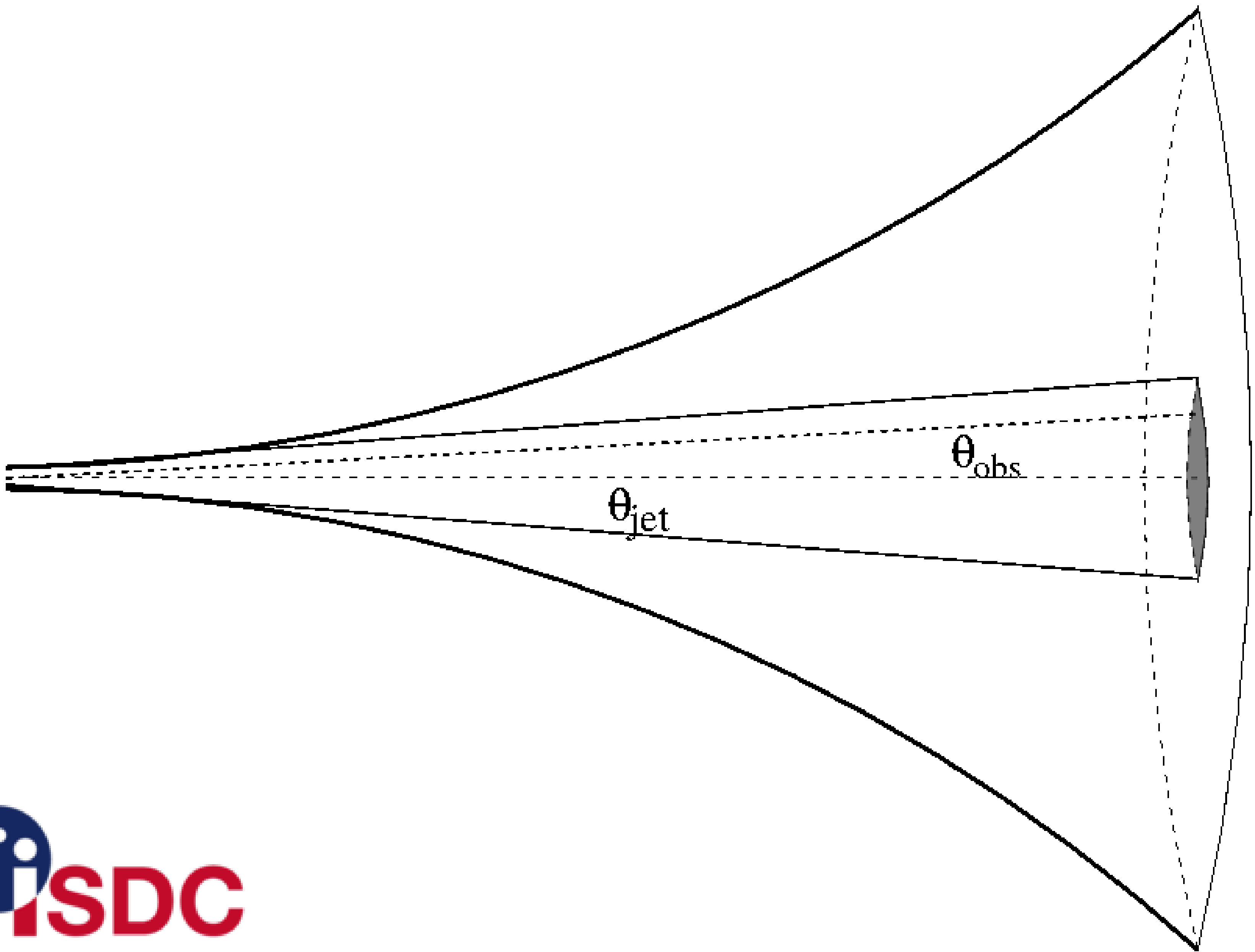
EGMF Constraints from Simultaneous Blazar Observations



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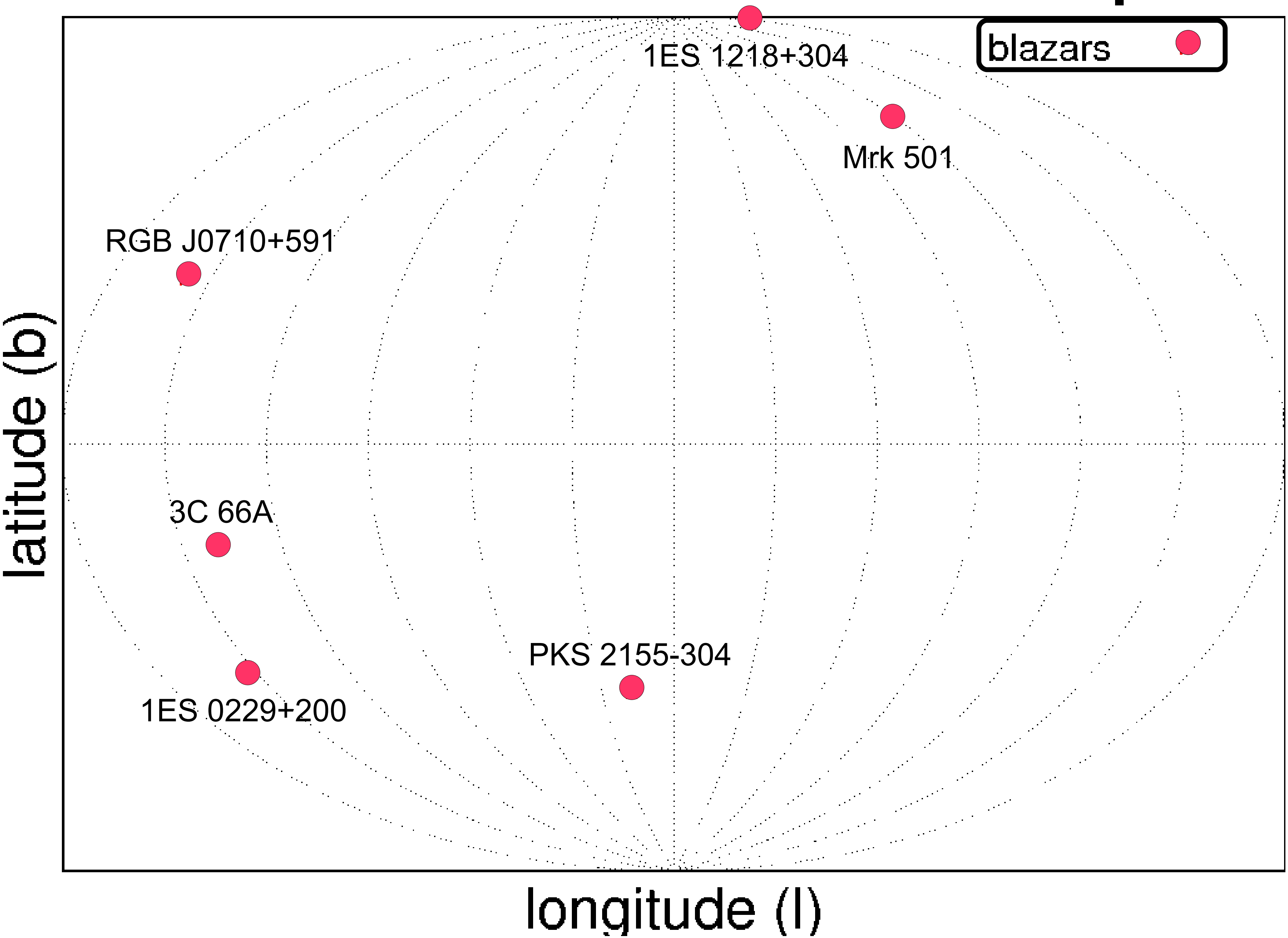
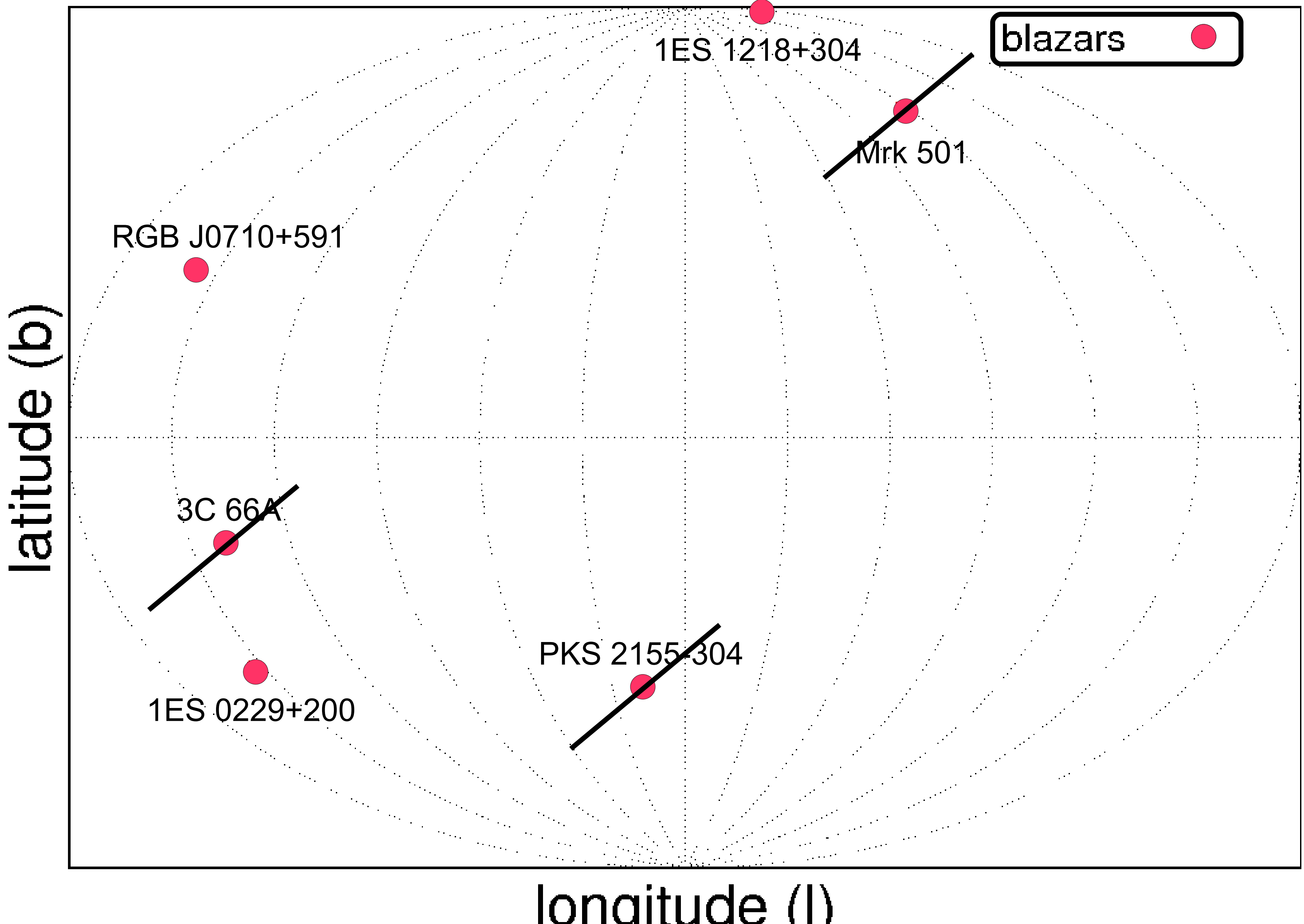
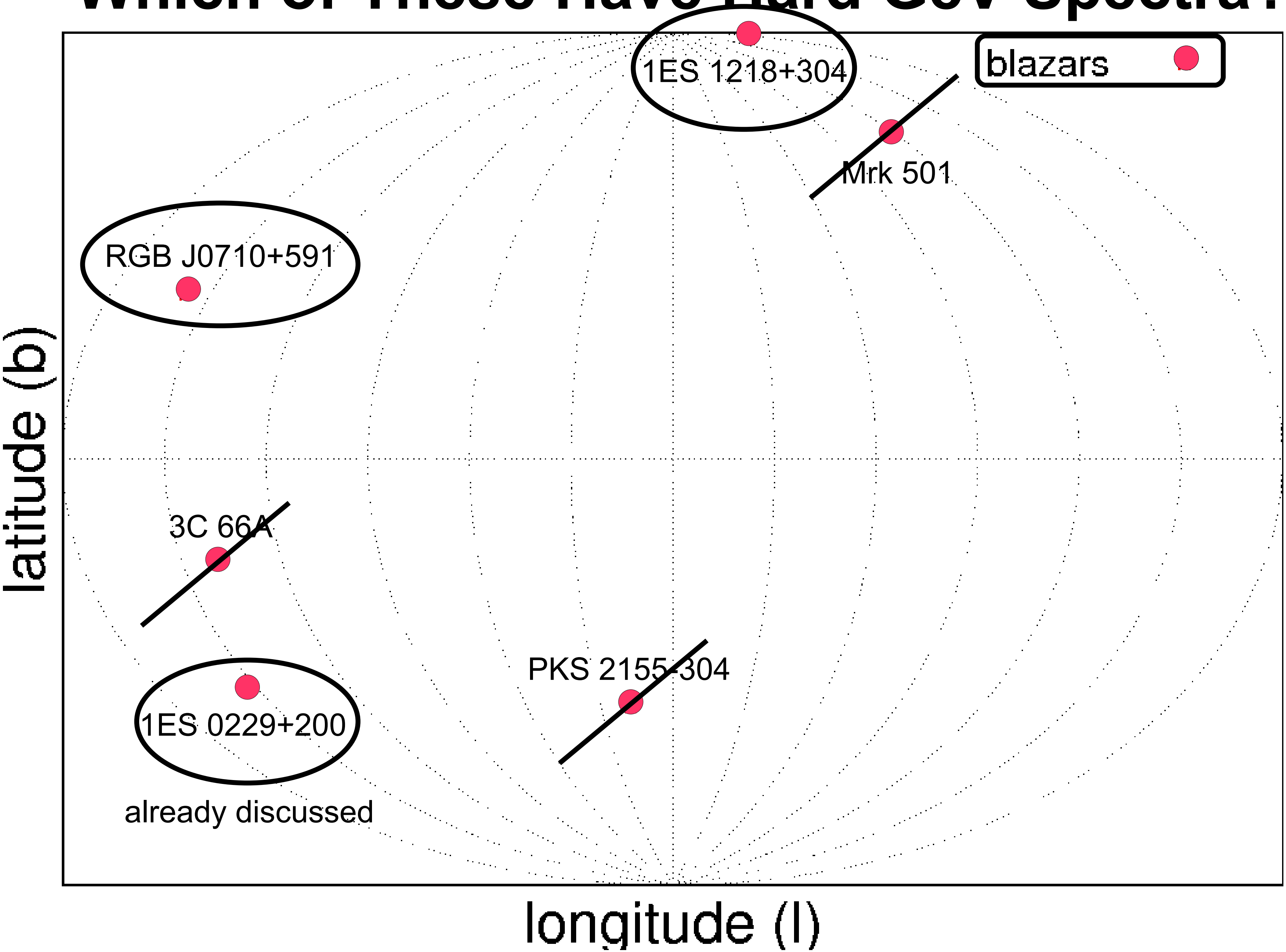
Which Blazars Have Simultaneous Spectra?



