22nd September 2020

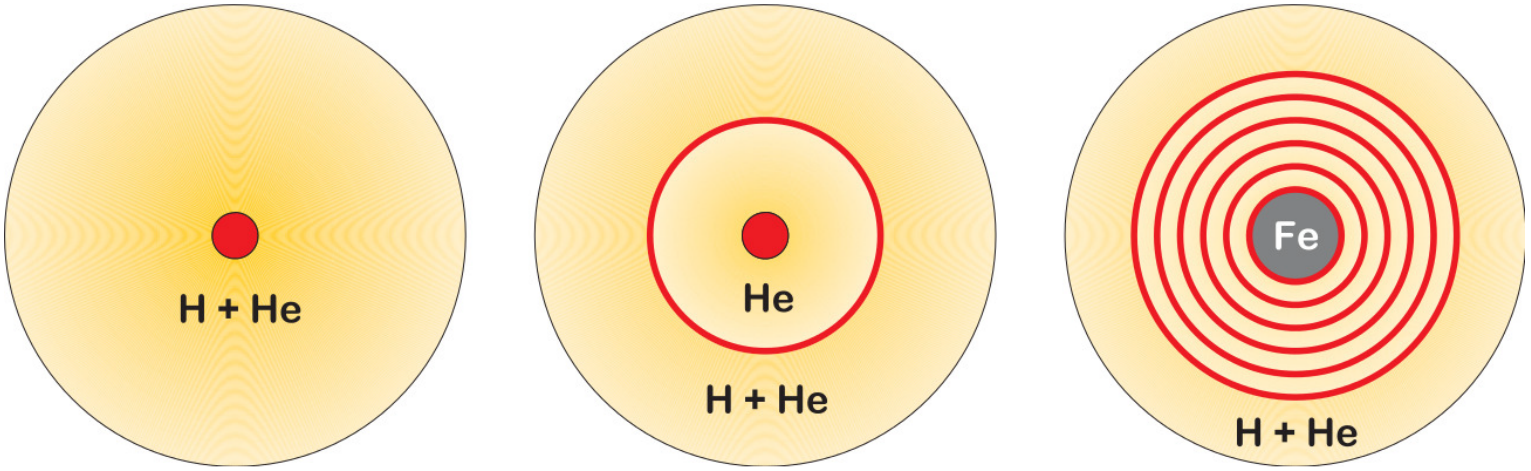
Bounds on axion-like particles from the diffuse supernova flux

Based on
F. Calore, P. Carenza, M. Giannotti, J. Jaeckel and A. Mirizzi,
arXiv:2008.11741 [hep-ph]

Pierluca Carenza
Bari Univ. & INFN

Core-Collapse Supernovae

For massive stars ($M > 8M_\odot$) the nuclear fusion produces heavy elements in an onion structure and a degenerate iron core



Iron in the core cannot be burnt and the star starts to collapse

ALP production and decay in SNe

ALPs in general interact with photons, nucleons and electrons...

- $\gamma + Ze \to a$ Primakoff conversion of photons, relevant in absence of coupling with nucleons
- $a \to \gamma\gamma$ decay channel which always produces photons

- $NN \to NNa$ NN bremmstrahlung, the most important production channel with the maximal coupling allowed by SN1987A ($g_{ap} = 1.2 \times 10^{-9}$)

  PC *et al.*, JCAP **10** (2019) no.10, 016

- $\gamma e^- \to a e^-$ electron Compton, suppressed by degeneracy
- $e^- + Ze \to e^- + a$ electron Primakoff, negligible production rate for $g_{ae} \sim 10^{-13}$ compared to other channels
- $a \to e^+ e^-$ relevant decay channel for $m_a > 1\,\mathrm{MeV}$

Diffuse SN ALP Background - DSNALPB

In analogy to neutrinos, the DSNALPB is created by all past SNe

$$\frac{d\phi_a(E_a)}{dE_a} = \int_0^\infty (1+z) \frac{dN_a(E_a(1+z))}{dE_a} [R_{SN}(z)] \left[\left| c \frac{dt}{dz} \right| dz \right]$$

