



Stanford  
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SLAC

FUTURE DARK MATTER SEARCHES WITH

MEGO

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY

<https://asd.gsfc.nasa.gov/amego/>

MANUEL MEYER,  
REGINA CAPUTO, MIGUEL SANCHEZ-CONDÉ,  
ON BEHALF OF THE AMEGO TEAM

AUGUST 11, 2017

TEVPA 2017

COLUMBUS, OH, USA

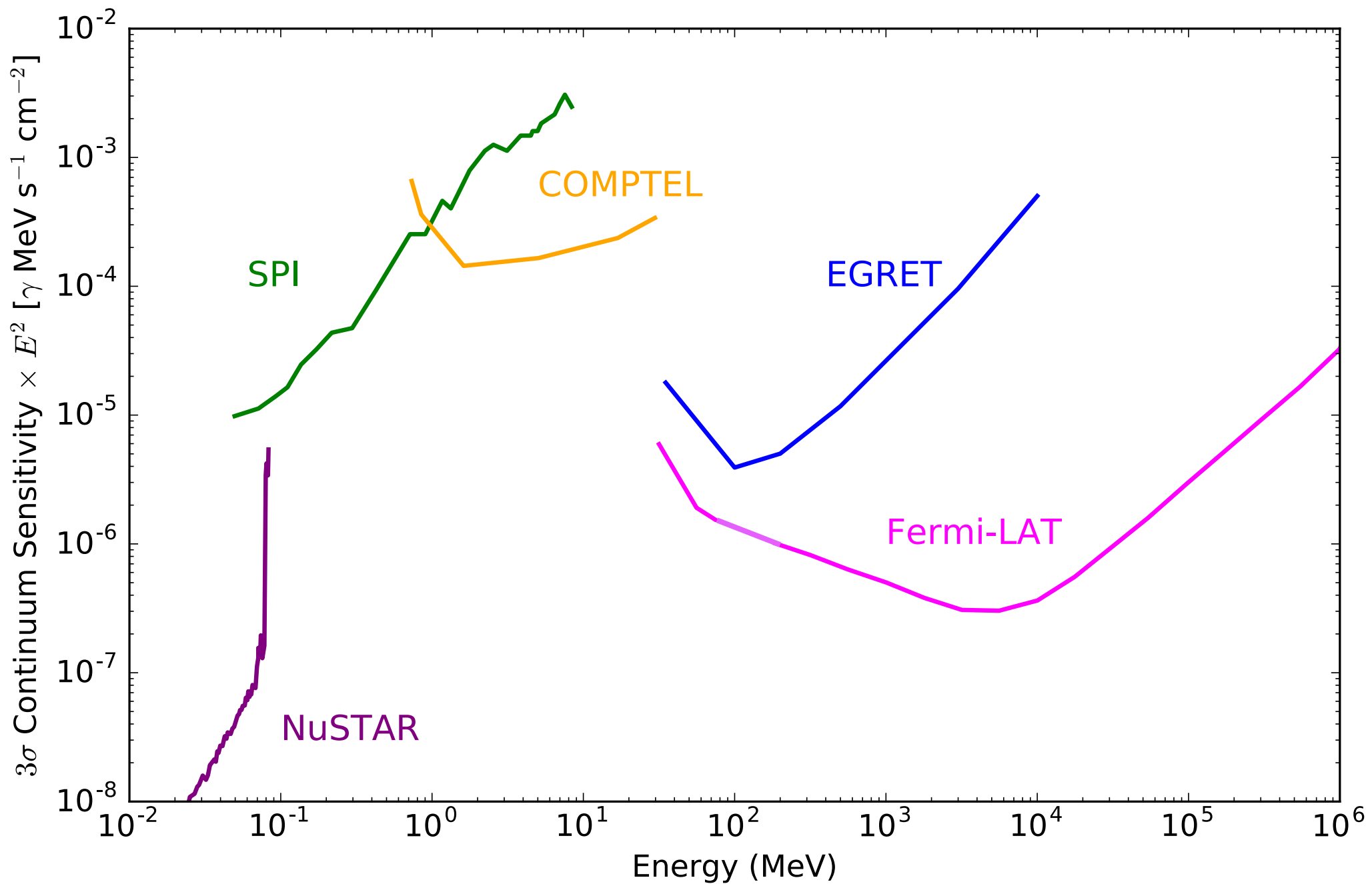
[MAMEYER@STANFORD.EDU](mailto:MAMEYER@STANFORD.EDU)

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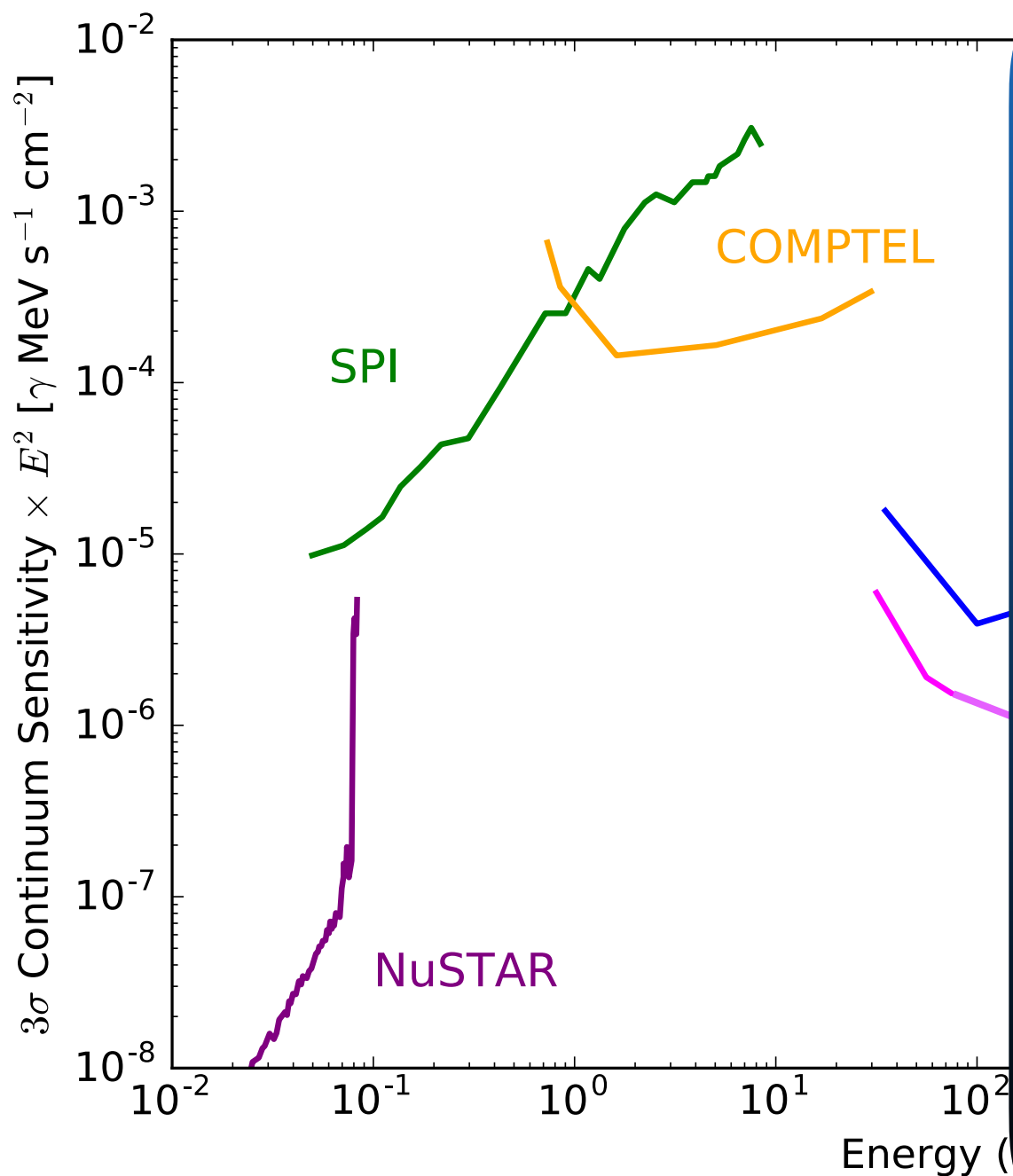
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# THE UNEXPLORED MeV SKY



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AMEG  
ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY

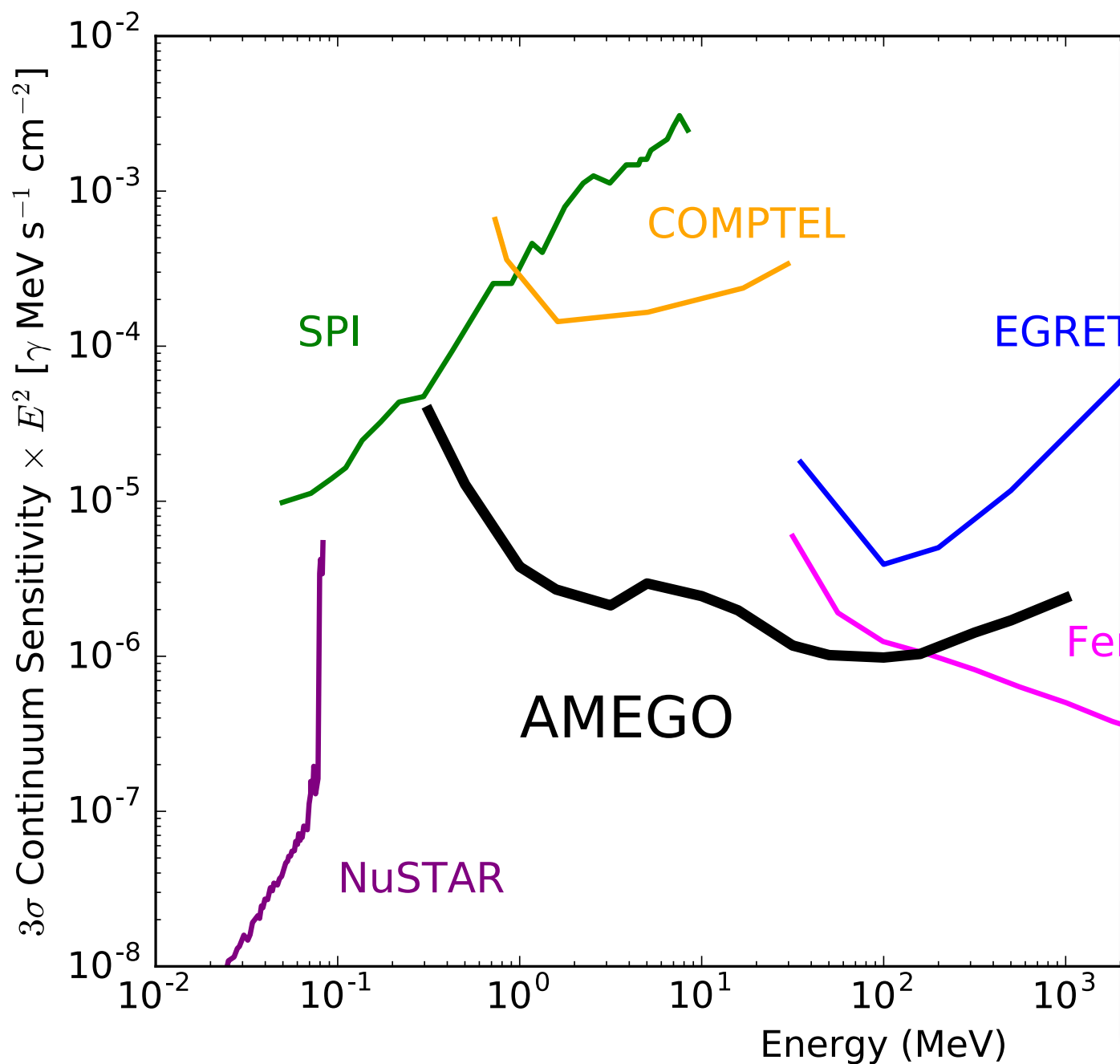


- Large gap in sensitivity of satellite missions between  $\sim 0.1$  and 100 MeV
- Challenging detection of  $\gamma$  rays in this regime: cross over for energy losses between Compton scattering and pair production

