BRIEF OVERVIEW AND FIRST TASKS

AXIONLIKE-PARTICLE AND INTERGALACTIC-MAGNETIC-FIELD SEARCHES WITH CTA

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CTA-GPROPA TASK FORCE MEETING

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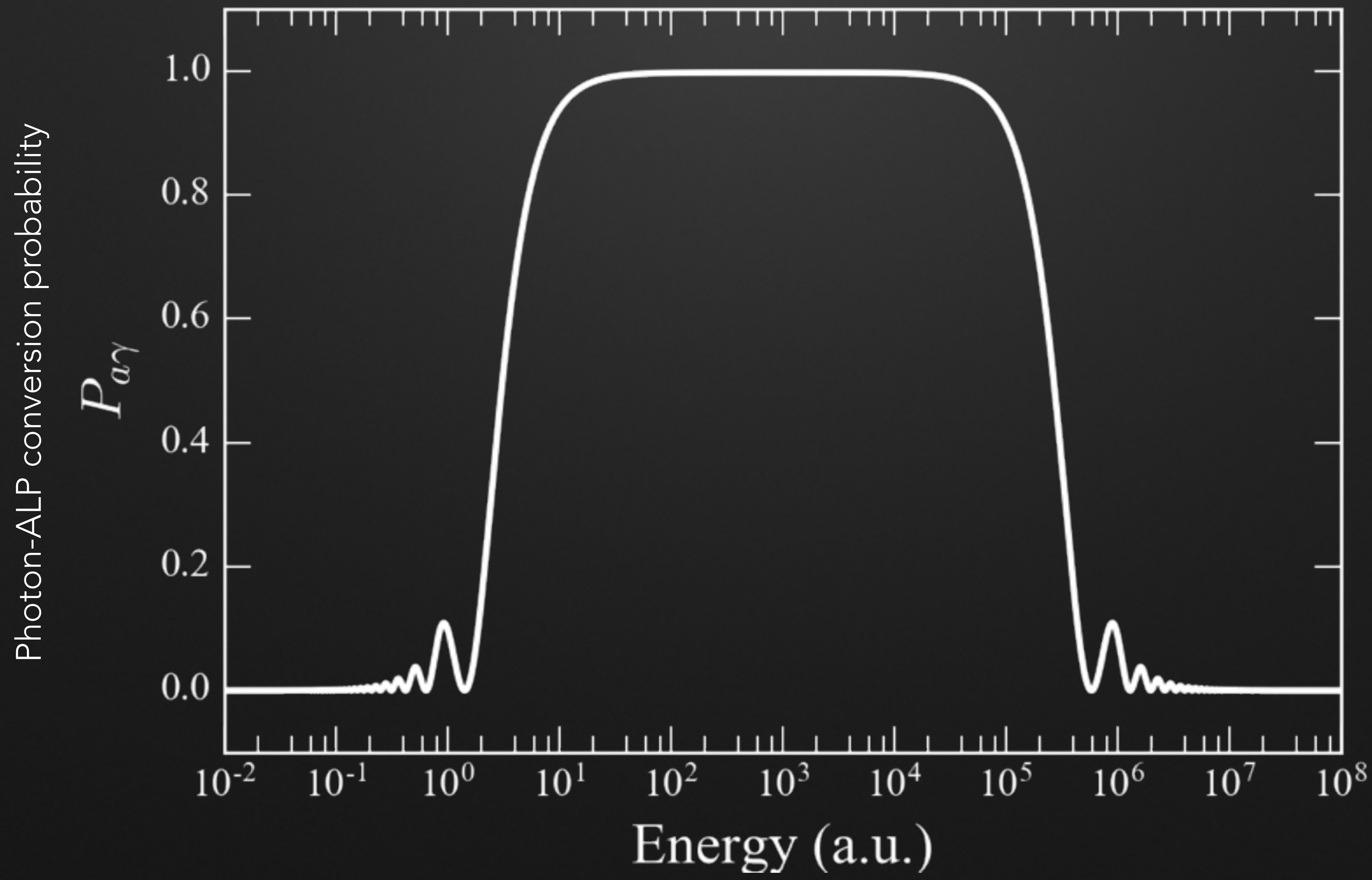
PHOTON-AXION/ALP MIXING

IN A COHERENT MAGNETIC FIELD

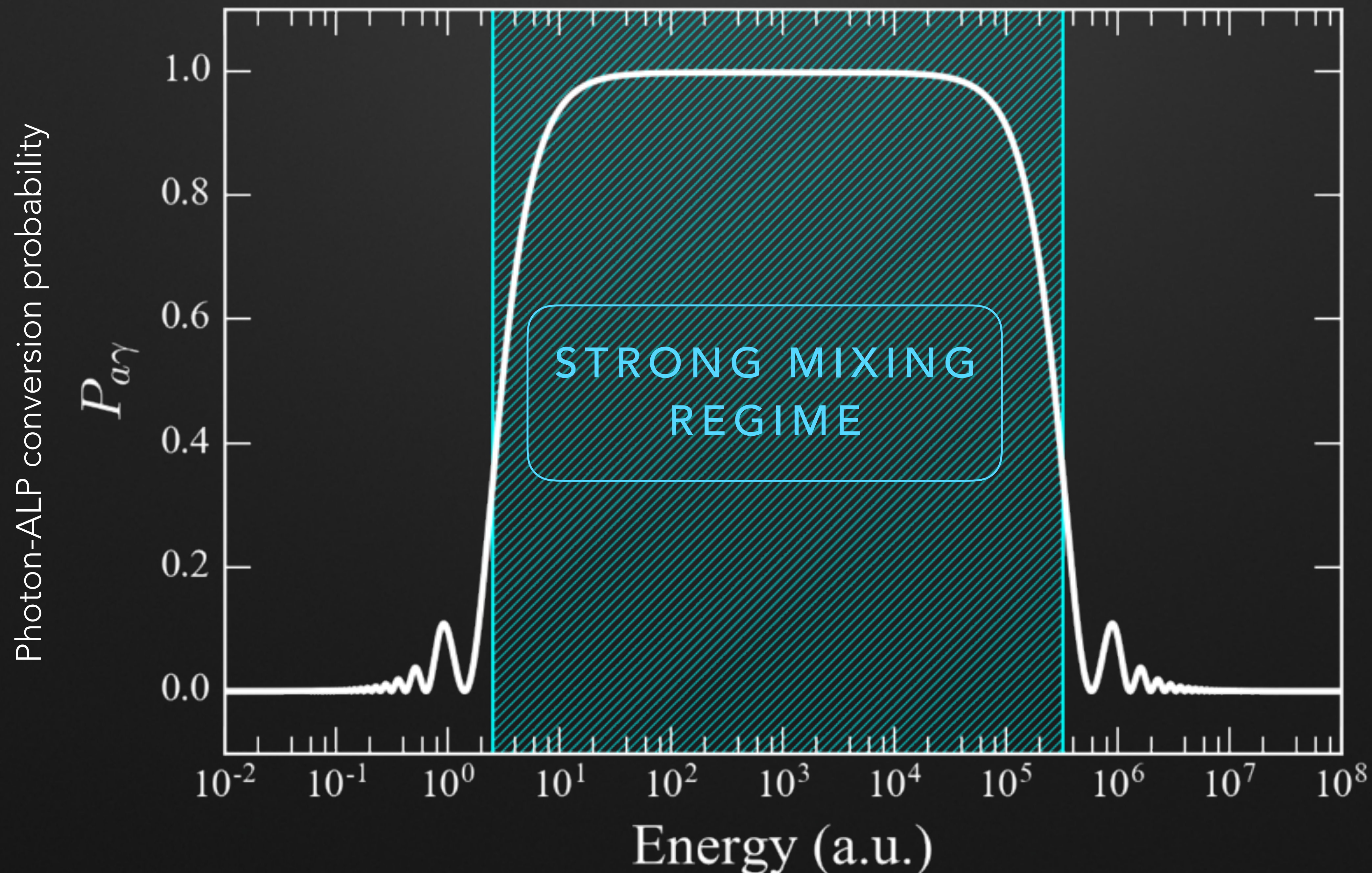
$$\mathcal{L}_{a\gamma} = -\frac{1}{4} g_{a\gamma} F_{\mu\nu} \tilde{F}^{\mu\nu} a = g_{a\gamma}\, \mathbf{E}\, \mathbf{B} a$$