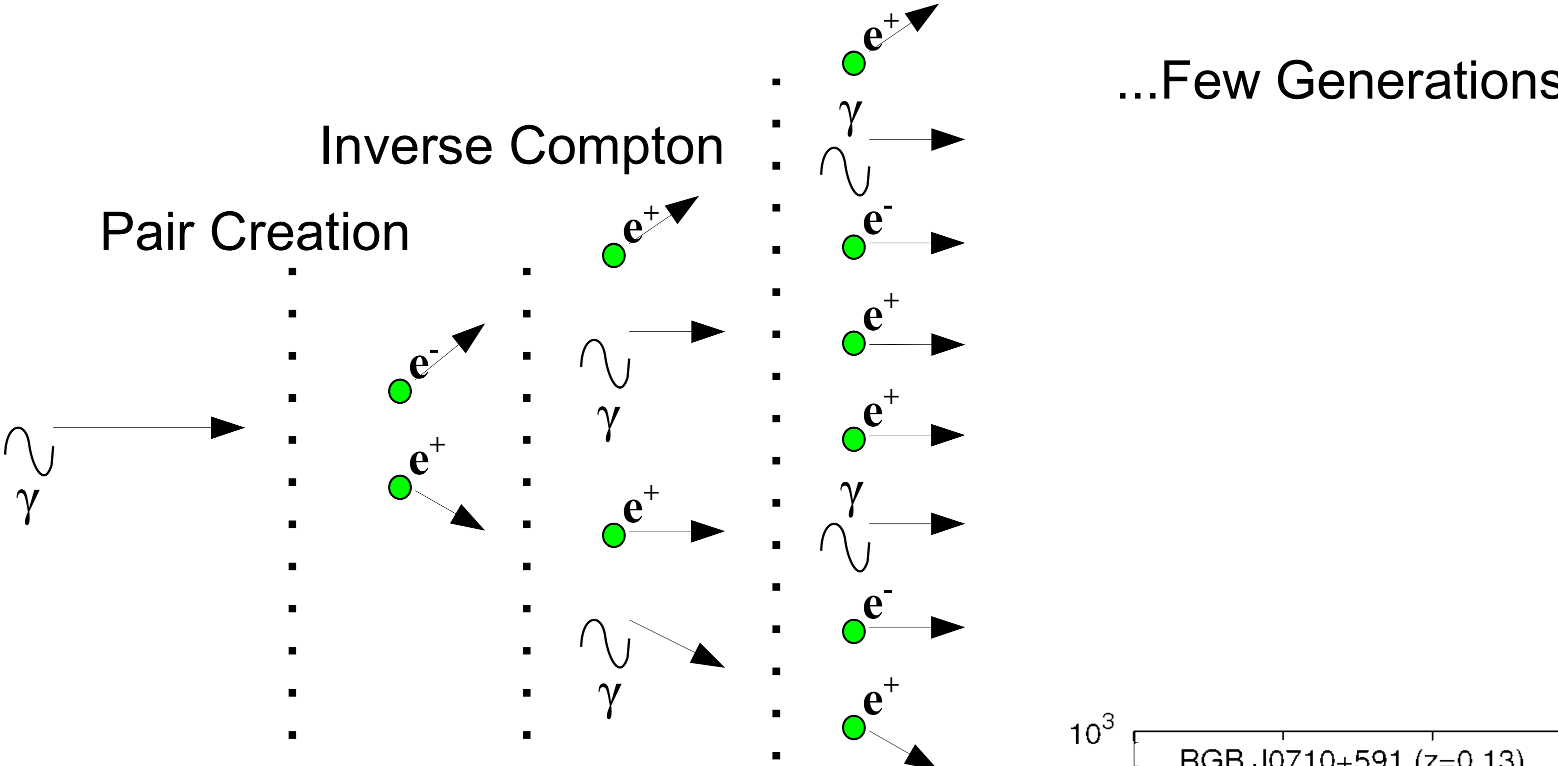
Which of These Have Hard GeV Spectra?

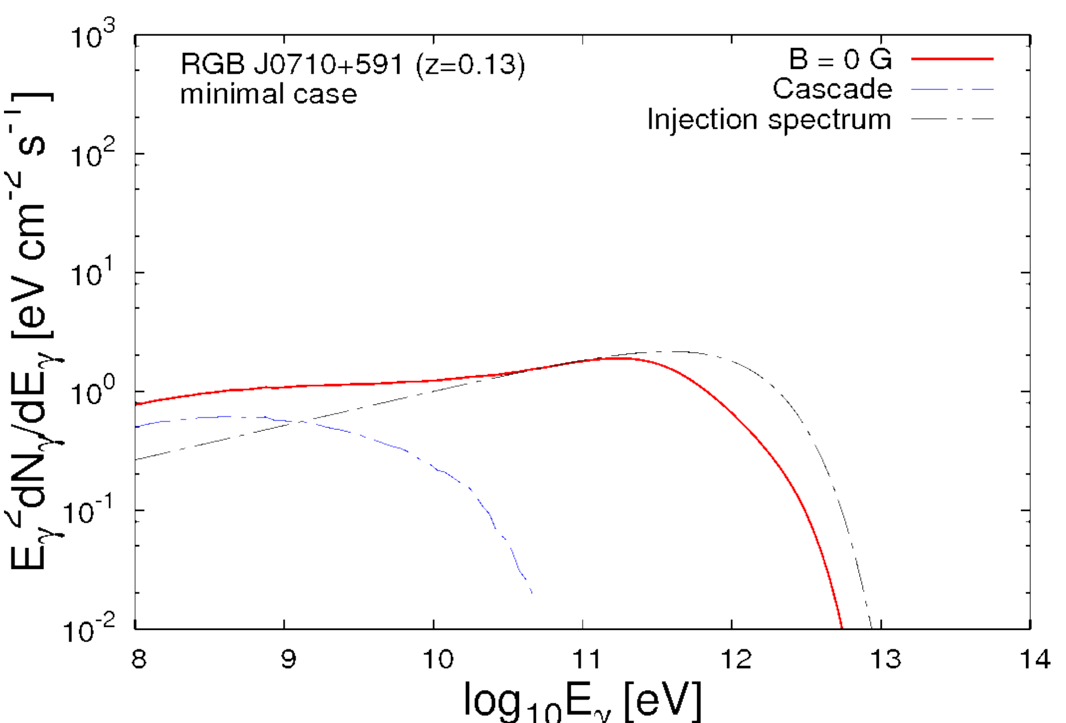


Which of These Have Hard GeV Spectra?

