THE SEARCH OF AXION-LIKE-PARTICLES WITH FERMI AND CHERENKOV TELESCOPES

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Photon/axion oscillations

- Axions were postulated to solve the strong CP problem in the 70s.
- Good Dark Matter candidates (axions with masses ≈ meV-μeV could account for the total Dark Matter content).
- They are expected to oscillate into photons (and viceversa) in the presence of magnetic fields:

$$\boxed{P_0 = (\Delta_B s)^2 \frac{\sin^2(\Delta_{\rm osc} s/2)}{(\Delta_{\rm osc} s/2)^2}.}$$

with

$$\Delta_B = \frac{B_t}{2M} \simeq 1.7 \times 10^{-21} M_{11} B_{\rm mG}\ {\rm cm}^{-1},$$

$$\Delta_{\rm osc}^2 \simeq (\Delta_{\rm CM} + \Delta_{\rm pl} - \Delta_a)^2 + 4\Delta_B^2,$$

Photon/axion oscillations are the main vehicle used at present in axion searches (ADMX, CAST…).

Some astrophysical environments fulfill the mixing requirements

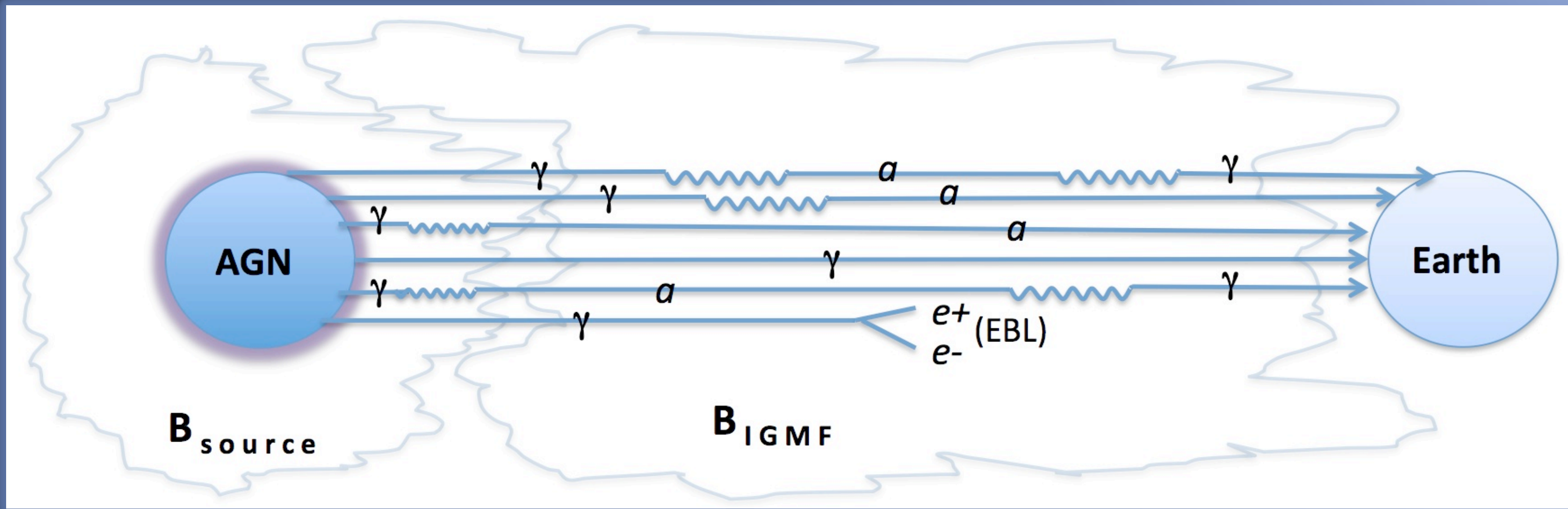
AGNs, IGMFs

$$\frac{15 \cdot B_G \cdot s_{pc}}{M_{11}} \geq 1$$

$M_{11} \geq 0.114$ GeV (CAST limit)