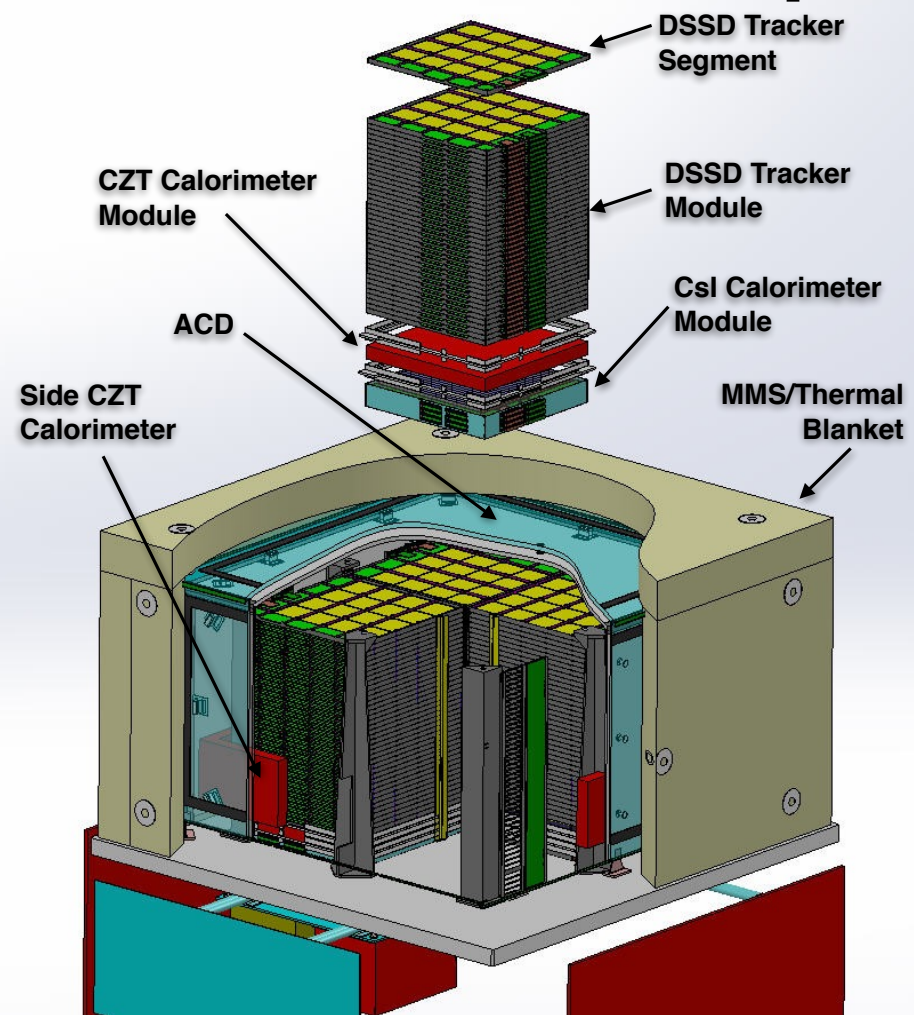


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ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



