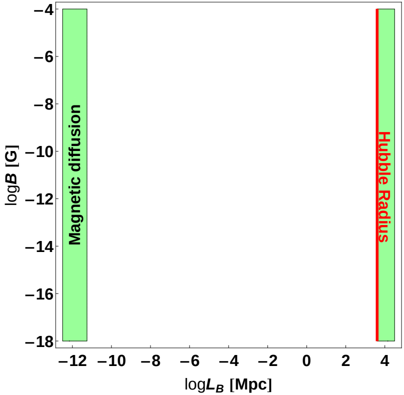

L_B cannot be larger than the Hubble Radius

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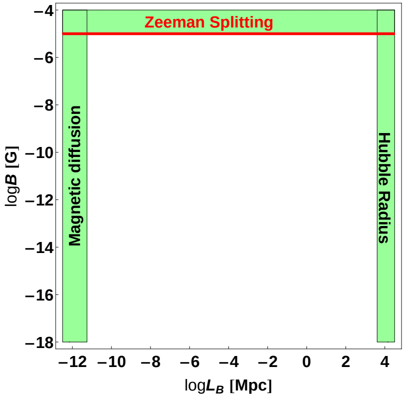

IGMF cannot be stronger than galactic magnetic fields

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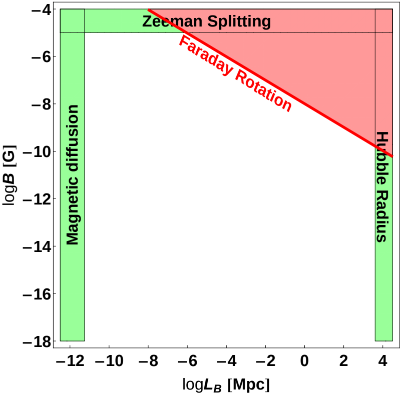

Non-observation of intergalactic FR for radio emisson from Quasars

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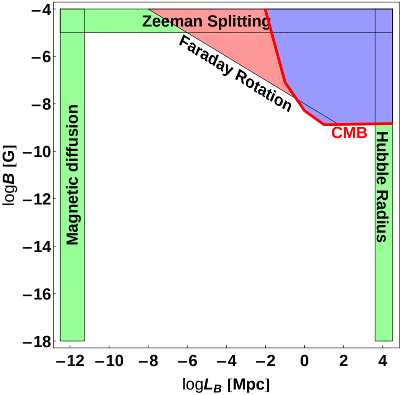
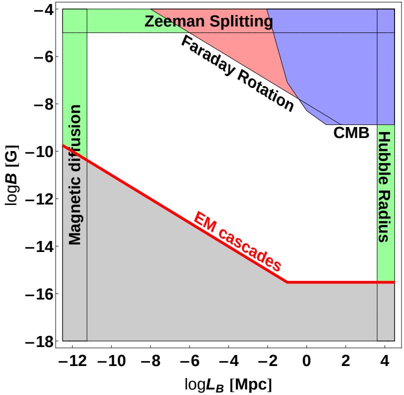


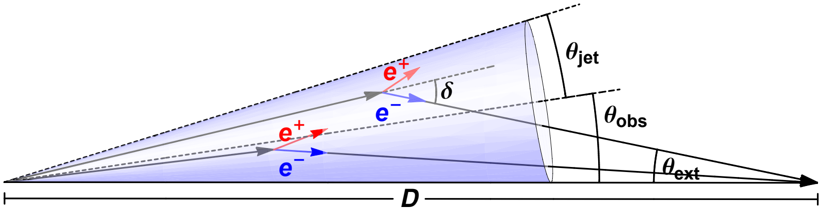
Non-observation of large scale angular anisotropies of the CMB

IGMF – Lower Bound on B? [Neronov and Semikoz, 2009]



Lower bound on B from gamma ray observations?

IGMF – Lower Bound on B?



- Gamma rays emitted from a blazar develop an electromagnetic cascade due to interactions with photon background fields via Pair Production and Inverse Compton (IC) scattering. The interaction of this cascade with the IGMF results in several observational features.

