Astrophysical motivations for axion-like particles

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Axion Strategy Meeting
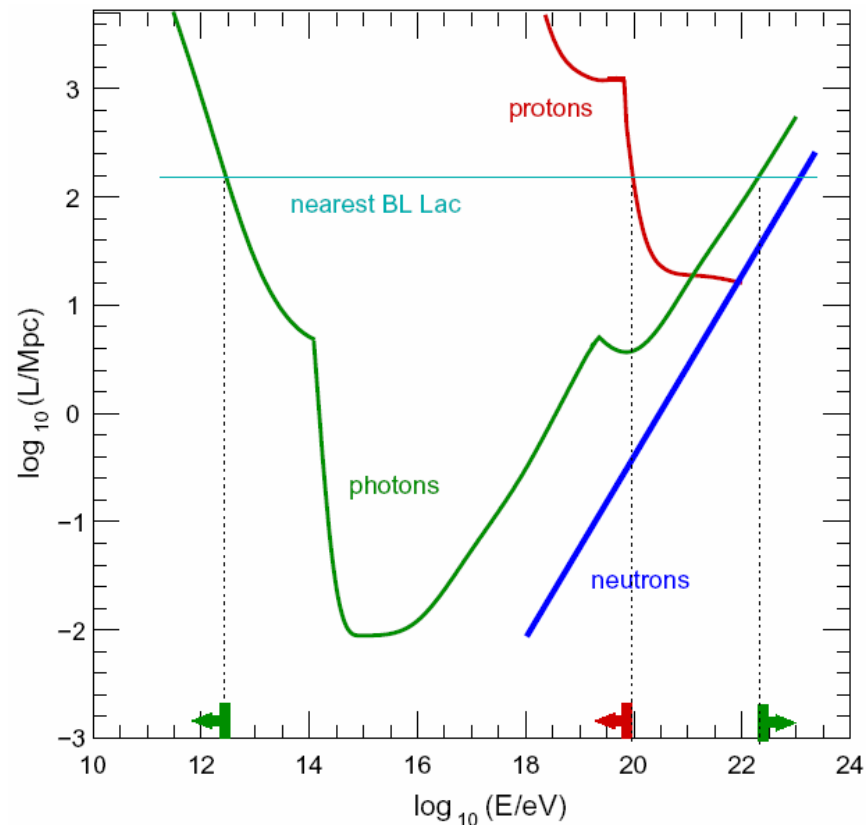*CERN, 27th January 2009*

ALP motivations

⇨ *quantitative:*

- **Infrared-TeV crisis in gamma-ray astronomy**
- **Neutral ultra-high-energy particles from BL Lacs**

⇨ *qualitative:*

- **White-dwarf luminosity function**
- **Correlations in quasar polarization**
- **Gamma rays through the Sun**

problems

- **Infrared-TeV crisis in gamma-ray astronomy**
- **Neutral ultra-high-energy particles from BL Lacs**

energetic photons cannot travel for long distances!

problems

- **Infrared-TeV crisis in gamma-ray astronomy**

  - TeV photons interact with infrared background
  - TeV flux from distant sources should be suppressed

  - spectra corrected for absorption are too flat (rising)
    - problems with emission models
    - farther the source – less the intrinsic spectral index

