DESY Theory Workshop

Measuring the Helicity of Intergalactic Magnetic Fields with Numerical Simulations in Astroparticle Physics

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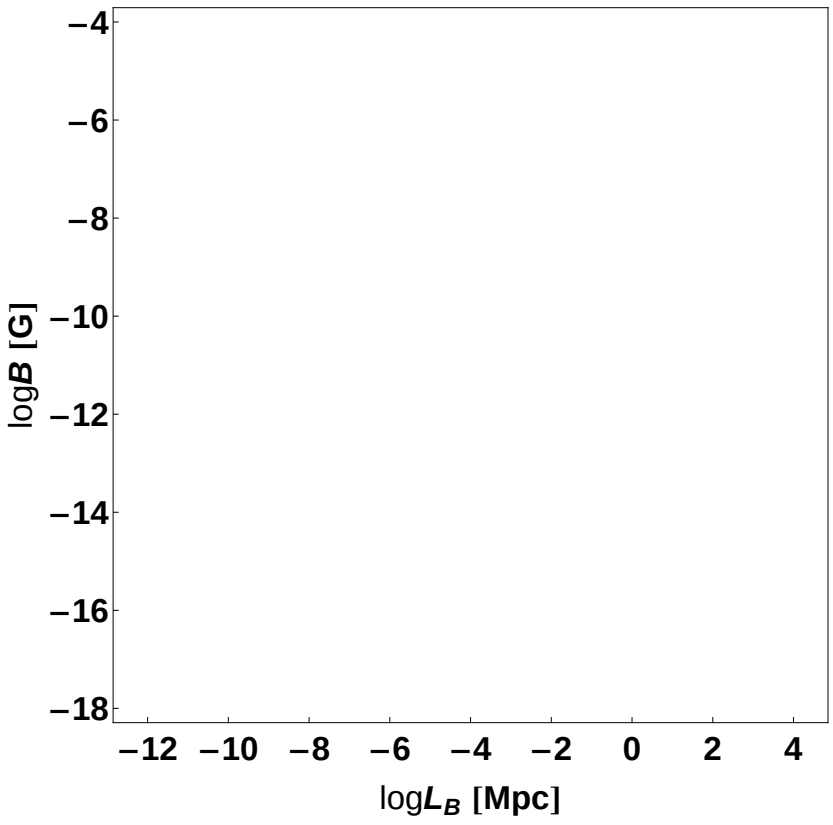
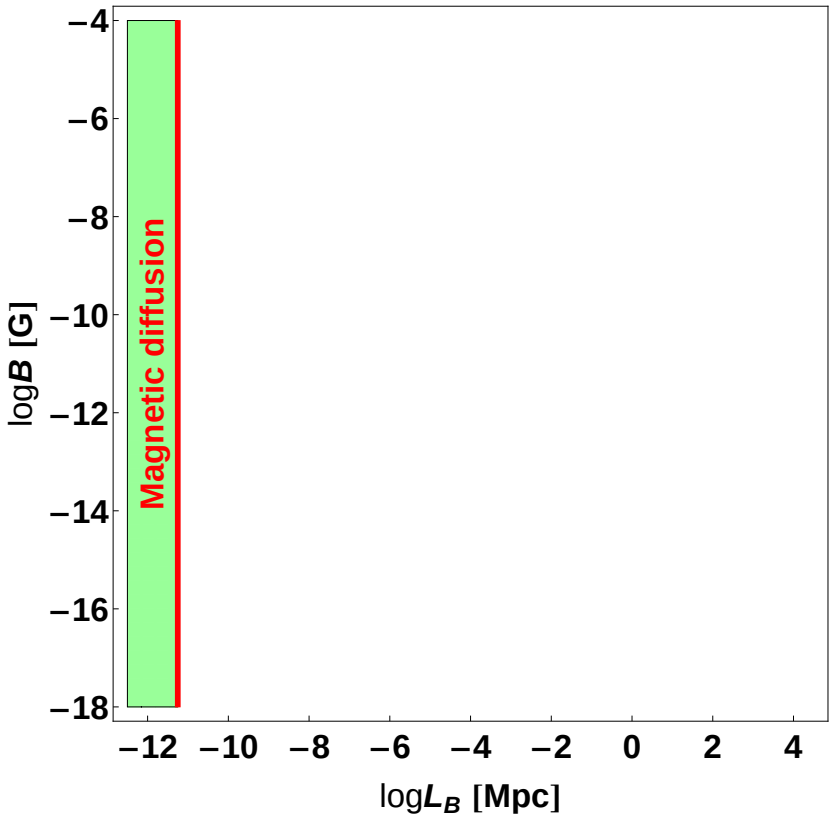
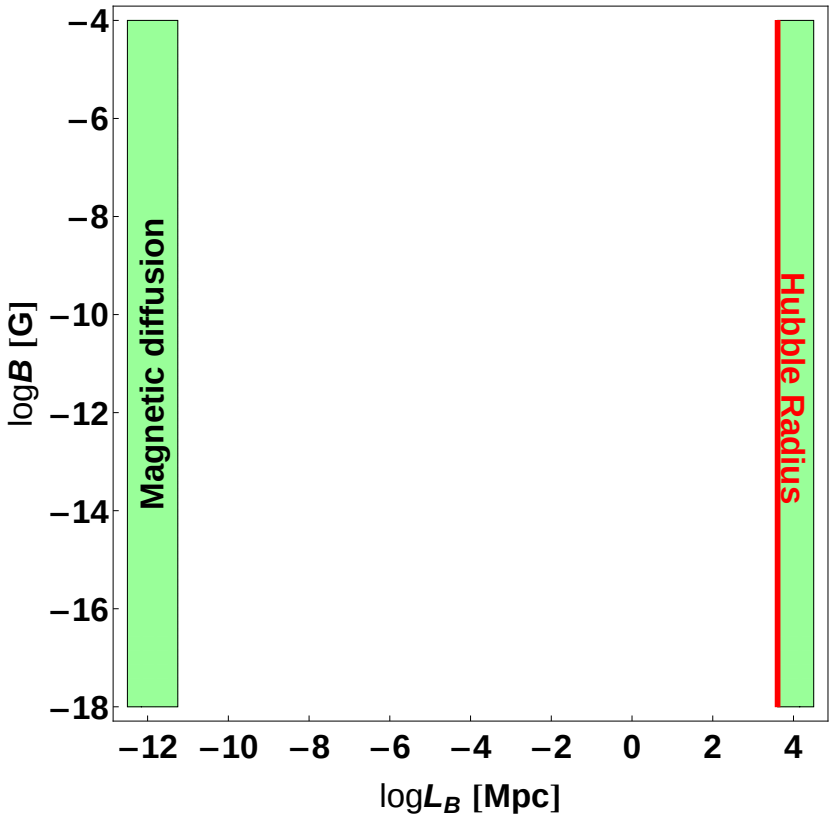