Limits on IGMF using Multimessengers

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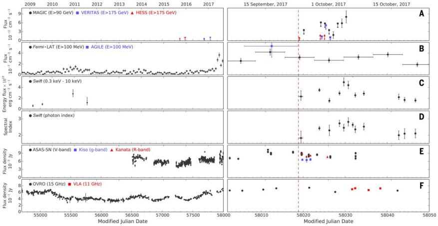
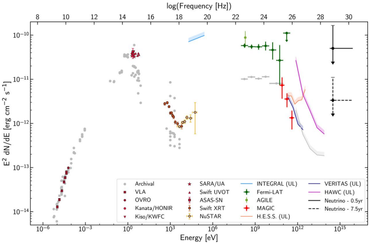
- A flaring object (flare duration $\Delta t_{\mathrm{flare}}$) which emits gamma rays and neutrinos simultaniously provides a measure for the time delay Δt_{IGMF} of the sec. gamma rays due to IGMF
- Of particular interest is the IceCube neutrino event IC-170922A [IceCube Collaboration, 2018] which is associated with the 2017 flare of the blazar TXS 0506+056 in the electromagn. spectrum [IceCube Collaboration et al., 2018]





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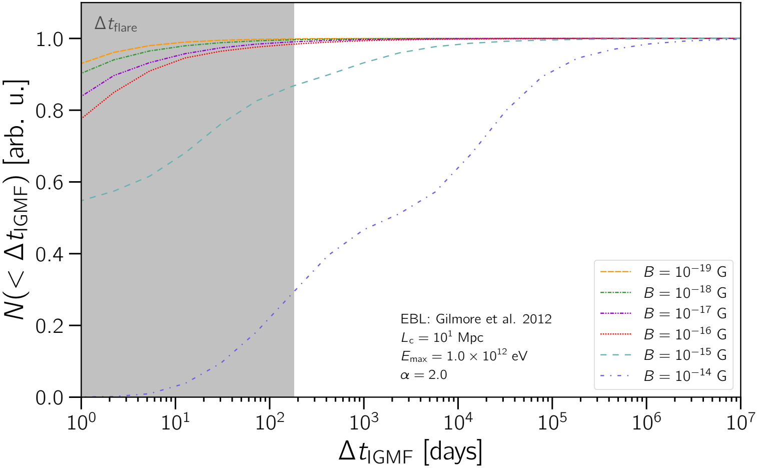

Cumulative distribution of time delays of gamma rays due to IGMF ($\Delta t_{\rm IGMF}$) for TXS 0506+056. The grey shaded region indicate the period of enhanced activity of the object ($\Delta t_{\rm flare}$)

Limits on IGMF using Multimessengers

- We simulate the emitted flux as

$$\frac{dN}{dE} = J_0 \begin{cases} E^{-\alpha_\mathrm{l}} \exp\left(-\frac{E}{E_{\mathrm{max,l}}}\right) & \text{"low" (non-flaring) state}\,, \\ \eta E^{-\alpha_\mathrm{h}} \exp\left(-\frac{E}{E_{\mathrm{max,h}}}\right) & \text{"high" (flaring) state}\,, \end{cases}$$

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- We use four different EBL models for the simulation of the propagation of the electromagnetic cascade with the CRPropa code [Alves Batista et al., 2016] and consider large ranges of B, L_c, E_{max} and α
- In order to analyze the data, we first determine the best-fit spectral parameters of the low state (i.e. $E_{\mathrm{max,l}}$ and α_{l}), and then scan over the remaining parameters (η, $E_{\mathrm{max,h}}$, α_{h}, B, L_c)

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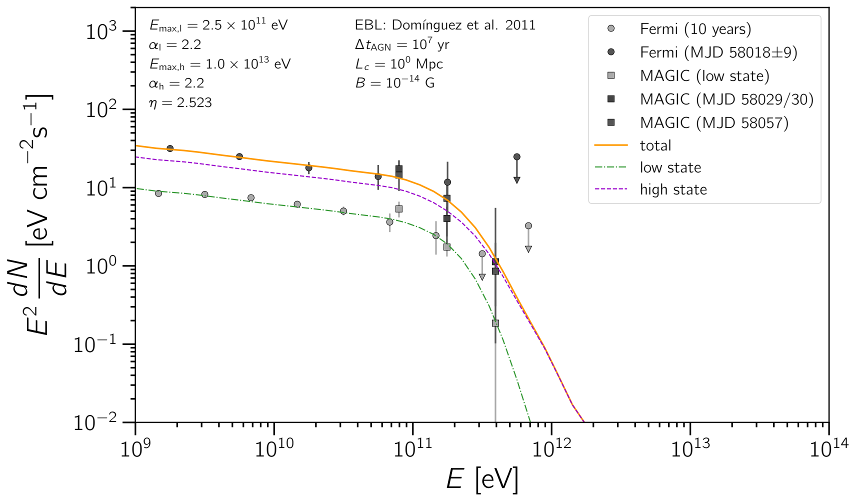