problems

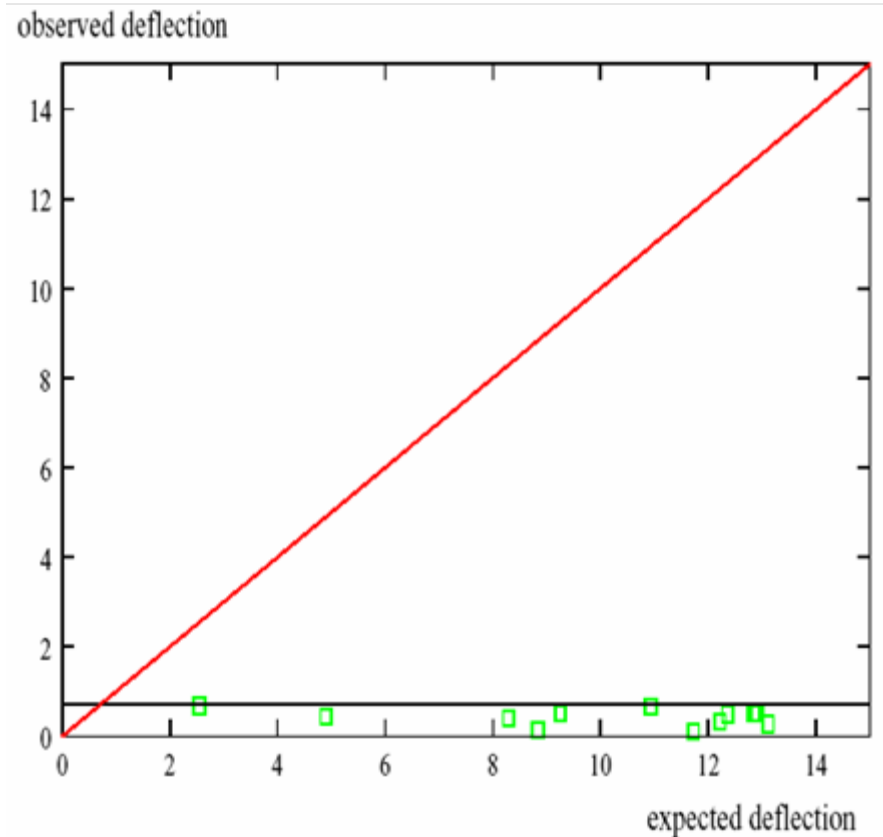## Neutral ultra-high-energy particles from BL Lacs

- *correlations with HiRes stereo events at the angular scale <1 degree*
- *energy >10^{18} eV*

