AXION WIGGLES IN HIGH-ENERGY PHOTON SPECTRA

Based on [2305.03604, 2111.08303]

(www.tuhogar.com)

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with Michael Kachelrieß
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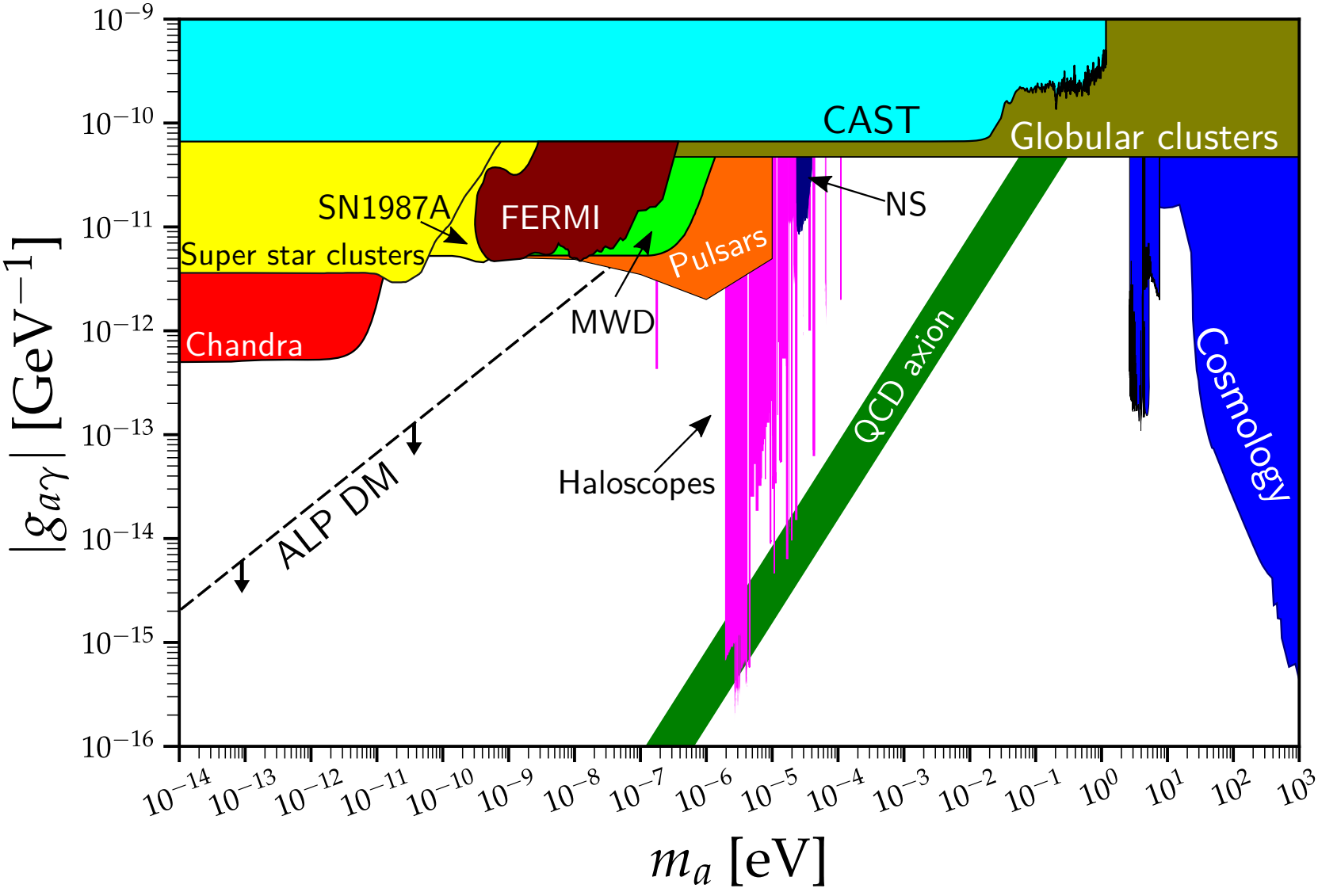
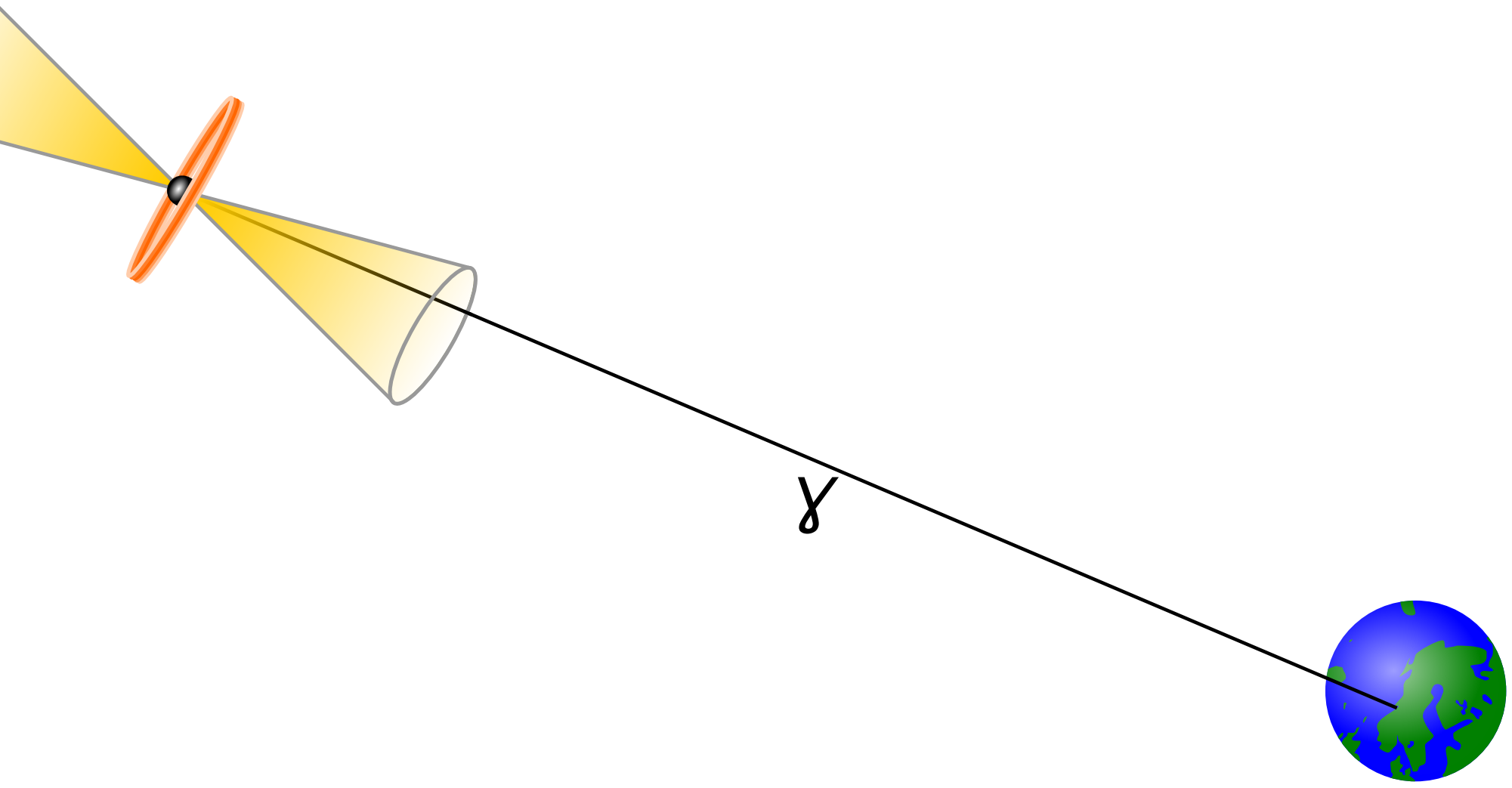
Light Dark World 2023

