Searching for effects of axion-like particles on the γ-ray transparency of the universe with the Fermi LAT and Cherenkov Telescopes

International Symposium on Cosmology and Particle Astrophysics 2017

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HELMHOLTZ ASSOCIATION

Fermi Gamma-ray Space Telescope

HUMBOLDT-UNIVERSITÄT ZU BERLIN

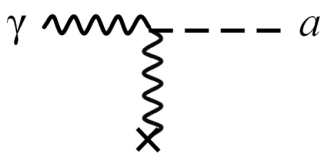
DESY

AXION LIKE PARTICLES IN ASTROPHYSICS

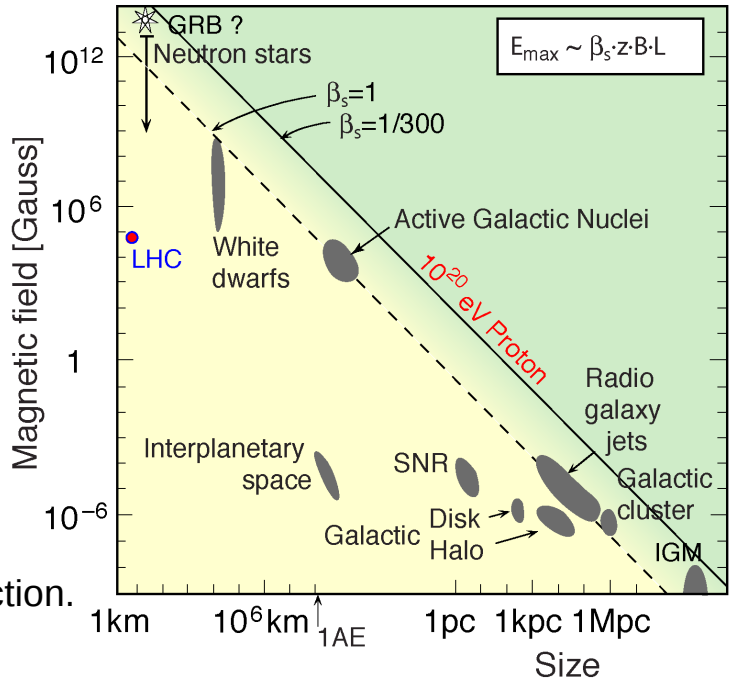
- Axions → Strong CP problem
- Beyond the Standard Model: axion-like particles

$$\mathcal{L}_{a\gamma} = -\frac{1}{4} g_{a\gamma} F_{\mu\nu} \tilde{F}^{\mu\nu} a = g_{a\gamma} \mathbf{E} \cdot \mathbf{B} a$$

- Oscillation under cosmic magnetic fields



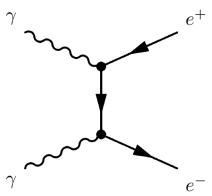
- Different cosmic magnetic fields scenarios
  Possibility of measuring axions in different energy ranges → γ-ray telescopes.

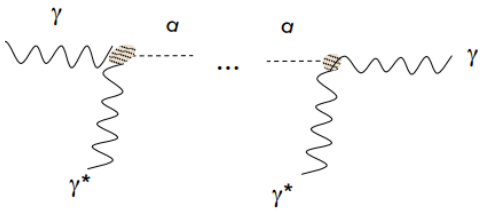


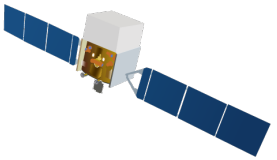
Hillas plot: original by Hillas, 1984 →
Hooper & Serpico 2007, axions connection.

TRANSPARENCY OF THE UNIVERSE TO γ RAYS

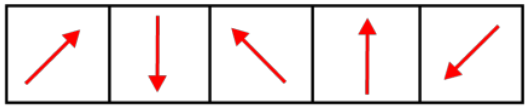
- Extragalactic background light causes photon attenuation.
- With ALPs:



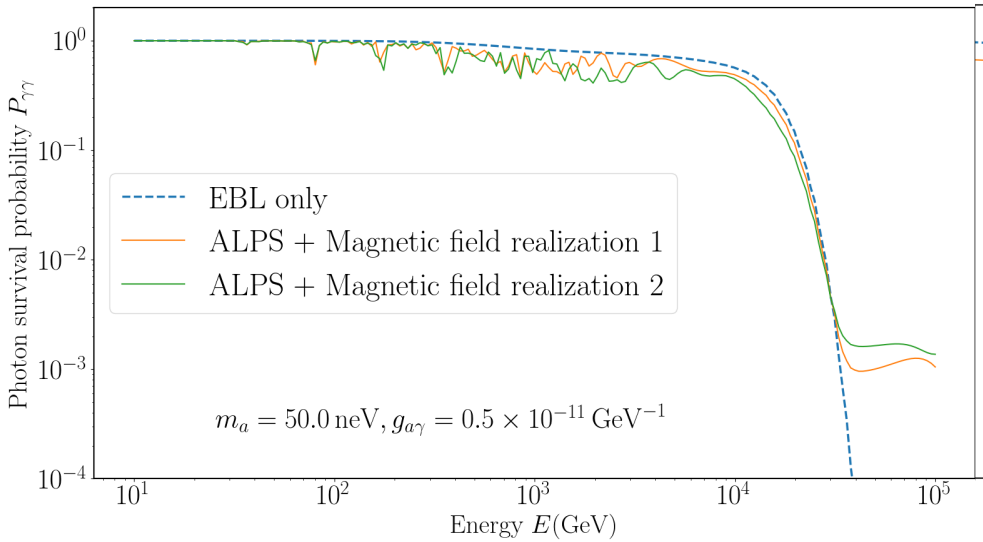




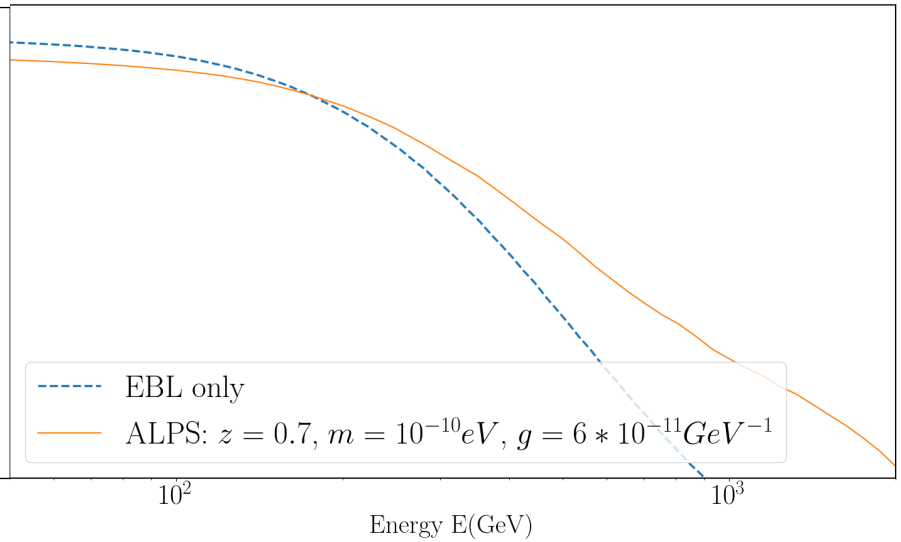
Magnetic field domains →



- Evade the absorption → Depends upon axion parameters and magnetic field regions.