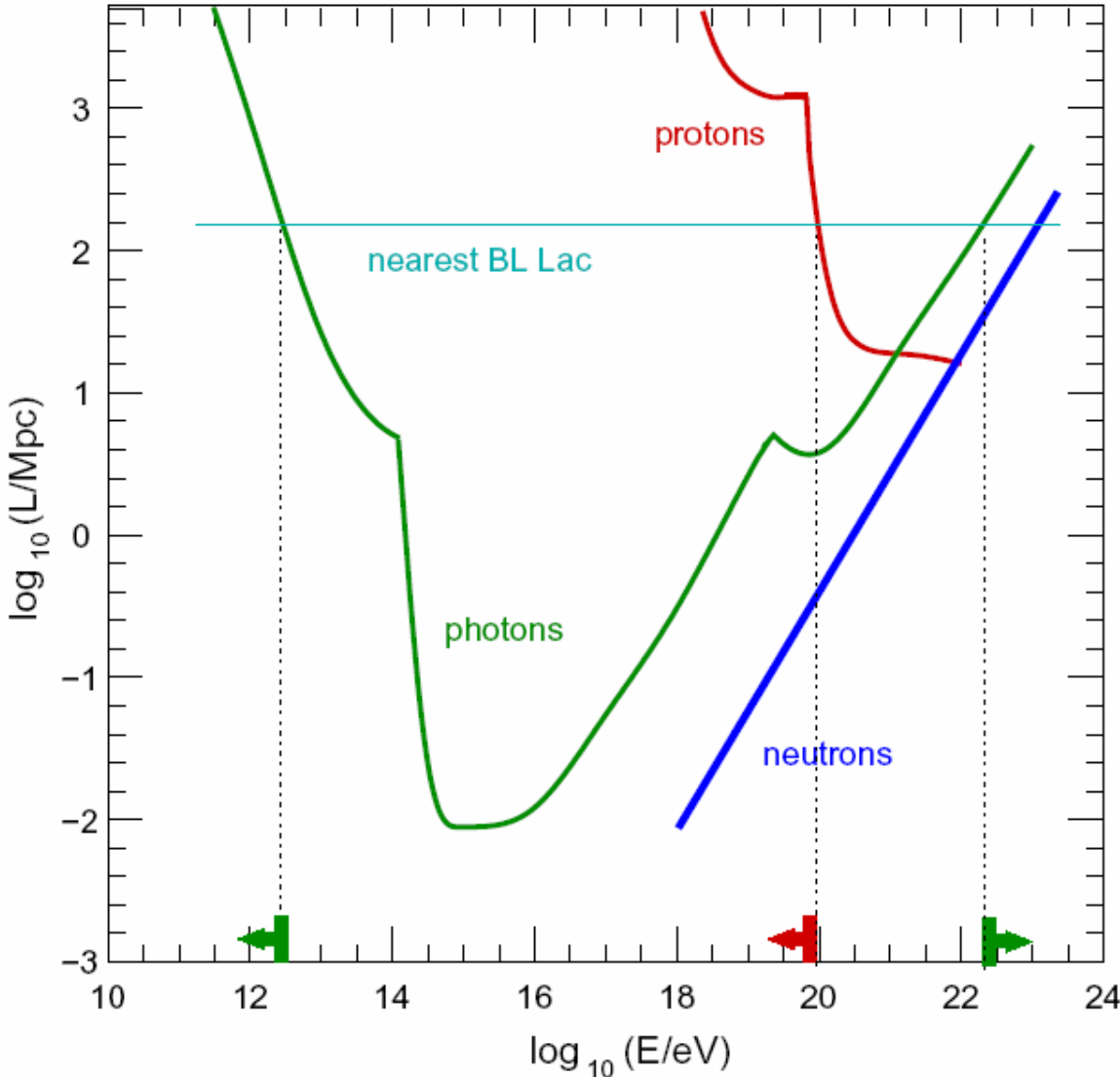*Gorbunov, Tinyakov, Tkachev, ST 2004*

HiRes collaboration 2005

…not deflected by the Galactic magnetic field
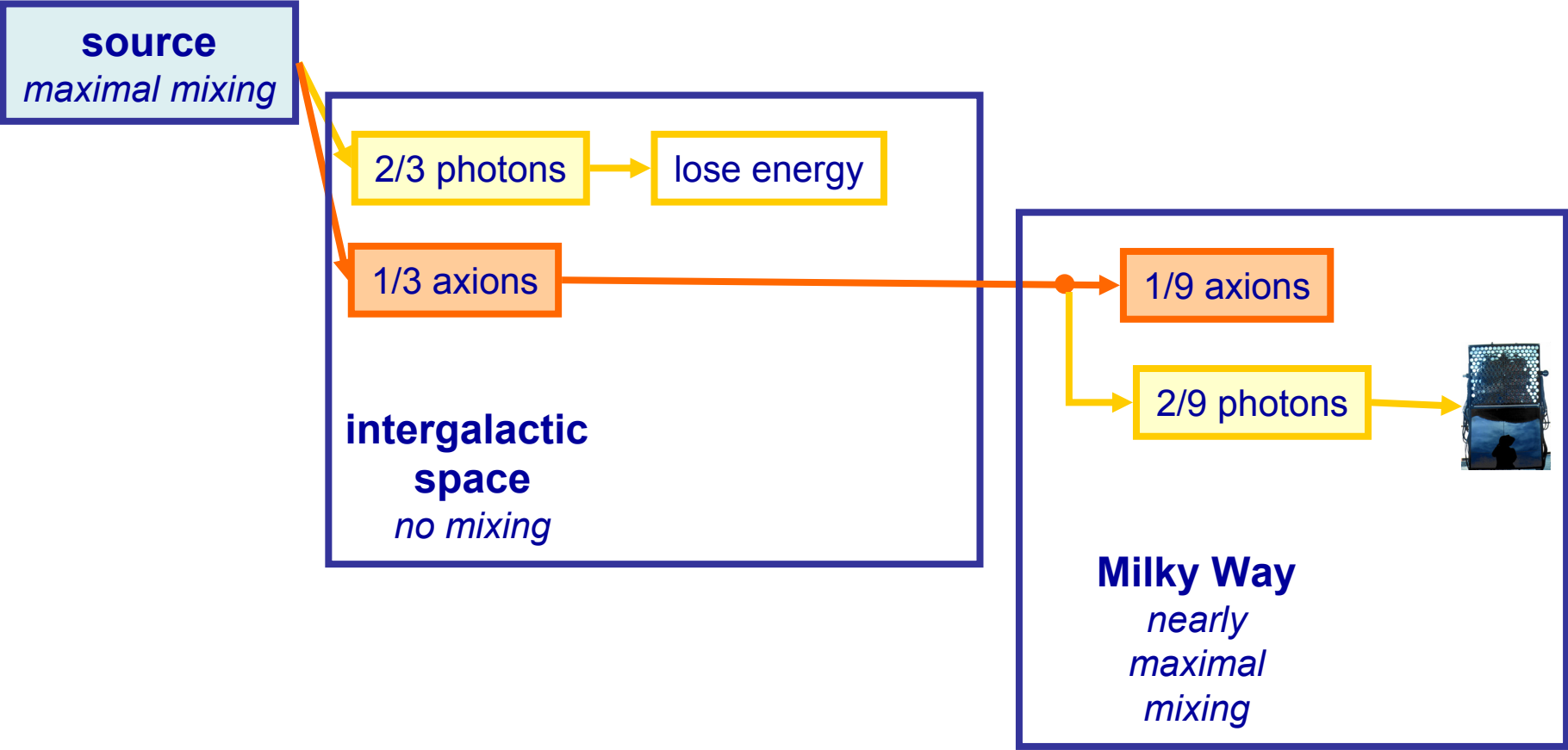
⇓

NEUTRAL !?