The axion parameter space

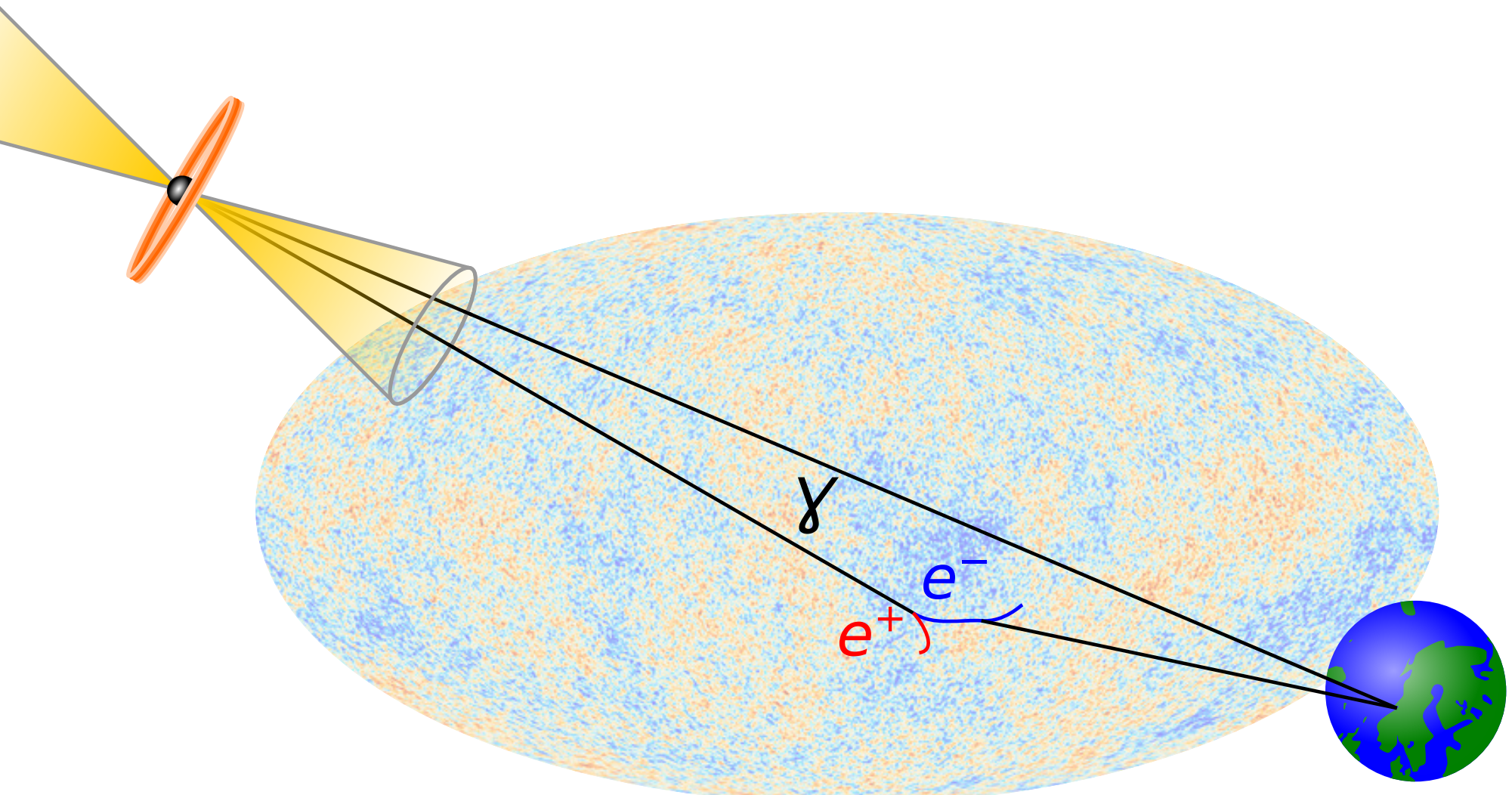


(adapted from [10.5281/zenodo.3932430])

Electromagnetic cascades



Electromagnetic cascades



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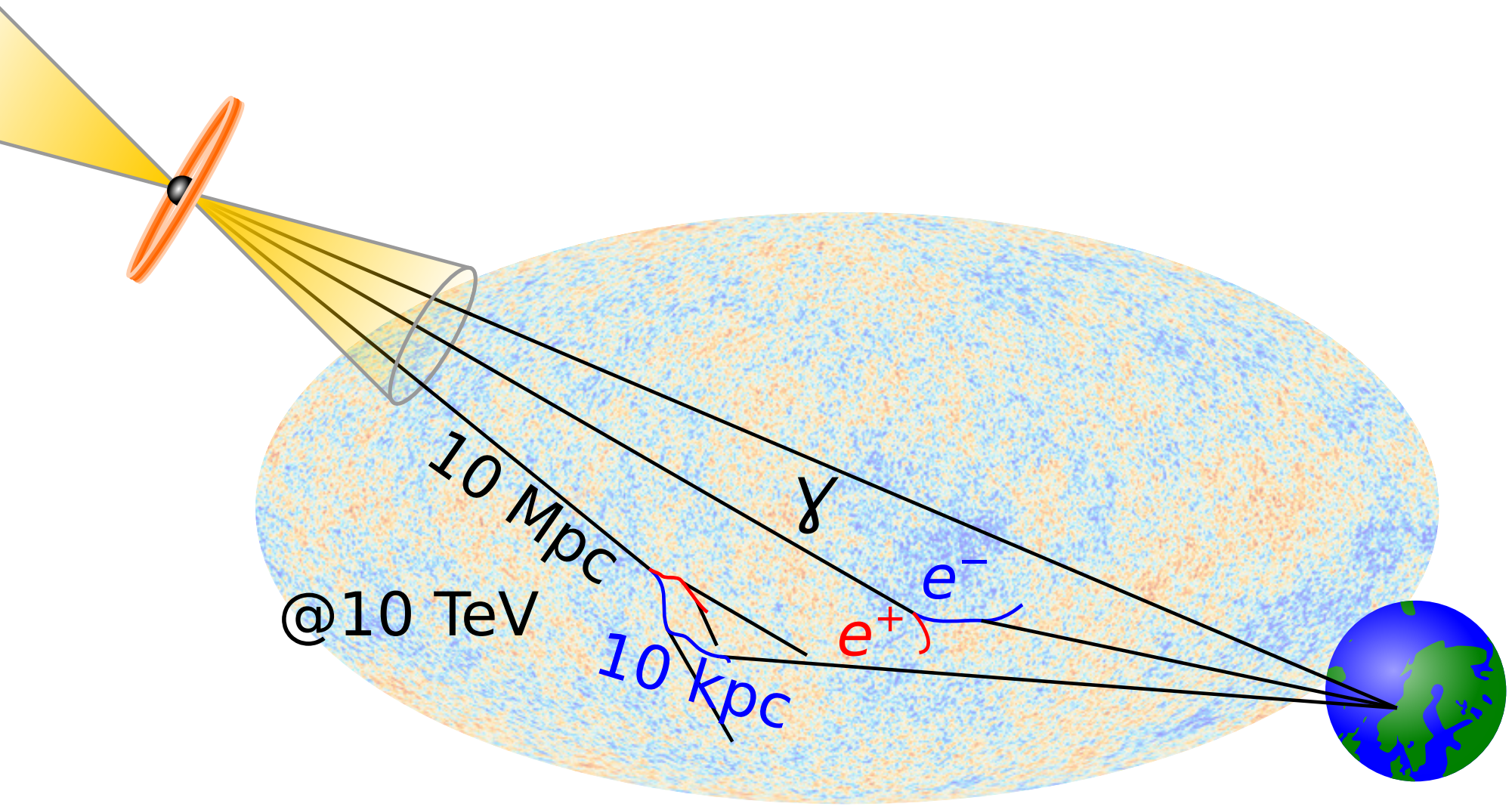
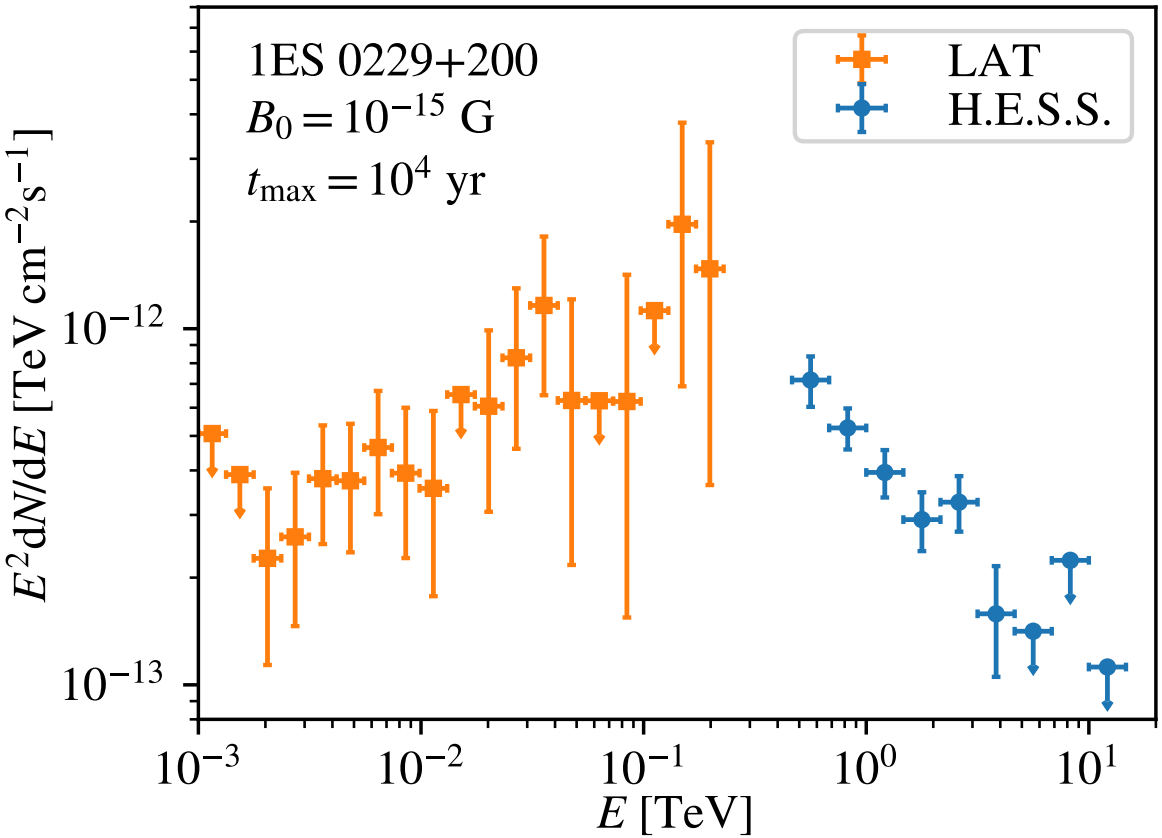


Simulated with Monte Carlo code ELMAG [1106.5508, 1909.09210]

Example: Probing intergalactic magnetic fields



Preliminary, JT, Meyer & Vazza in prep.