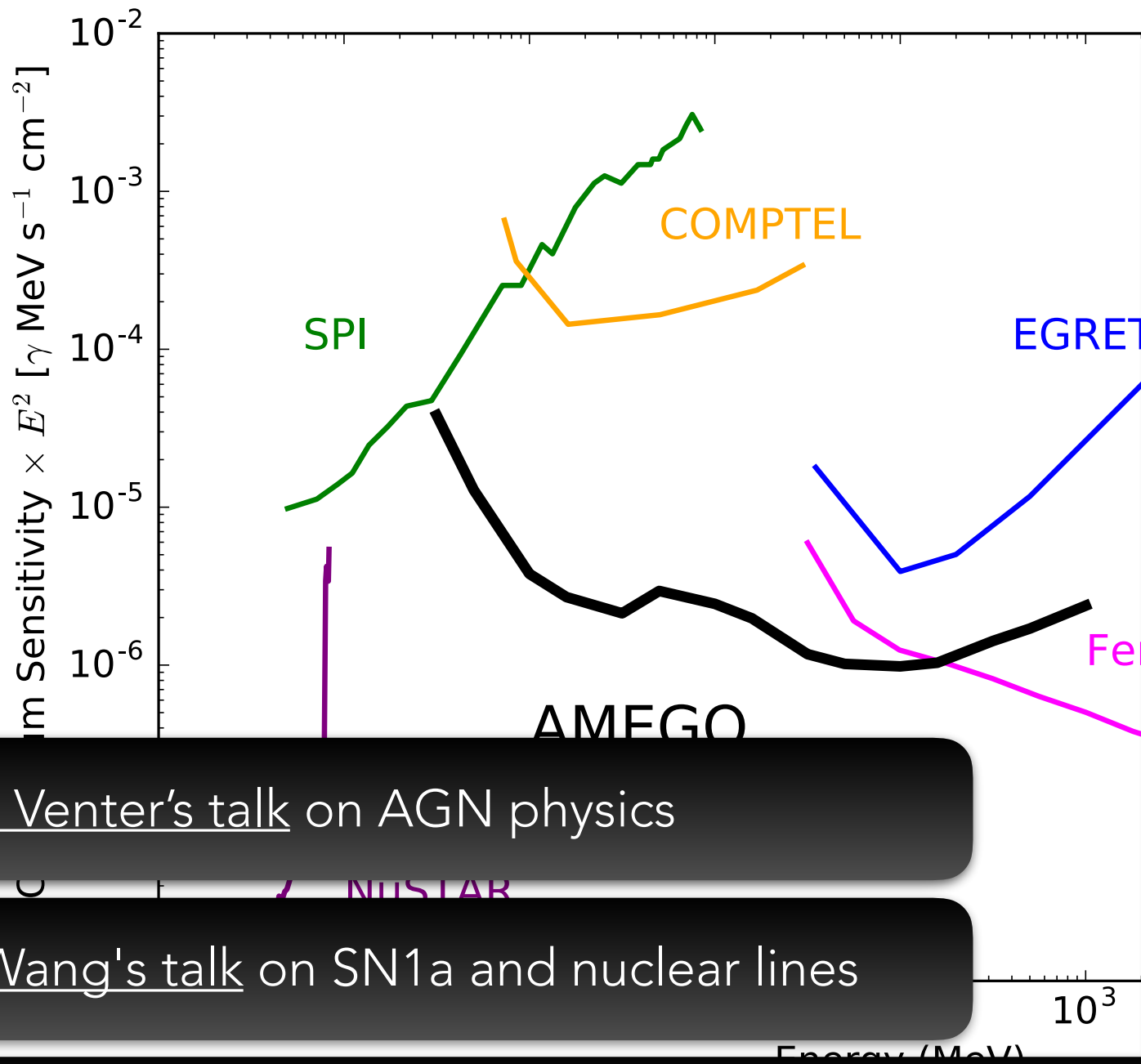
## AMEGO Concept



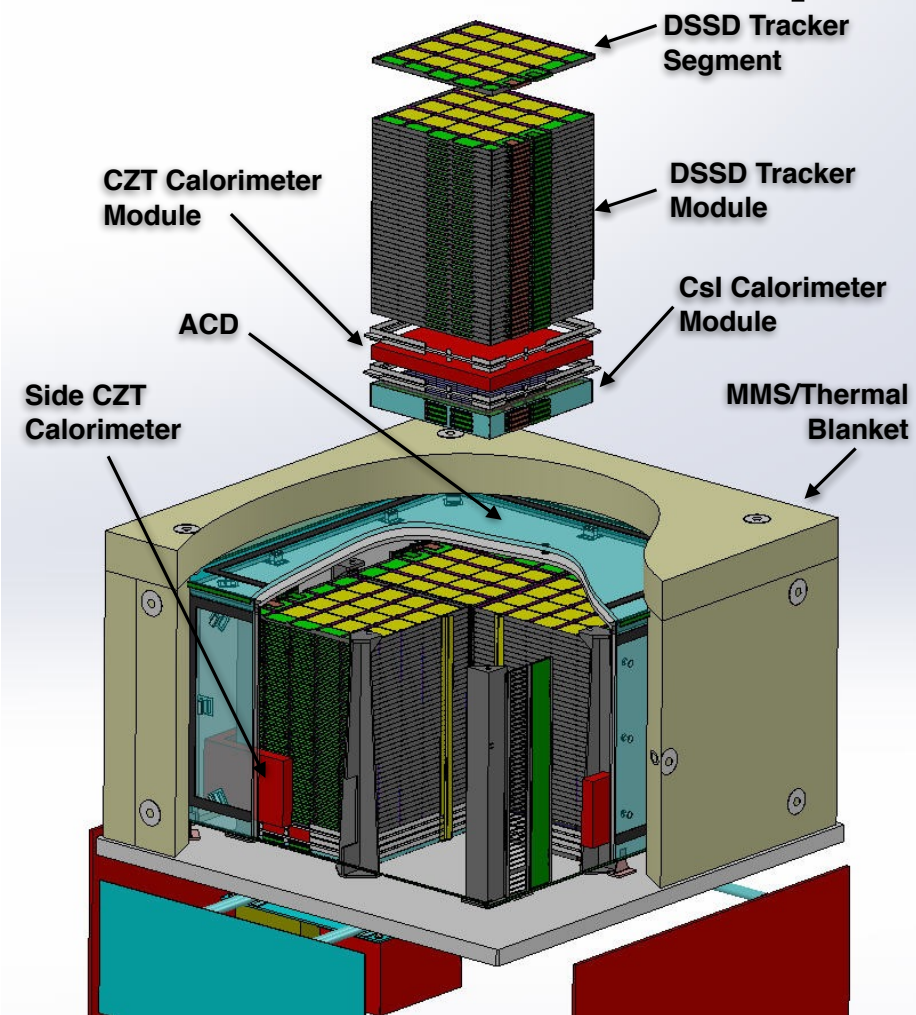


# THE UNEXPLORED MeV SKY

AMEGO  
ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



## AMEGO Concept



See [Tonia Venter's talk](#) on AGN physics

See [Xilu Wang's talk](#) on SN1a and nuclear lines

See [Jeremy Perkins' talk](#) for more details and a full mission overview



MEGO

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY

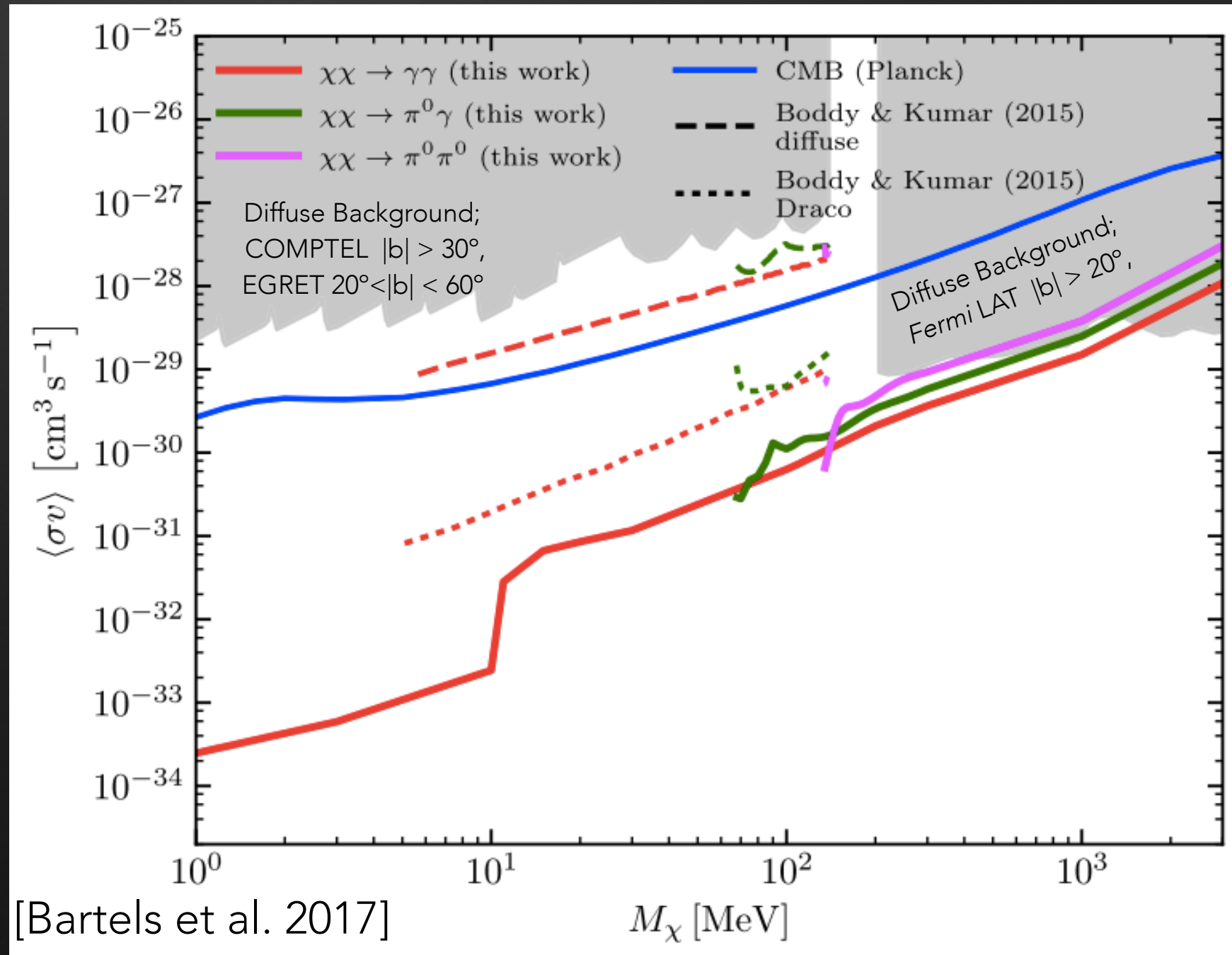
# PROBING WIMP DARK MATTER

# SENSITIVITY FOR A SIGNAL FROM SELF-ANNIHILATING DARK MATTER

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



- Considered  $10^\circ \times 10^\circ$  ROI around GC, one year exposure
- e-ASTROGAM like characteristics
- Energy losses, propagation, Galactic diffuse emission taken into account



[Bartels et al. 2017]

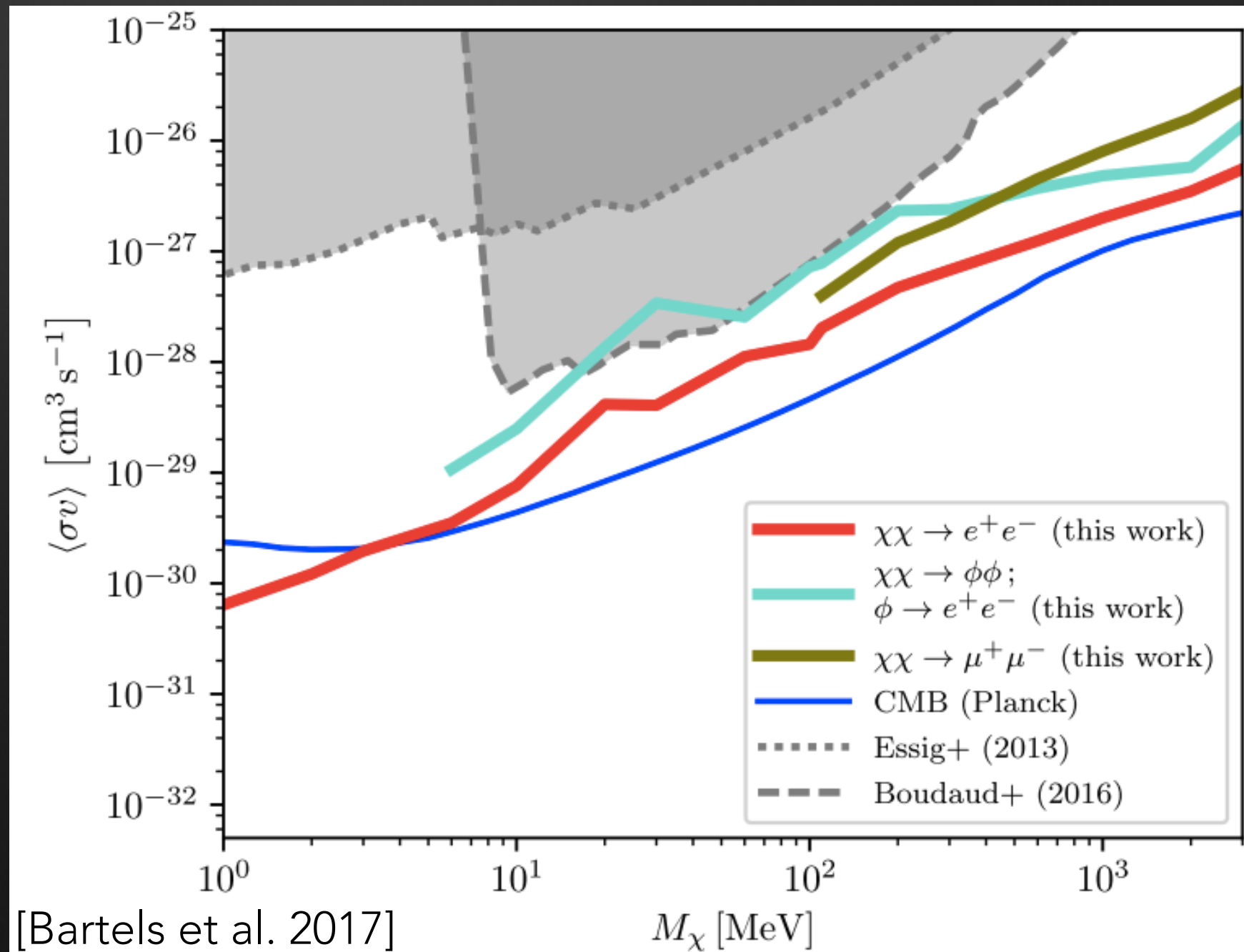


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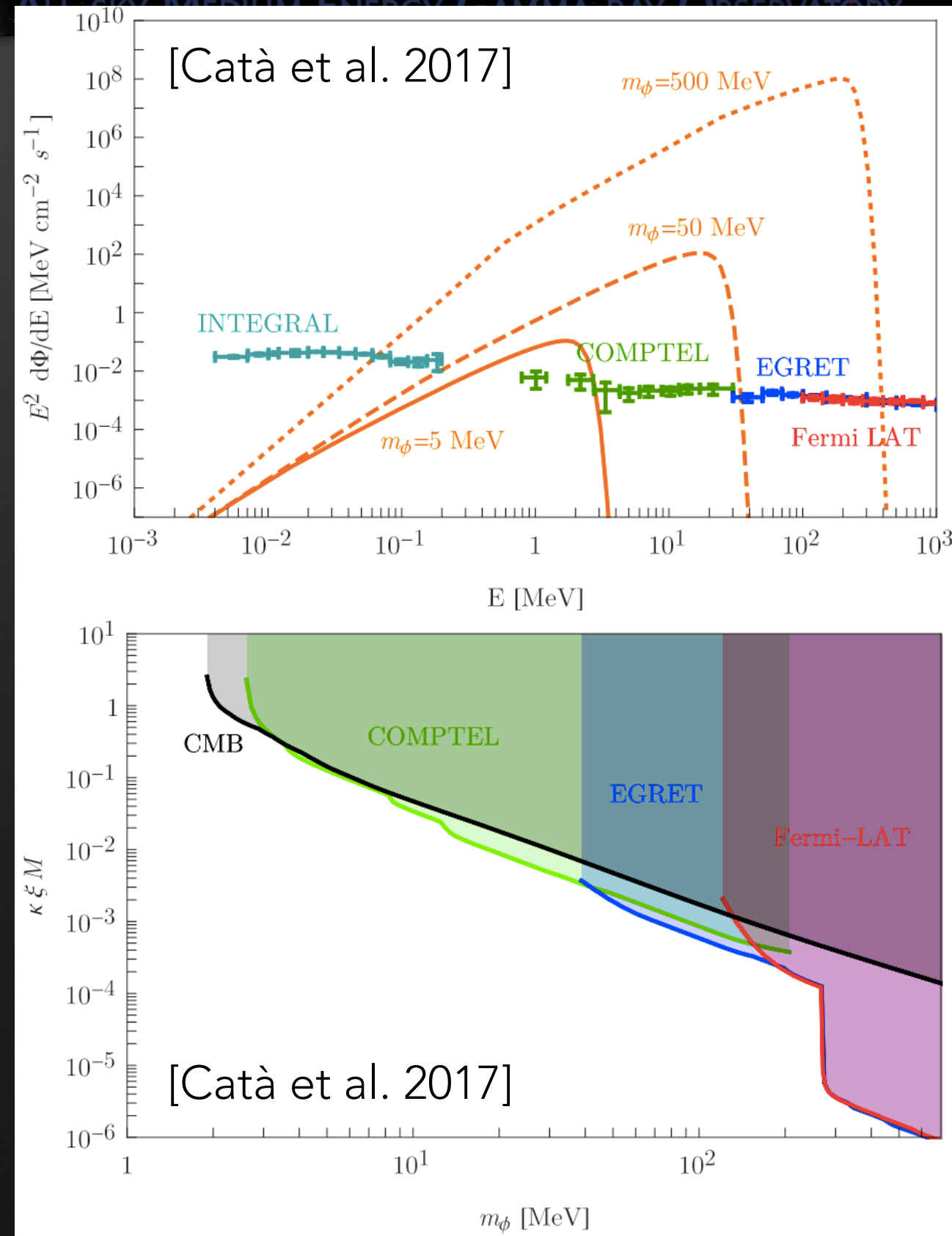