Neutral particles are problematic

Explanation

photon – ALP mixing! ☺

source
maximal mixing

2/3 photons → lose energy

1/3 axions → 1/9 axions

2/9 photons

intergalactic space
no mixing

Milky Way
nearly maximal mixing

ALP – photon mixing

maximal mixing conditions:

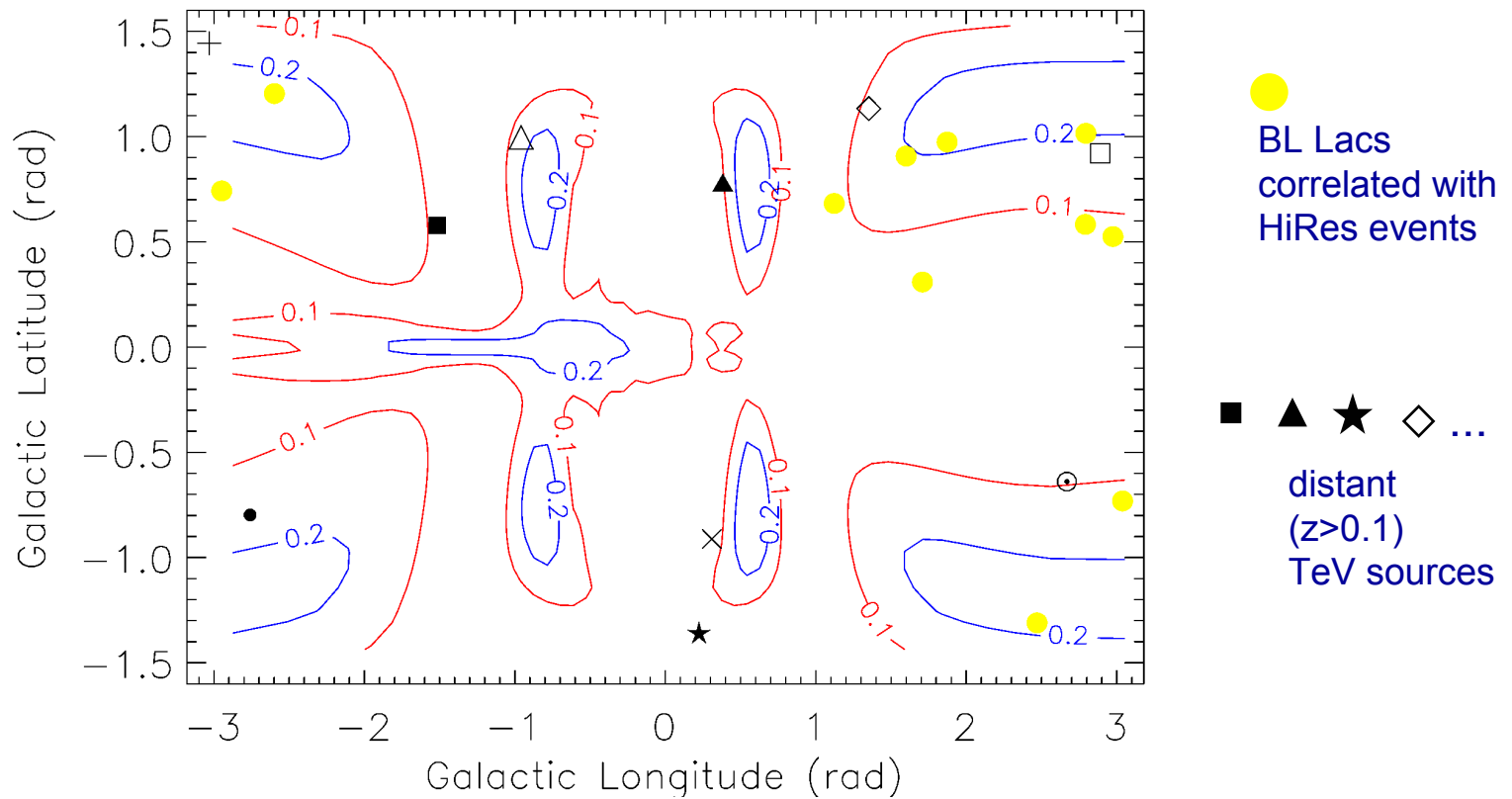$$\Delta_m \ll 2\Delta_M \qquad \Delta_p \ll 2\Delta_M \qquad L \gtrsim \frac{\pi}{\Delta_{\mathrm{OSC}}}$$

ALP – photon mixing: consequences

conversion in the Milky Way depends on direction!