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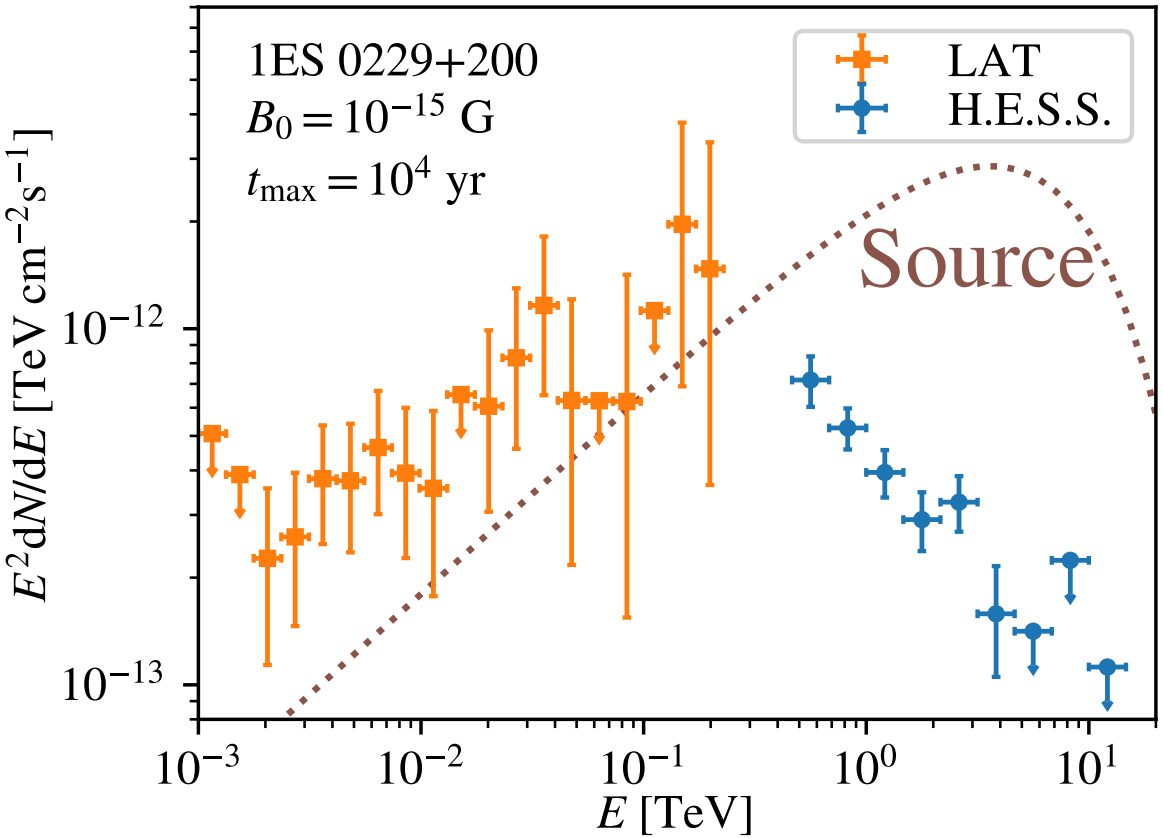

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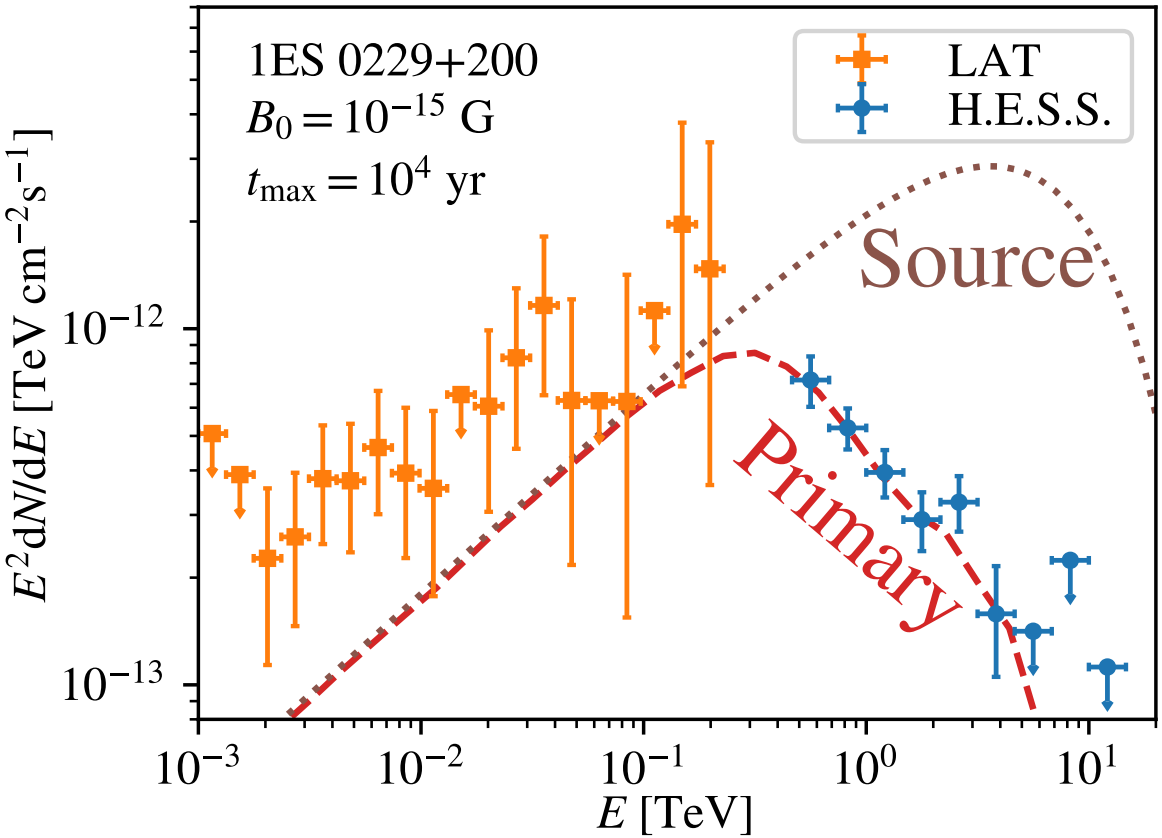

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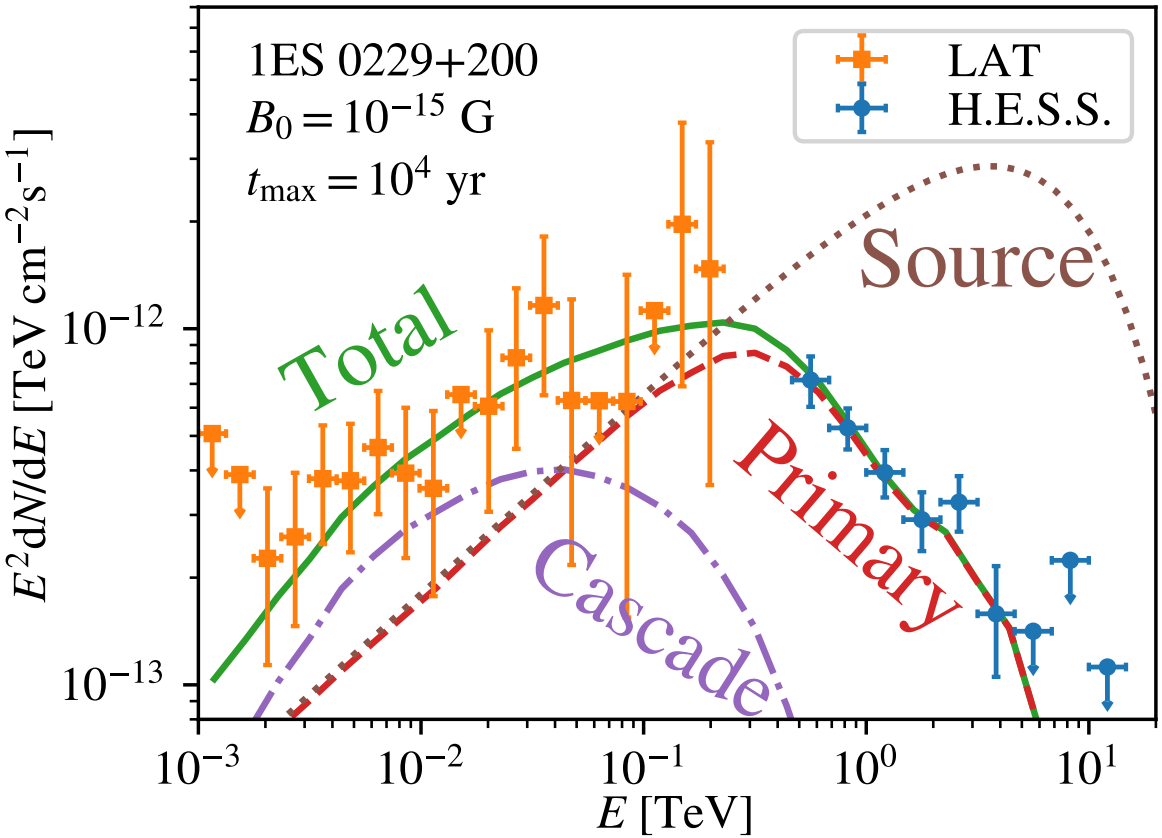