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# MOTIVATED MeV-GeV DM MODELS

- MeV-GeV DM models often strongly constrained with CMB measurements [see e.g. Tracy Slatyer's talk]
- CMB constraints can be avoided for p-wave (velocity dependent) annihilation\*
- Constraints from diffuse  $\gamma$  rays for decaying DM coupled to gravity can surpass CMB bounds [see Sebastian Ingehütt's talk]



\*See e.g. Boehm & Fayet (2004), Pospelov et al. (2008), D'Agnolo & Ruderman (2015), Chu et al. (2016), Choi et al. (2016), Pappadopulo et al. (2016), Hochberg et al. (2014)



MEGO

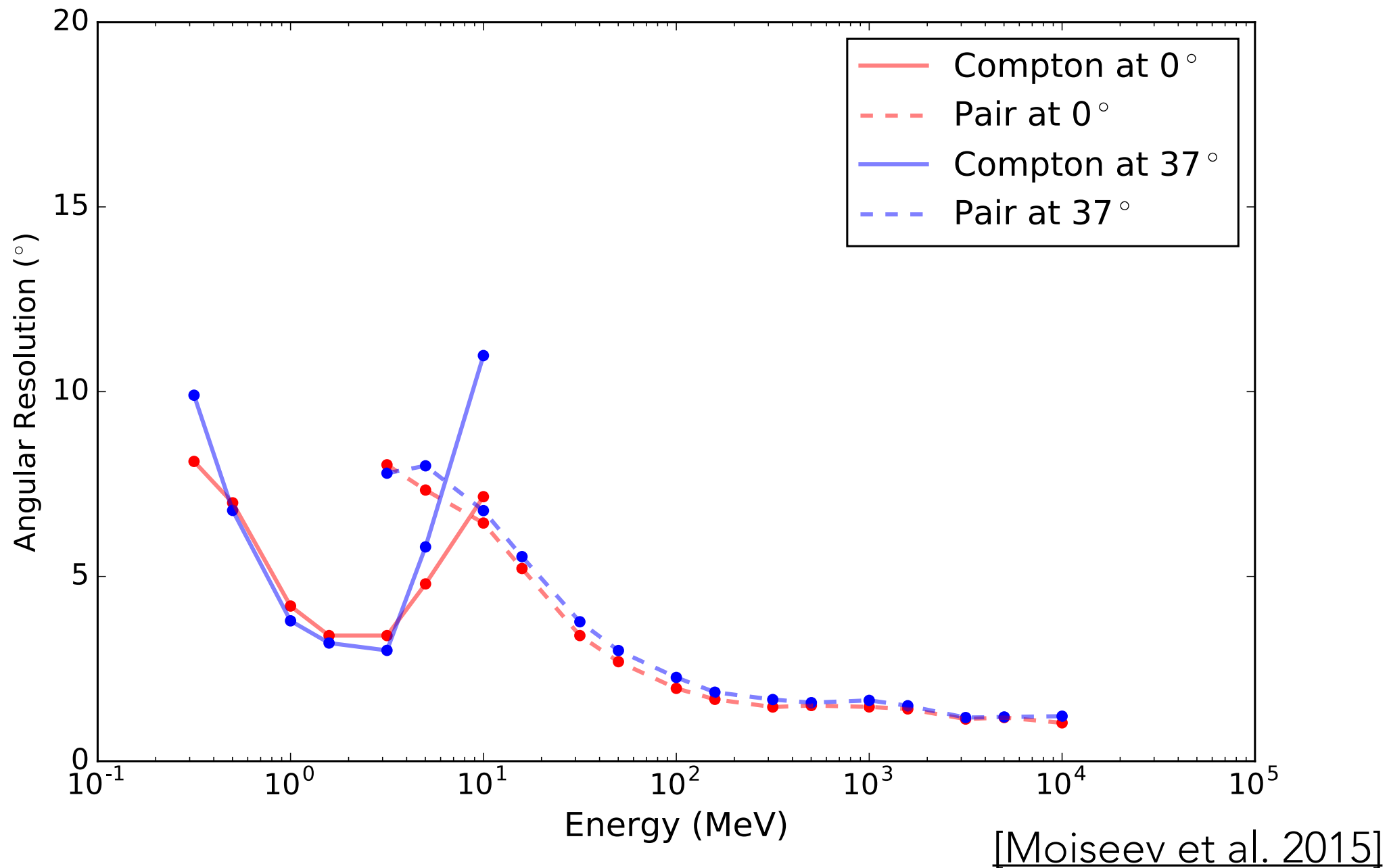
ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY

PROBING THE DARK MATTER  
INTERPRETATION OF THE GALACTIC  
CENTER EXCESS

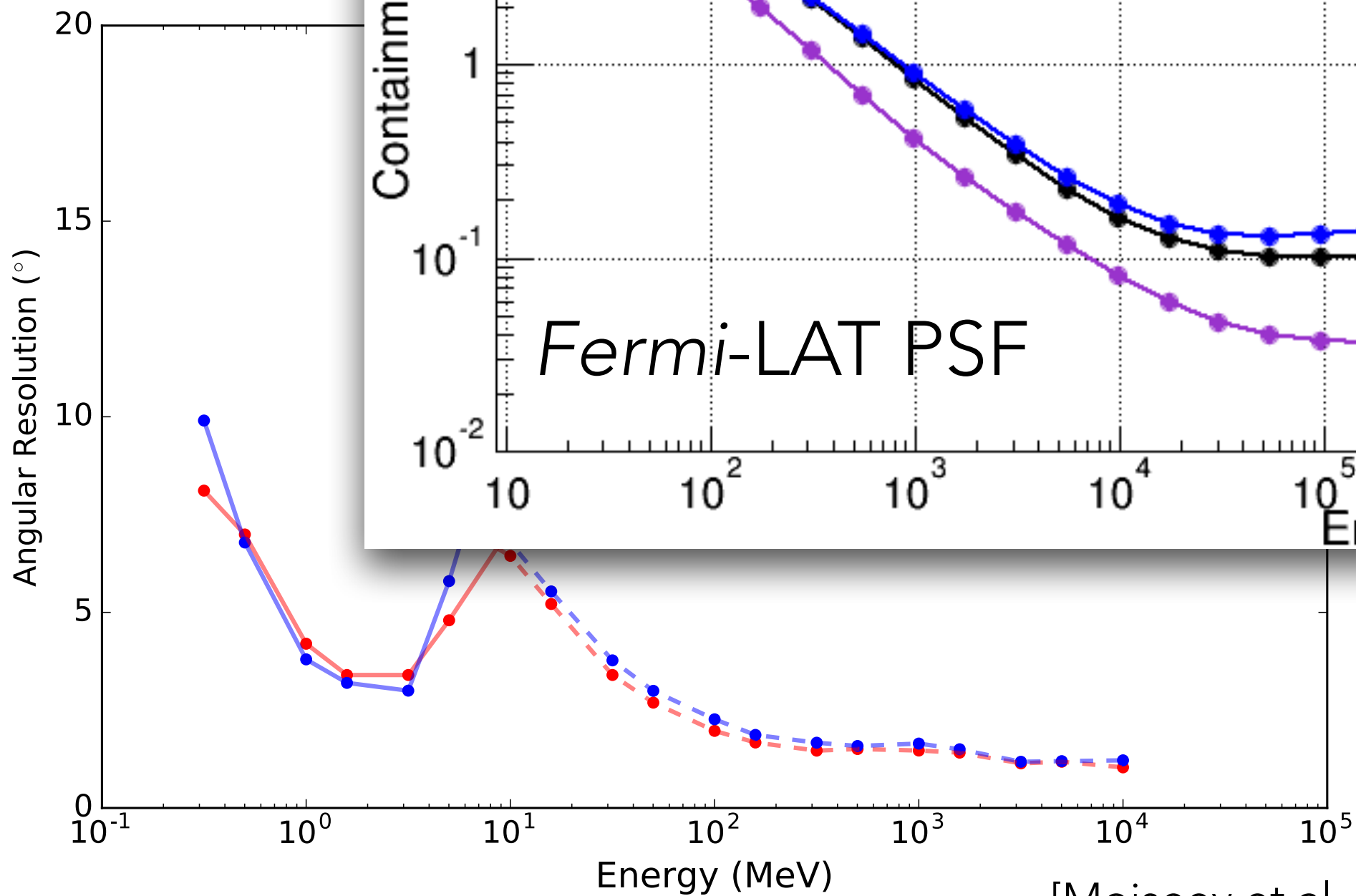


# AMEGO ANGULAR RESOLUTION

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



# AMEGO AN



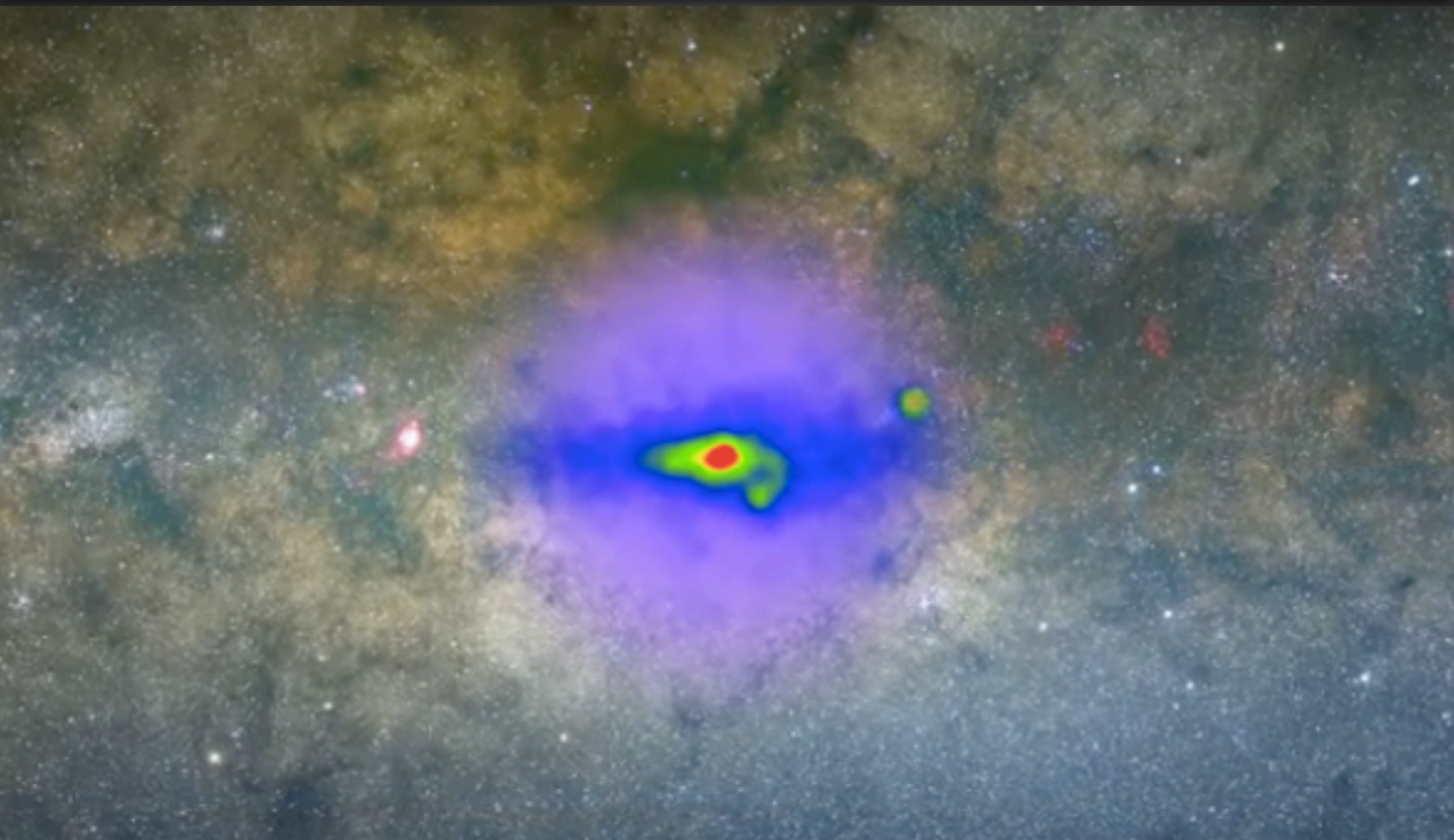
*Fermi-LAT PSF*

[Moiseev et al. 2015]