IGMF - Standard Constraints [Neronov and Semikoz, 2009]



Resistive decay due to magnetic diffusion removes short correlation lengths L_B

IGMF - Standard Constraints [Neronov and Semikoz, 2009]



L_B cannot be larger than the Hubble Radius

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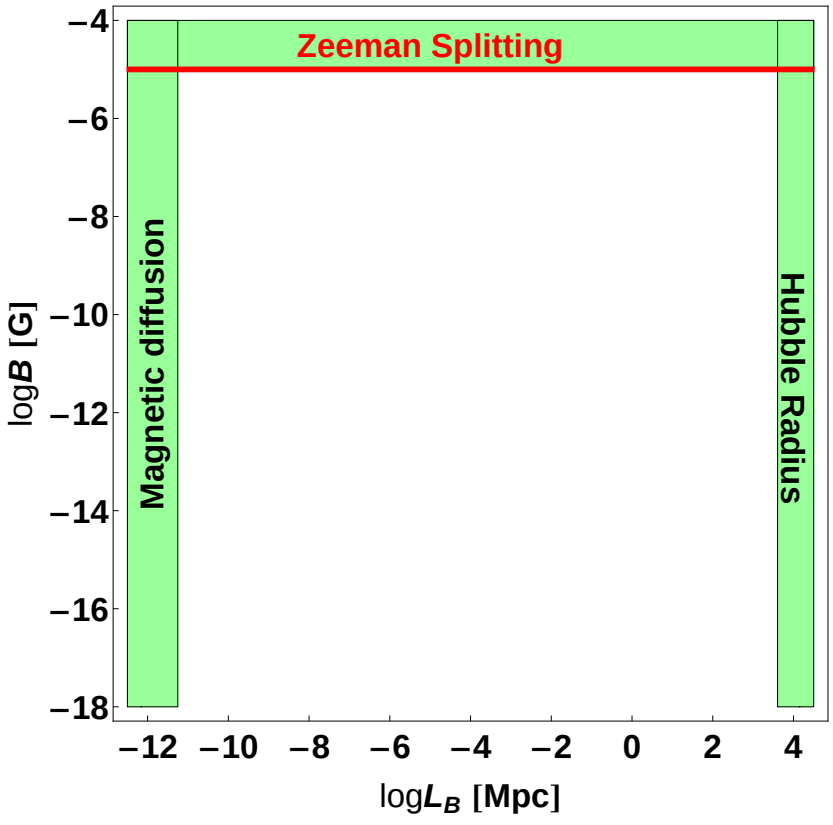