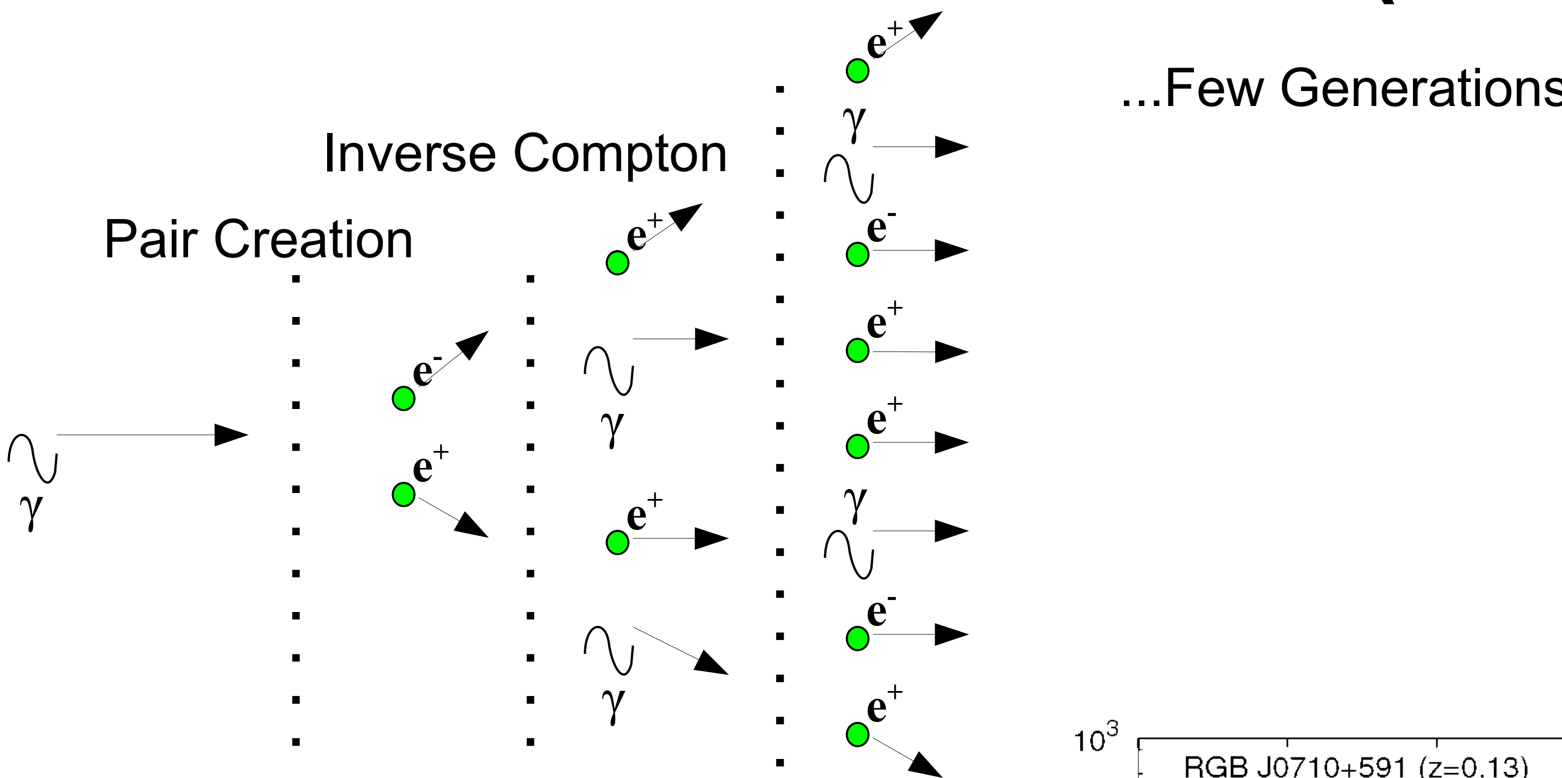


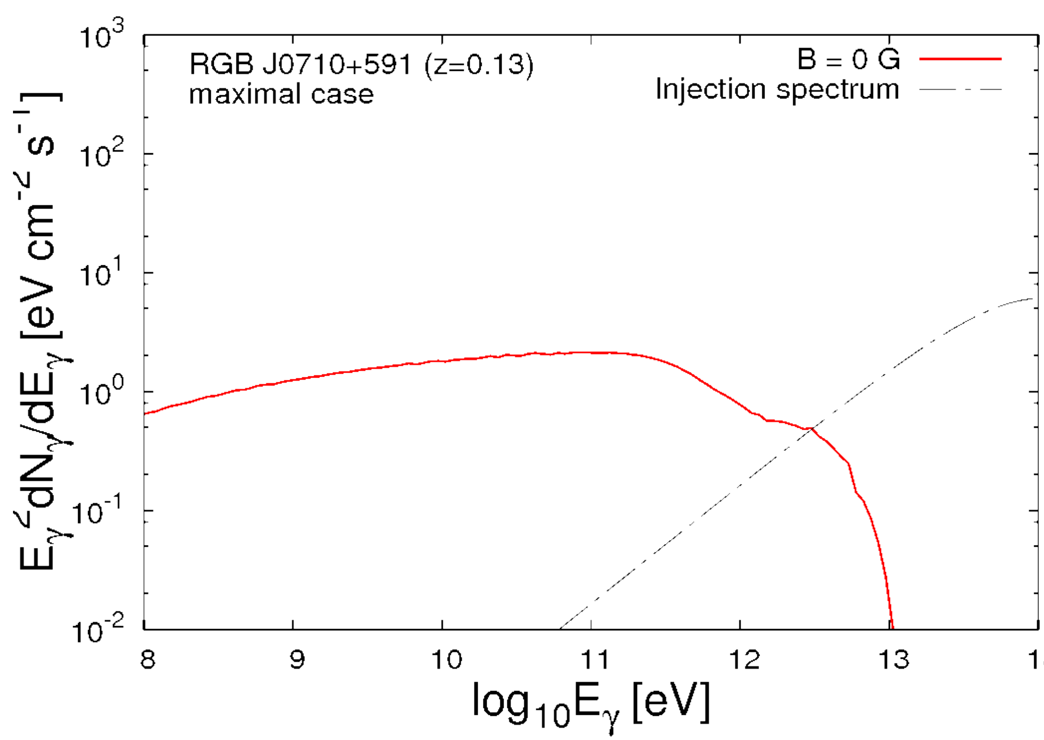
Blazar Fed Cascades (minimal)





Blazar Fed Cascades (maximal)