# PIN-POINTING THE GeV EMISSION IN THE GALACTIC CENTER

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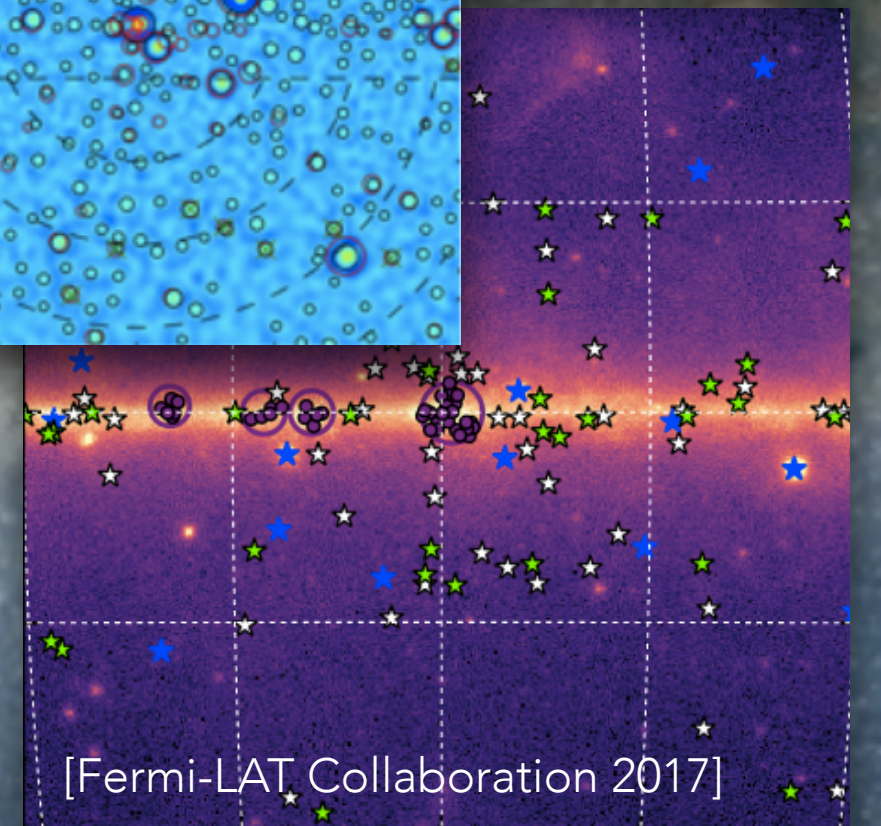
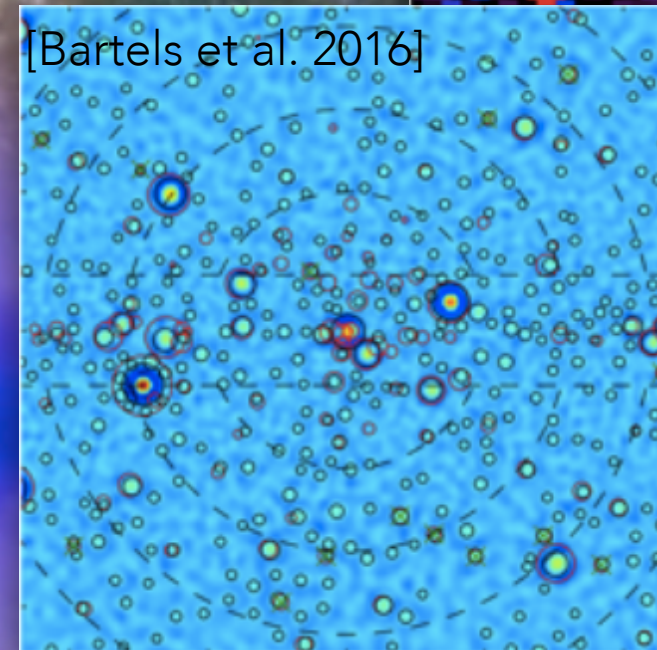
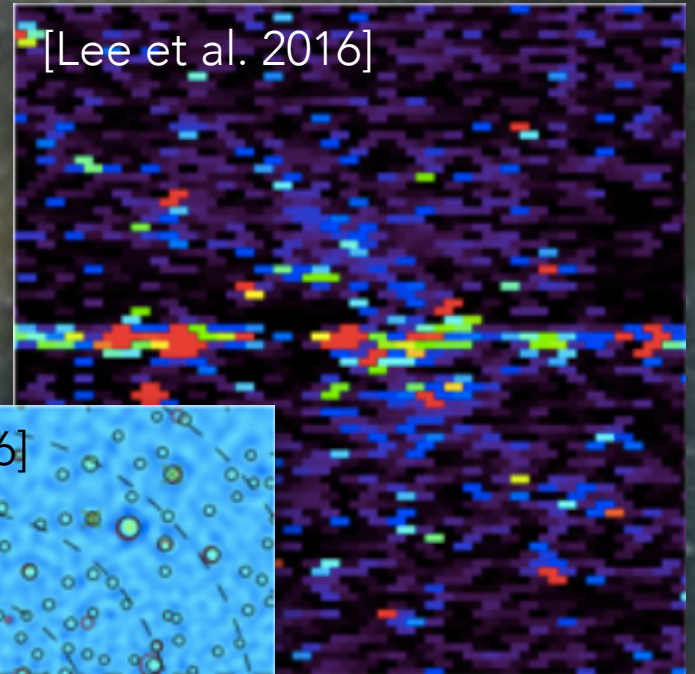
- GeV excess observed with Fermi LAT in the Galactic Center [see e.g. [Tracy Slatyer's](#) or [Daniele Gaggero's](#) talks]
- Possible astrophysical origin: population of MSP pulsars [see e.g. [Richard Bartels'](#) or [Mattia Di Mauro's](#) talks]
- AMEGO can probe this hypothesis due to improved PSF and sensitivity to lower  $\gamma$ -ray energies



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MEGO

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# PROBING AXIONLIKE PARTICLES

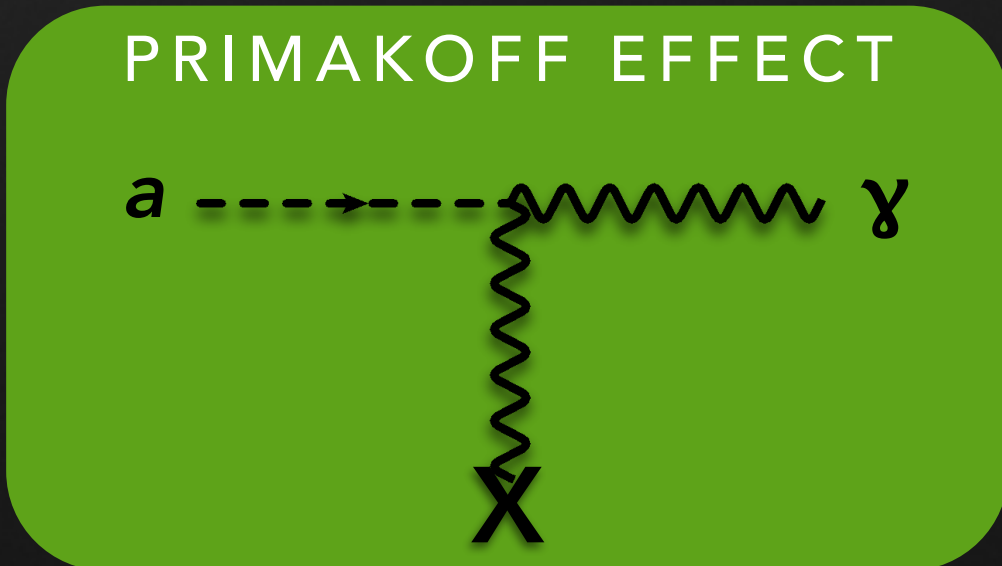
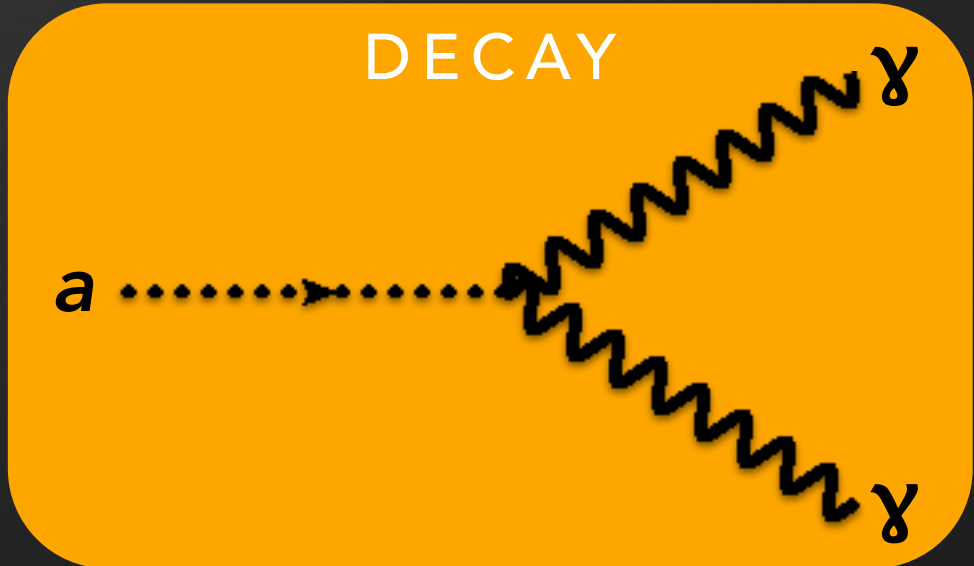


# AXIONS AND AXIONLIKE PARTICLES



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

- Axion: proposed as by-product of solution of strong CP problem in QCD
- **Axion mass proportional to photon coupling**
- **Axionlike particles (ALPs):**
  - plethora of **ALPs predicted in string theory** (axiverse) and other standard model extensions
  - Mass and photon coupling independent parameters
- **Axions and ALPs are DM candidates**



[Peccei & Quinn 77; Wilczek 78; Weinberg 78; Preskill et al. 83; Abbott & Sikivie 83; Witten 84; e.g. Arvanitaki et al. 09; Cicoli et al. 12; Arias et al. 2012; Raffelt & Stodolsky 1988]