BL Lacs correlated with HiRes events
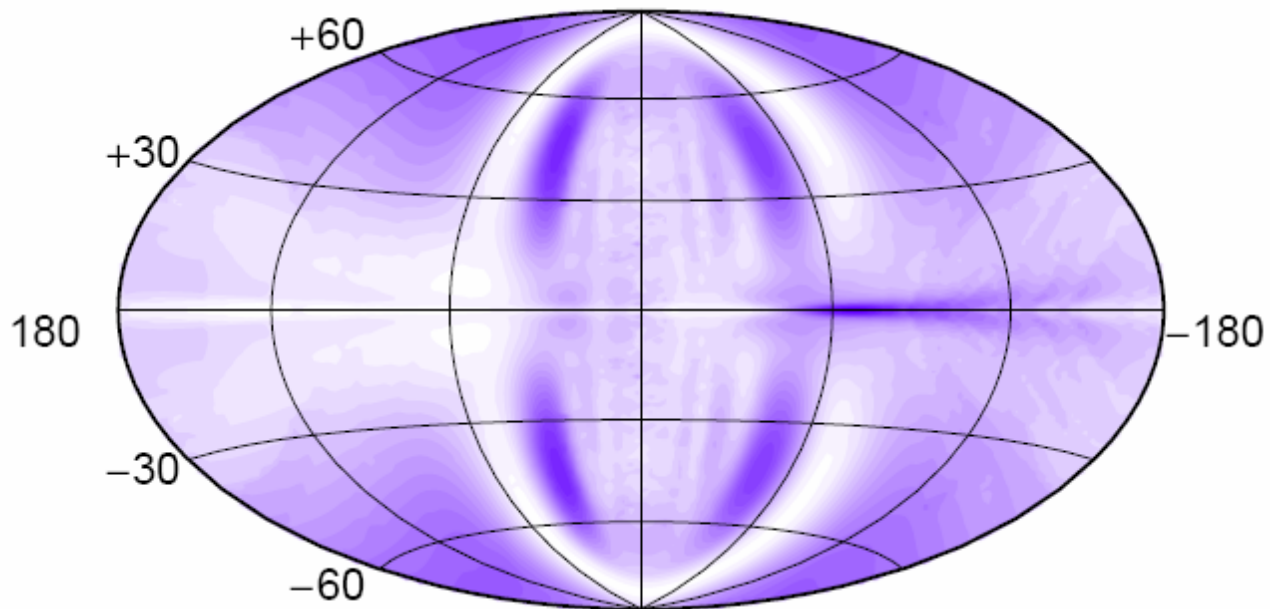
distant (z>0.1) TeV sources