- M_{11}: coupling constant inverse ($g_{a\gamma}/10^{11}$ GeV)
- B_G: magnetic field (G)
- s_{pc}: size region (pc)

Source and intergalactic mixing working together



AGNs located at cosmological distances will be affected by both mixing in the source and in the IGMF:

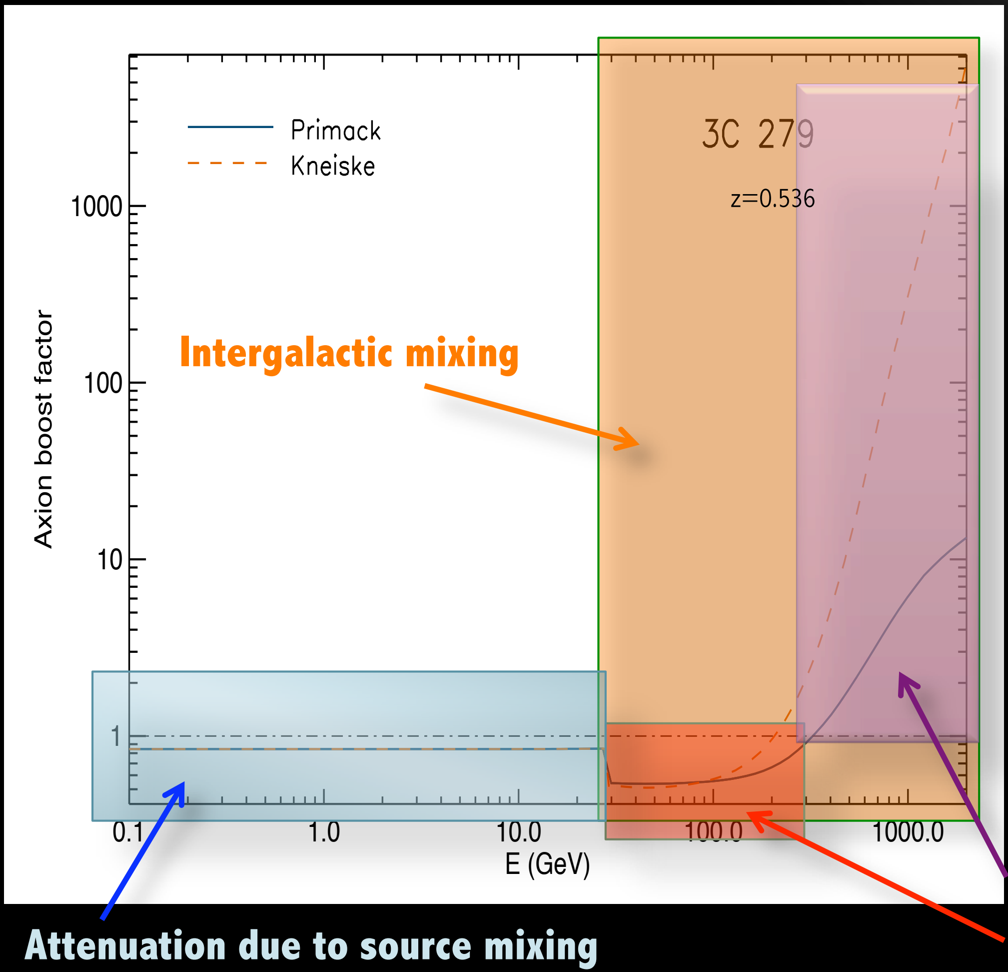
A. Source mixing: attenuation
B. IGM mixing: attenuation and/or enhancement