# FUTURE ALP CONSTRAINTS USING SPECTRAL IRREGULARITIES

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY

- Prime target: NGC 1275, central radio galaxy of Perseus cluster
- Bright  $\gamma$ -ray emitter
- Central B field of cluster:  $25 \mu\text{G}$  [Taylor et al. 2006]
- Used to constrain ALPs using *Fermi*-LAT observations [Ajello et al. 2016]



Hubble image of NGC 1275

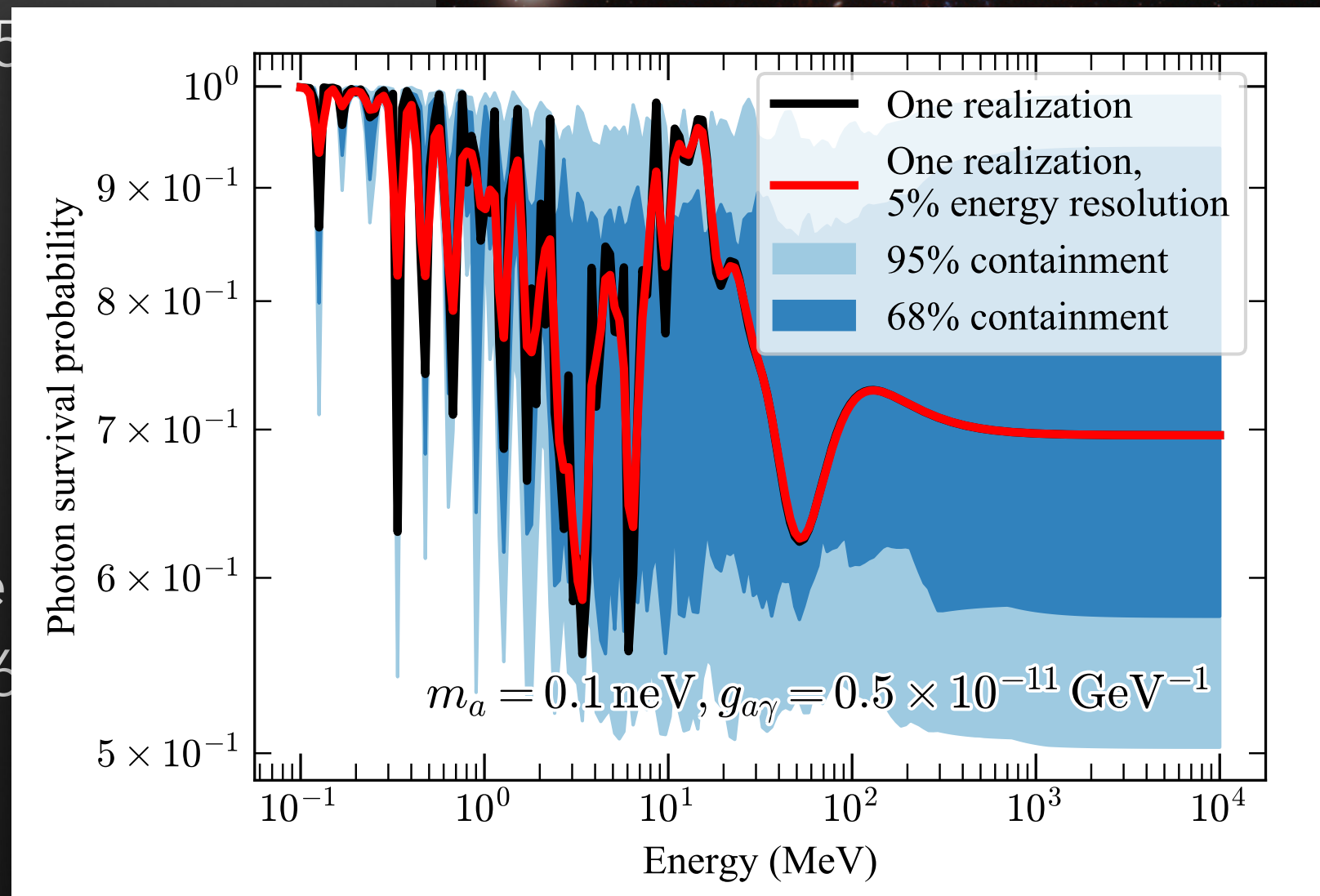
<http://hubblesite.org/newscenter/archive/releases/2008/28/image/a/>



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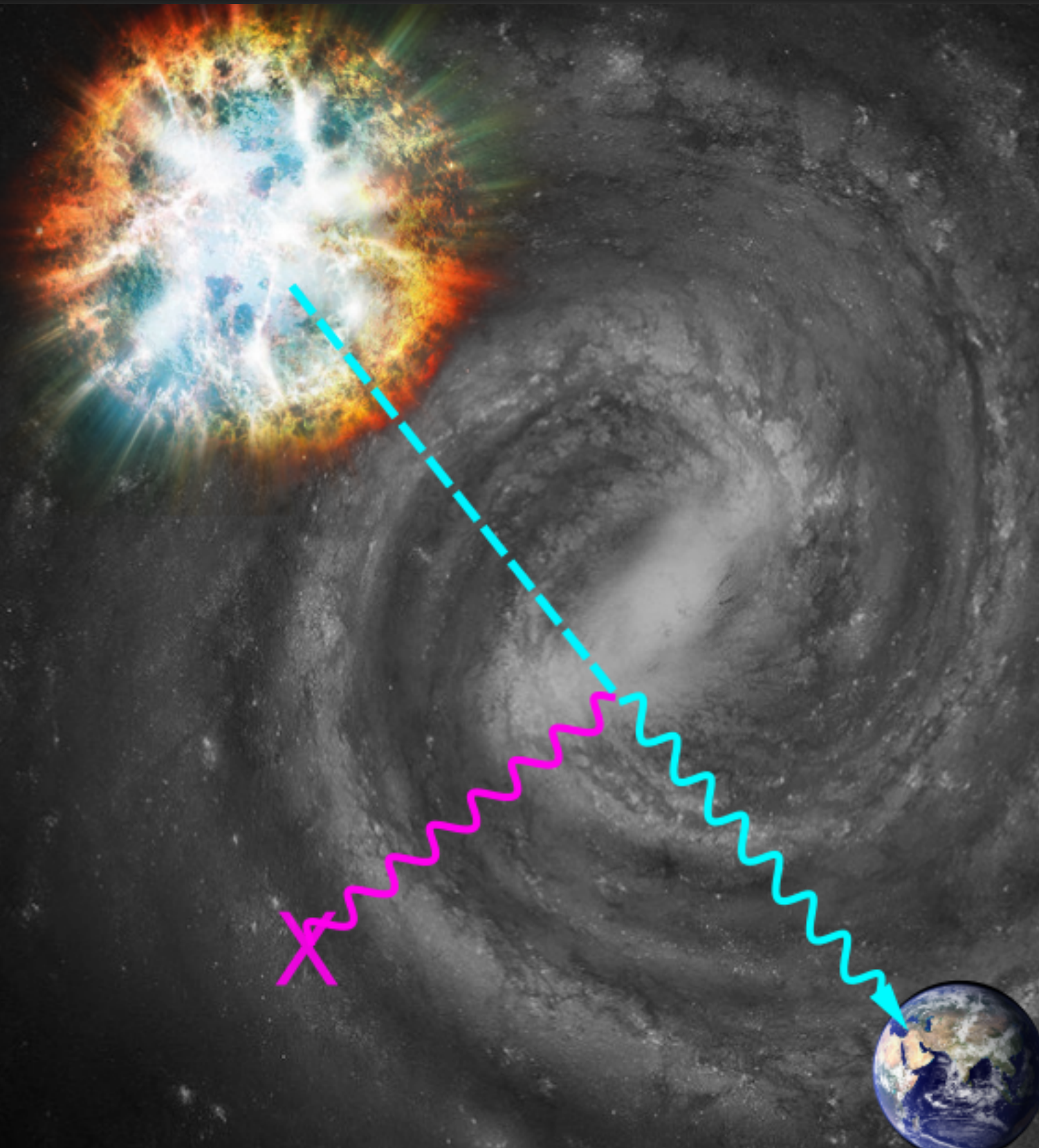


**Photon-ALP oscillations including random B-field in Perseus cluster ( $10 \mu\text{G}$ ) and Galactic Magnetic field**



# ALP SEARCHES USING CORE-COLLAPSE SUPERNOVAE

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



[Meyer et al. 2017]

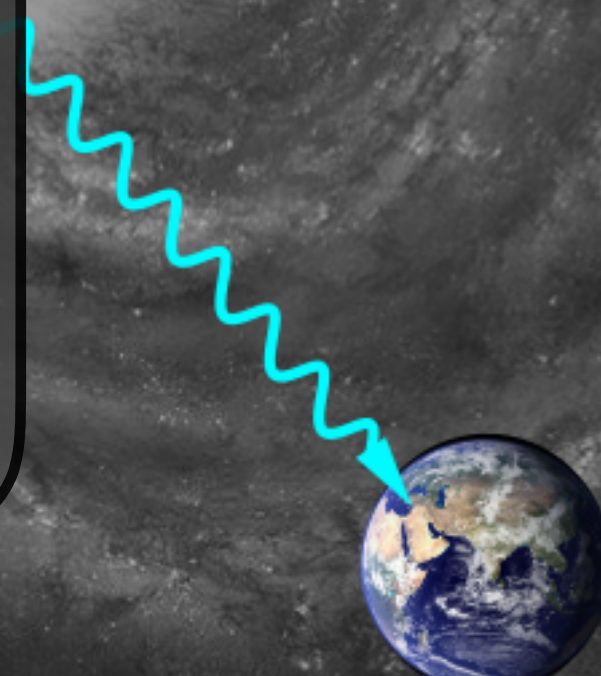


# ALP SEARCHES USING CORE-COLLAPSE SUPERNOVAE

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



- ALPs produced in a core-collapse SN explosion via Primakoff process in burst lasting **10s of seconds**
- Burst would arrive **simultaneous with neutrino burst**
- Could **convert into gamma-rays in Galactic magnetic field**
- Non-observation of signal from **SN1987A** with Gamma-Ray Spectrometer on Solar Maximum Mission satellite still **strongest bounds for ALPs with masses  $m_a \lesssim 1\text{neV}$**  [Payez et al. 2015]