contours – conversion probability

contours and TeV sources – Simet, Hooper, Serpico 2007

ALP – photon mixing: consequences

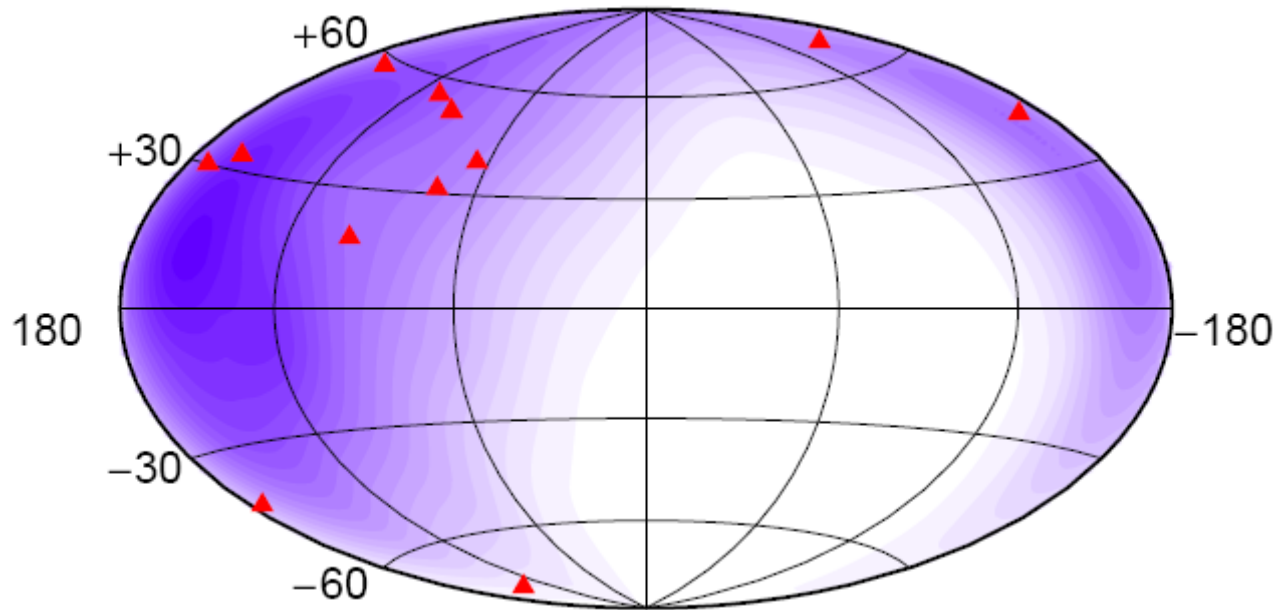## conversion in the Milky Way depends on direction!

conversion probability, M=7.5×10^{10} GeV, m=10^{-8} eV
galactic coordinates

Fairbairn, Rashba, ST 2009

ALP – photon mixing: consequences
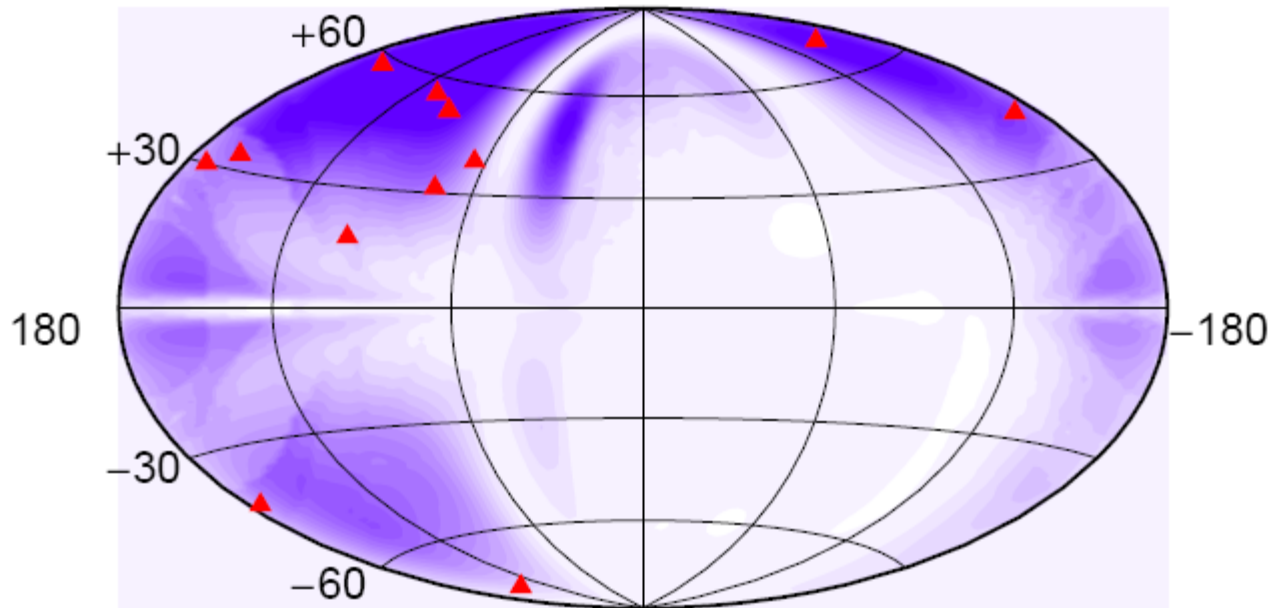
HiRes stereo exposure + correlated events

inconsistent (Kolmogorov-Smirnov P=0.02)

stereo exposure E>10^{19} eV
correlated events from Gorbunov et al. 2004
galactic coordinates