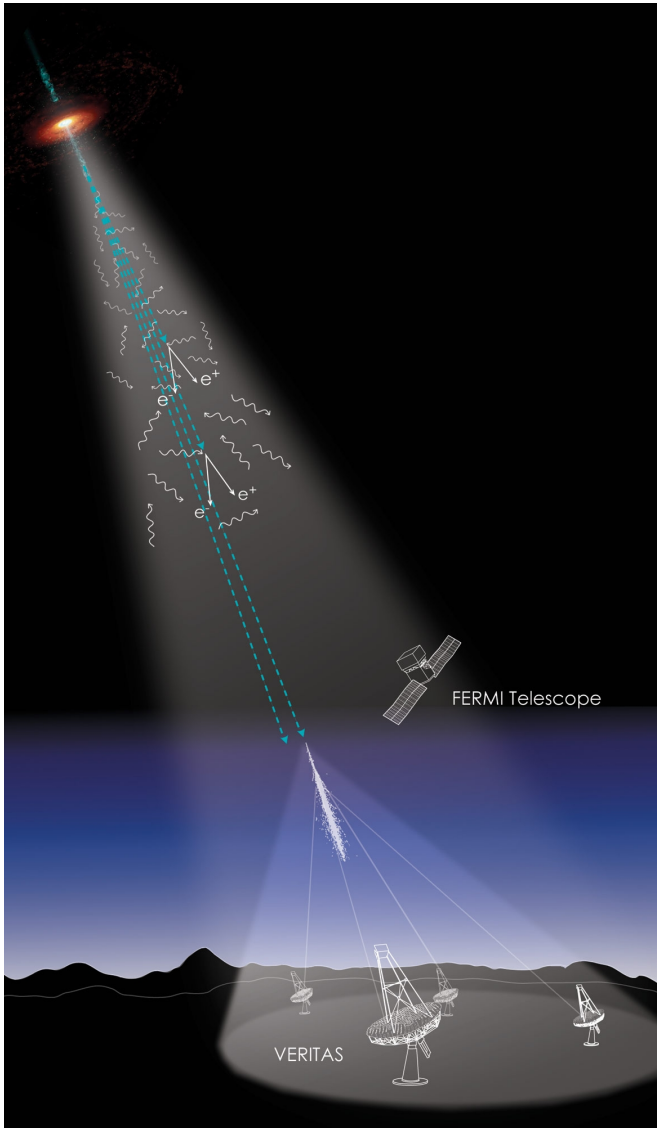
Mixing in galaxy cluster B field

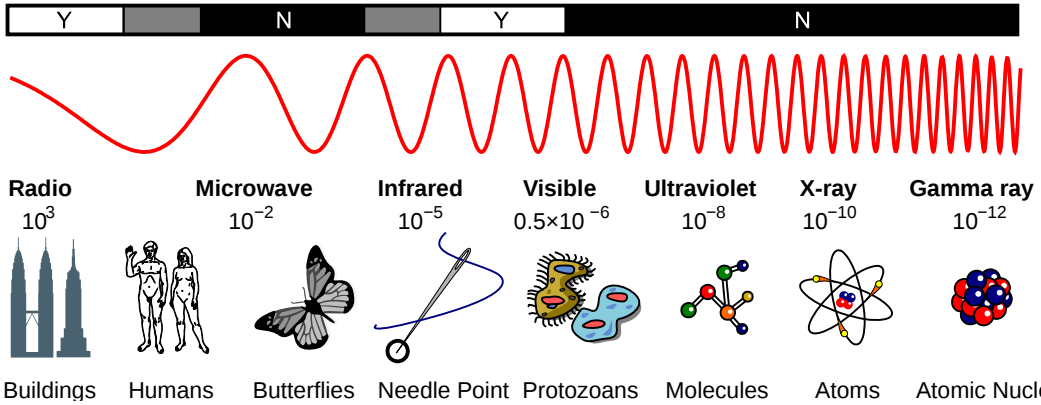


Mixing in intergalactic B field.

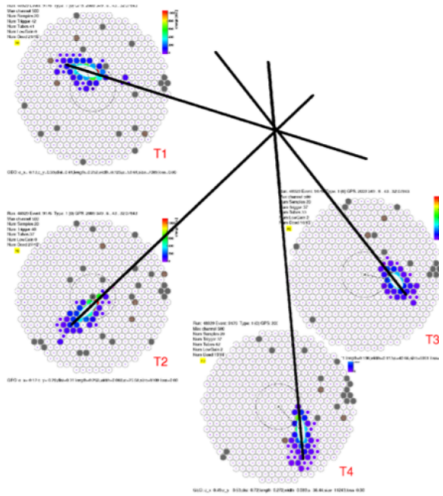
Fermi NGC 1275: PhysRevLett.116.161101
Plots: gammaALPs by M.Meyer, https://github.com/me-manu/gammaALPs