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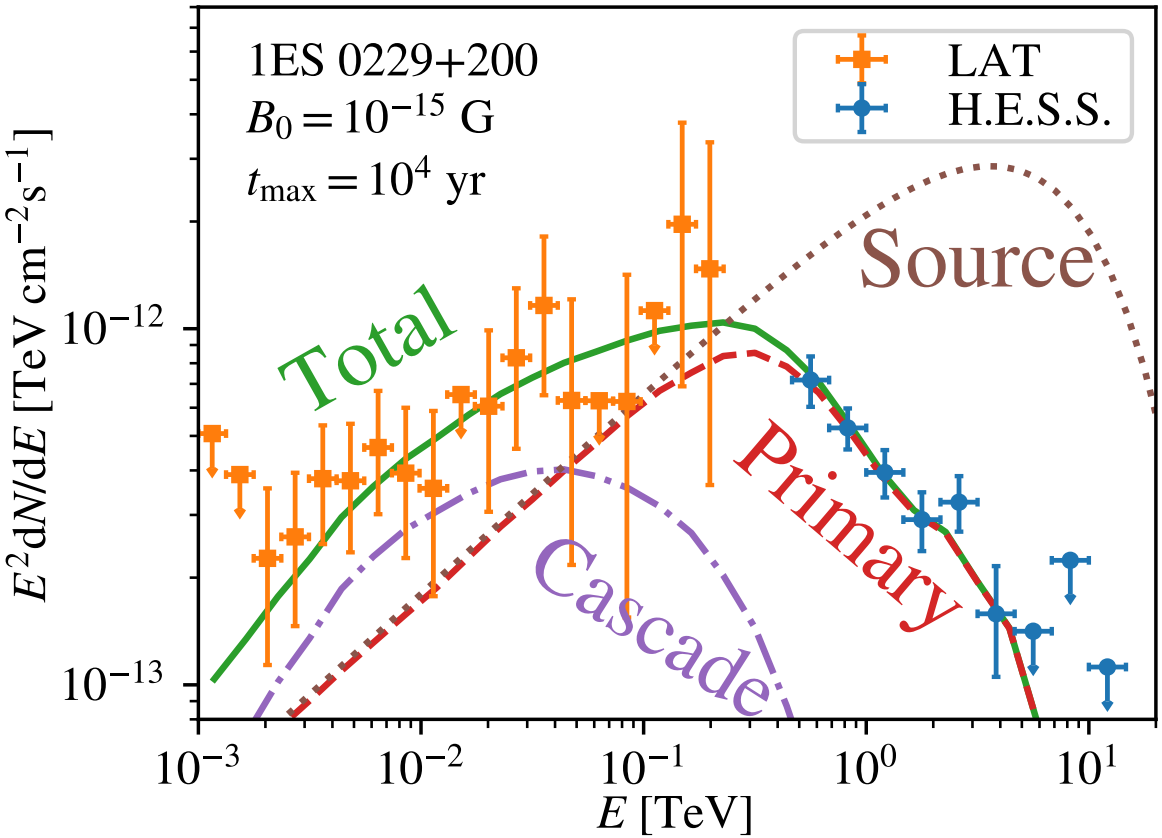

The cascade spectrum depends on the intergalactic magnetic fields!

- The intergalactic magnetic fields must be of primordial origin
- $B \gtrsim 10^{-14}$ G

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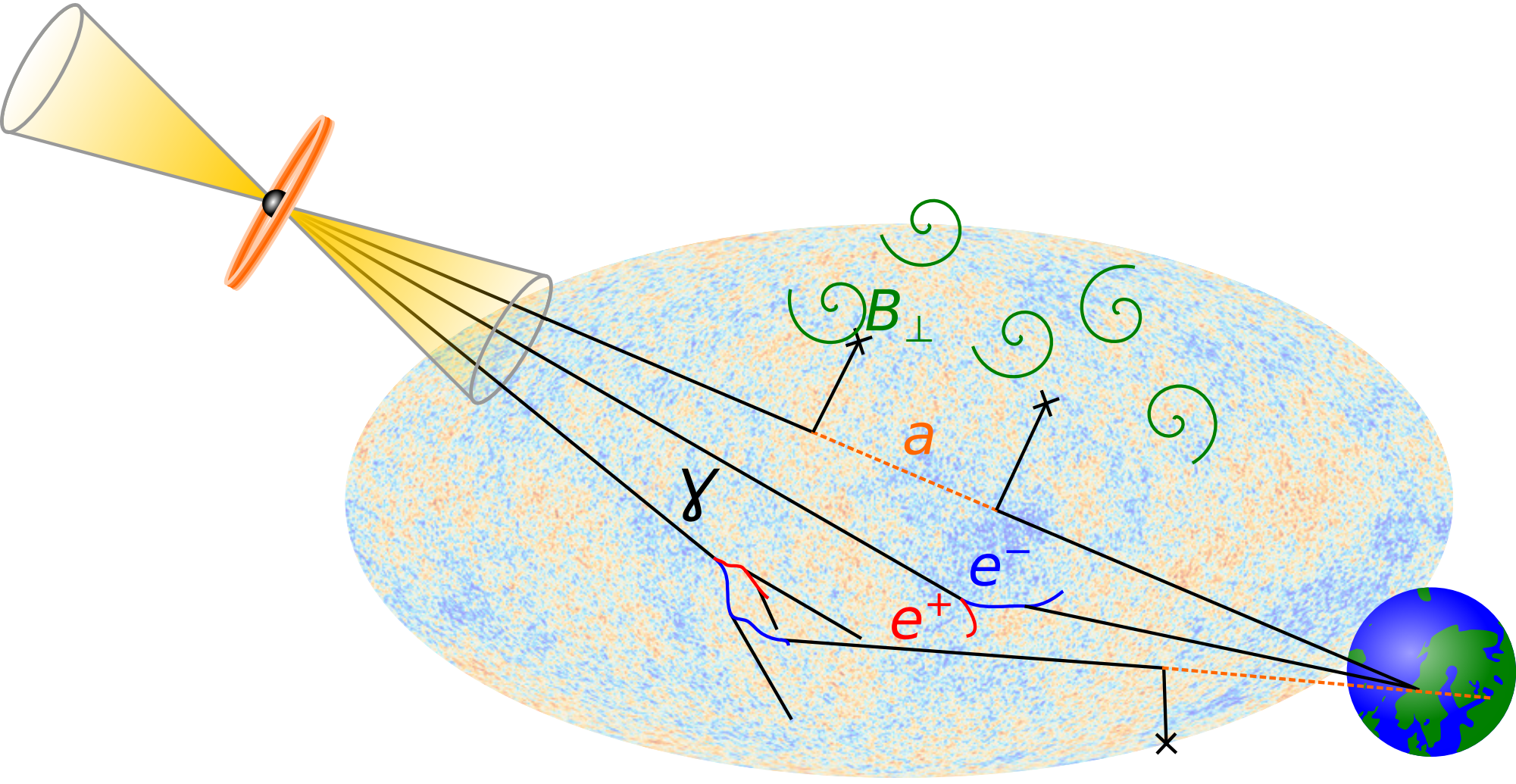
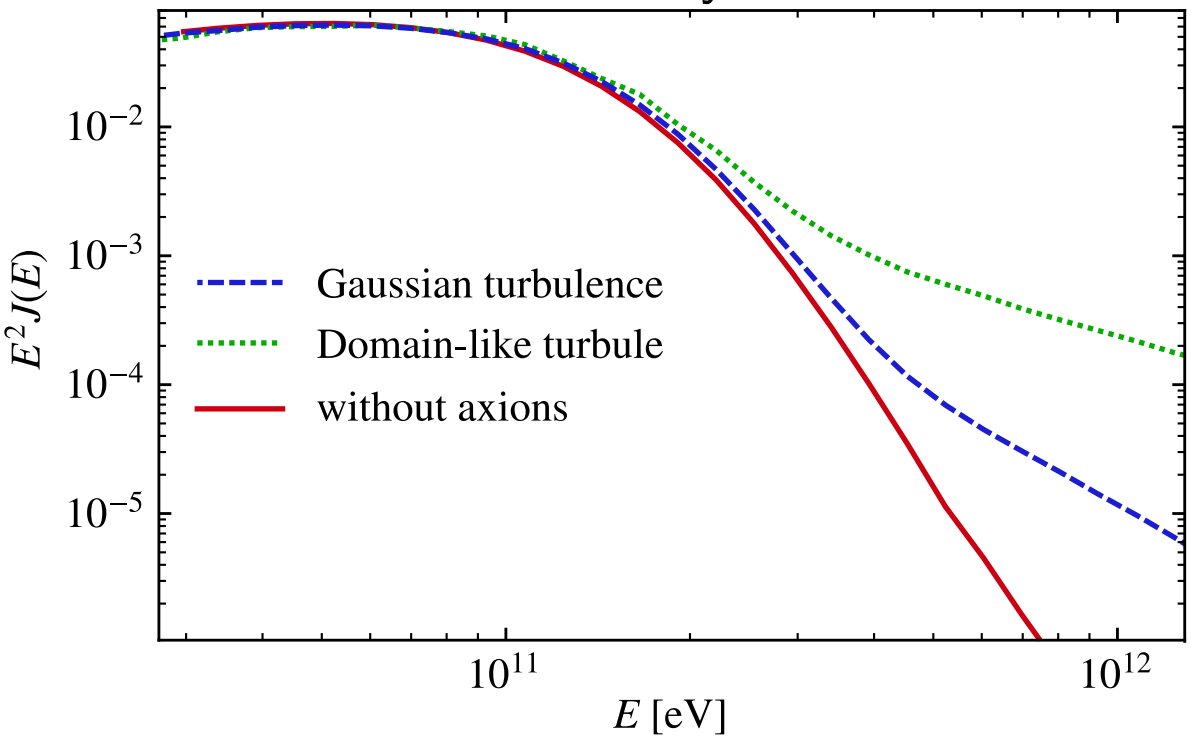
Photon-axion oscillations