Fairbairn, Rashba, ST 2009

ALP – photon mixing: consequences

HiRes stereo exposure times conversion probability
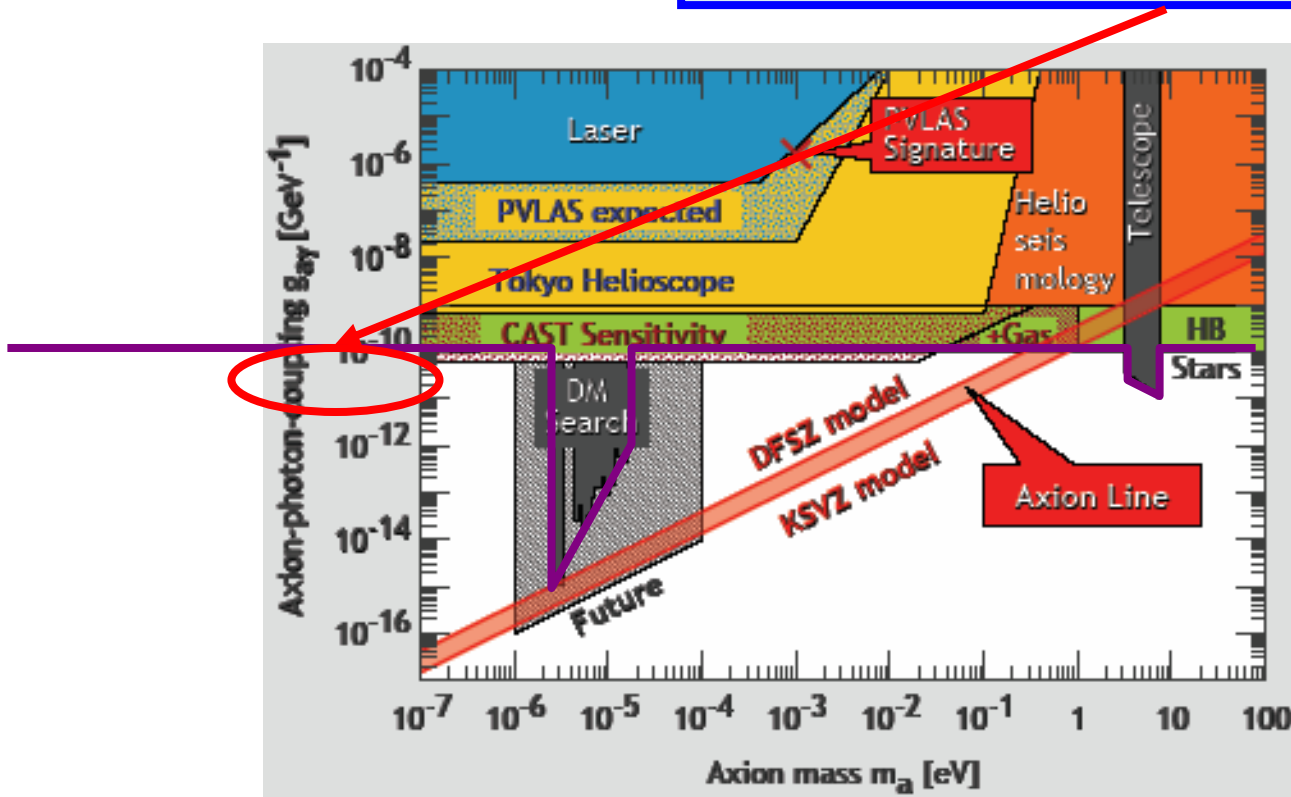

consistent (Kolmogorov-Smirnov P=0.17)

conversion probability, $M=7.5 \times 10^{10}$ GeV, $m=10^{-8}$ eV
stereo exposure $E > 10^{19}$ eV
correlated events from Gorbunov et al. 2004
galactic coordinates

Fairbairn, Rashba, ST 2009

Parameters of ALP required

- for the IR-TeV problem
  AND
- for the UHE-BLL problem

$M \sim (10^{10} \ldots 10^{11})$ GeV, $m \sim (10^{-9} \ldots 10^{-7})$ eV

plot – Raffelt 2008

ALP motivations

➡ *qualitative:*

- **White-dwarf luminosity function**
- **Correlations in quasar polarization**
- **Gamma rays through the Sun**

ALP motivations

- **White-dwarf luminosity function**

  favours an axion coupled to electrons

$$M = (C_e/C_\gamma) \times 3 \times 10^{12} \text{ GeV}$$

Isern et al 2008

ALP motivations

⇨ *qualitative:*

- **Correlations in quasar polarization**

    - polarization vectors correlated at Gpc scales
    - probably local origin
    - again ALP effects in the Milky Way??