[Raffelt & Stodolsky 1988]

PHOTON-AXION/ALP MIXING

IN A COHERENT MAGNETIC FIELD



[Raffelt & Stodolsky 1988]

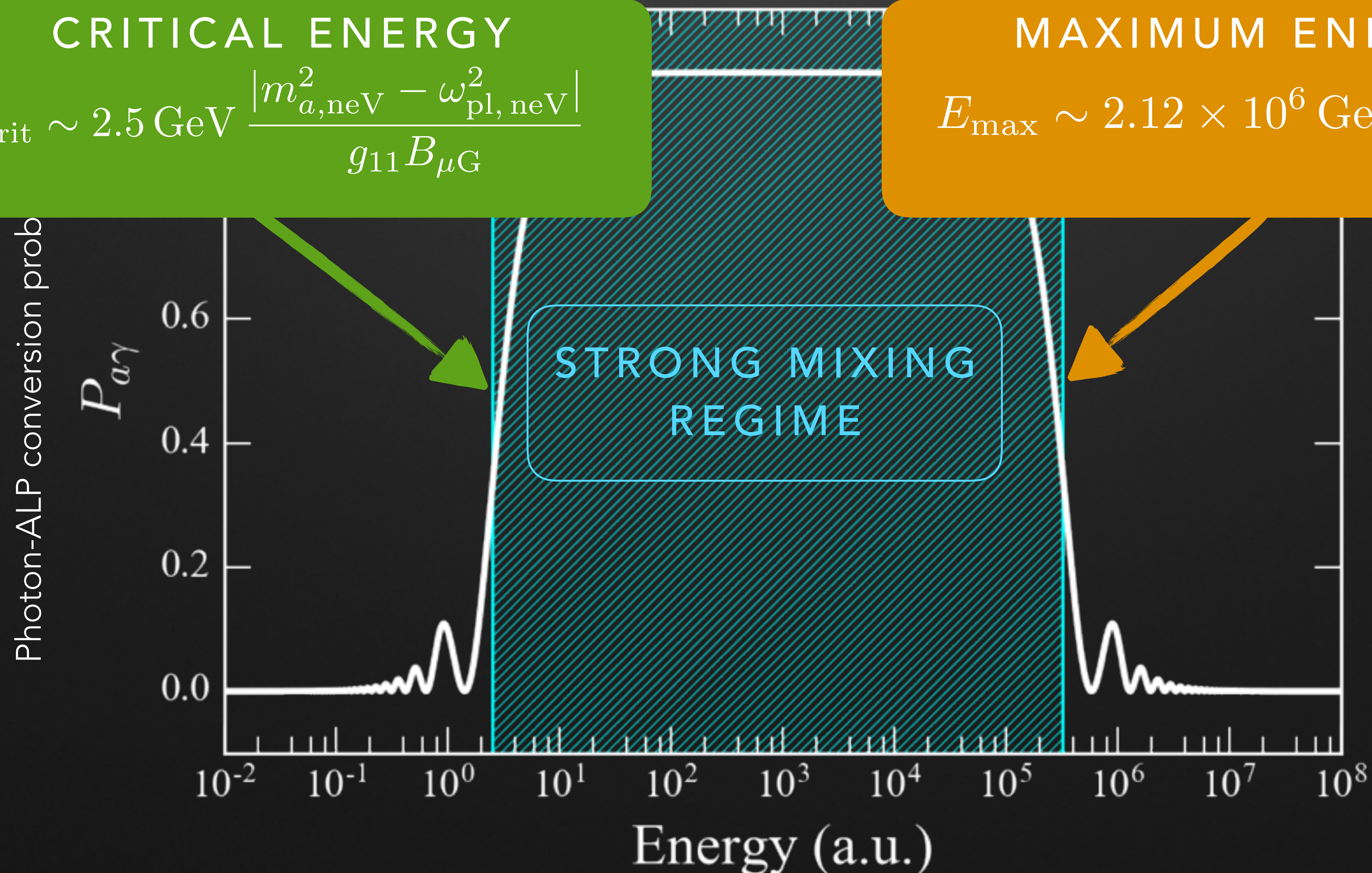
PHOTON-AXION/ALP MIXING

CRITICAL ENERGY

$$E_{\mathrm{crit}} \sim 2.5\,\mathrm{GeV}\,\frac{|m^2_{a,\mathrm{neV}} - \omega^2_{\mathrm{pl,\,neV}}|}{g_{11} B_{\mu\mathrm{G}}}$$

MAXIMUM ENERGY

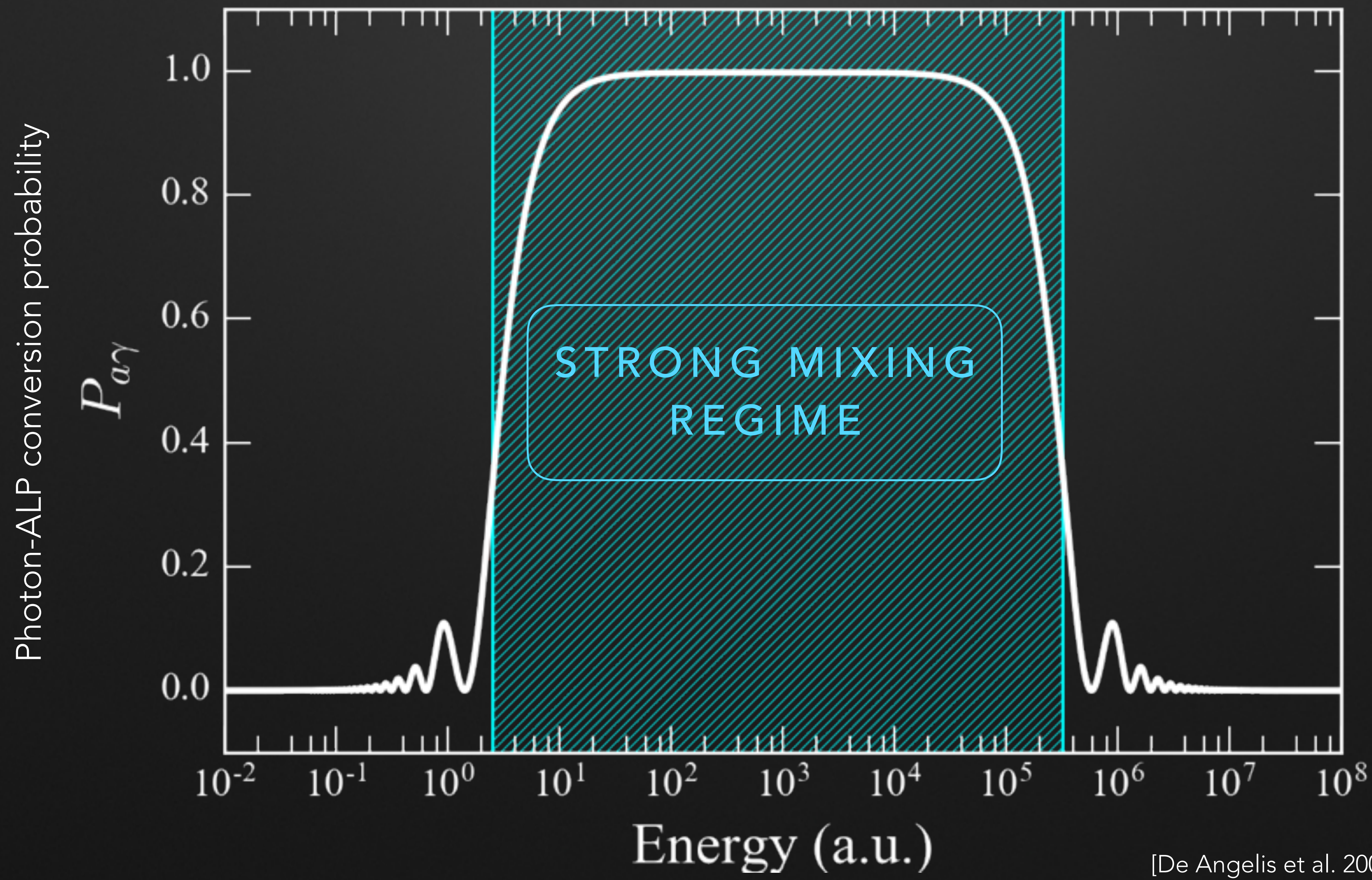
$$E_{\max} \sim 2.12 \times 10^6\,\mathrm{GeV}\,g_{11} B^{-1}_{\mu\mathrm{G}}$$