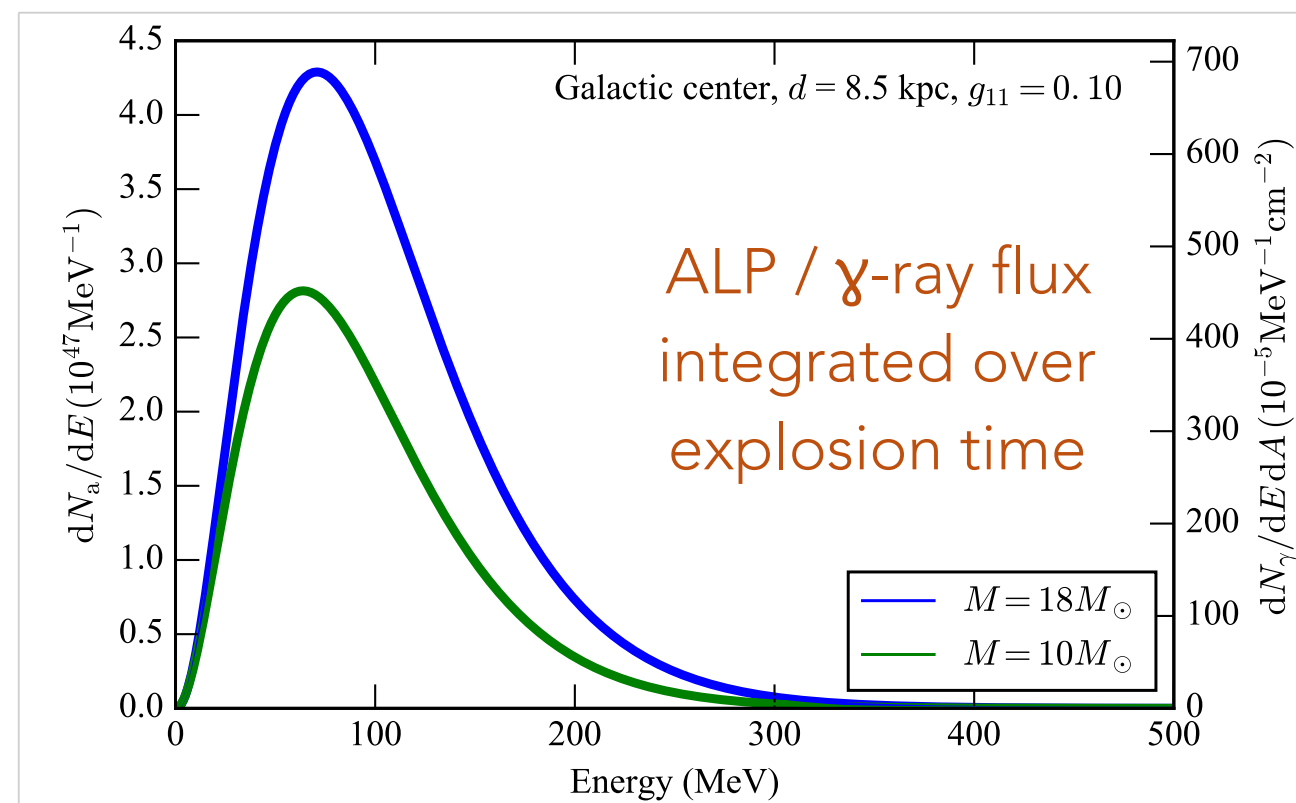


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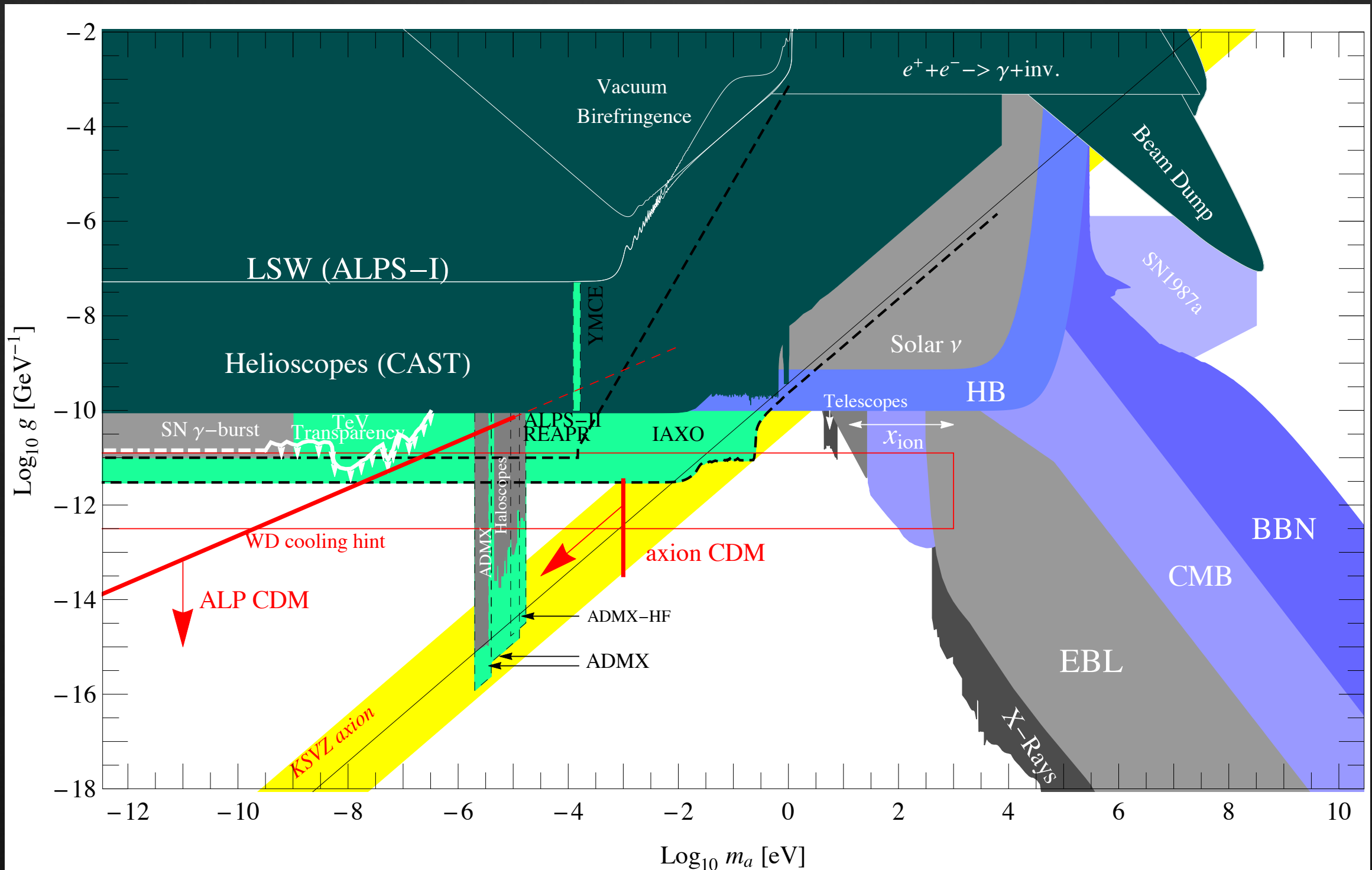


**Large FoV** and **small PSF** of AMEGO promise similar sensitivity as *Fermi* LAT for ALPs in case of a Galactic core-collapse SN within FoV