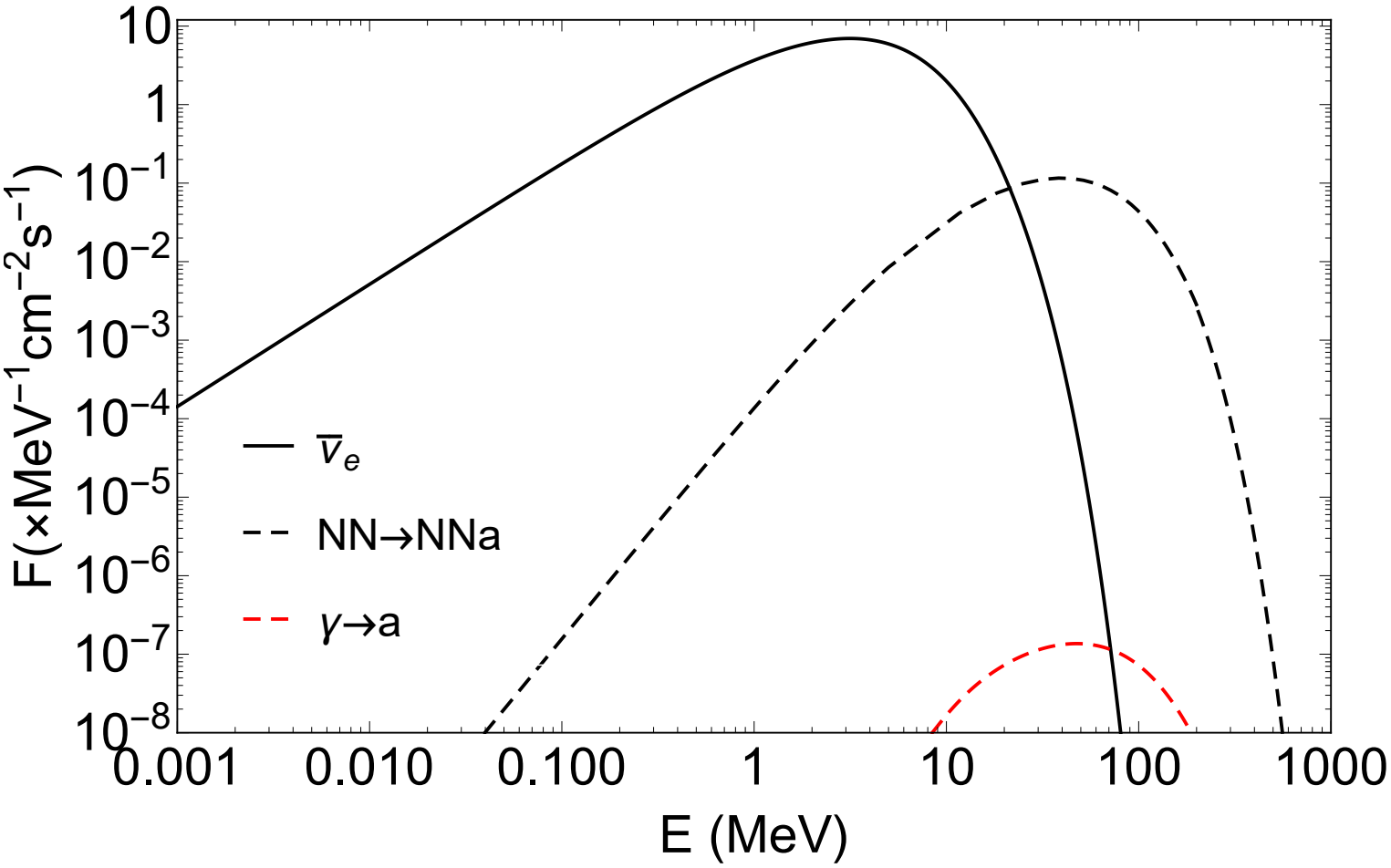
Where:

- dN_a/dE is the SN ALP flux
- R_{SN} is the cosmological SN rate
- dt/dz depends on the cosmological parameters