[Raffelt & Stodolsky 1988]

PHOTON-AXION/ALP MIXING

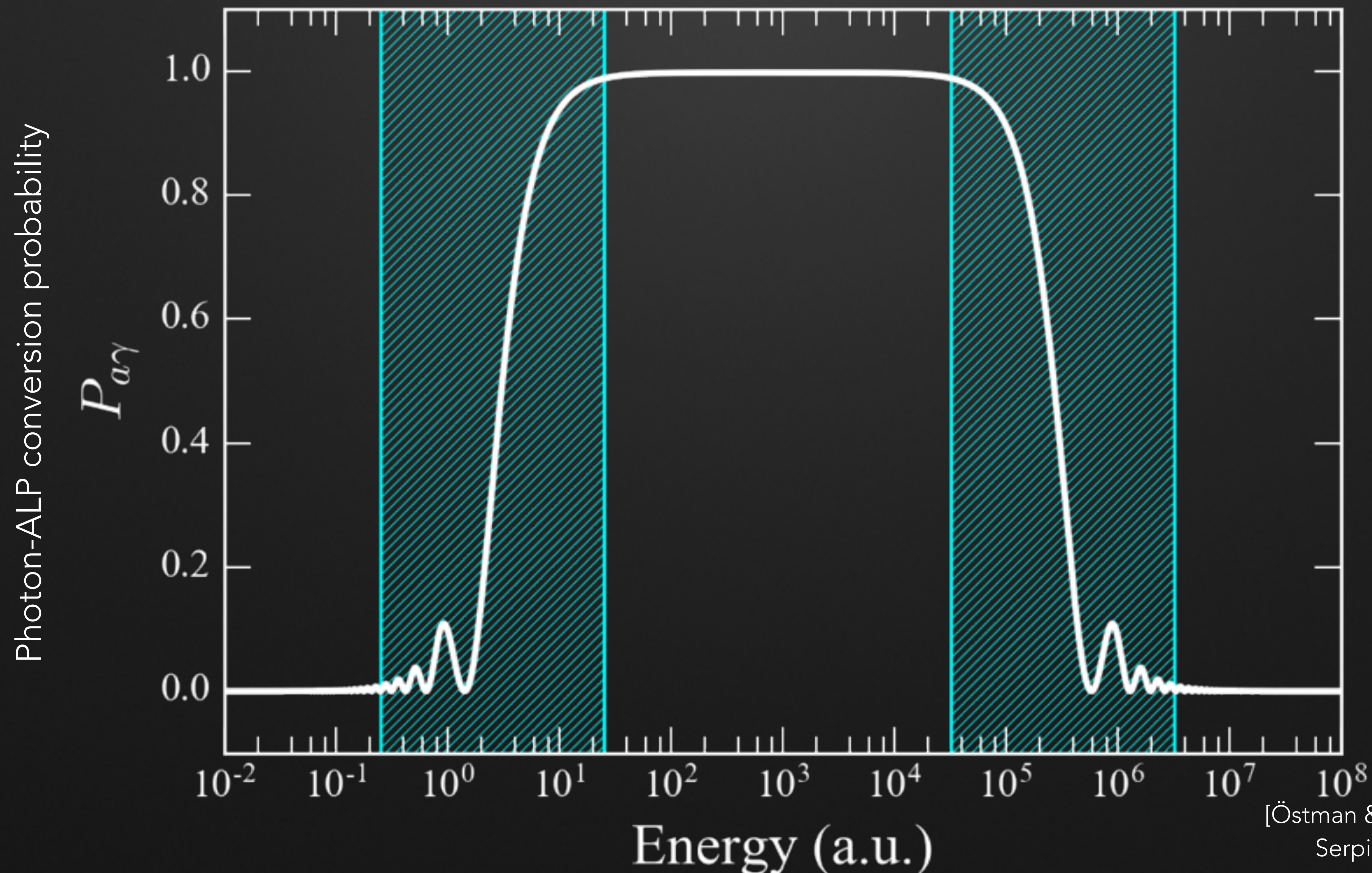
1st Observable: axions/ALPs do not get absorbed during propagation, might lead to a boost in photon flux



[De Angelis et al. 2007,2011; Simet et al. 2008; Mirizzi & Montanino 2009; Sánchez-Conde et al. 2009;Domínguez & Sánchez-Conde 2011; MM et al. 2013; MM & Conrad 2014]