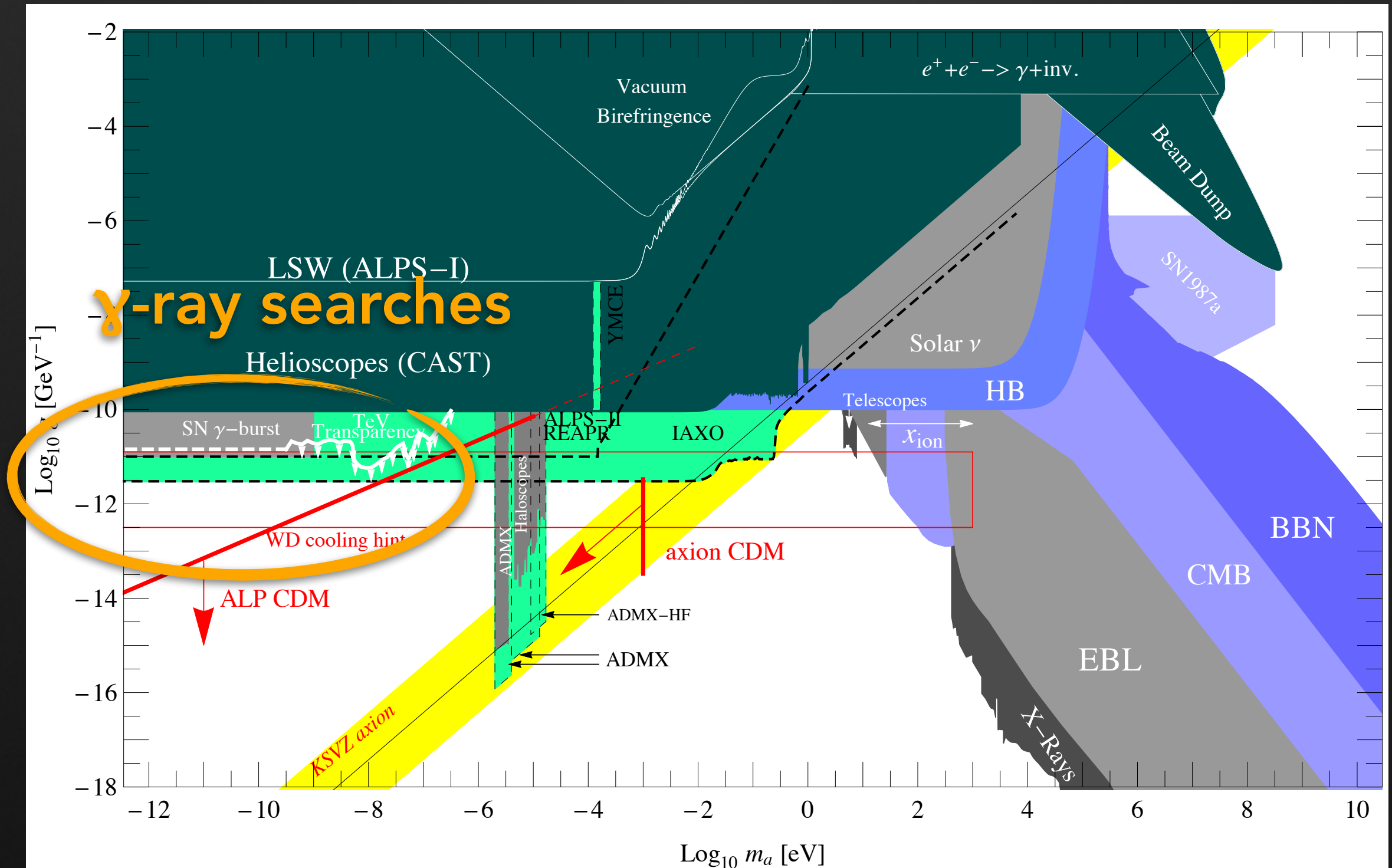
# AMEGO SENSITIVITY TO ALP<sub>s</sub>

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY



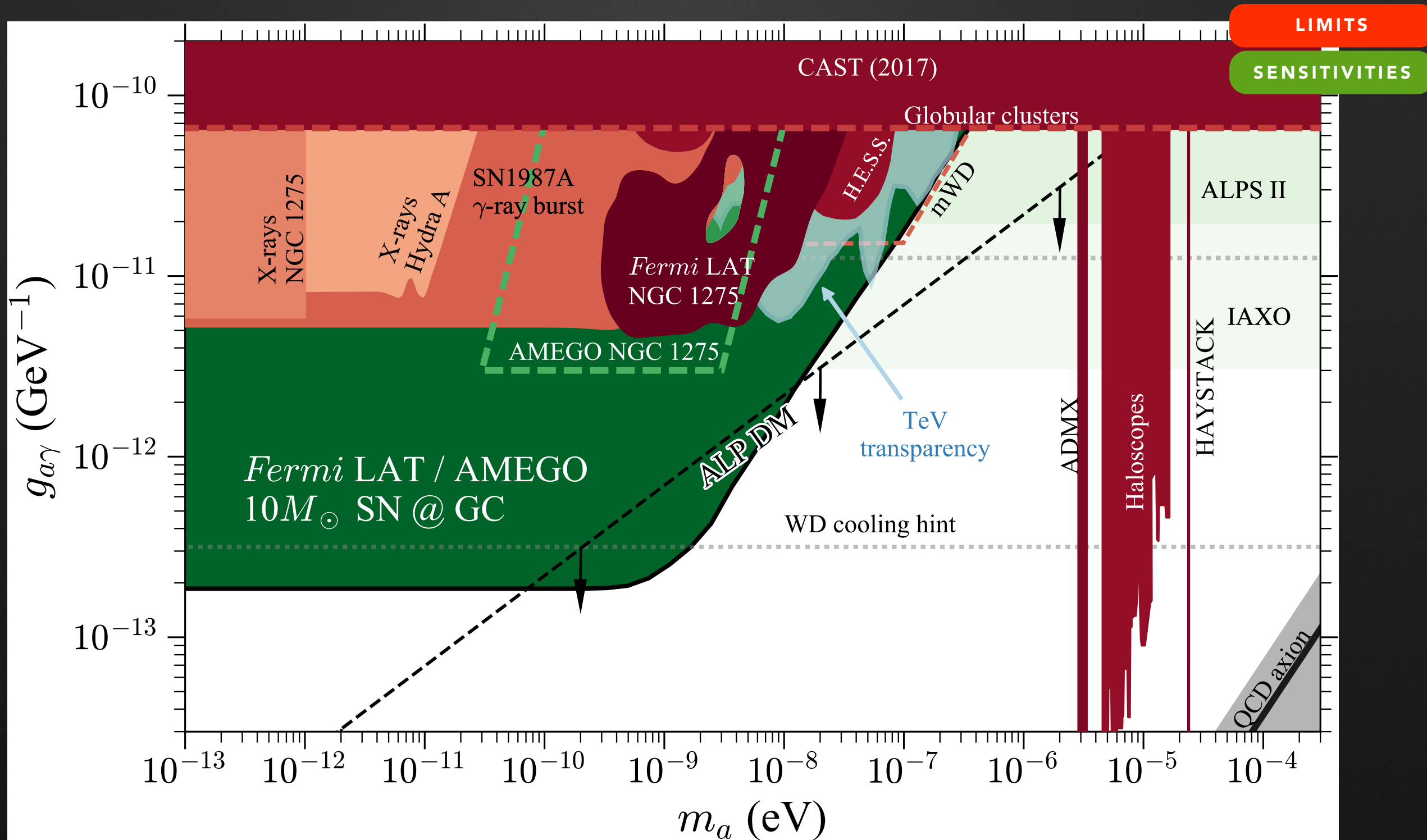
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# AMEGO SENSITIVITY TO ALP<sub>s</sub>

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY





# CONCLUSIONS



- AMEGO: new mission concept to probe  $\gamma$ -ray sky in the MeV-GeV regime
- AMEGO features large FoV, small PSF, high energy resolution + capability to measure polarization
- Unprecedented sensitivity to probe decaying and self-annihilating sub-GeV WIMP DM
- Excellent sensitivity to probe light axionlike particle DM
- Proposed for NASA decadal review

<https://asd.gsfc.nasa.gov/amego/>

# CONCLUSIONS



- AMEGO: new mission concept to probe  $\gamma$ -ray sky in the MeV-GeV regime
- AMEGO features large FoV, small PSF, high energy

Planned to write dedicated White Papers for AMEGO science, let us know if you would like to contribute!



- Proposed for NASA decadal review

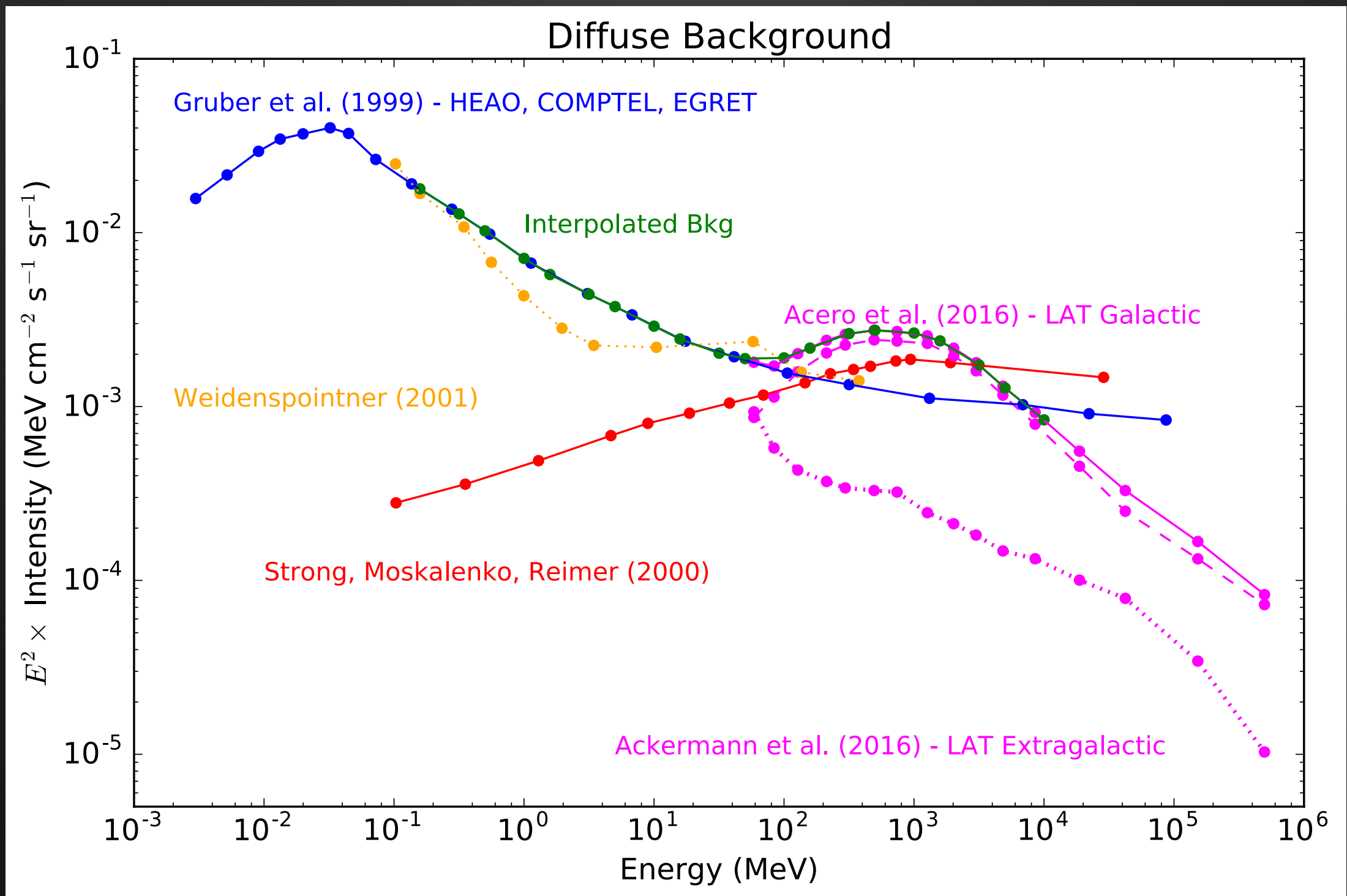
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BACK UP

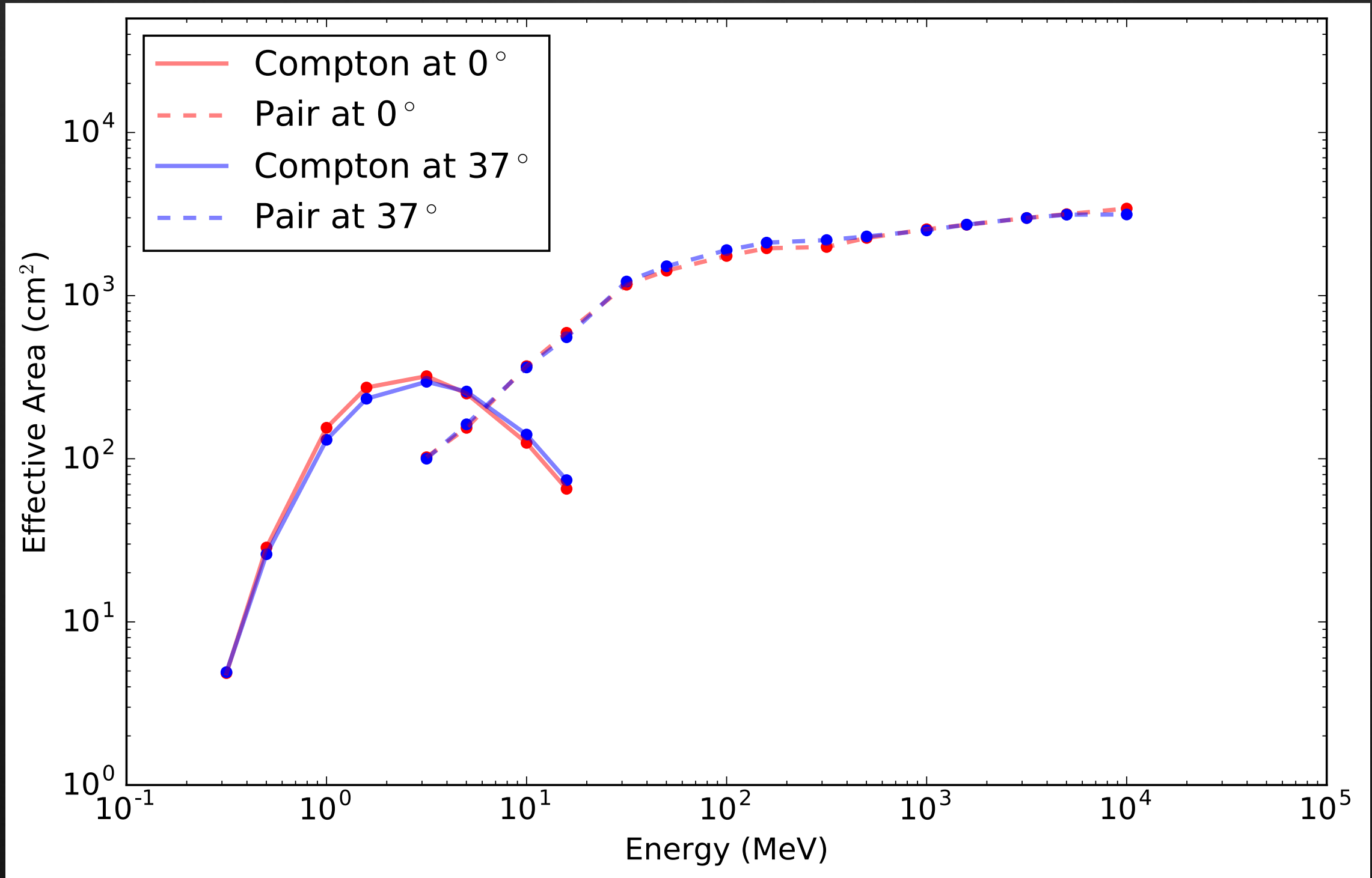
# DIFFUSE BACKGROUND

ALL-SKY MEDIUM ENERGY GAMMA-RAY OBSERVATORY





# EFFECTIVE AREA



# AMEGO EVENT TYPES