IGMF cannot be stronger than galactic magnetic fields

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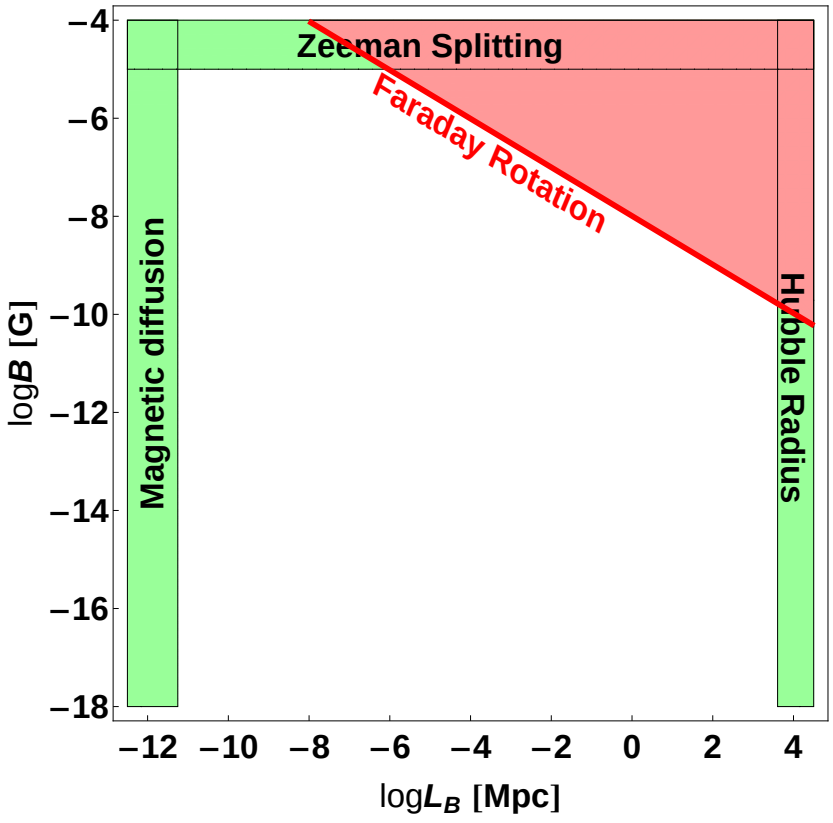

Non-observation of intergalactic Faraday Rotation for radio emisson from Quasars

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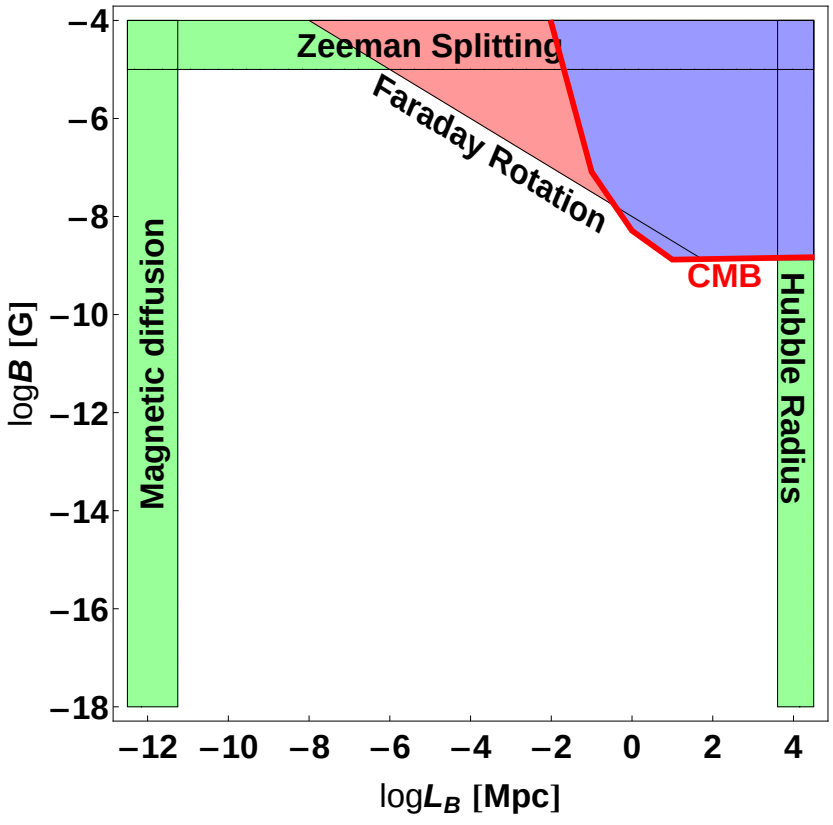
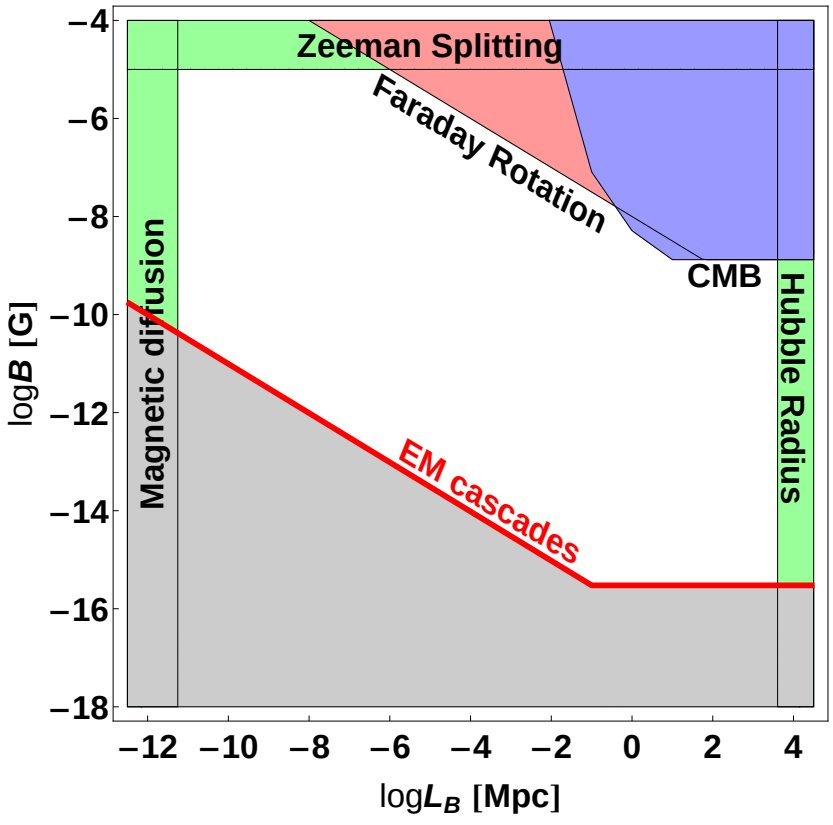