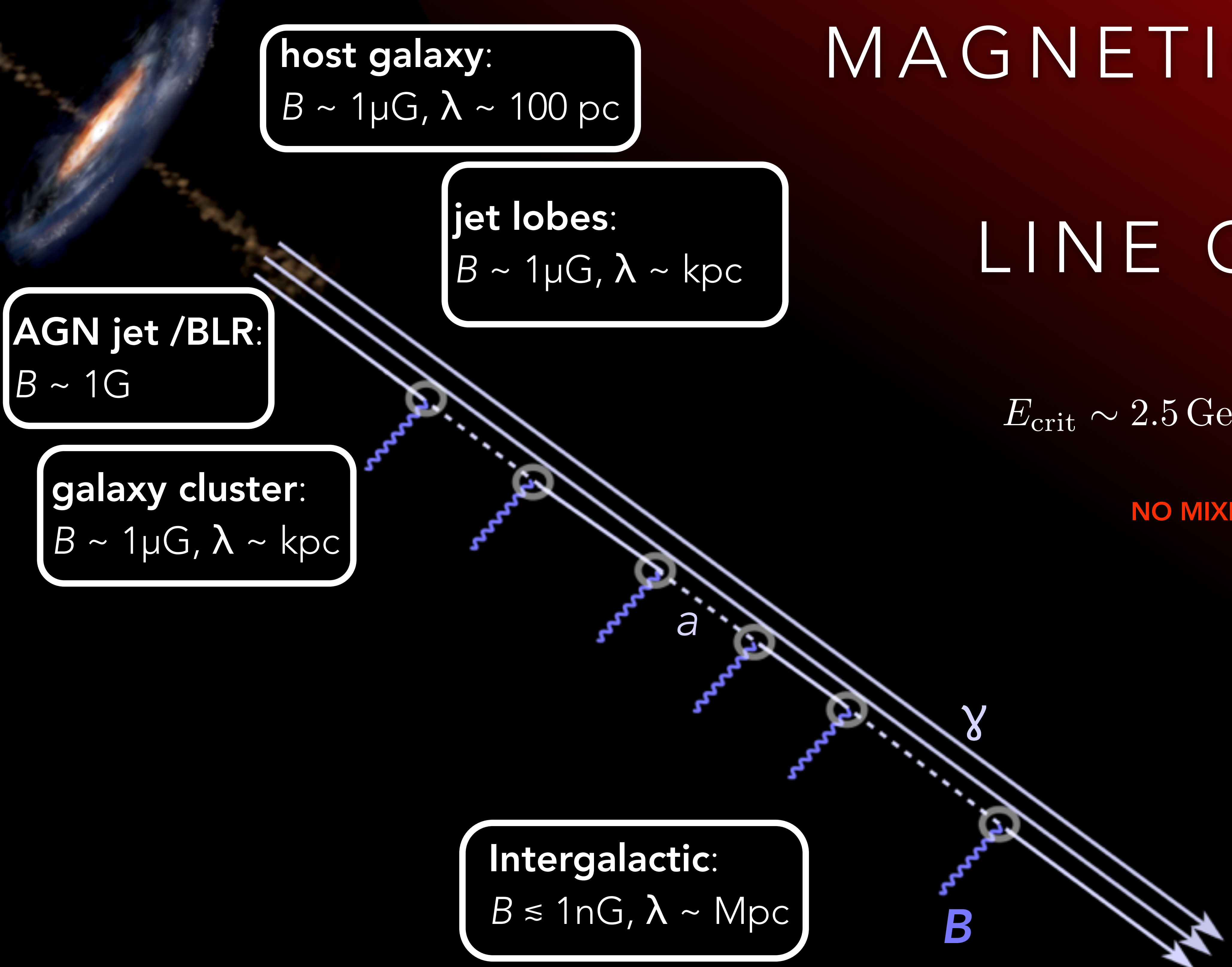
PHOTON-AXION/ALP MIXING

2nd Observable: irregularities in energy spectrum around E_{crit} and E_{max}



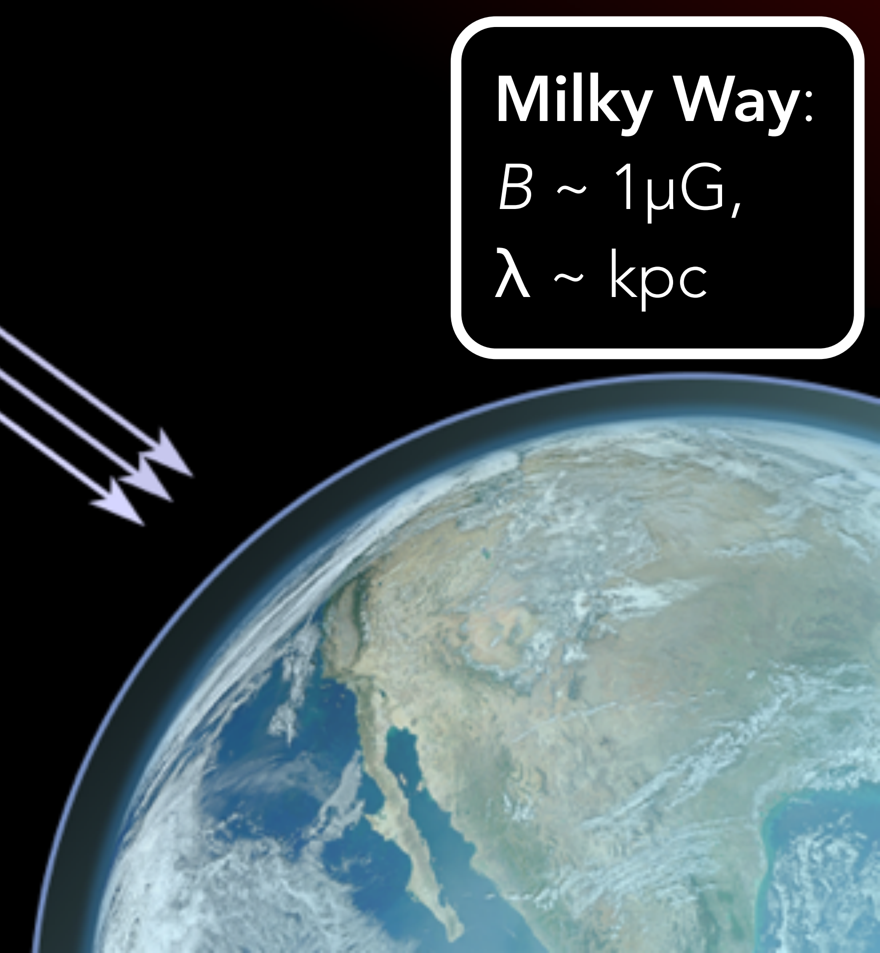
[Östman & Mörtsell 2005; Hooper & Serpico 2007; Mirizzi et al 2007; Hochmuth & Sigl 2007; De Angelis et al. 2008; Wouters & Brun 2012,2013; Abramowski et al. 2013; Ajello et al. 2016; Berg et al. 2016]

MAGNETIC FIELDS ALONG LINE OF SIGHT



$$E_{\rm crit} \sim 2.5\,{\rm GeV}\,\frac{|m^2_{a,{\rm neV}} - \omega^2_{\rm pl,\,neV}|}{g_{11} B_{\mu{\rm G}}}$$

NO MIXING WITH AXIONS, ALPs ONLY!

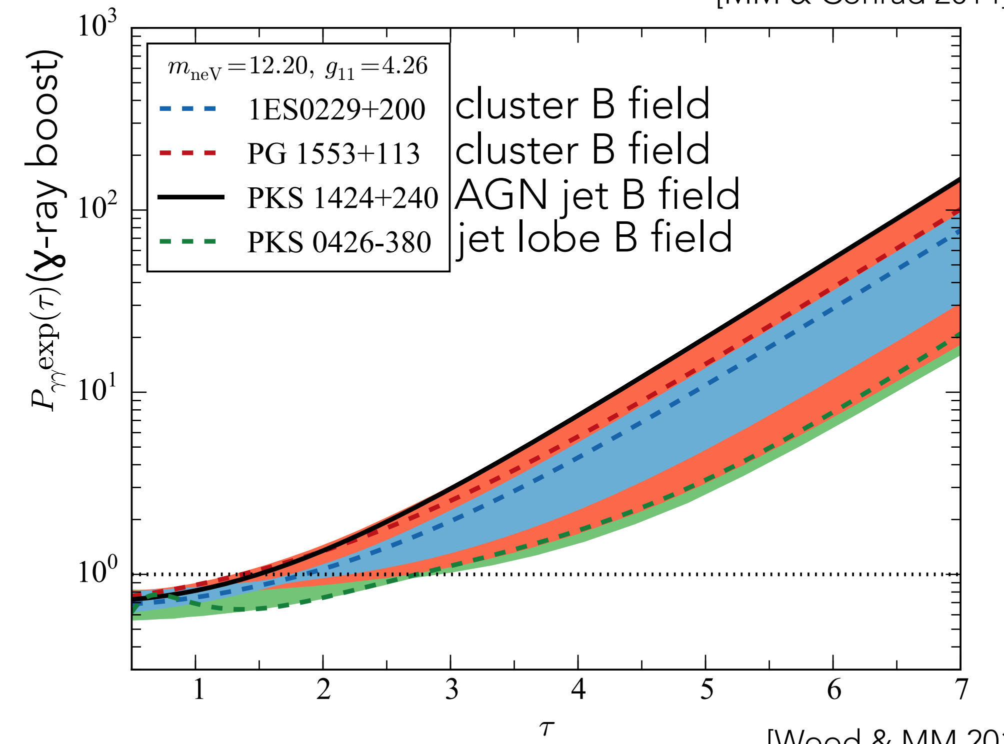


[Czaki et al. 2003, De Angelis et al., 2007, 2008, 2011; Mirizzi et al., 2007; Hochmuth & Sigl 2007; Simet et al. 2008; Mirizzi & Montatnino 2009; Sánchez-Conde et al. 2009; Fairbairn et al. 2011; Domînguez & Sánchez-Conde 2011;Horns et al. 2012; Tavechhio et al. 2012, 2015; Wouters & Brun 2012,2013; Mena & Razzaque 2013; Abramowski et al. 2013; MM et al. 2014, MM & Conrad 2014; Galanti et al. 2015]