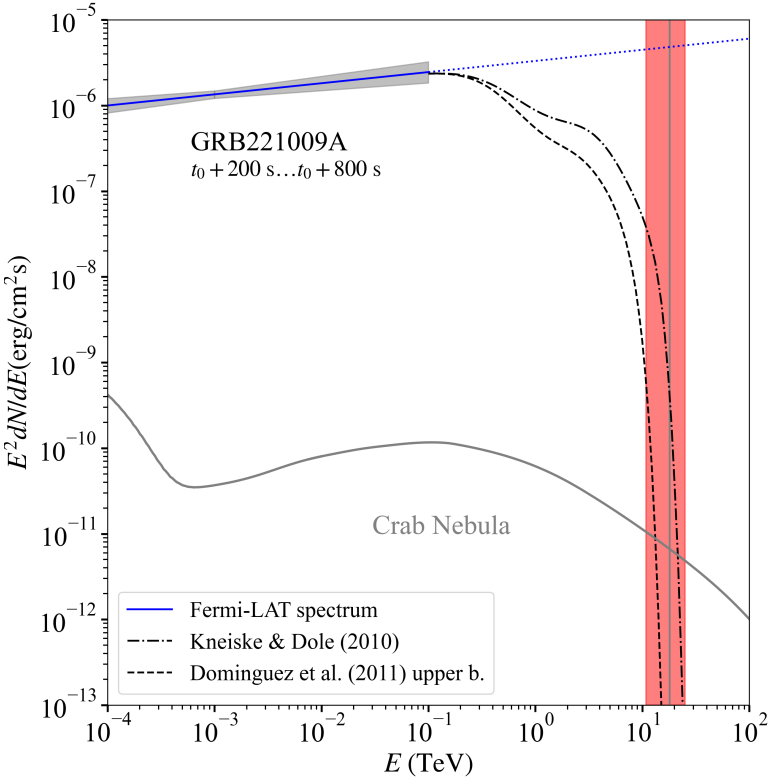
1. Decreased opacity of the Universe

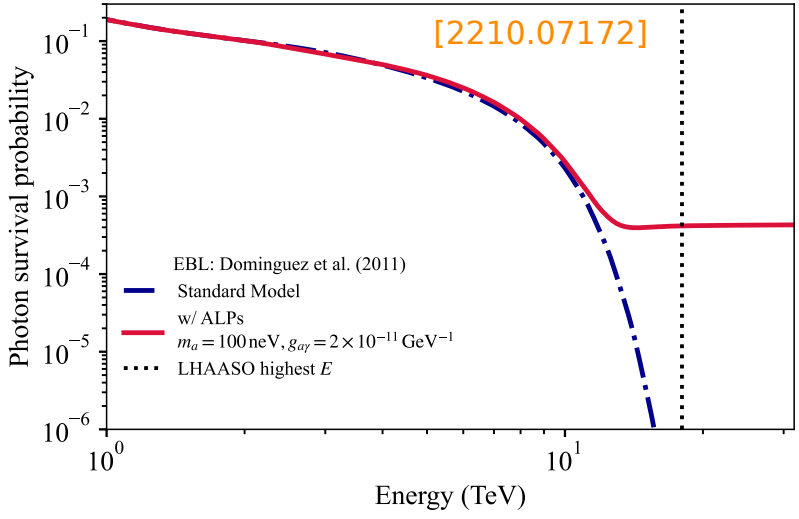
Axions are not attenuated by the EBL!



Example: GRB221009A

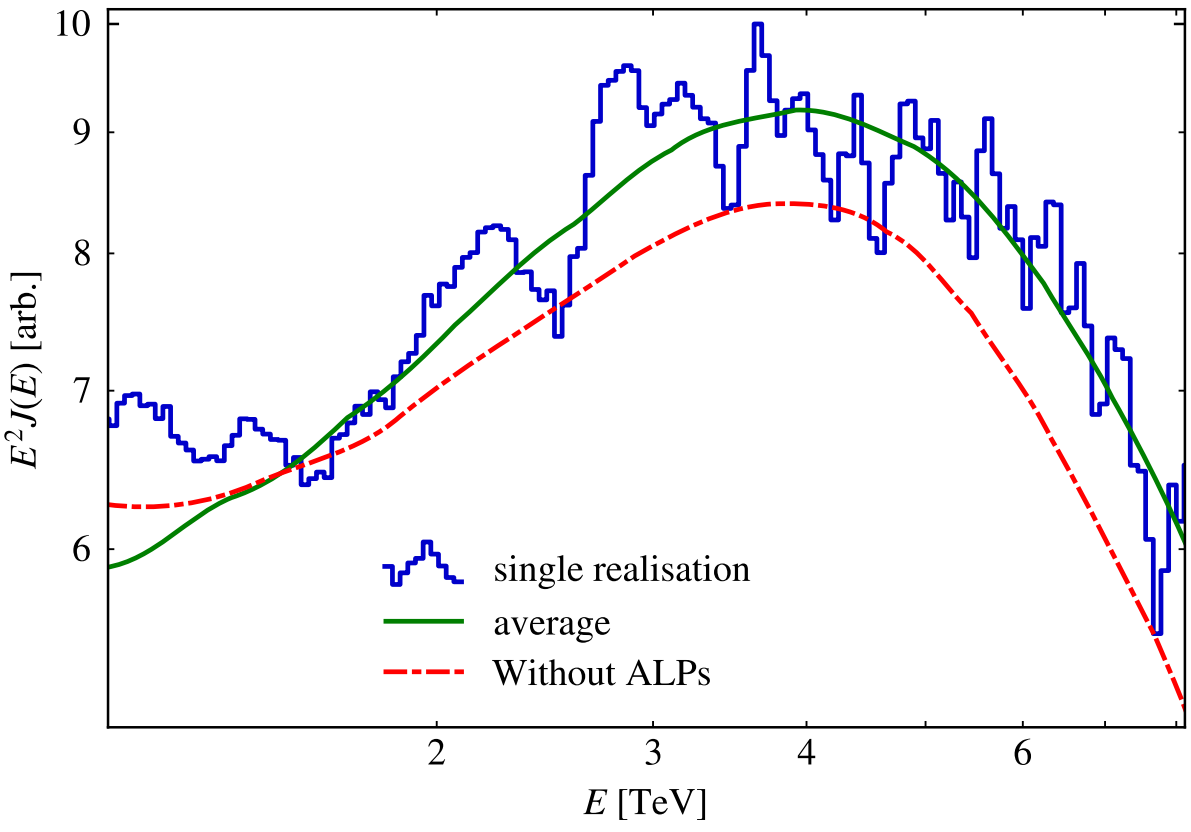
Photon-axion oscillations can explain the 18 TeV LHAASO events!





Galanti et al. [2210.05659], Baktash et al. [2210.07172], Carenza & Marsh [2211.02010], Troitsky [2210.09250]...