Payez, Cudell, Hutsemekers 2008

ALP motivations

- **Gamma rays through the Sun**

    - bright GeV quasar eclipsed by the Sun
    - zero GeV flux from the Sun
    - non-zero EGRET flux during the eclipse?
    - mixing with inert particle (weird ALP parameters)

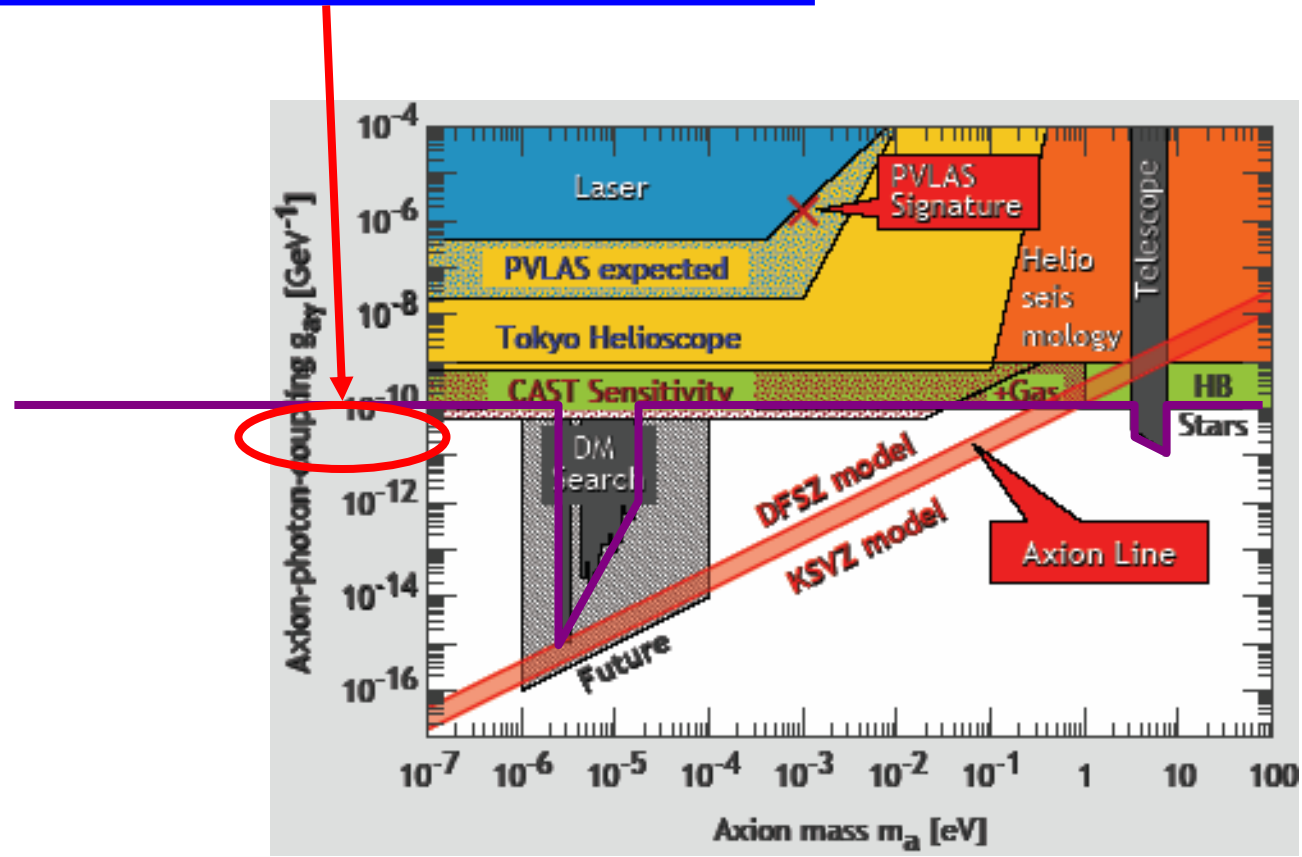*Fairbairn, Rashba, ST 2007*

Conclusion:

ALP motivated

quantitatively and qualitatively

from astrophysical observations

Conclusion:

keep looking!
(not only here)

$M \sim (10^{10} \dots 10^{11})$ GeV, $m \sim (10^{-9} \dots 10^{-7})$ eV

plot – Raffelt 2008