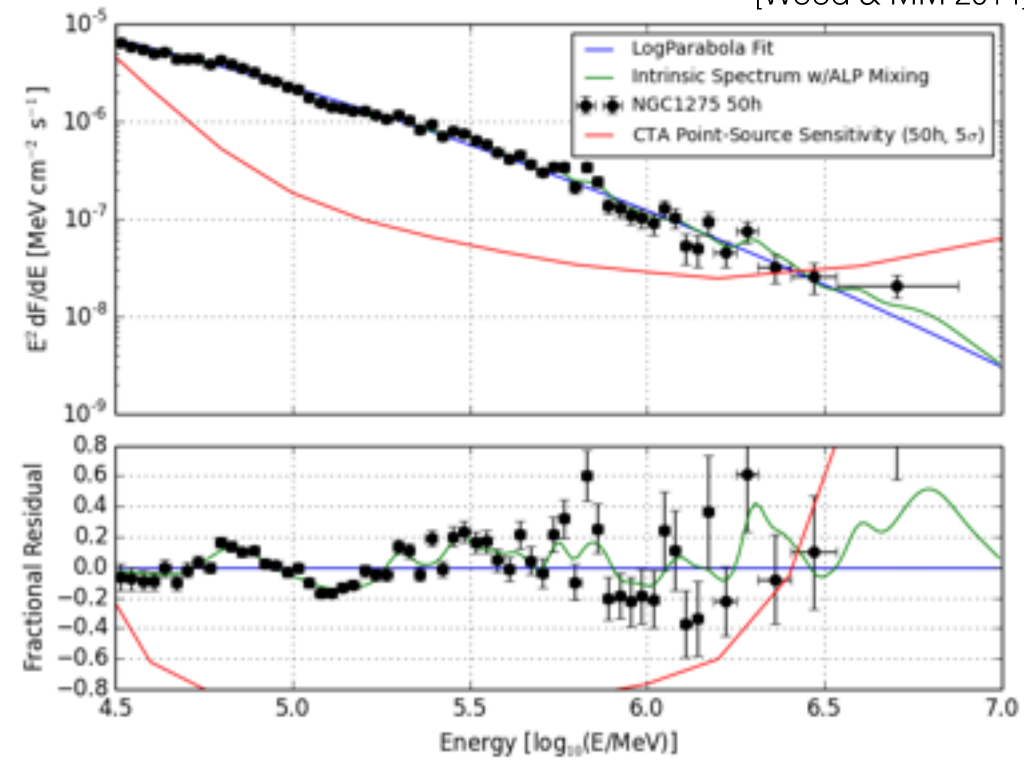
WHAT DO WE NEED FOR ALP STUDY?

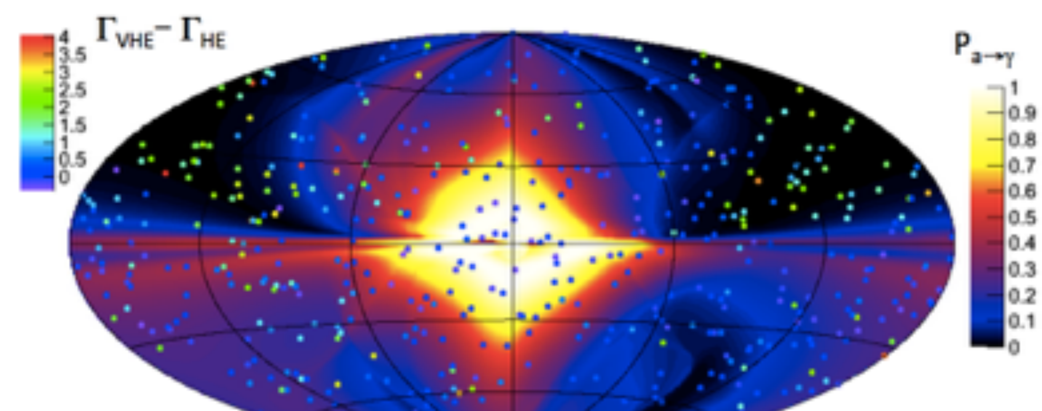
- Search for reduced opacity:
    - Bright sources for which we can measure spectrum out to large optical depths (for absorption on EBL) ⇒ **flares best suited?**
    - **“Smoking gun” to find evidence** for ALPs, but if we don’t see a boost could be due to intr. spectrum ⇒ **difficult to set constraints?**
- Search for spectral irregularities:
    - Bright sources with high signal to noise
    - Constraints & Detection possible, only probes limited range of ALP masses
    - Good knowledge about intervening B fields
    - IRFs optimized for energy dispersion
- **Search for Anisotropies of spectral hardening**
- **Knowledge about intervening magnetic fields**
  [create a data base for magnetic fields for all considered sources?]
- **Numerical code to calculate photon-ALP conversion**
  e.g. https://github.com/me-manu/PhotALPsConv

[MM & Conrad 2014]



[Wood & MM 2014]



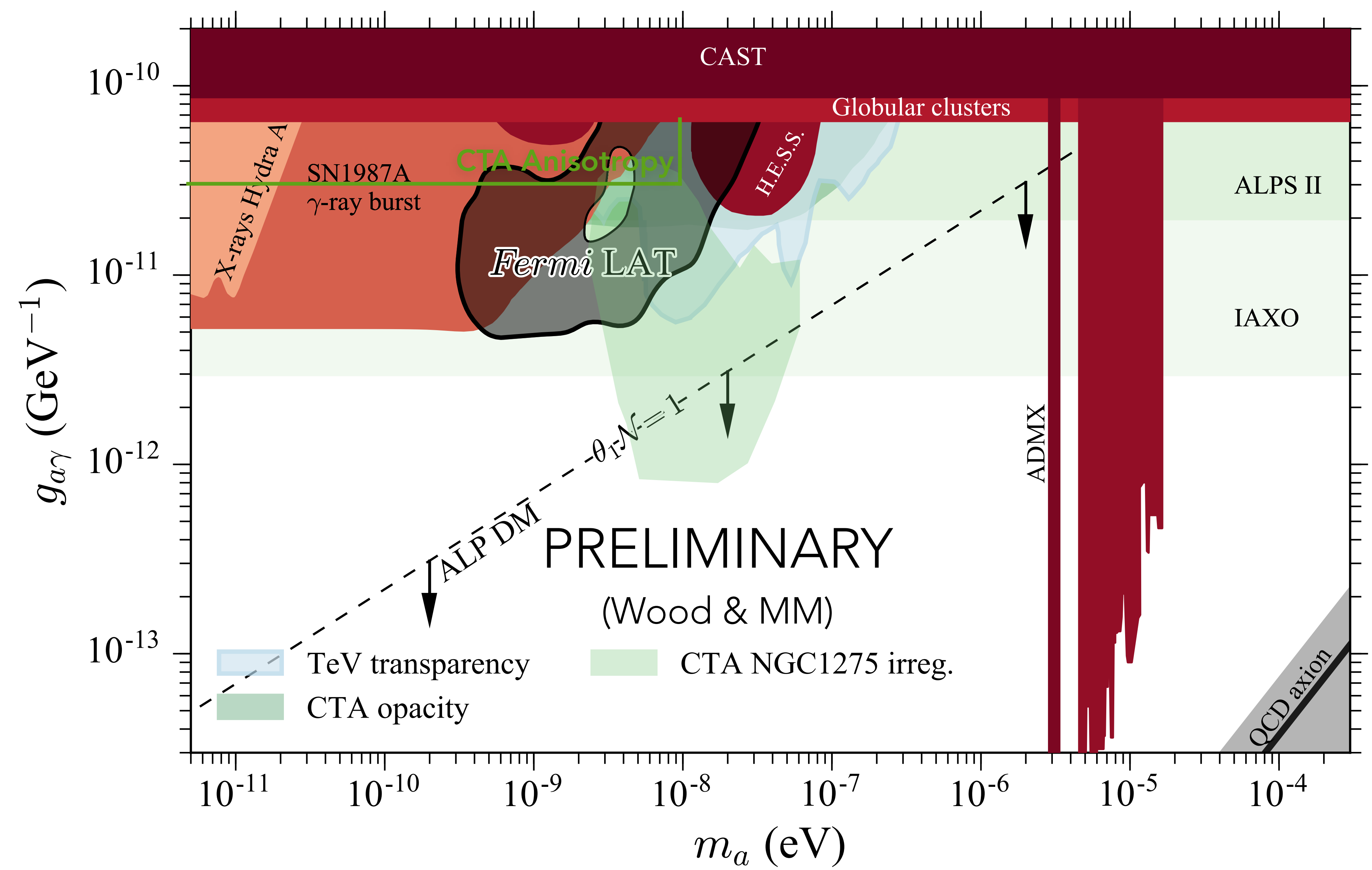


[Wouters & Brun 2014]