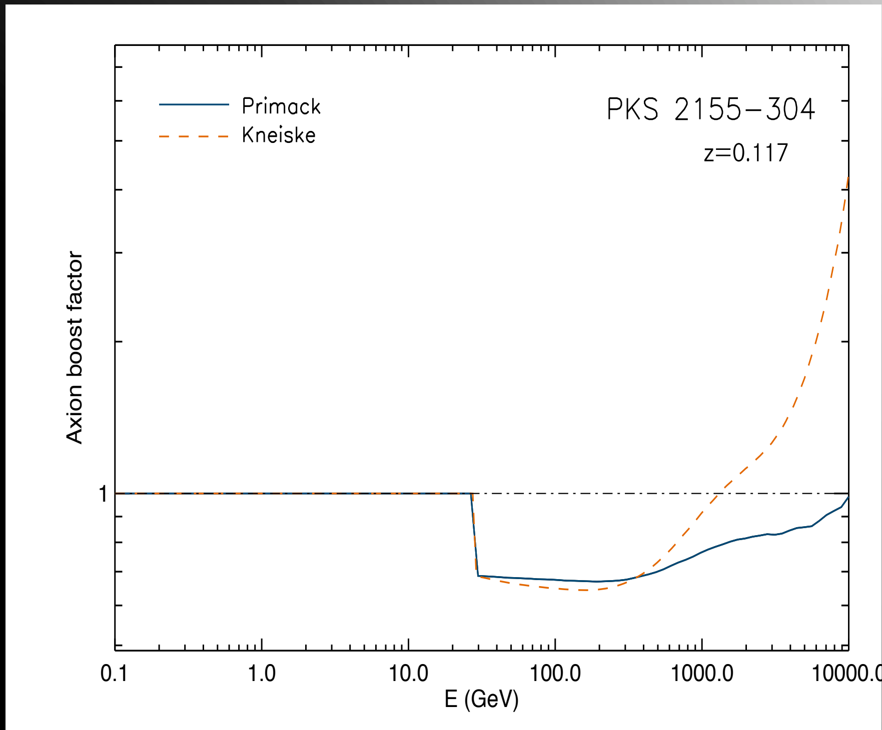
In order to observe both effects in the gamma-ray band, we need ultralight axions.

$$E_{crit}(GeV) \equiv \frac{m_{\mu eV}^2 \ M_{11}}{0.4 \ B_G}$$

Axion boosts

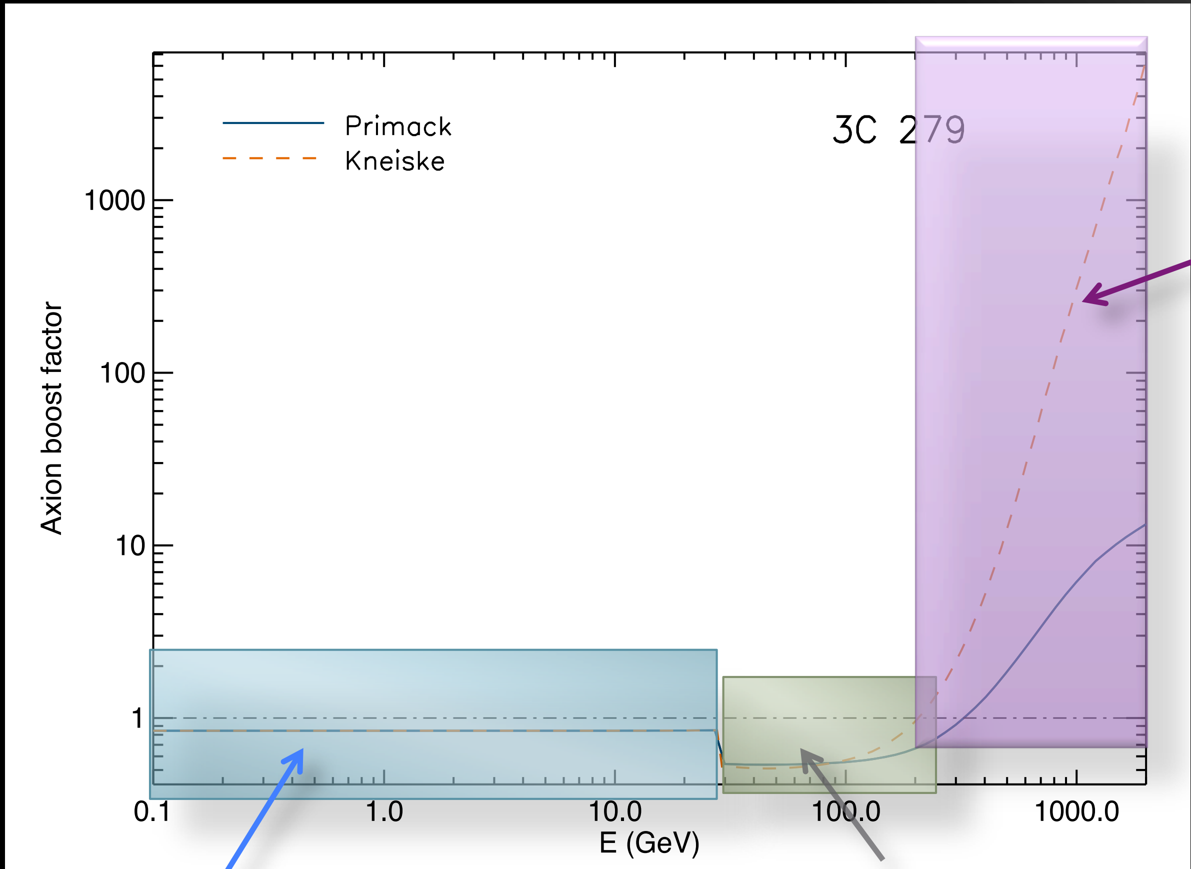
Axion boost =(Flux w axions) / (Flux w/o axions)