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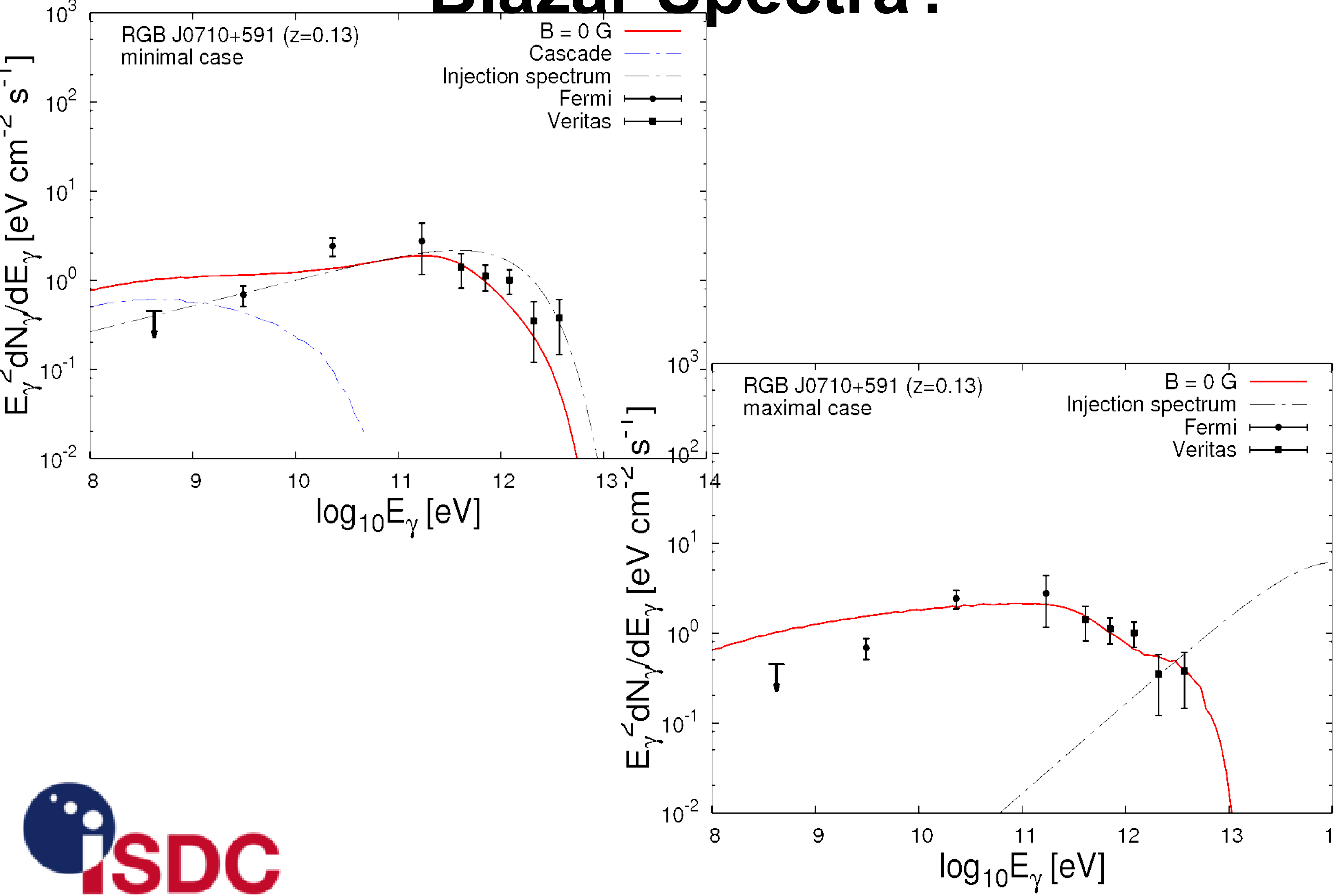
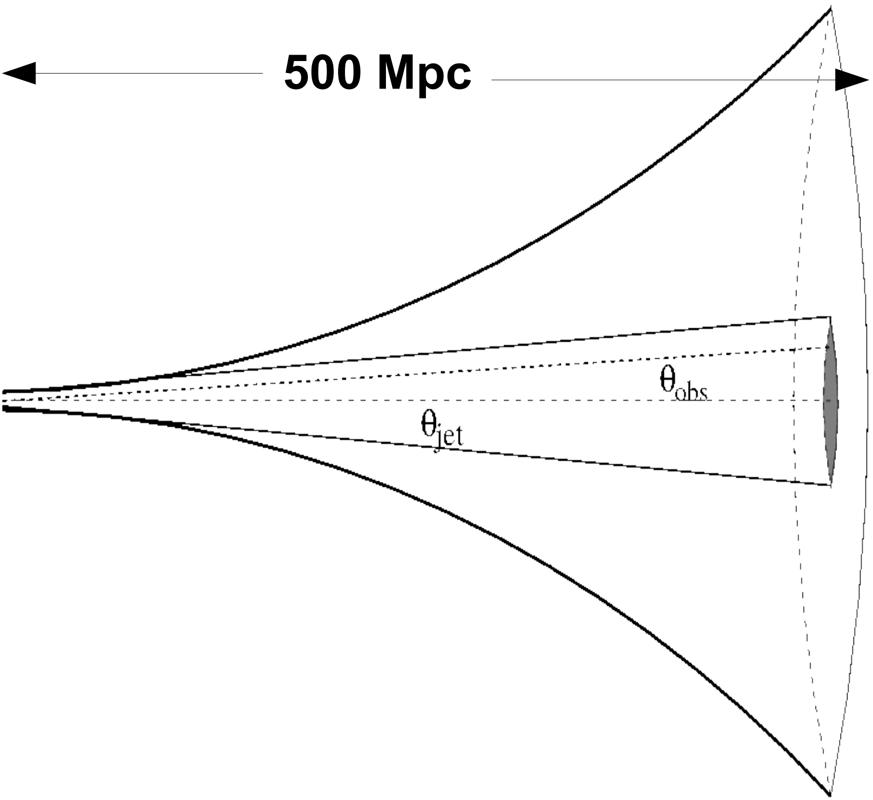
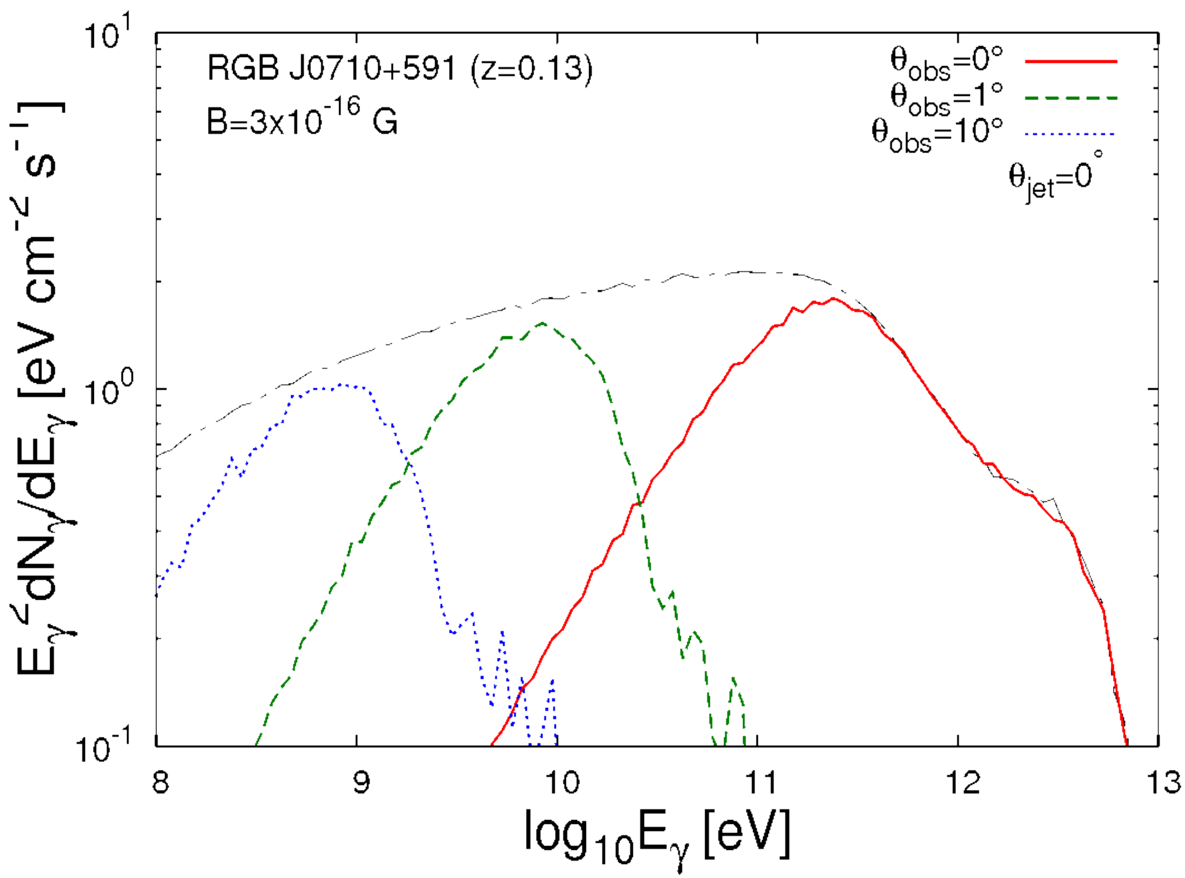
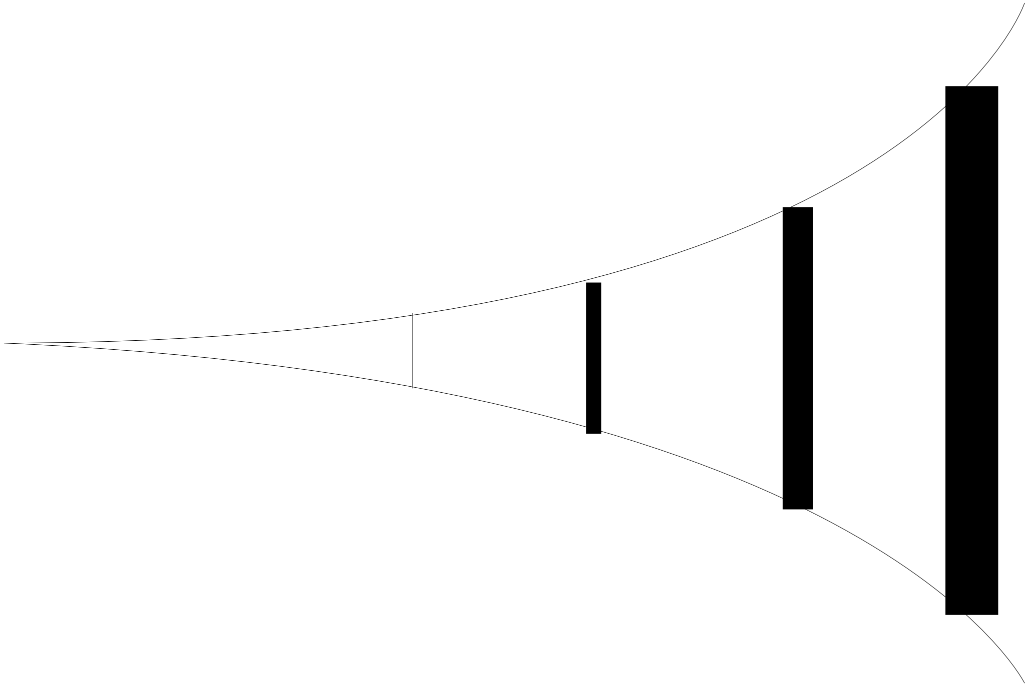
Max + Min Cascade Contributions to Blazar Spectra?