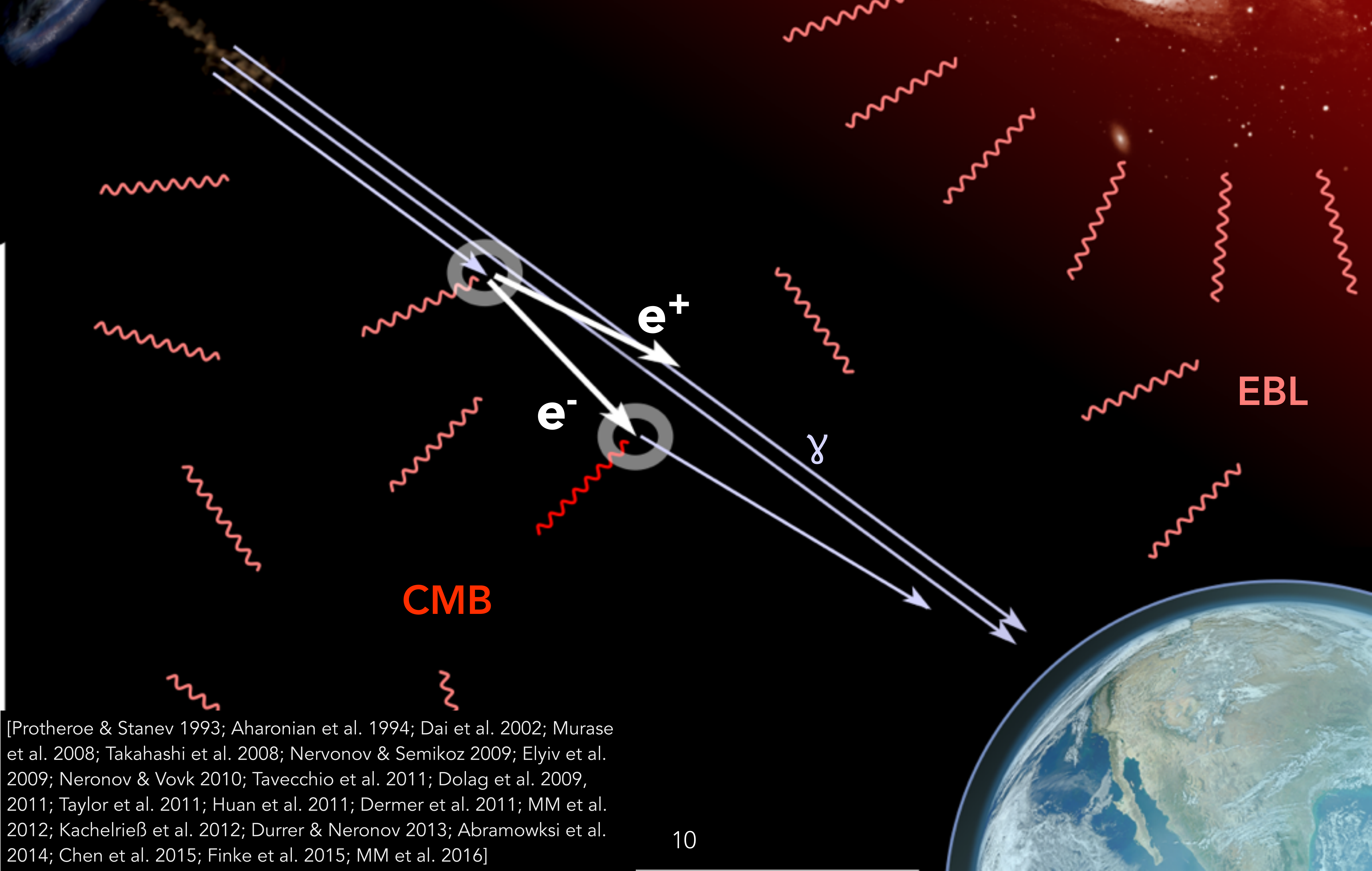
CONSTRAINTS & SENSITIVITIES

LIMITS

SENSITIVITIES

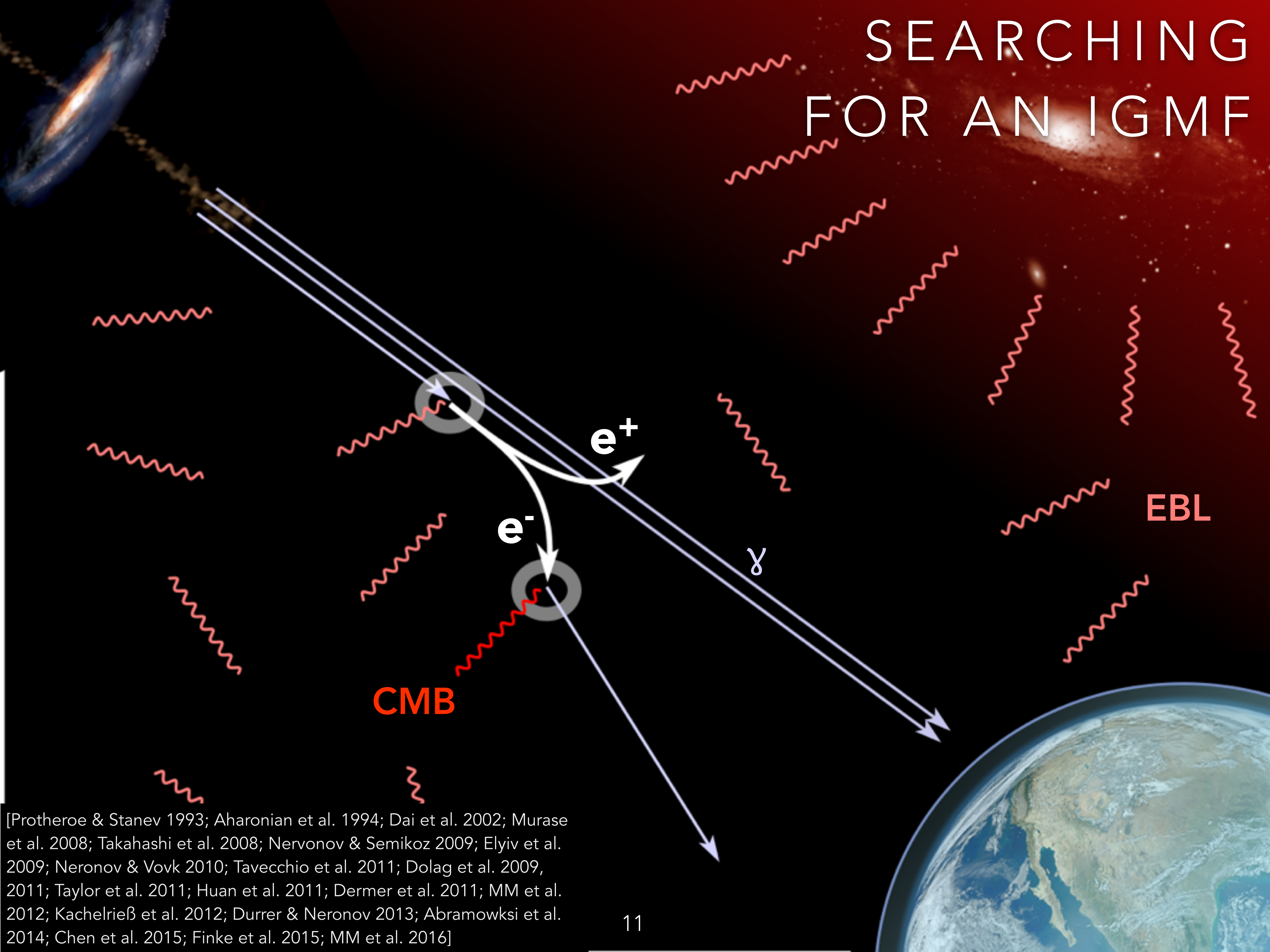


SEARCHING FOR AN IGMF



[Protheroe & Stanev 1993; Aharonian et al. 1994; Dai et al. 2002; Murase et al. 2008; Takahashi et al. 2008; Nervonov & Semikoz 2009; Elyiv et al. 2009; Neronov & Vovk 2010; Tavecchio et al. 2011; Dolag et al. 2009, 2011; Taylor et al. 2011; Huan et al. 2011; Dermer et al. 2011; MM et al. 2012; Kachelrieß et al. 2012; Durrer & Neronov 2013; Abramowksi et al. 2014; Chen et al. 2015; Finke et al. 2015; MM et al. 2016]