- ✓ Larger axion boosts for distant sources.
- ✓ The more attenuating the EBL, the larger the axion boosts.

Observational strategy with Fermi and IACTs



IACTs observations

Look for systematic intensity **enhancements** at energies where the EBL is important.

Distant (z > 0.2) sources at the highest possible energies (>1 TeV), to push EBL models to the extreme.

Source and EBL model dependent, but very important enhancement expected in some cases.

Fermi/LAT and/or IACTs

Look for intensity **drops** in the residuals ("best-model"-data).

Source model dependent.

Powerful, relatively **near** AGNs.

Fermi/LAT and/or IACTs

Look for intensity **drops** in the residuals.

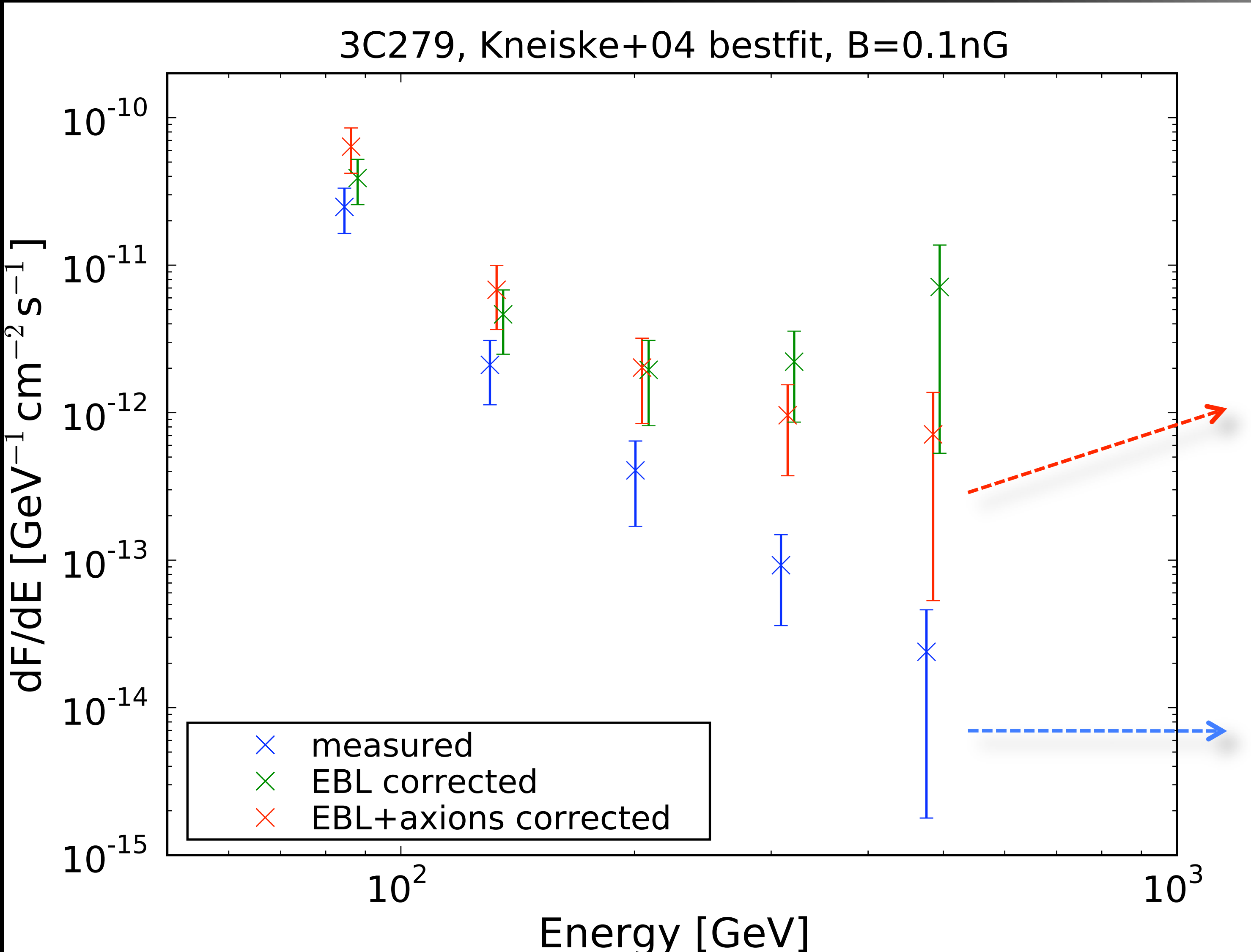
Only depends on the IGMF and axion properties (mass and coupling constant).