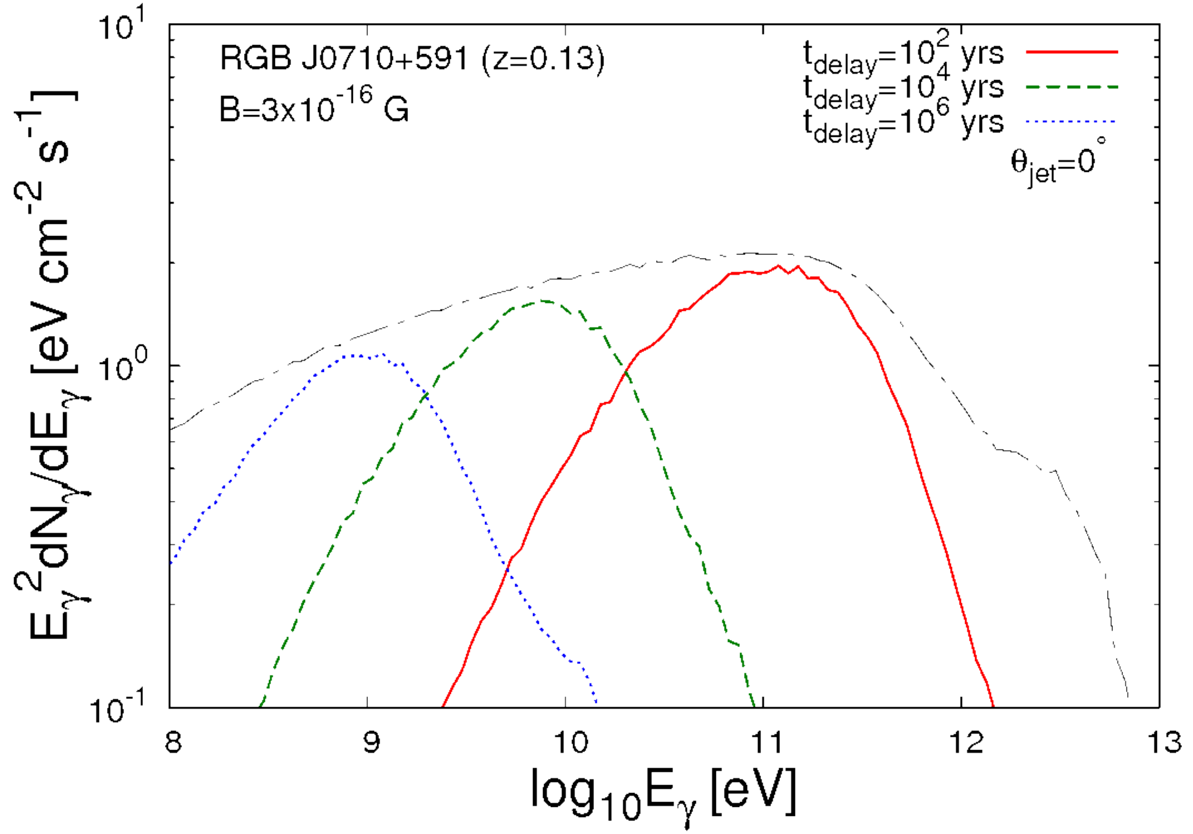
Spatial Decomposition of Spectrum







Temporal Decomposition of Spectrum



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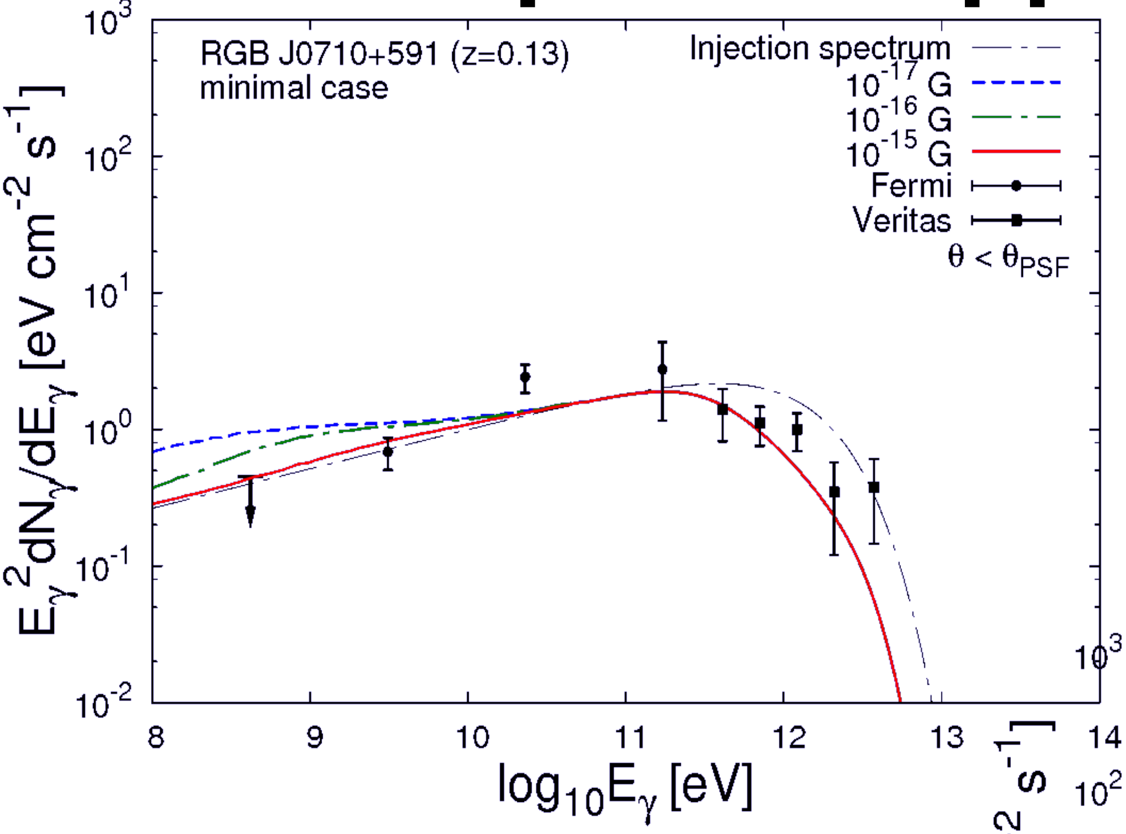
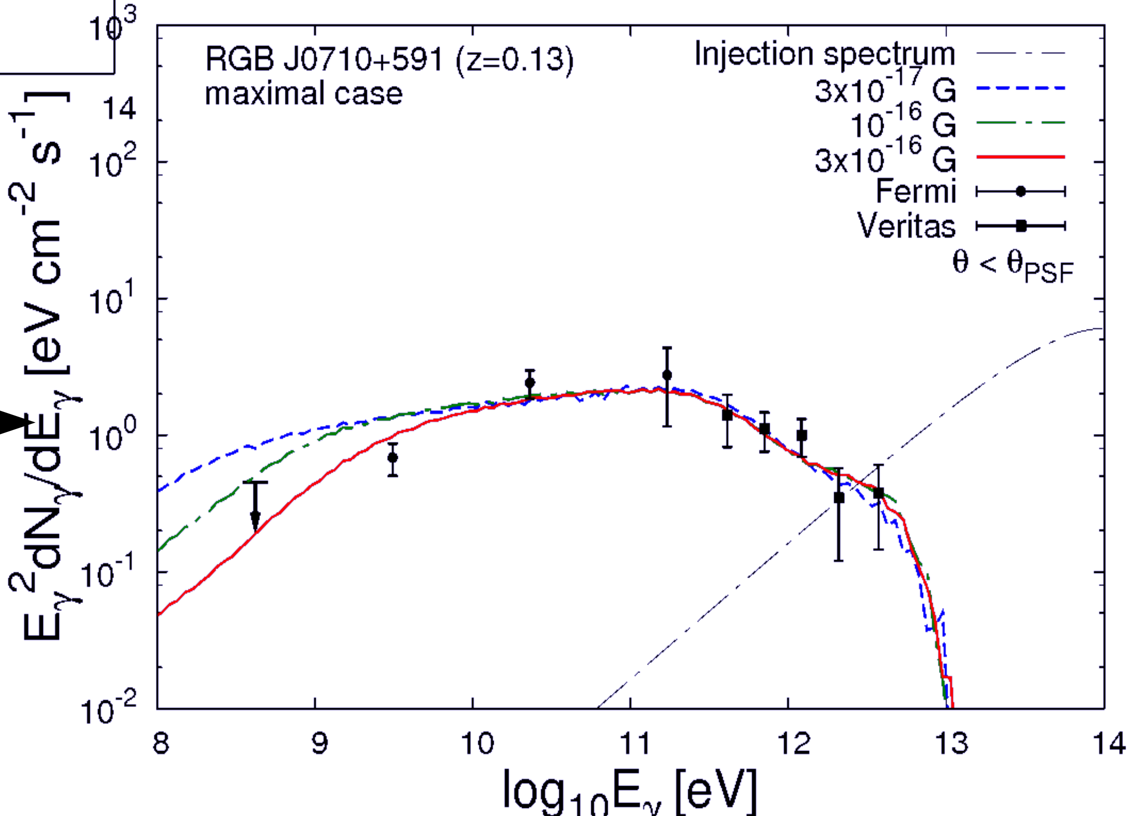
B-Field Spatial Suppression of Cascade



Minimal case

Maximal case



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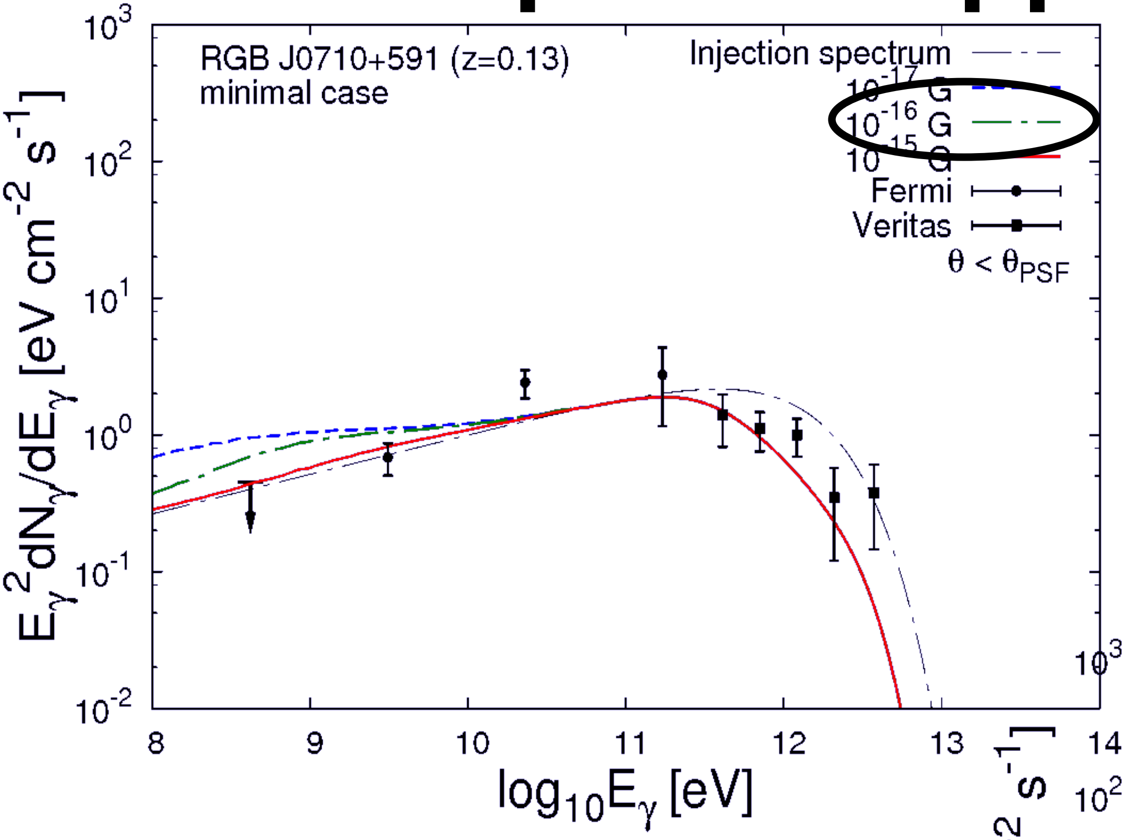
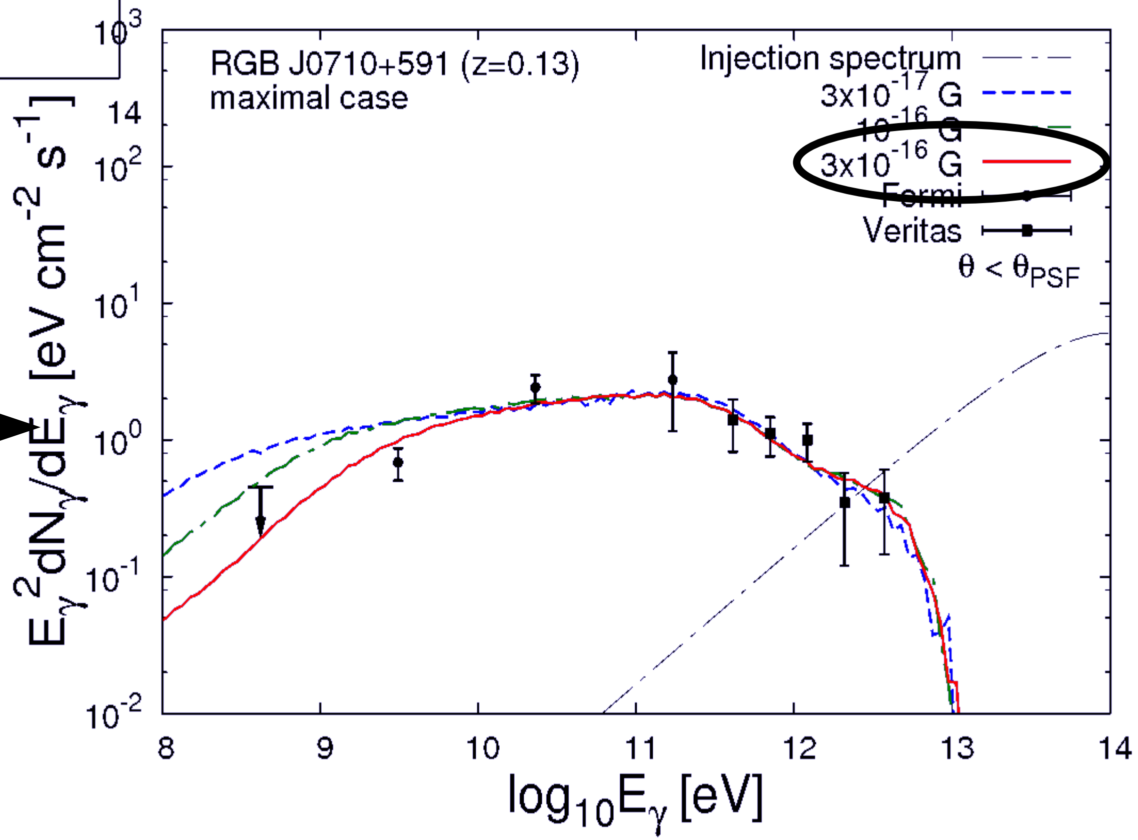
B-Field Spatial Suppression of Cascade