γ-RAY ASTRONOMY



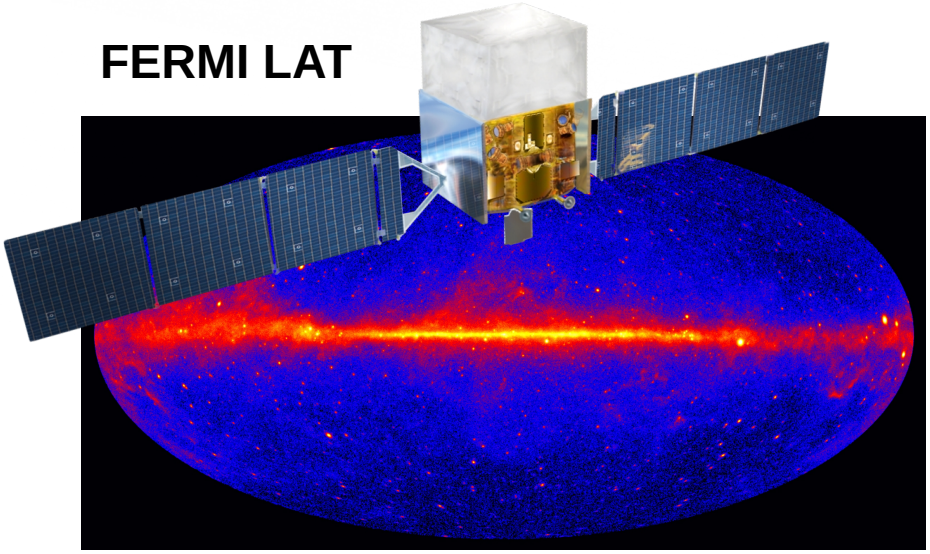


← Atmosphere



THE FERMI LAT AND CHERENKOV TELESCOPES

FERMI LAT

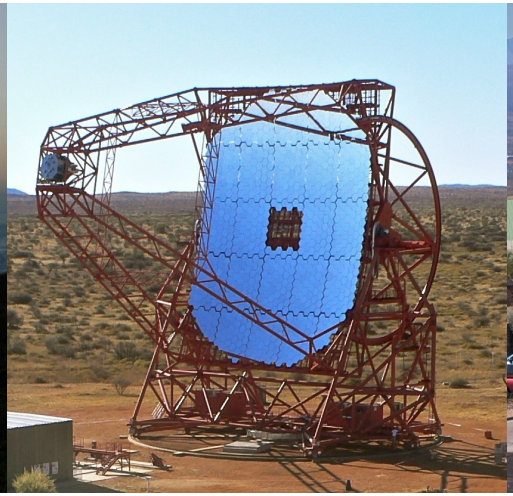


Energy	30MeV-800GeV
Effective Area	$1m^2$
Point Spread Function	0.8° at 1 GeV
Field of View	2.4 sr
Orbit	564 km, 96 min

Energy	85 GeV-30TeV
Effective Area	$100000m^2$
Angular Resolution	0.08° at 1 TeV
Field of View	3.5°
Observation time/y	750h +200h(moon)