Independent of the sources -> CLEAR signature!

Are we detecting axions already?

- Recent gamma observations might already pose substantial challenges to the conventional models to explain the observed source spectra and/or EBL density.
  - The VERITAS Collaboration recently claimed a detection above 0.1 TeV coming from 3C66A (z=0.444). EBL-corrected spectrum harder than 1.5 (Acciari+09).
  - TeV photons coming from 3C 66A? (Neshpor+98; Stepanyan+02). Difficult to explain with conventional EBL models and physics.
  - The lower limit on the EBL at 3.6 μm was recently revised upwards by a factor ~2, suggesting a more opaque universe (Levenson+08).
  - Some sources at $z = 0.1 - 0.2$ seem to have harder intrinsic energy spectra than previously anticipated (Krennrich+08).
- While it is still possible to explain the above points with conventional physics, the axion/photon oscillation would naturally explain these puzzles:
  - More high energy photons than expected.
  - Softer intrinsic spectrum when including axions.

Axions are our friends



Softer intrinsic spectrum with axions

We can observe the spectrum up to higher energies with axions

(Sánchez-Conde & Dominguez, in prep.)

[3C279 data points from the MAGIC Collaboration, Albert et al. 2008]

CONCLUSIONS

- If axions exist, they could **distort the spectra** of astrophysical sources importantly.
- If photon/axion mixing in the IGMFs, then also mixing in the source.
  For $\mathbf{m_{axion} \approx 10^{-10}}$ **eV -> gamma** ray energy range.
- Photon/axion mixing in both the source and the IGM are expected to be at work over several decades in energy -> **joint effort of Fermi and current IACTs** needed.
  - Fermi/LAT instrument expected to play a key role, since it will detect thousands of AGNs (up to z~5), at energies where the EBL is not important.
  - IACTs specially important at higher energies (>300 GeV), where the EBL is present.
- Main **caveats**: the effect of photon/axion oscillations could be attributed to conventional physics in the source and/or propagation of the gamma-rays towards the Earth.
- However, **detailed observations of AGNs** at different redshifts and different flaring states could be used to identify the signature of an effective photon/axion mixing.