Non-observation of large scale angular anisotropies of the CMB

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



Lower bound on B from gamma ray observations?

Magnetic Helicity

- The magnetic helicity H is defined as $H = \int_V \mathbf{A} \cdot \mathbf{B} \, \mathrm{dV}$, where $\mathbf{A}$ is the vector potential

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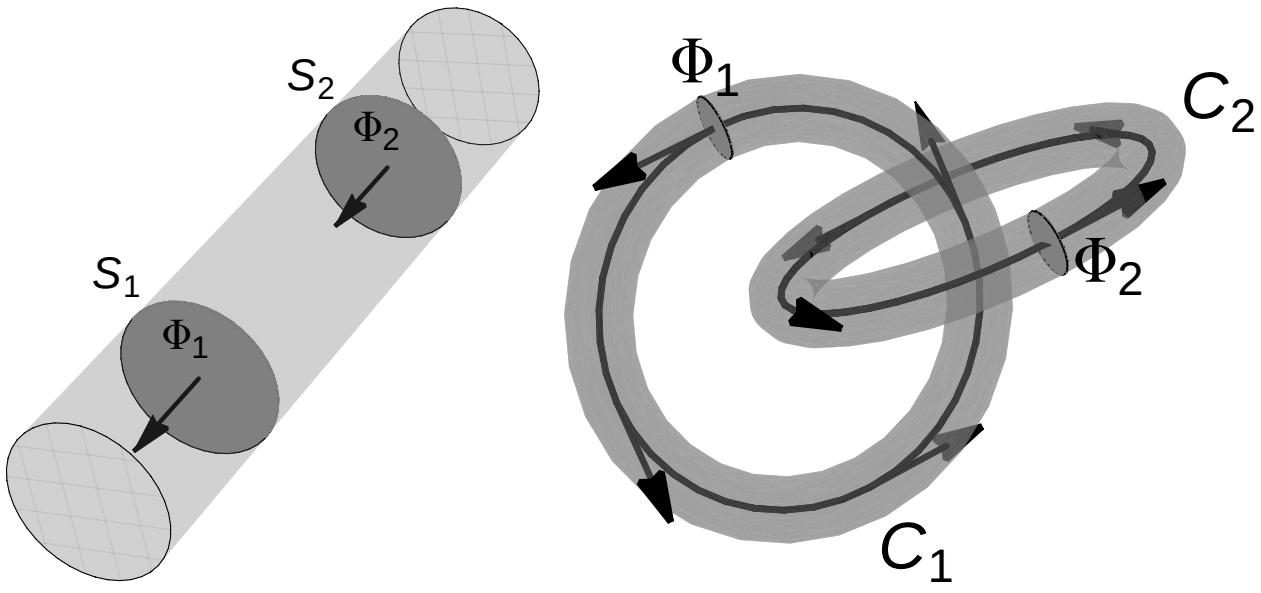
- It is connected to the linkage numbers of magnetic field lines (infinitisemal magnetic flux tubes)