2. Wiggles ("irregularities") in photon spectra



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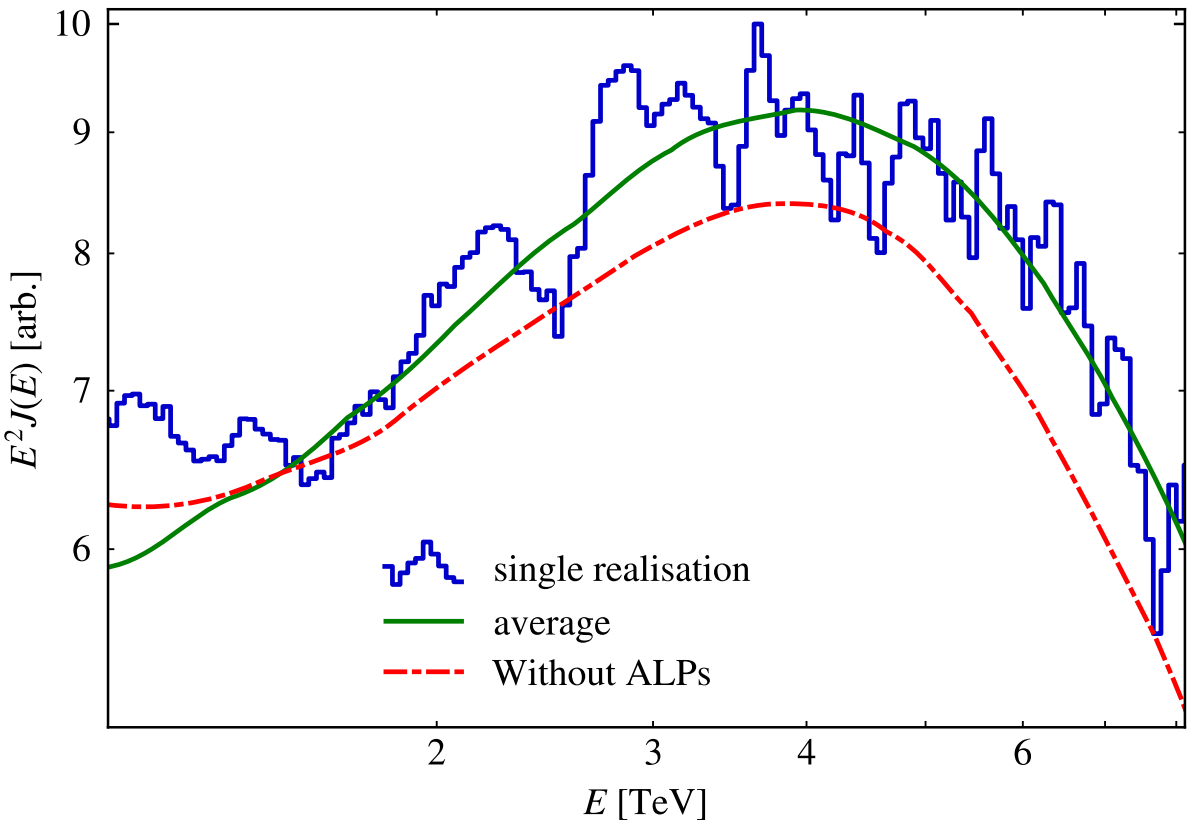

The "irregularities" have the same regular behaviour as in a homogeneous magnetic field

A direct detection of axion wiggles

Idea: Use the energy dependence of the wiggles as observable

$$G(k) = \left| \int_{\eta_{\min}}^{\eta_{\max}} \mathrm{d}\eta \, q(\eta) \mathrm{e}^{\mathrm{i}\eta k} \right|^2 \approx \left| \frac{1}{N} \sum_{\text{events}} \exp\{\mathrm{i}\eta k\} \right|^2$$

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Two main advantages:

1. A detection method independent of the modeling of the magnetic fields

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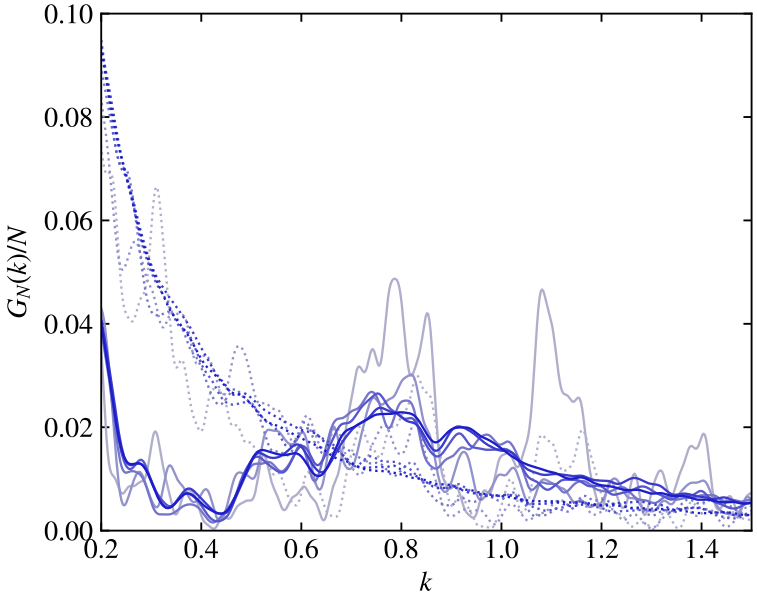
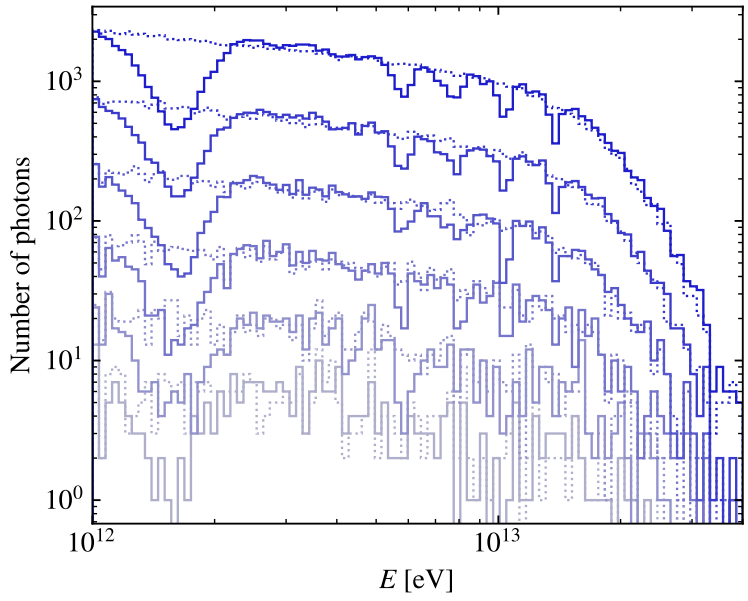
Two main advantages:

1. A detection method independent of the modeling of the magnetic fields
2. Few photons are needed

A direct detection of axion wiggles

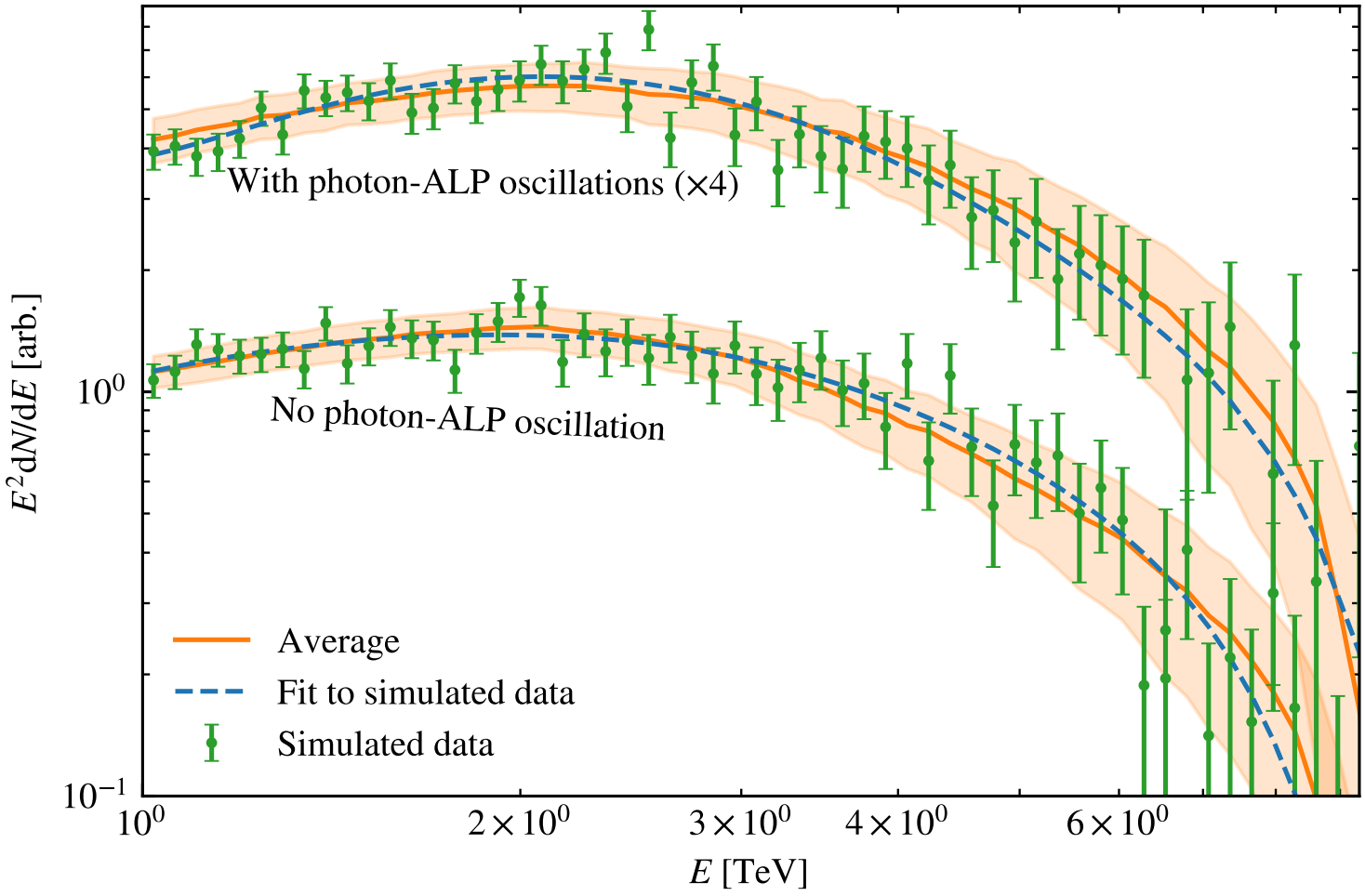




A peak indicate an energy dependent fluctuation

characteristic for axions

Example: PKS 2155-304 with CTA

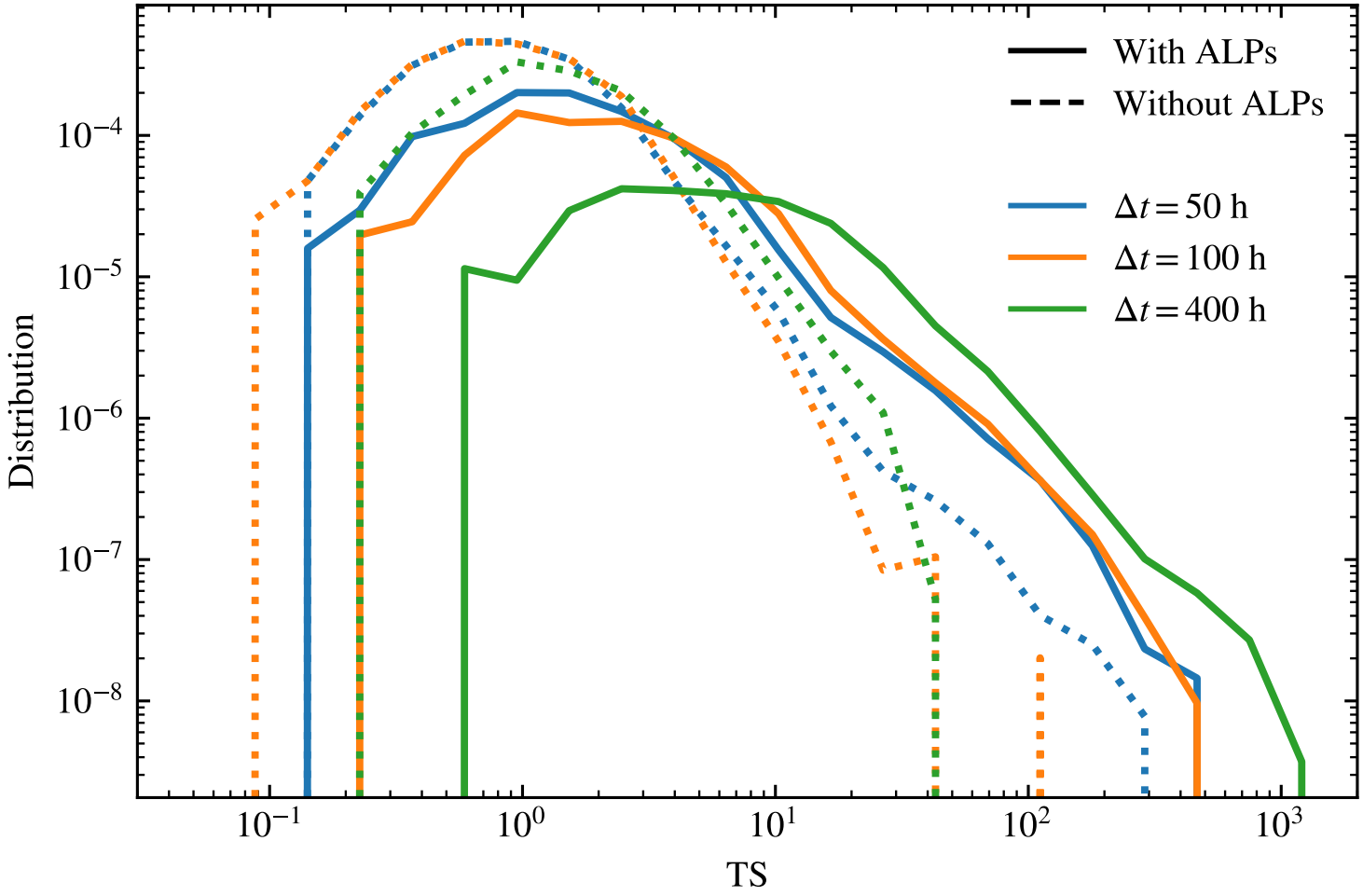


50h detection time with CTA

Difficult to find a signal with a standard χ^2 analysis

Example: PKS 2155-304 with CTA

TS: Area under the curve of $|G(k) - G_B(k)|$

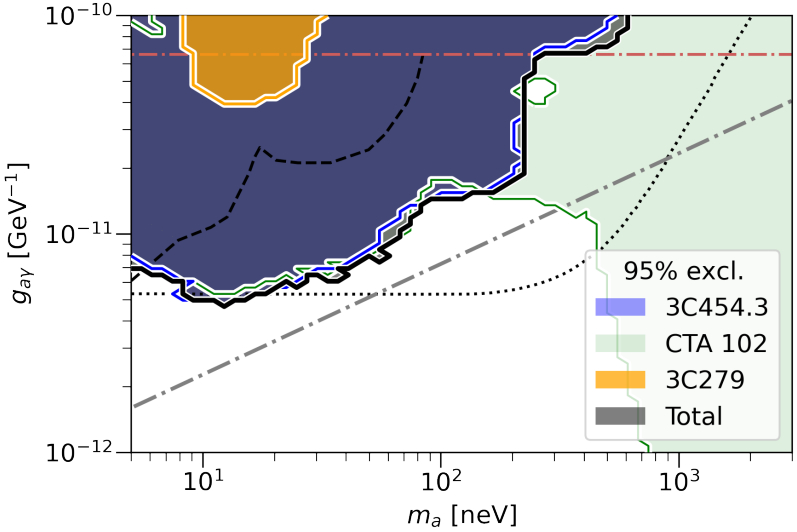


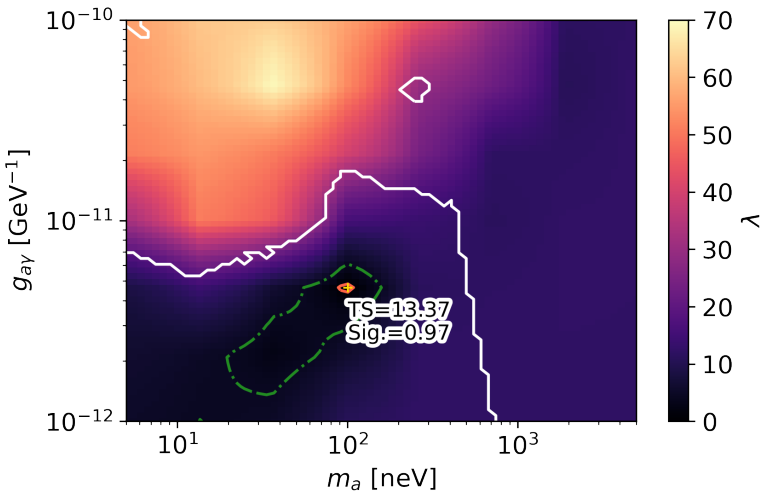
The key in the search for axion wiggles lies in the tail of the probability distribution!

Is there a signal in the Fermi data?

with M. Meyer

A small (1σ) preference for axions in a new Fermi analysis of the quasar CTA102 Davies, Meyer & Cotter (2022):