Minimal case

Maximal case



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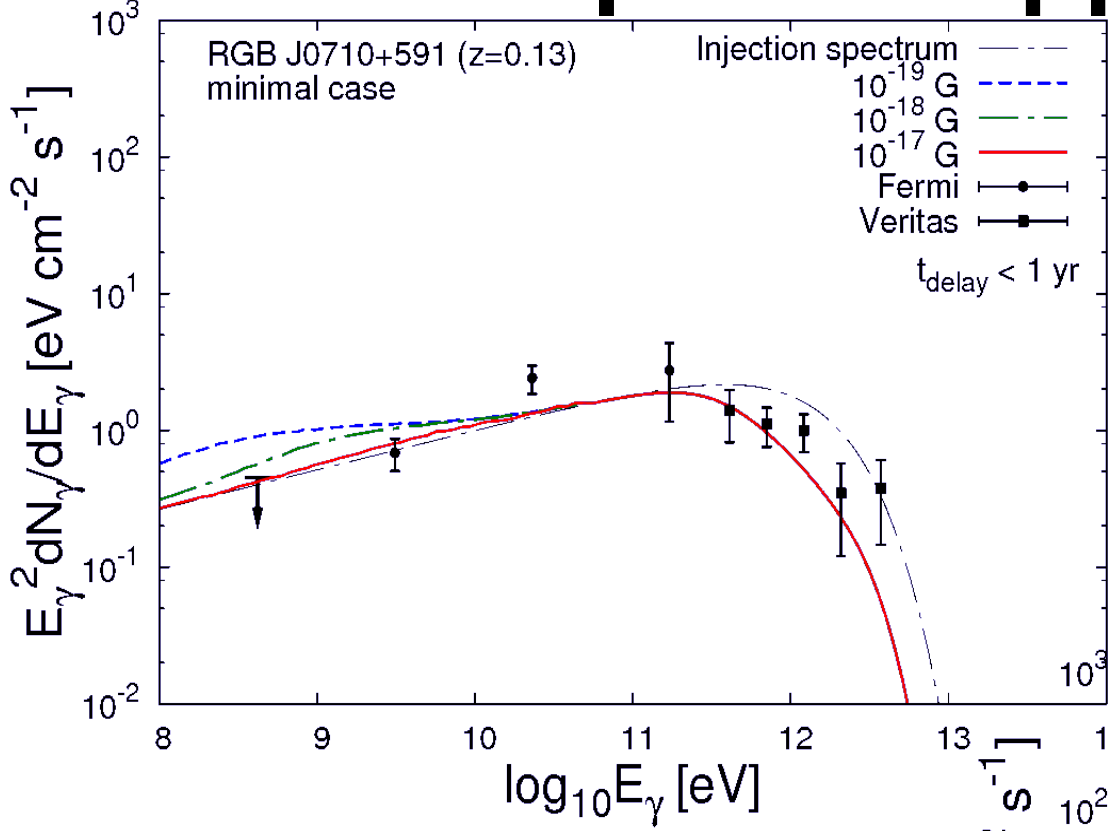
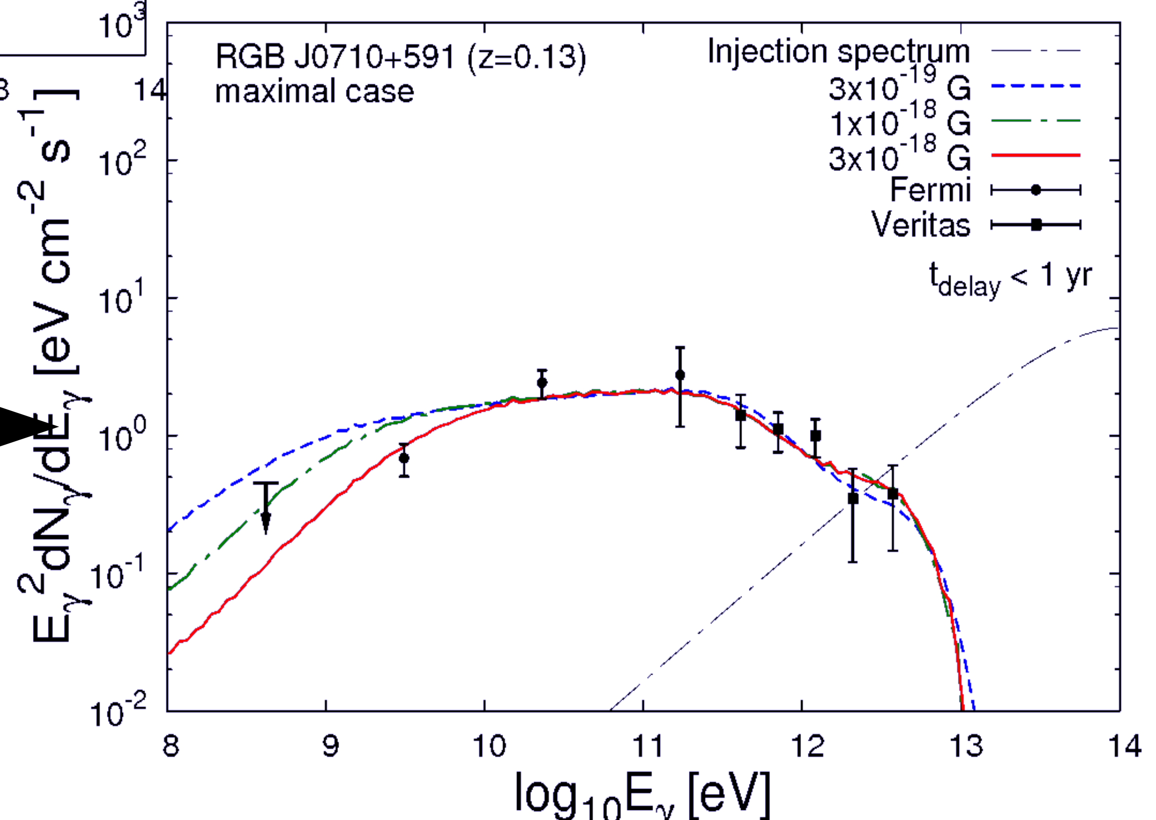
B-Field Temporal Suppression of Cascade