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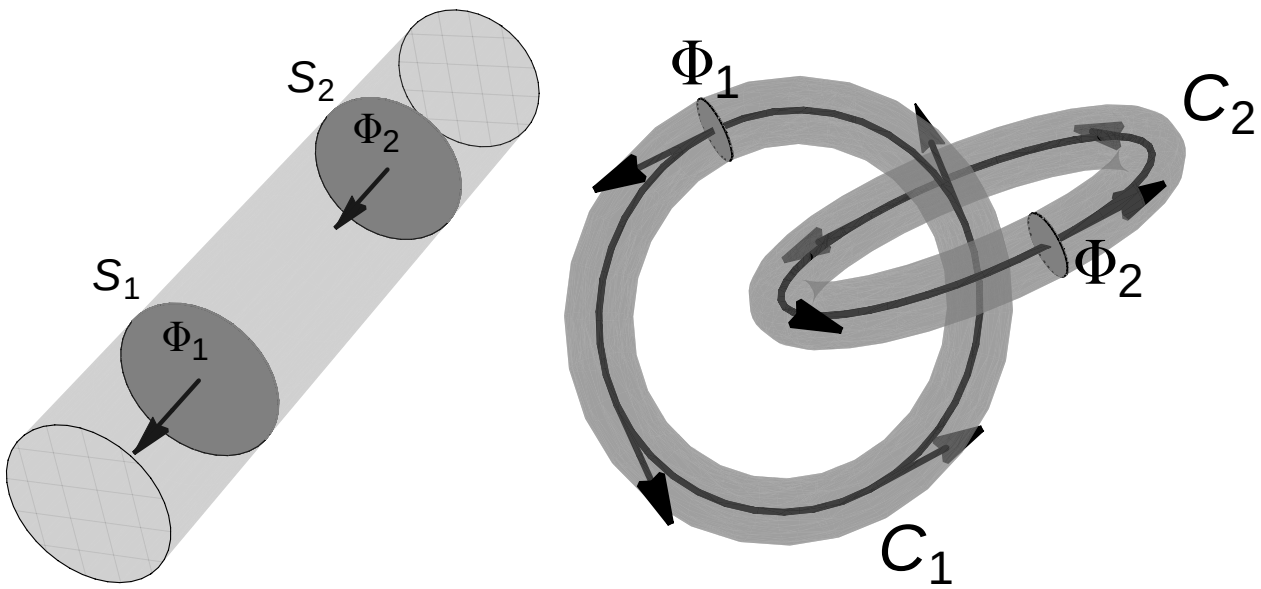


- Important since it is a conserved quantity and hence influences the time evolution of IGMF [Saveliev et al., 2013b]

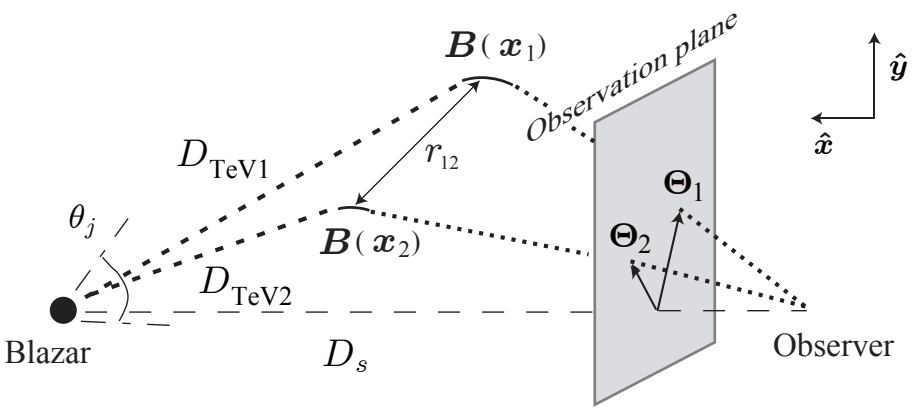
Measurement of Primordial Magnetic Helicity

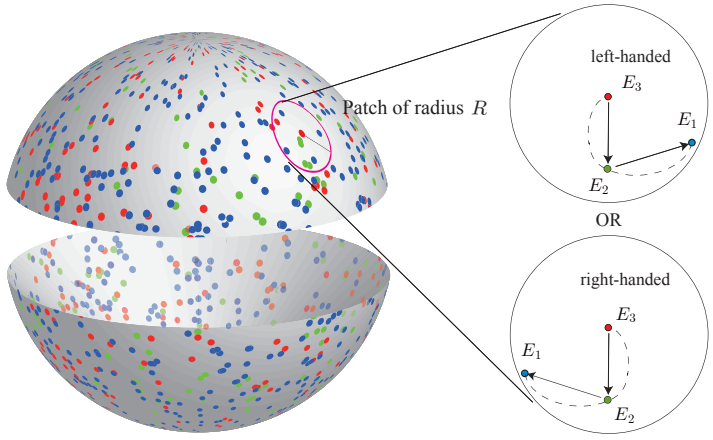
It has been shown that [Tashiro and Vachaspati, 2013]

$$G(E_1, E_2) = \left\langle (\Theta_1 \times \Theta_2) \cdot \frac{\mathbf{x}}{|\mathbf{x}|} \right\rangle \propto \frac{1}{2}\mathcal{H}(r_{12})r_{12}$$

for a known blazar position; otherwise (with $E_3 > E_2 > E_1$)

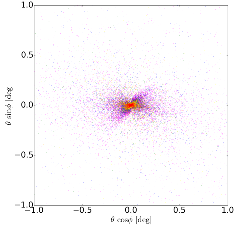
$$G(E_1, E_2, E_3) = \left\langle [(\Theta_1 - \Theta_3) \times (\Theta_2 - \Theta_3)] \cdot \frac{\mathbf{x_3}}{|\mathbf{x_3}|} \right\rangle \propto \frac{1}{2}\mathcal{H}(r_{12})r_{12}$$