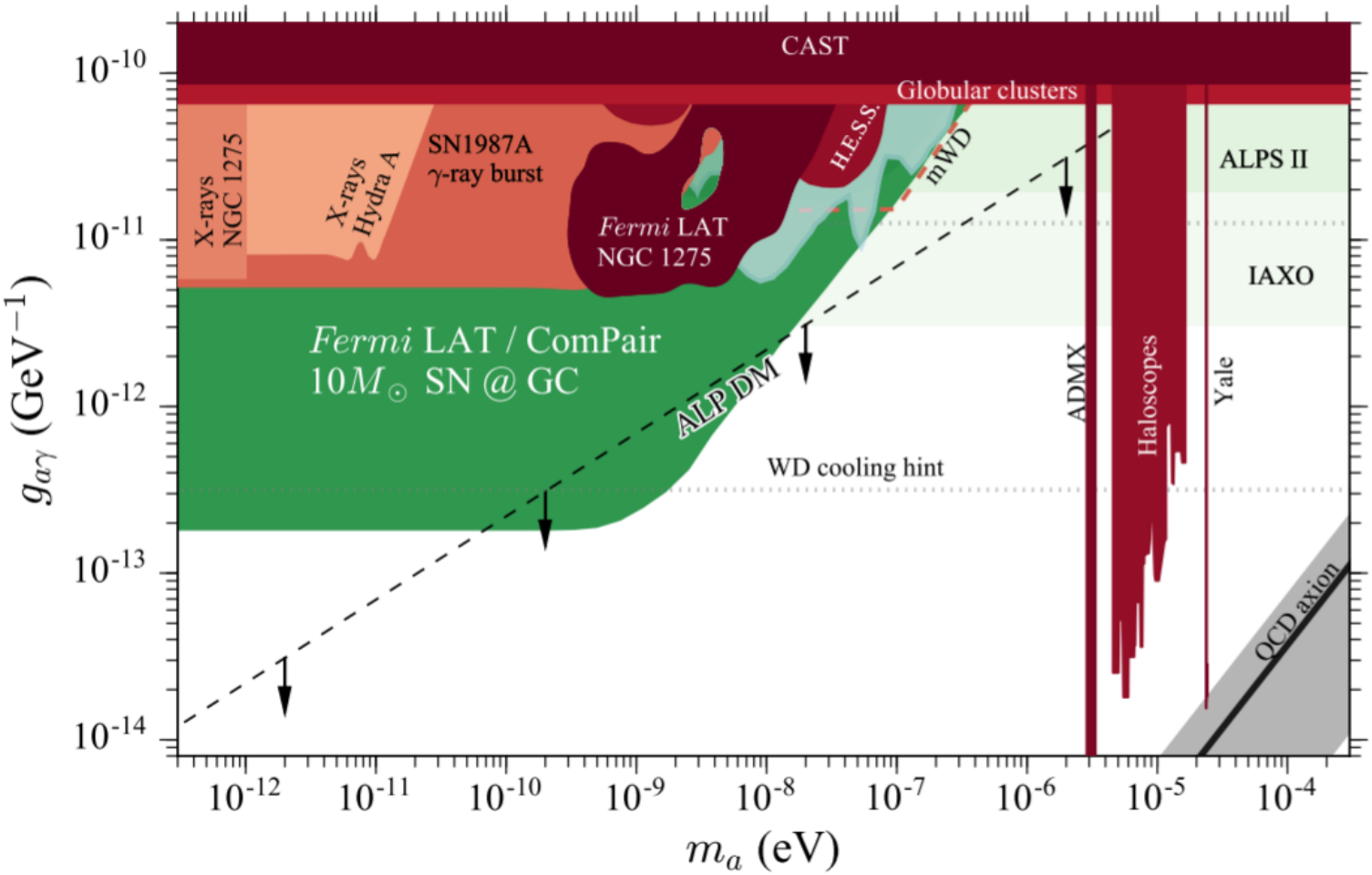
MAGIC

HESS



VERITAS