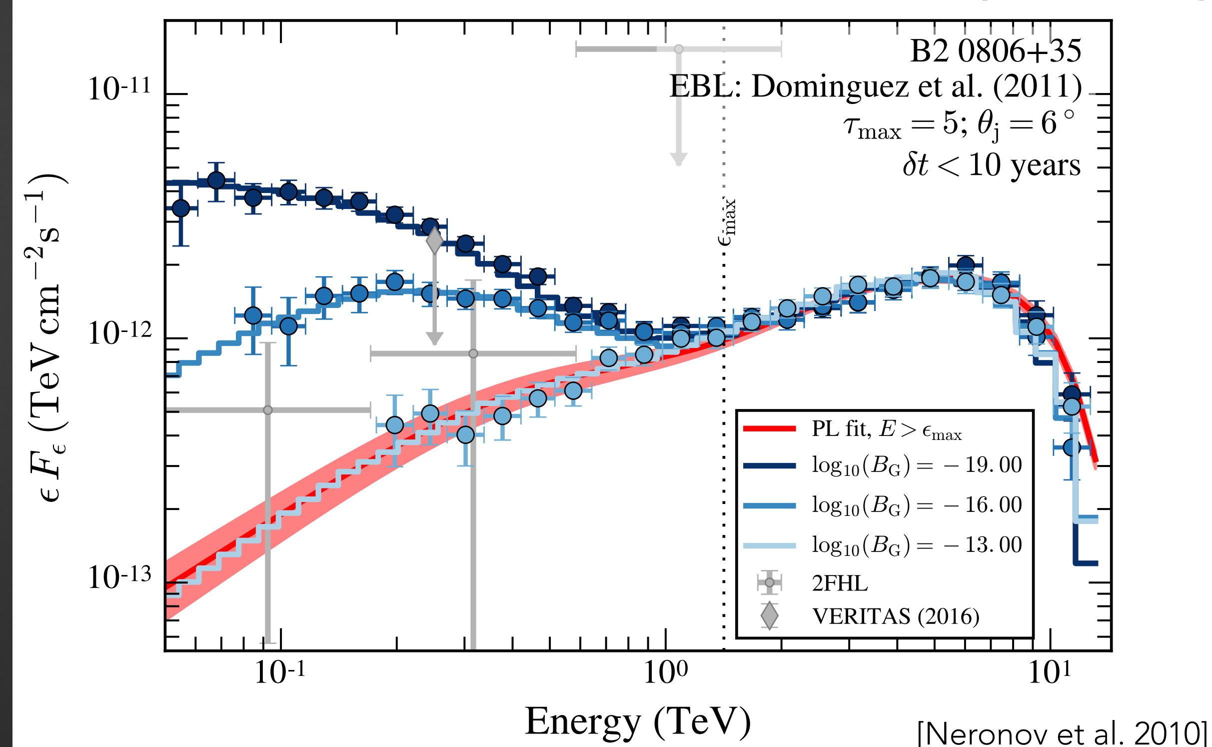
SEARCHING FOR AN IGMF

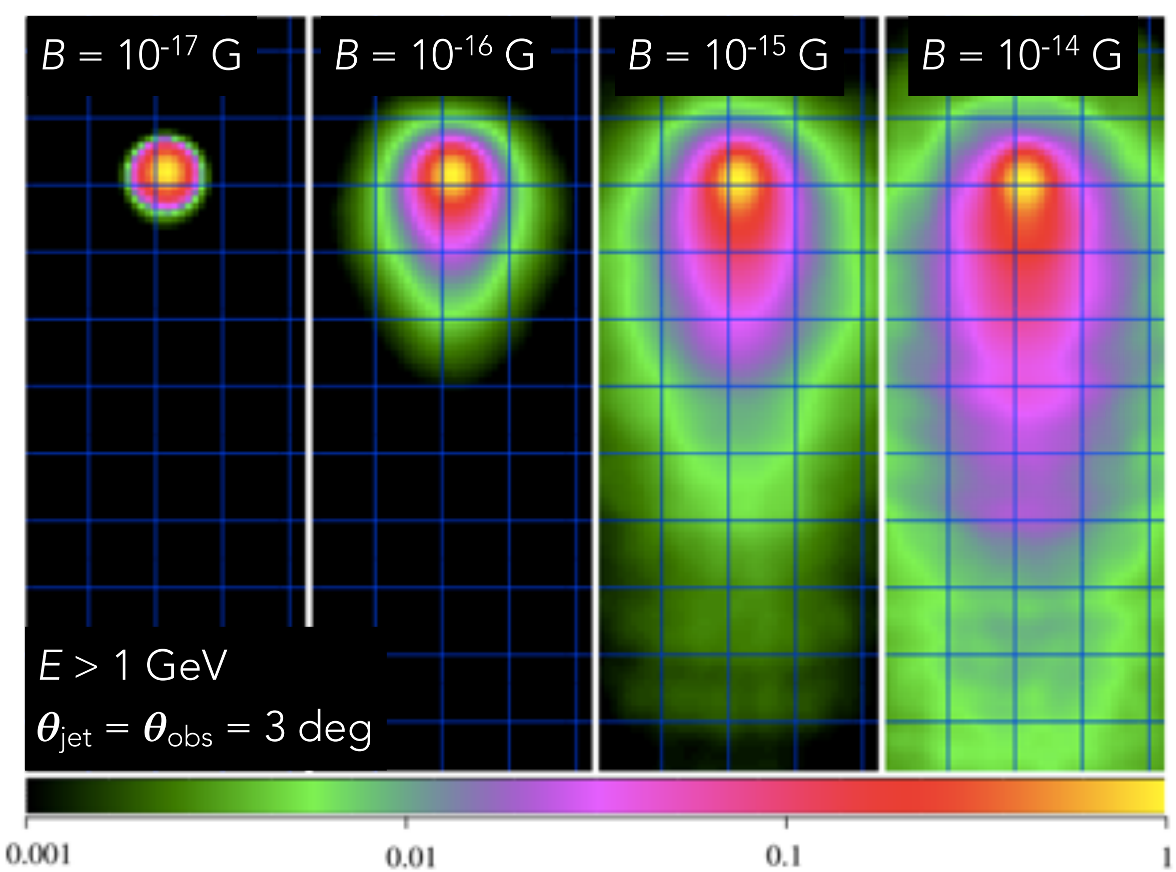


[Protheroe & Stanev 1993; Aharonian et al. 1994; Dai et al. 2002; Murase et al. 2008; Takahashi et al. 2008; Nervonov & Semikoz 2009; Elyiv et al. 2009; Neronov & Vovk 2010; Tavecchio et al. 2011; Dolag et al. 2009, 2011; Taylor et al. 2011; Huan et al. 2011; Dermer et al. 2011; MM et al. 2012; Kachelrieß et al. 2012; Durrer & Neronov 2013; Abramowksi et al. 2014; Chen et al. 2015; Finke et al. 2015; MM et al. 2016]

OBSERVABLES

- **Cascade spectral component**
- Extended ɣ-ray emission (**Pair Halos**)
- Time delayed ɣ-ray emission (**Pair Echos**)
- **Depends on**: IGMF, EBL, intrinsic spectrum, maximum ɣ-ray energy, redshift, viewing angle, jet opening angle, bulk Lorentz factor, …