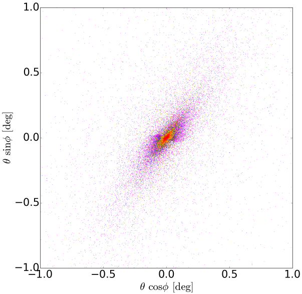


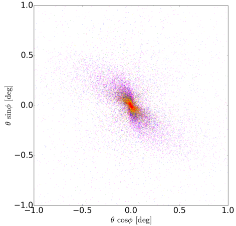


[Tashiro et al., 2014]

Helicity Analysis – Sky Maps [Alves Batista et al., 2016]

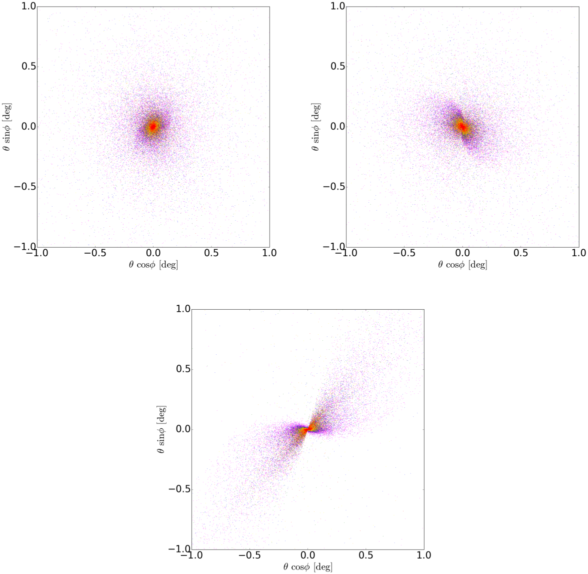






Sky maps for maximally negative and positive helicity (left) and no helicity (top), $B = 10^{-15}\,\mathrm{G}$, $L_B \simeq 120\,\mathrm{Mpc}$.

Helicity Analysis – L_B [Alves Batista et al., 2016]



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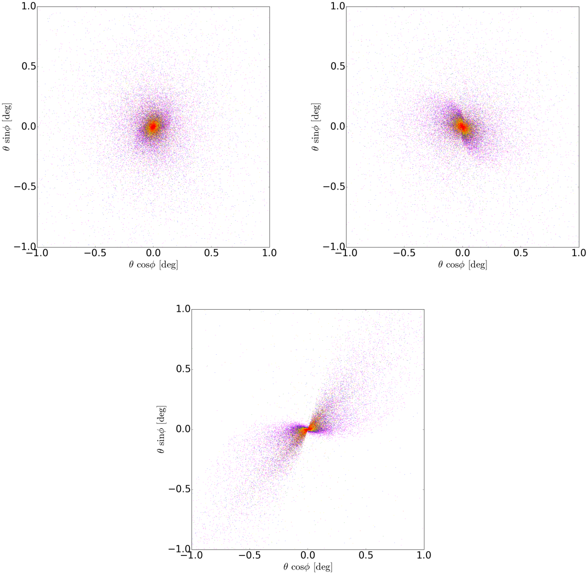

Measurement of IGMF Helicity Using UHECR

Calculation of correlation between source positions
[Kahniashvili and Vachaspati, 2006]

- For example: Take N pairs (indexed with α) of sources with each having the same separation vector $\mathbf{\Delta} = \mathbf{X}_{\mathrm{B}} - \mathbf{X}_{\mathrm{A}}$

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- As the energy loss also depends on the traveled distance, conclusions about the IGMF structure may be made

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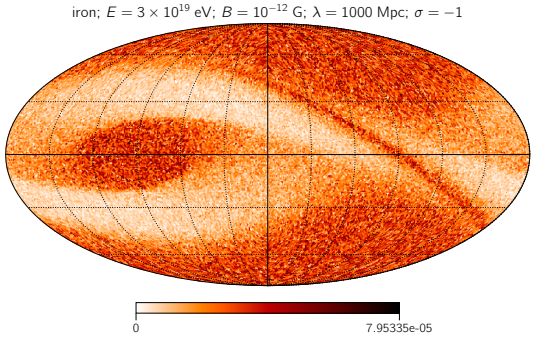