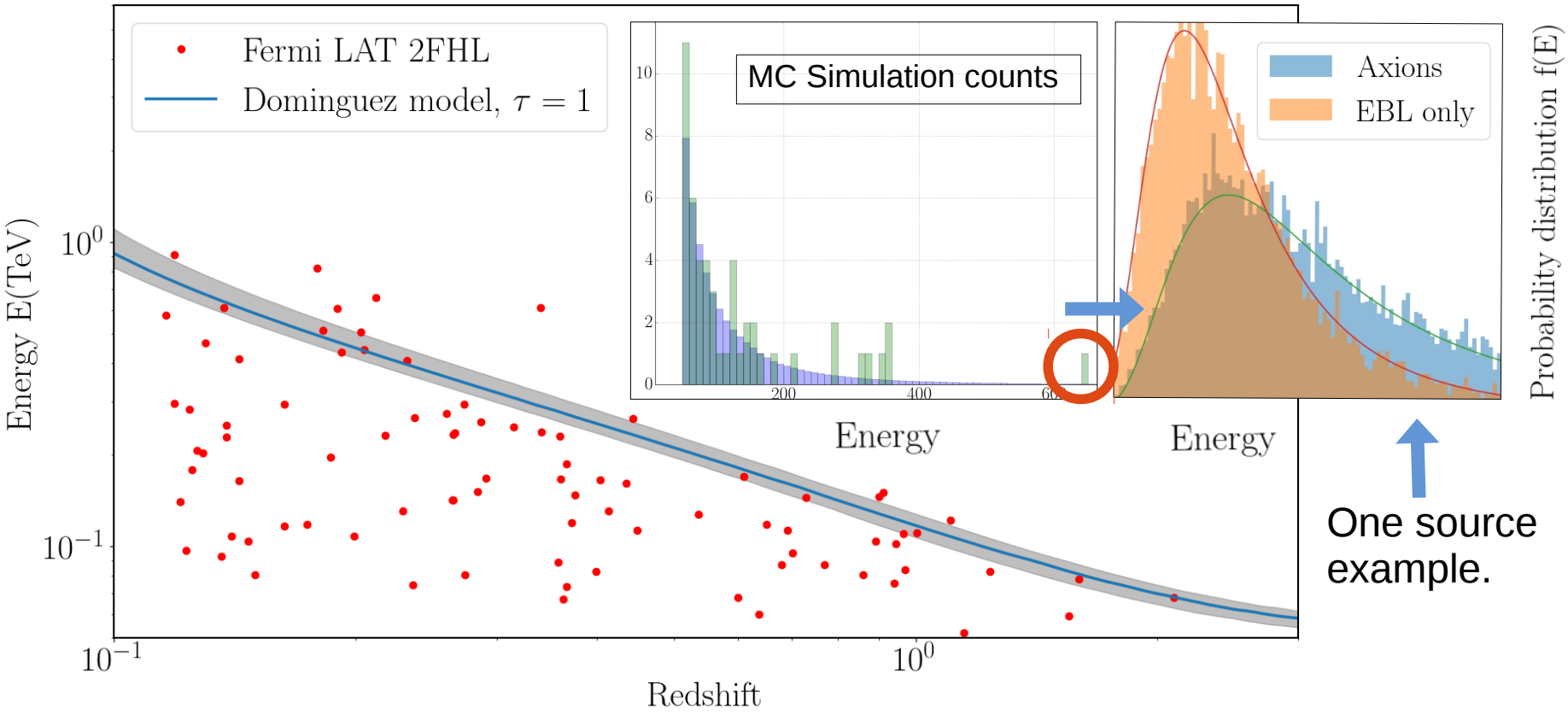
AXION-LIKE PARTICLES, WHERE DO WE STAND NOW?