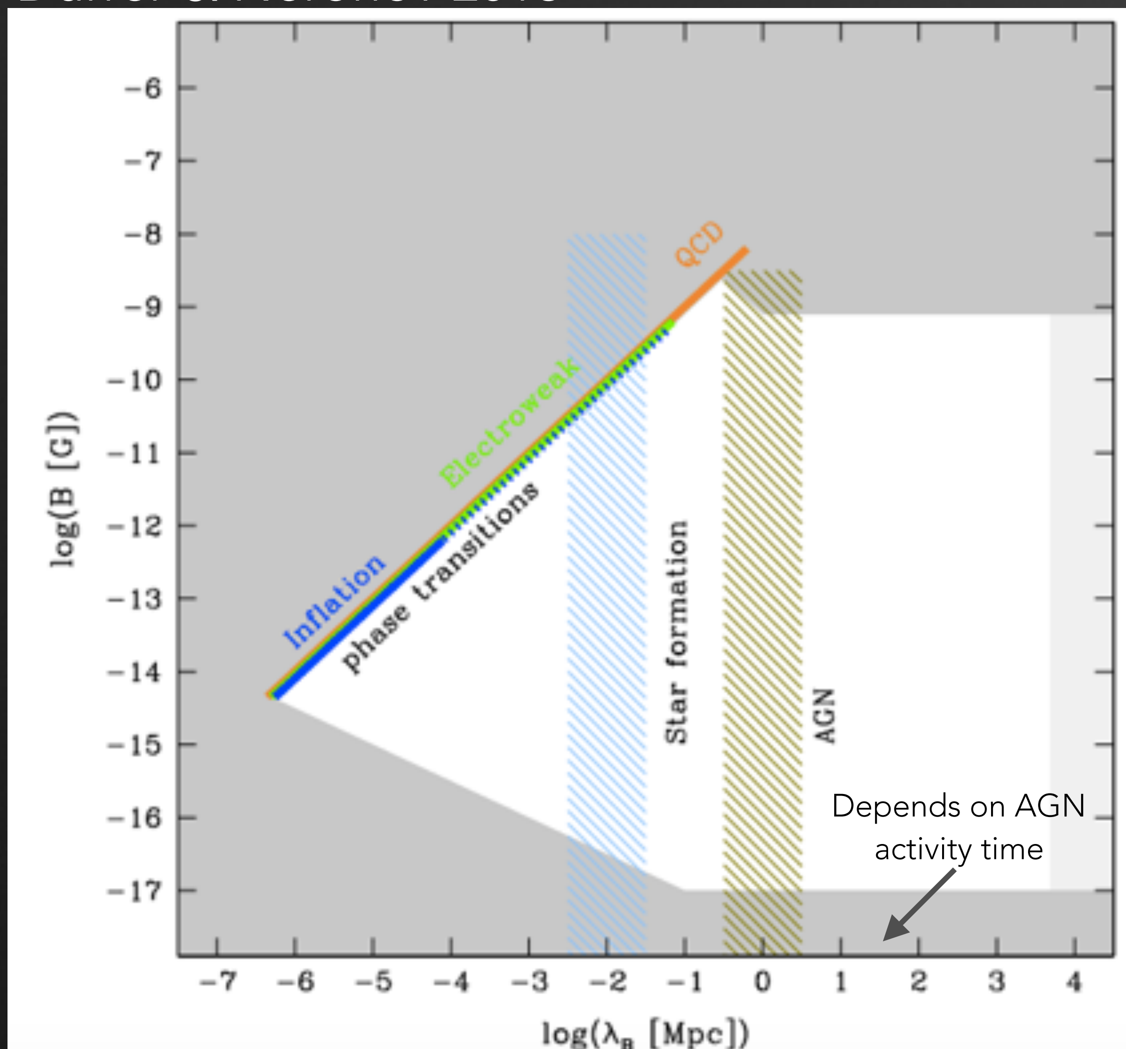


WHAT DO WE NEED FOR IGMF STUDY?

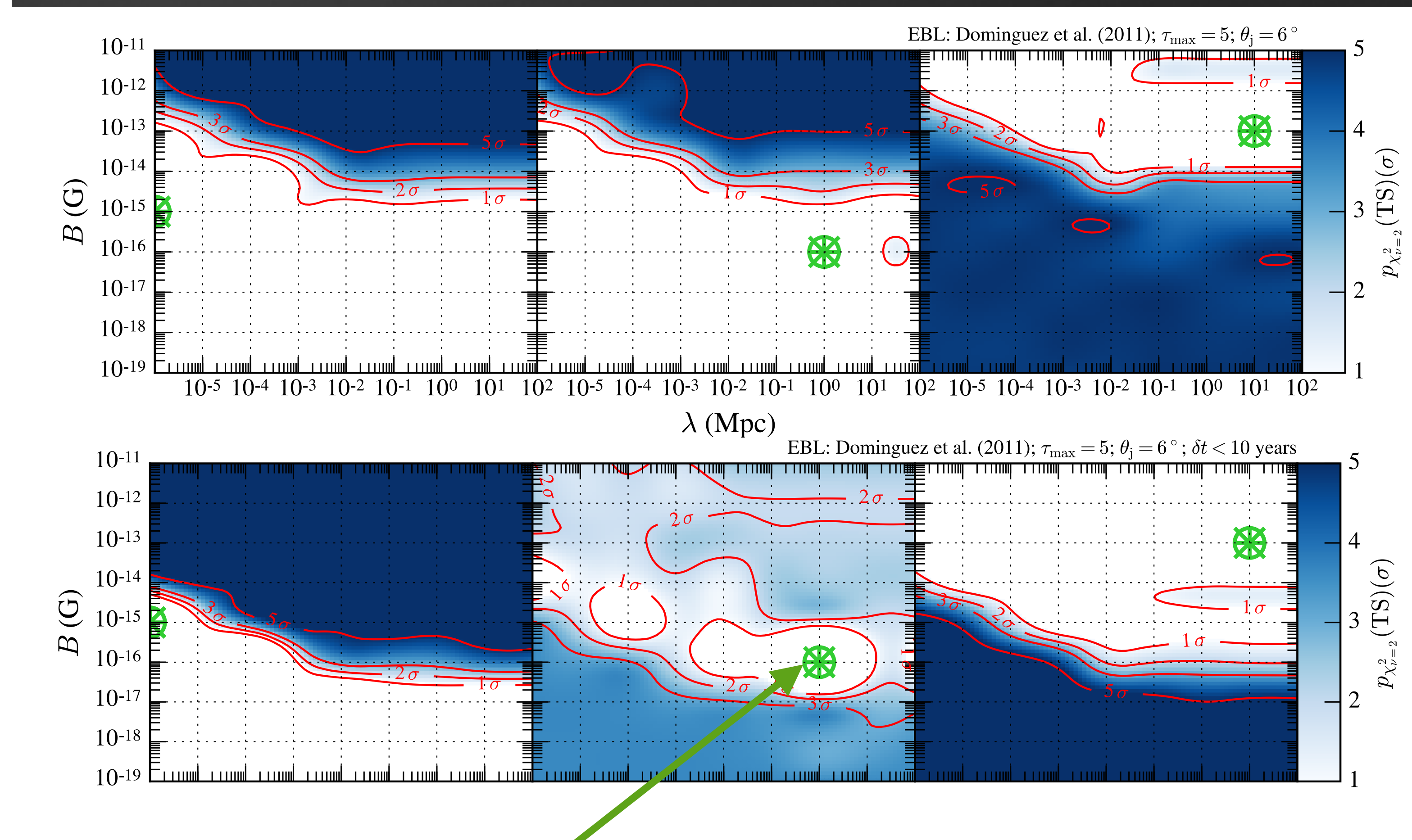
- **Cascade spectral component, pair halos:** Sources with hard intrinsic spectra that extend to high values of the optical depth (EHBLs)
- **Pair echoes:** Flaring sources, GRBs, full sky survey for ghost halos
- **Scope discussion**: do we want to fully model the pair halos?
- **Code to model the cascade:** semi-analytical models (e.g. Dermer et al. 2011), 1D Monte Carlo (e.g. ELMAG), 3D Monte Carlo (not publicly available? → soon in 2-3 months, see Alves Batista et al. 2016, arxiv:1607.00320)

CURRENT CONSTRAINTS & SENSITIVITY

Durrer & Neronov 2013



MM et al. 2016



Assumed true value of B field

- **Possible Improvements**:
  - Including full updated IRFs
  - Considering pair halo and cascade simultaneously in the likelihood
  - Including more sources, ghost halos, …