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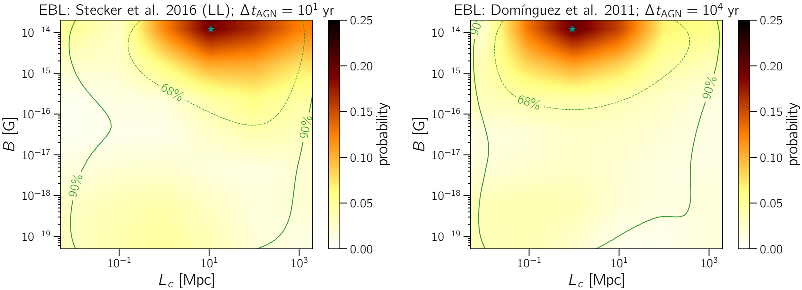

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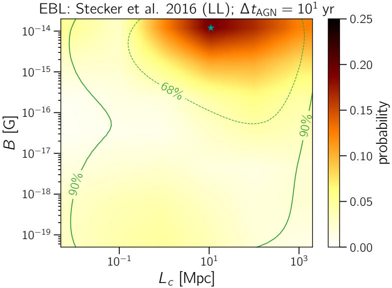

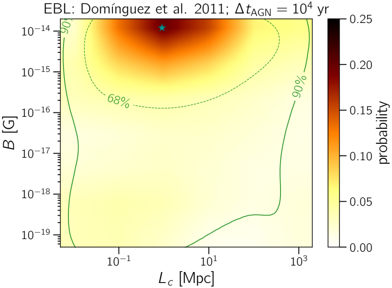

- For two of the EBL models we could reject the $B = 0$ hypothesis
- For these two models it is possible to constrain the magnetic field strength B *and* the correlation length L_c [Alves Batista and Saveliev, 2020]

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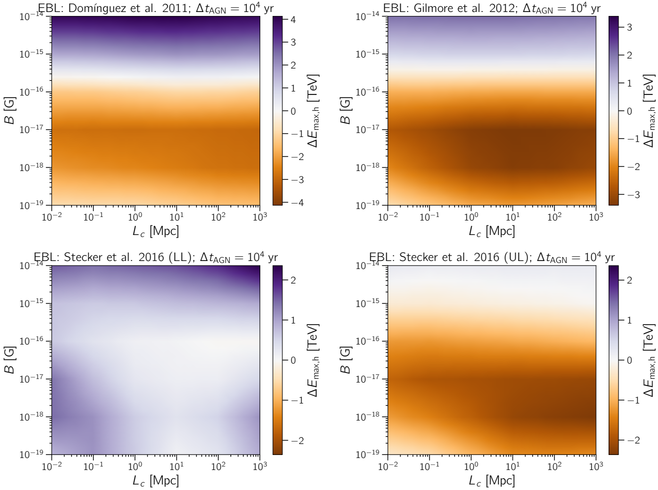

- IGMF have a significant impact on the determination of the intrinsic spectral properties of the source [Saveliev and Alves Batista, 2021]

Conclusions and Outlook

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- Gamma ray observations are a well-known tool for constraining IGMF
- Using flaring events which emit photons *and* neutrinos simultaniously provides a new opportunity to set limits on IGMF, in particular, for the first time, also on the correlation length L_c
- We have also shown that IGMF have to be taken into account when determining the intrinsic spectral properties of a source
- In the future we will extend our analysis to other flaring objects to obtain more robust magnetic field limits and extend the parameter space, in particular considering higher magnetic field strengths.

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