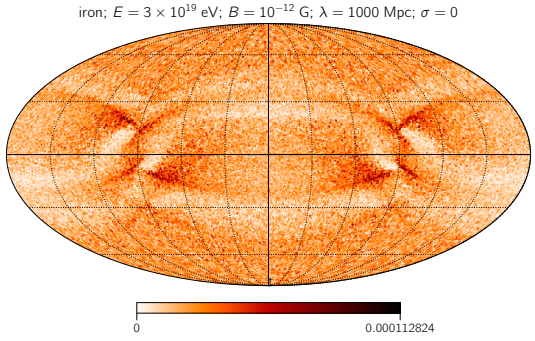

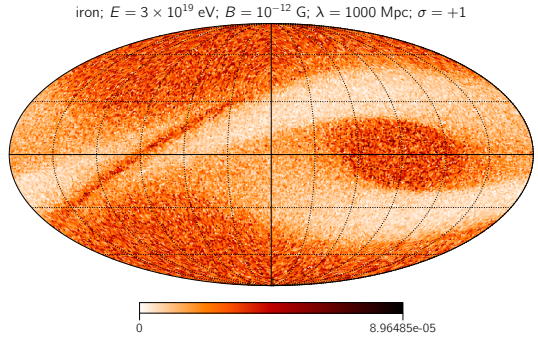

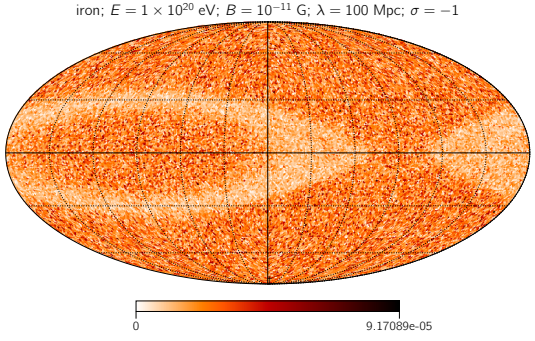

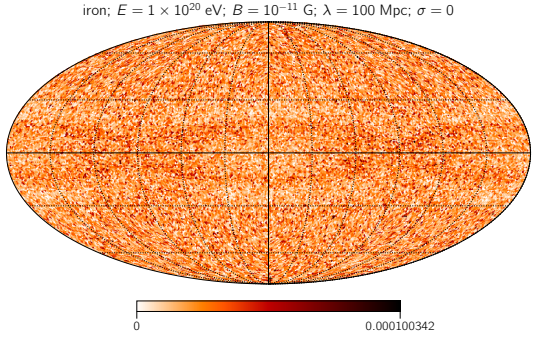

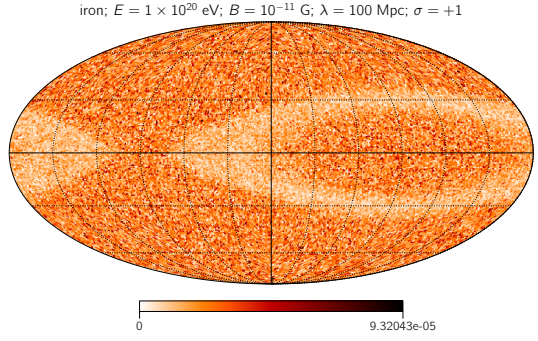

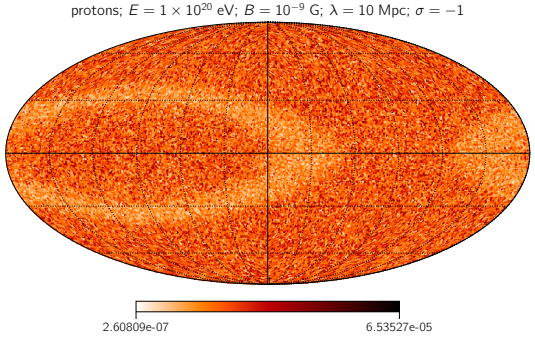

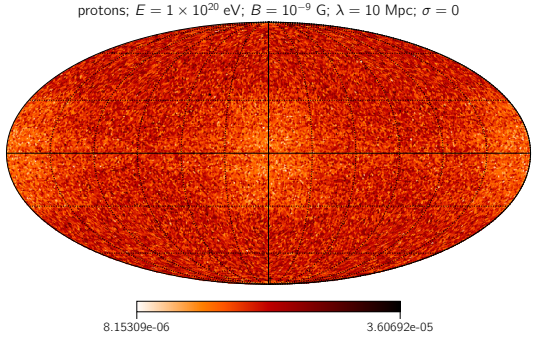

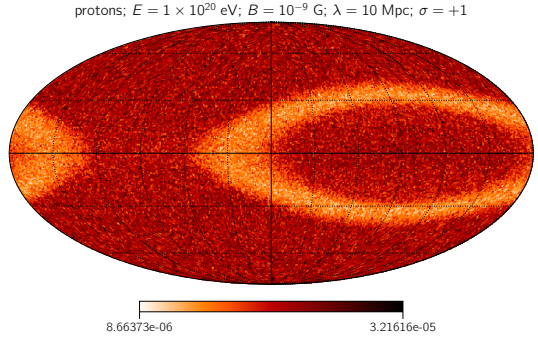

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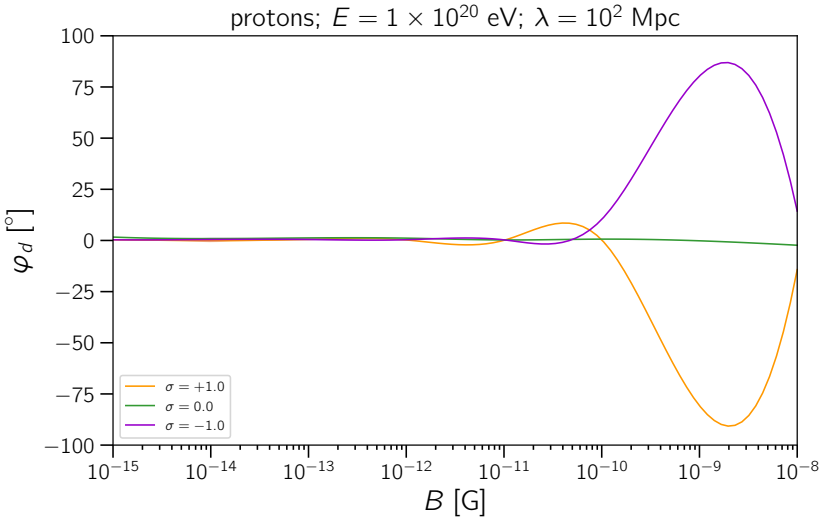