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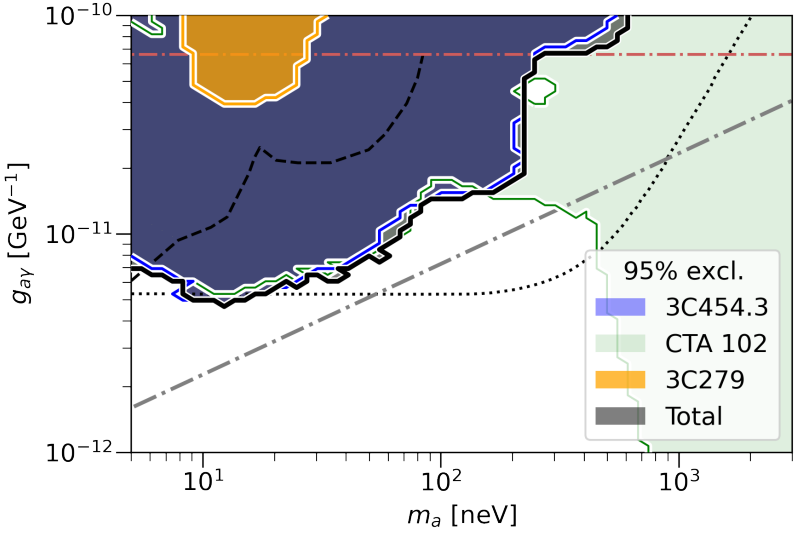
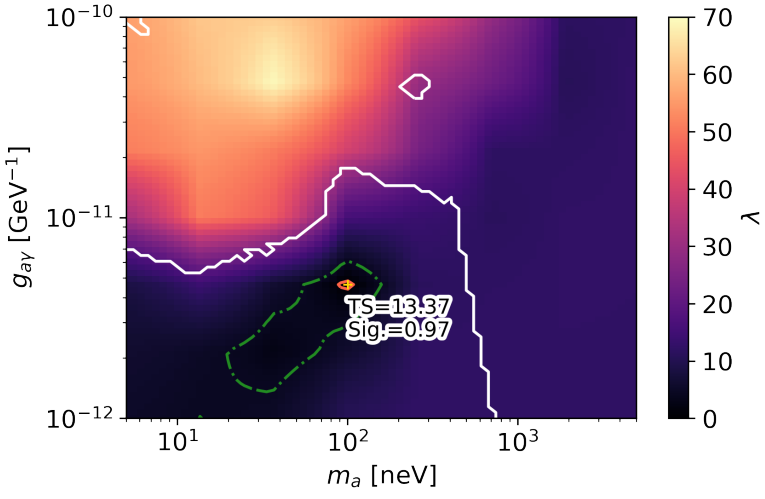
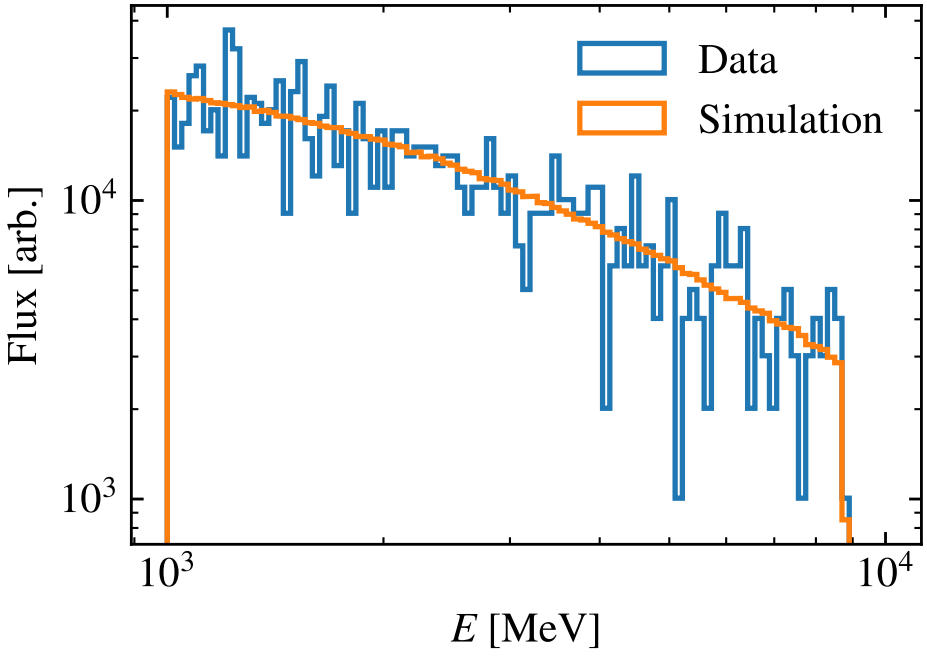
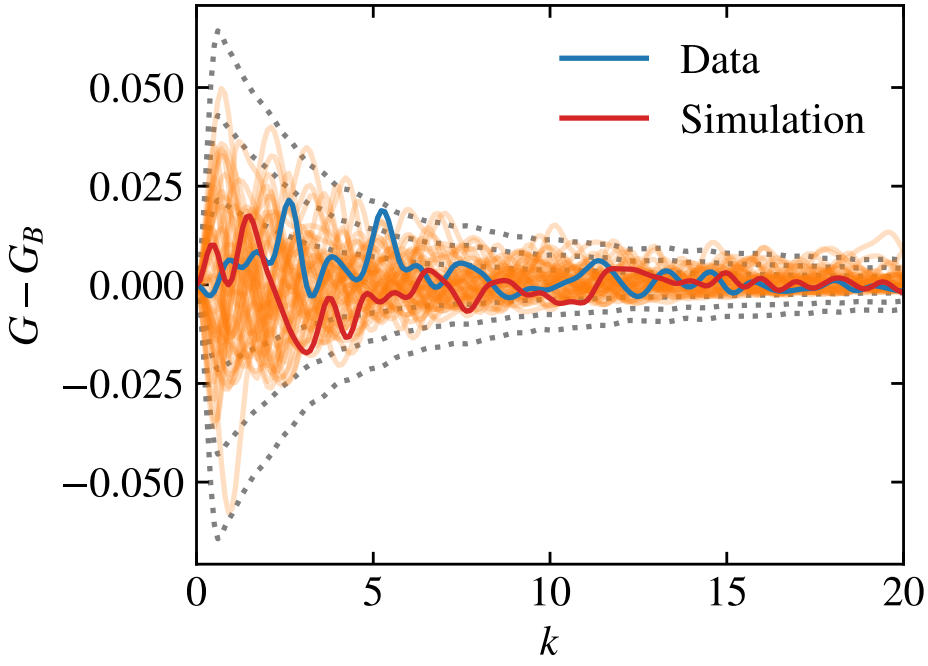




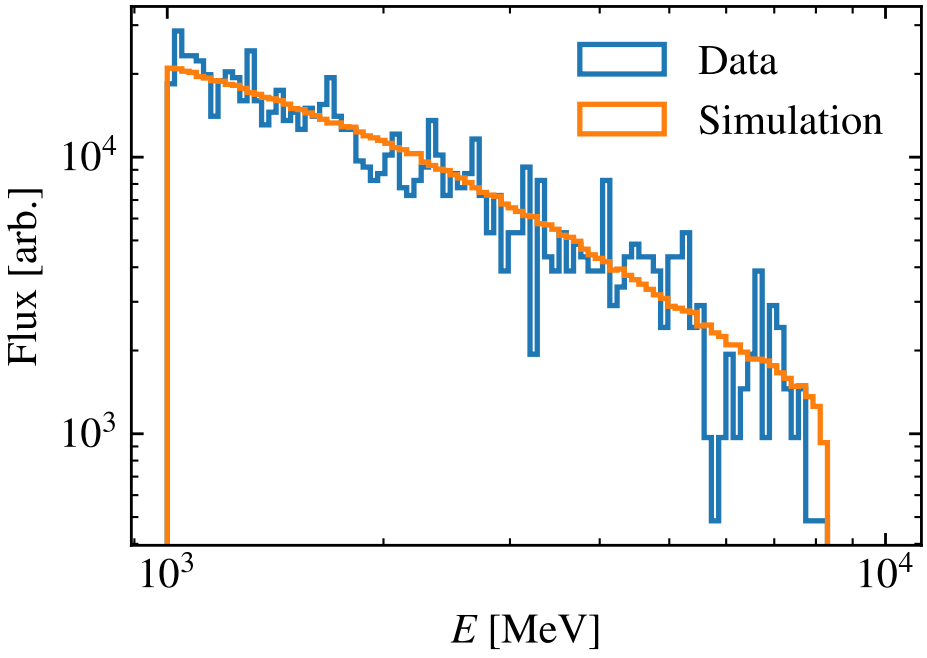
The Fermi tools gtobssim and gtselect makes it easy to look for axion wiggles!

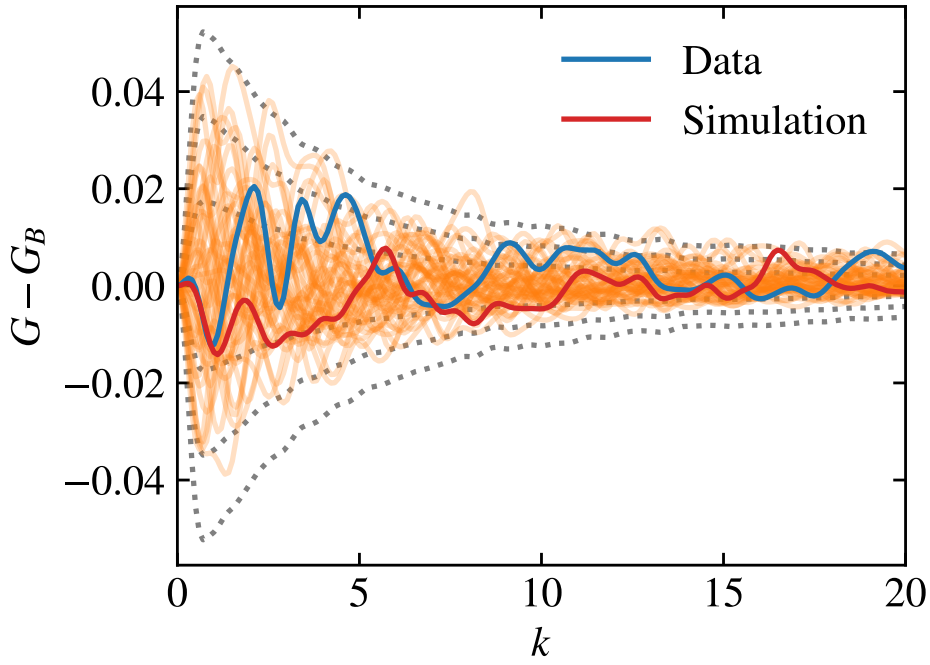
CTA 102


Data
Simulation
Flux [arb.]
10^4
10^3
10^3
10^4
E [MeV]


Data
Simulation
0.050
0.025
0.000
−0.025
−0.050
$G - G_B$
0
5
10
15
20
k

3C454.3


Data
Simulation
Flux [arb.]
10^4
10^3
10^3
10^4
E [MeV]


Data
Simulation
$G - G_B$
0.04
0.02
0.00
−0.02
−0.04
0
5
10
15
20
k

Summary

- Photon-axion oscillations imprint wiggles with known energy dependence on high-energy photon spectra

- Axion wiggles can probed with the discrete power spectrum

  Pros: Sensitive, and independent of the magnetic field modeling
  Cons: Difficult to set upper limits

- The variation in realistic magnetic field models might increase the sensitivity for photon-axion oscillations