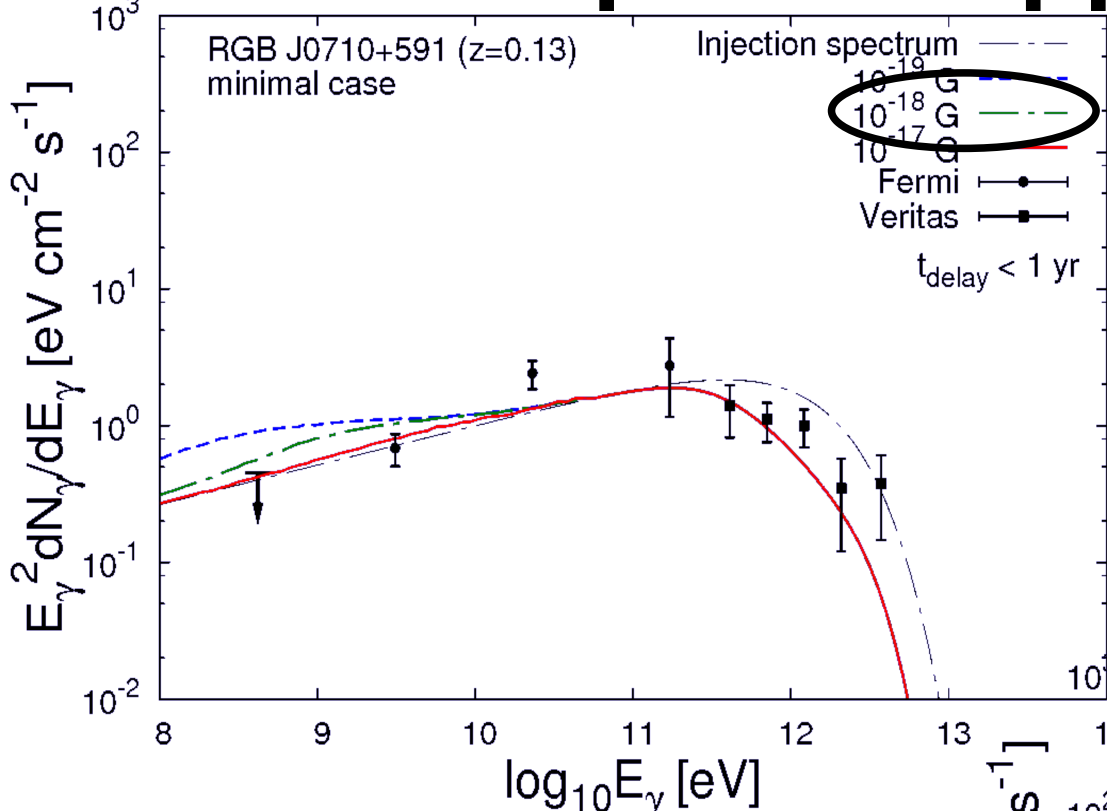


Minimal case

Maximal case

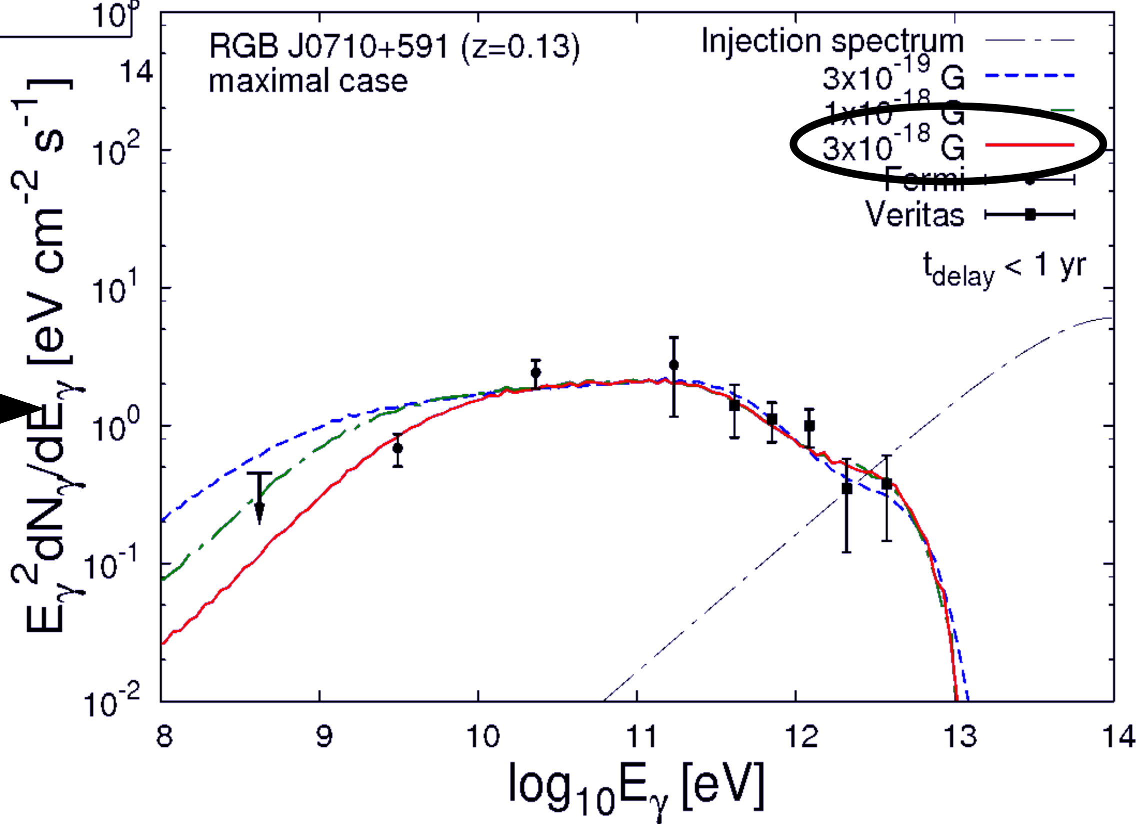


B-Field Temporal Suppression of Cascade



Minimal case

Maximal case



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Conclusions

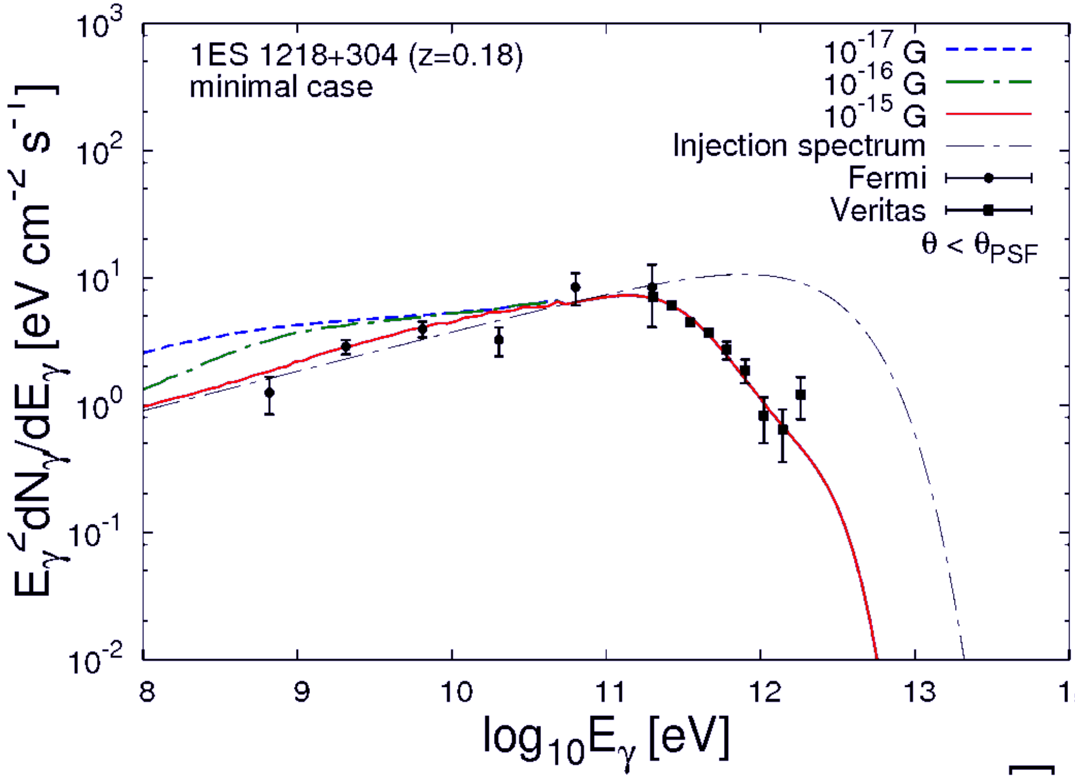
- Simultaneous GeV and TeV observations of 3 blazars with hard (GeV) spectra suggest a suppression of the cascade component is required

- Both spatial and temporal suppression mechanisms of the cascade component are viable

- A spatial suppression origin leads to a lower bound of $B\sim10^{-16}$G (this bound quietly assumes that the blazar is not variable on $\sim10^{5}$ yr timescales).

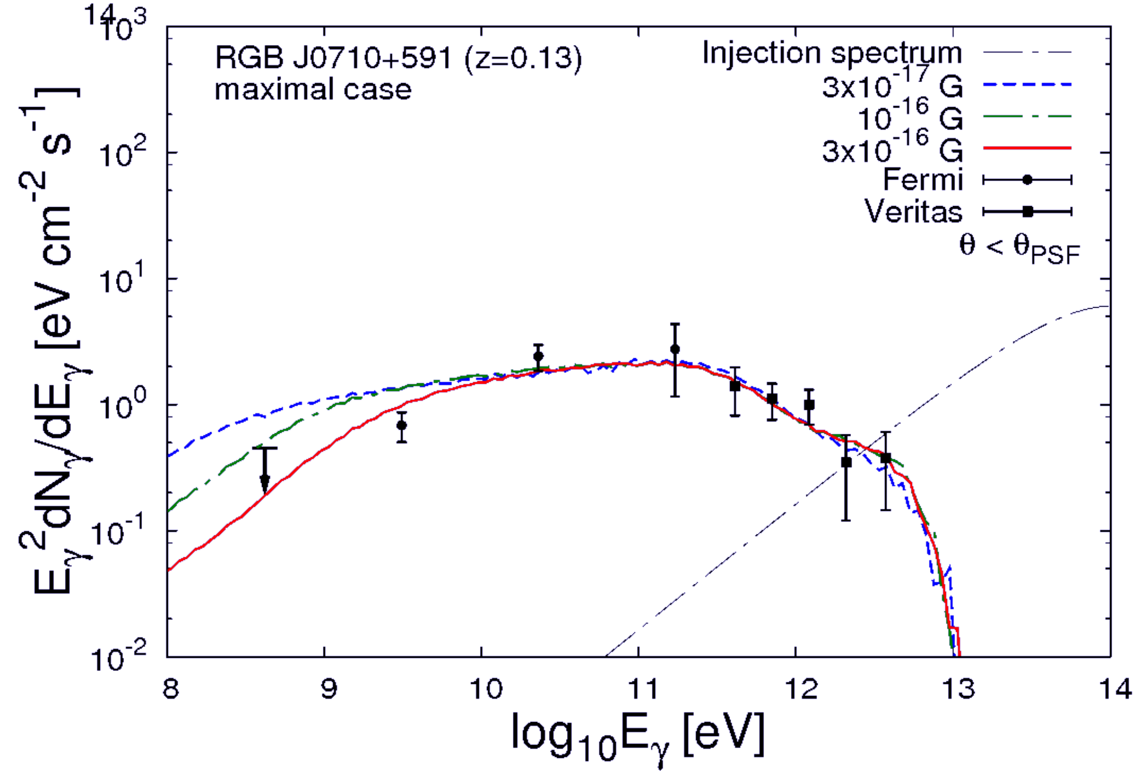
- A temporal suppression origin, with variability on ~1yr timescales leads to a much more conservative lower bound of $B\sim10^{-18}$G

B-Field Spatial Suppression of Cascade



Minimal case

Maximal case



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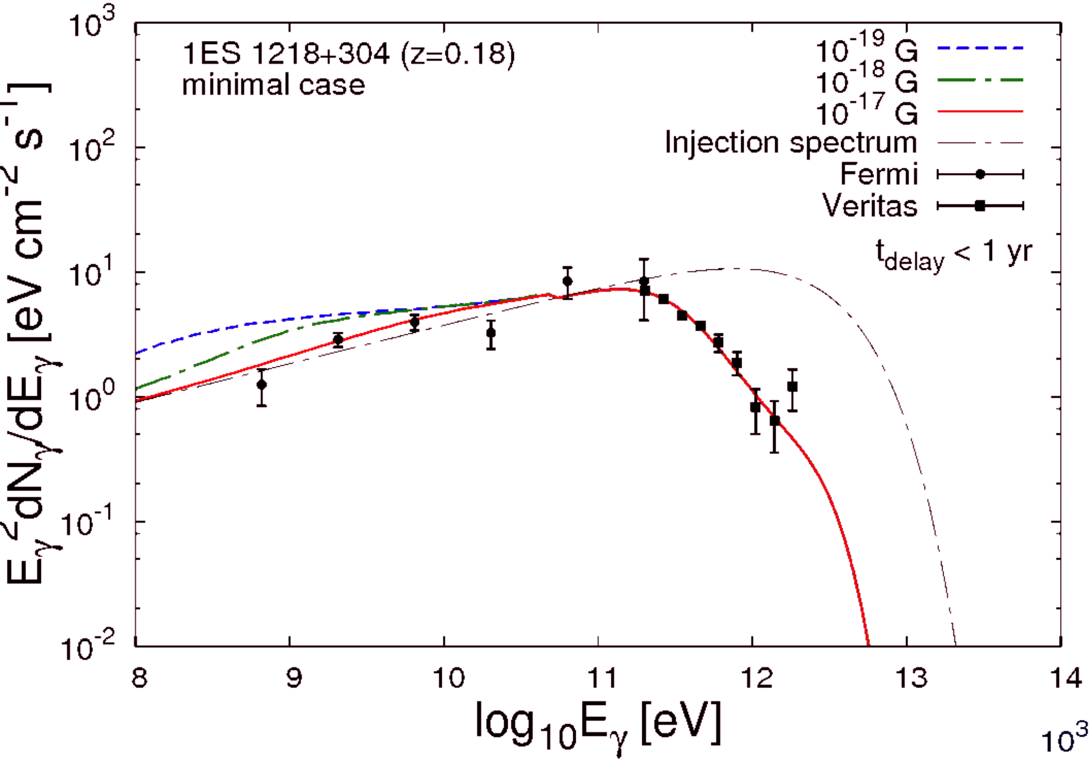
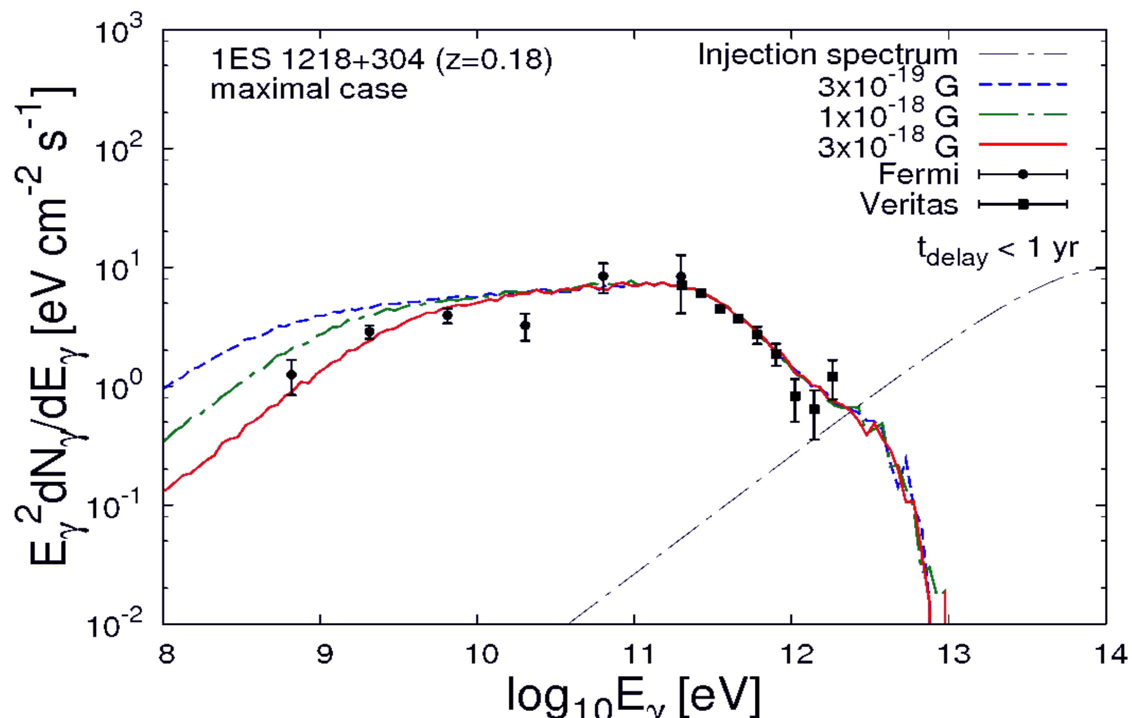
B-Field Temporal Suppression of Cascade