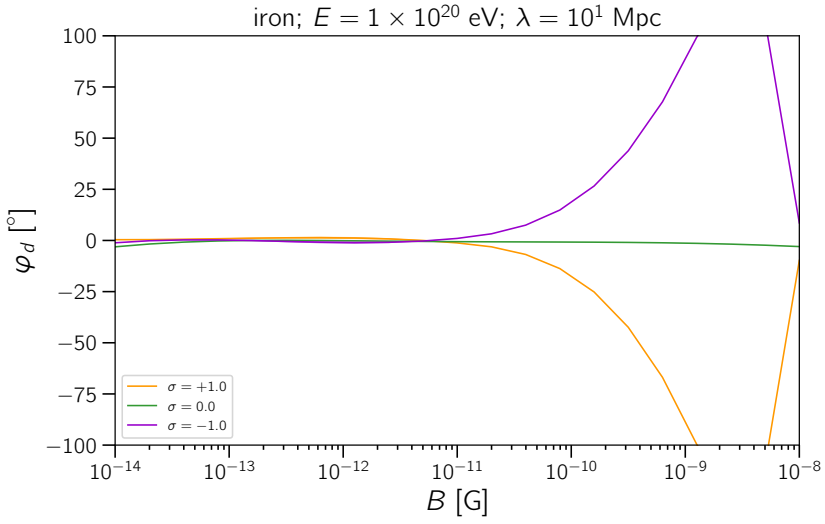

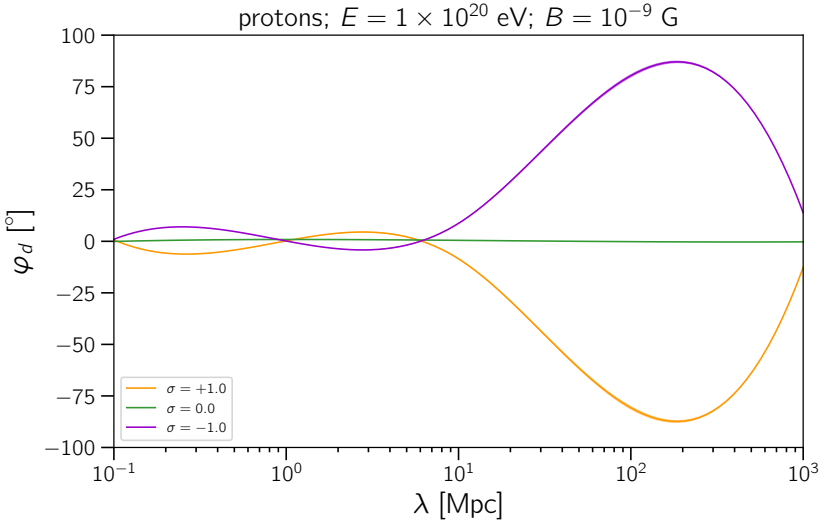

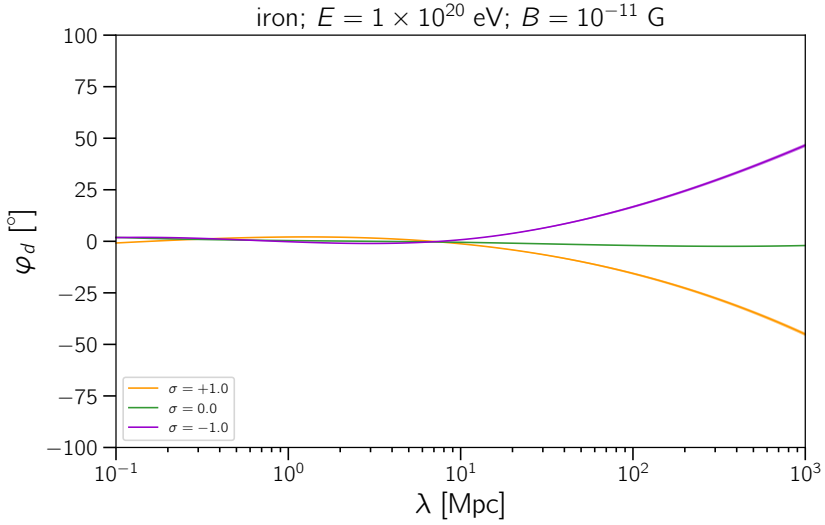

Conclusions and Outlook

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- Another possibility is to use UHECR, being, however, quite challenging from the data analysis side
- In the future: Extention to more realistic scenarios and combination of the methods by using secondaries of UHECR


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