The Fermi Large Area Telescope as a Galactic Supernovae Axionscope, Phys.Rev.Lett. 118 (2017) no.1, 011103.

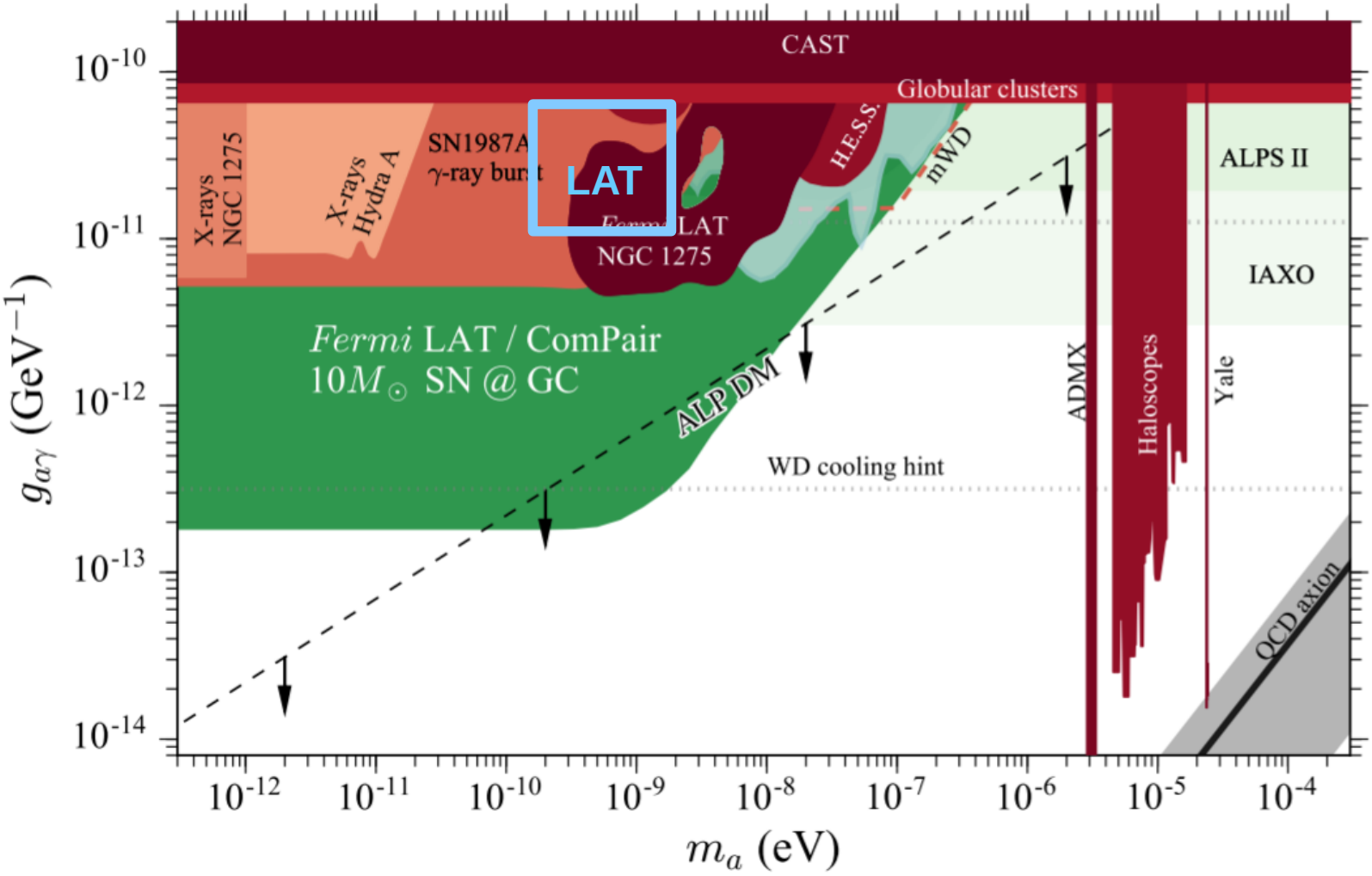
STUDY OF THE TRANSPARENCY OF THE UNIVERSE WITH THE FERMI LAT

- Analyze set of active galactic nuclei and determine the highest energetic photon for each one.
- Simulate highest ernergy photon values for each source.
- Likelihood ratio test to distinguish between models, with and without axions.



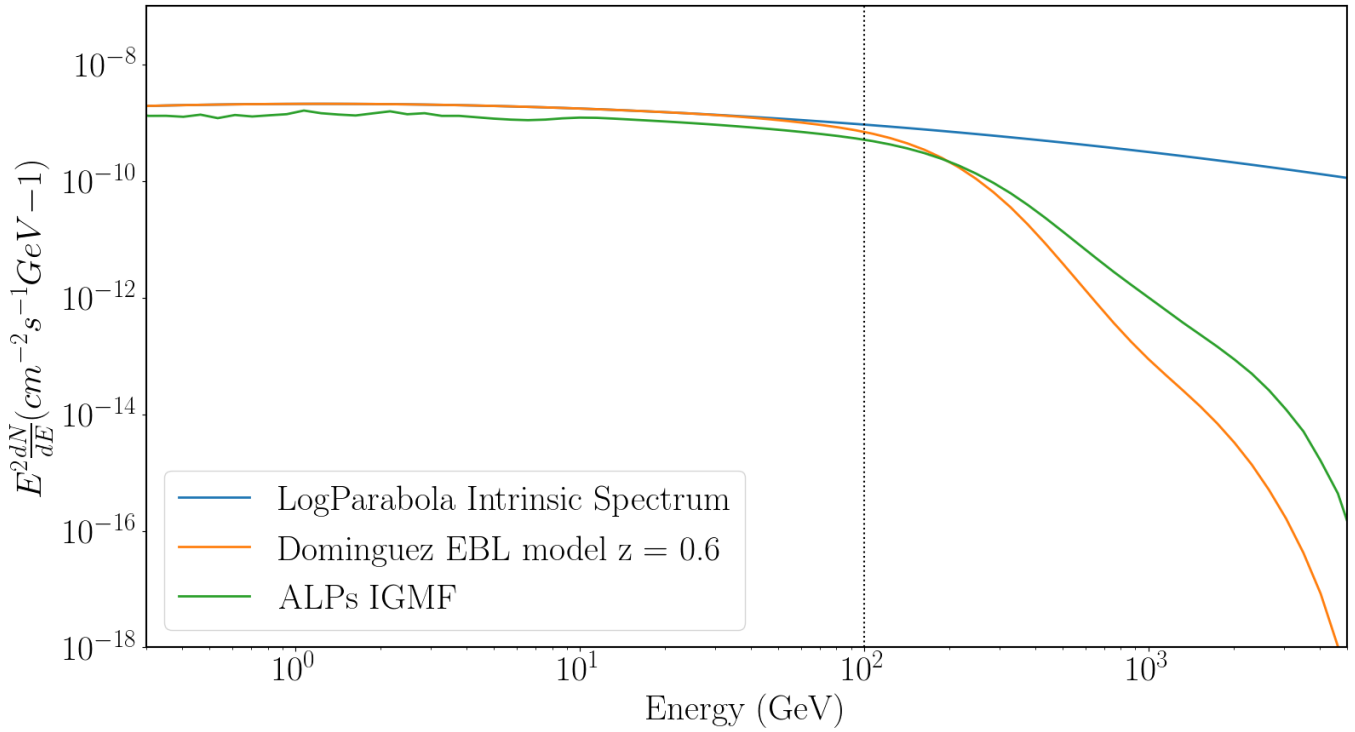
One source example.