Minimal case

Maximal case



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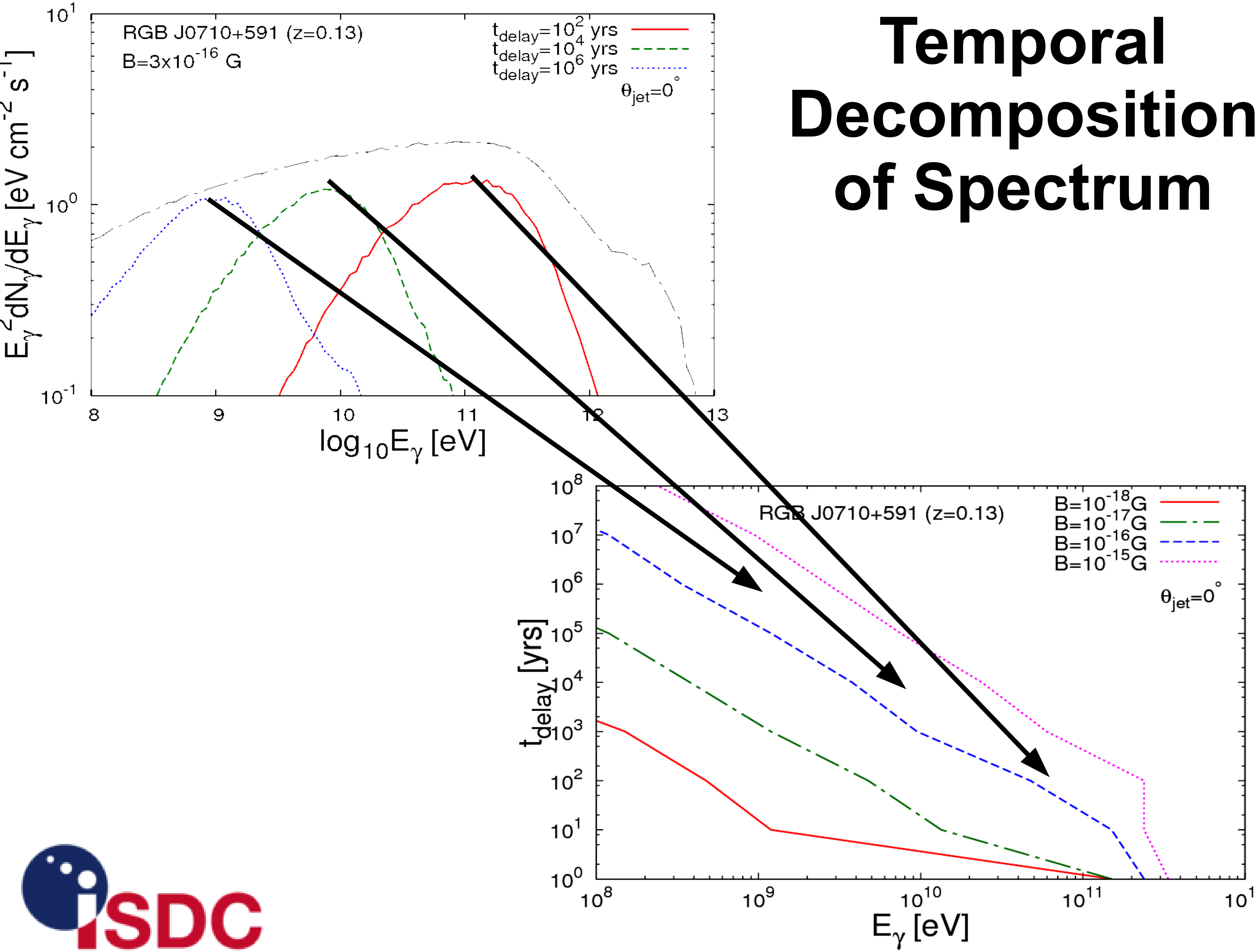
Temporal Decomposition of Spectrum



Why 10^{-15} G?

Need to suppress IC flux with an energy of $\sim 10^9$ eV

$$E_\gamma^{\rm IC} \approx \Gamma_e^2 E_\gamma^{\rm bg}$$

$$E_\gamma^{\rm IC} = 10^9 \text{ eV} \qquad E_\gamma^{\rm bg} \approx 10^{-3} \text{ eV}$$

So, $\Gamma_e = 10^6$ ie. $E_e \approx \text{TeV}$

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Why 10^{-15} G?

So, $\Gamma_e = 10^6$ ie. $E_e \approx \mathrm{TeV}$

IC flux suppression occurs when electron flux starts to be isotropised.

The deflection angle in each mag. patch is

$$\alpha = \frac{L_{\rm coh}}{R_{\rm Larmor}}$$

$$R_{\rm Larmor} \approx 1 \left(\frac{E_e}{\rm TeV}\right)\left(\frac{10^{-15}\ {\rm G}}{B}\right)\ {\rm Mpc}$$

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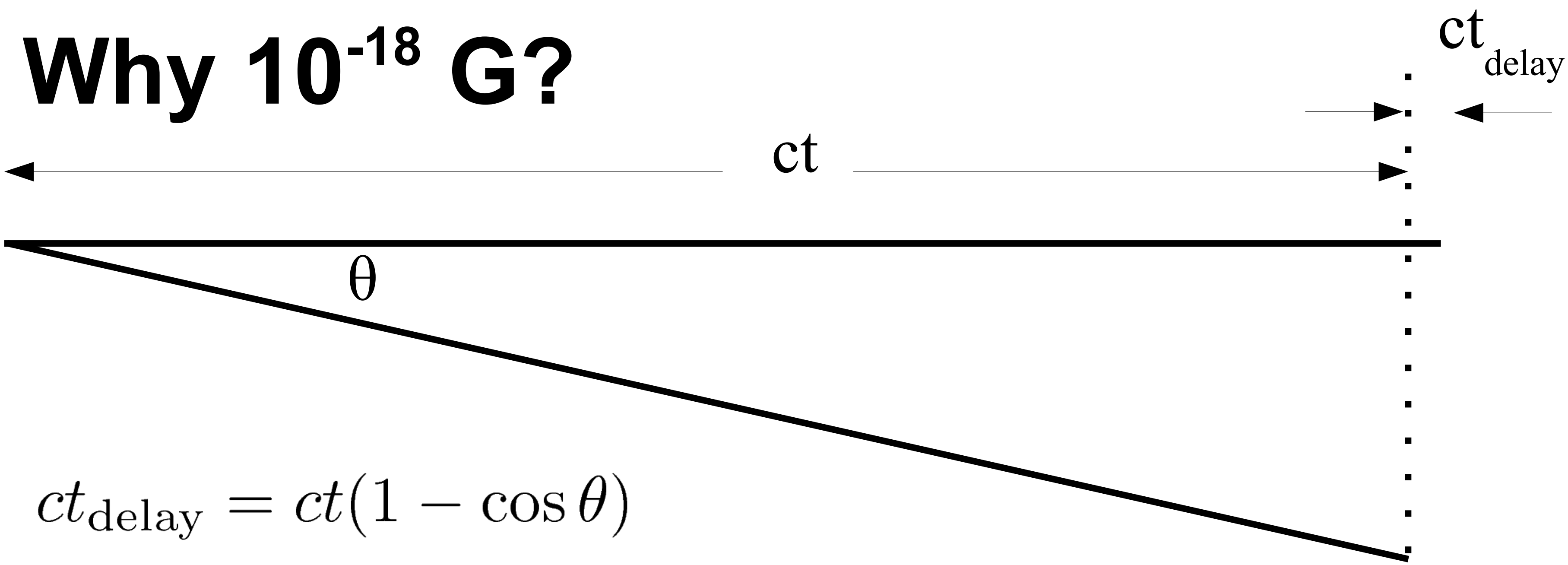
Why 10^{-18} G?



$$ct_{\rm delay} = ct(1 - \cos\theta)$$

$$ct_{\rm delay} \approx \theta^2 ct$$

$$\theta = \alpha \left(\frac{ct}{L_{\rm coh}}\right)^{1/2} = \frac{L_{\rm coh}}{R_{\rm Larmor}} \left(\frac{ct}{L_{\rm coh}}\right)^{1/2}$$

$$R_{\rm Larmor} \approx 1 \left(\frac{E_e}{\rm TeV}\right) \left(\frac{10^{-18}\ {\rm G}}{B}\right)\ {\rm Gpc}$$

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Why 10^{-18} G?

$$ct_{\rm delay} \approx \theta^2 ct$$

$$\theta = \alpha \left(\frac{ct}{L_{\rm coh}}\right)^{1/2} = \frac{L_{\rm coh}}{R_{\rm Larmor}} \left(\frac{ct}{L_{\rm coh}}\right)^{1/2}$$

$$R_{\rm Larmor} \approx 1 \left(\frac{E_e}{\rm TeV}\right) \left(\frac{10^{-18}\ {\rm G}}{B}\right)\ {\rm Gpc}$$

Since, $ct = 500\ {\rm Mpc}$

$$t_{\rm delay} = 10^3 \left(\frac{10^{-18}\ {\rm G}}{B}\right)^2\ {\rm yr}$$

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