SEARCH REGION WITH THE FERMI LAT



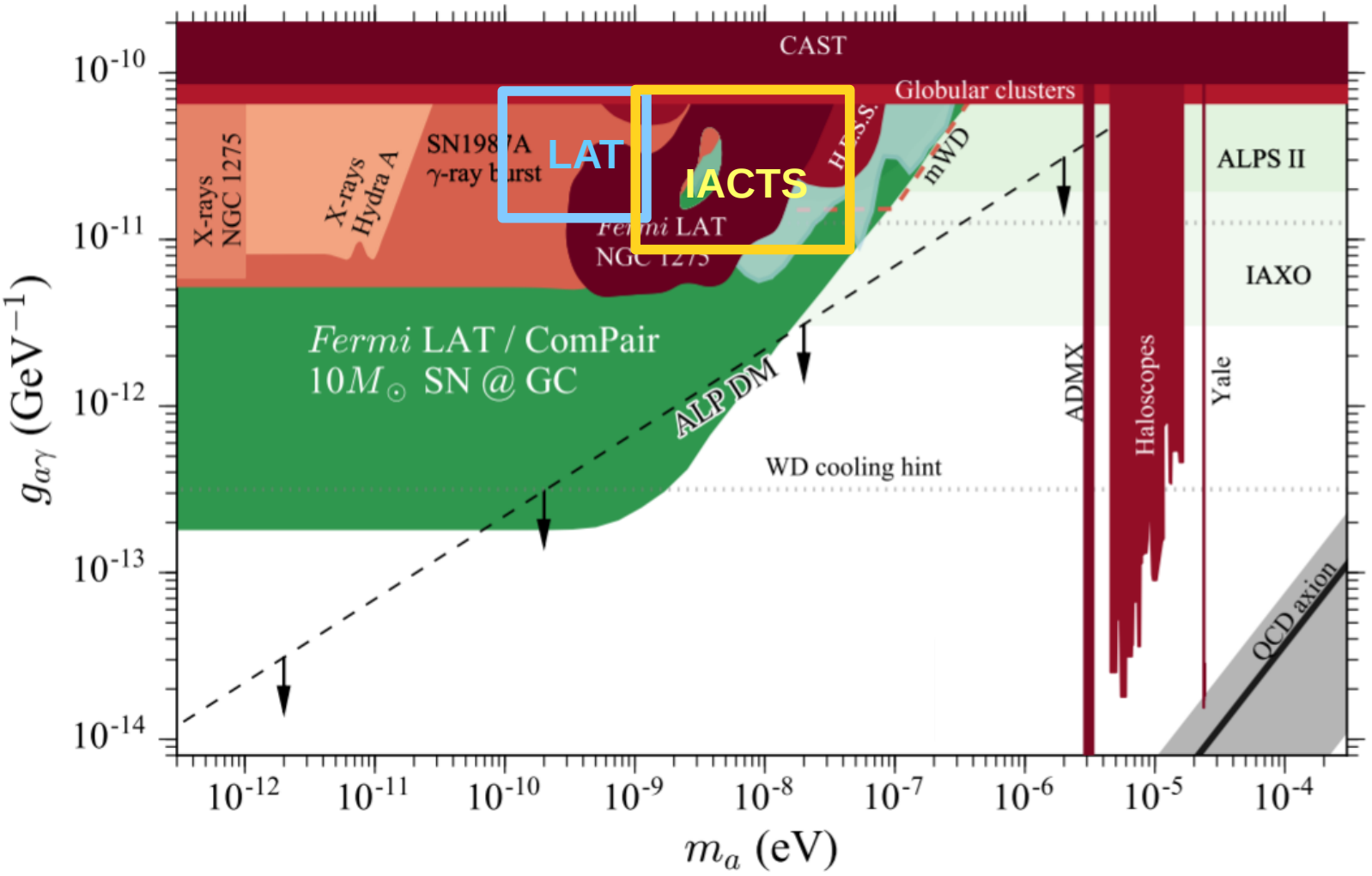
SPECTRAL ANALYSIS IN THE TEV RANGE

- Choose a set of sources observed by Fermi and cherenkov telescopes.
- Extract the intrinsic spectrum using Fermi.
- Test for models with and without axions.
- Include a systematic study of magnetic field uncertainties.



←Fermi LAT→ ←IACTS→

SEARCH REGION WITH IACTS



SUMMARY

- The extragalactic background light adds opacity to the universe that increases with redshift and energy.
- Photons can oscillate into axion-like particles under the presence of cosmic magnetic fields.
- For some magnetic fields and axion-like particles parameters there is a change in the transparency of the universe to γ rays.
- Search for these effects with current γ-ray telescopes in specific regions of the parameter space.

THANKS FOR YOUR ATTENTION!