G. G. Raffelt *et al.*, Phys. Rev. D **84** (2011), 103008

DSNALPB

The DSNALPB is peaked to higher energies than DSNB

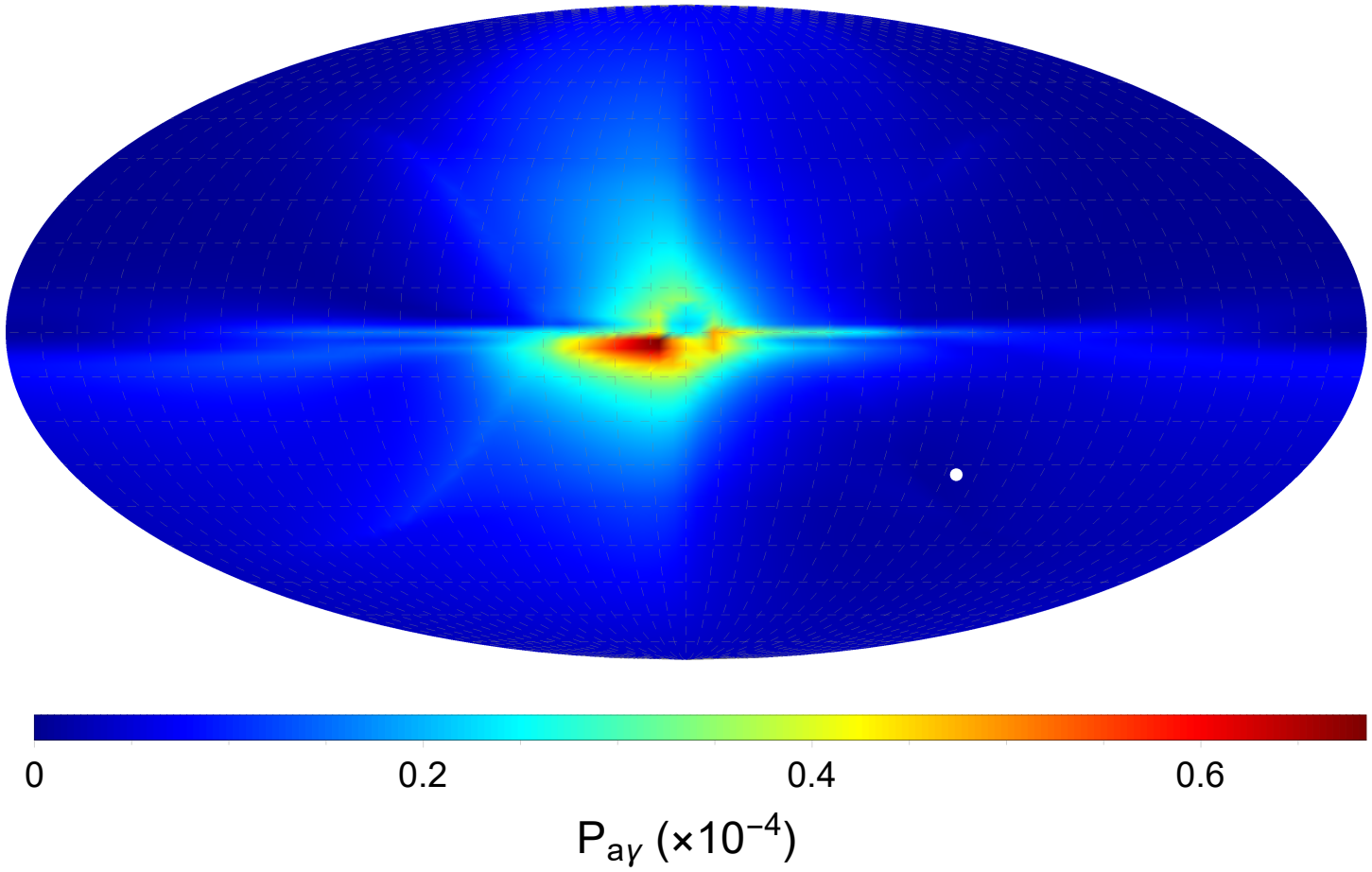


DSNALPB with $g_{ap} = 1.2 \times 10^{-9}$ and $g_{a\gamma} = 5.3 \times 10^{-12}$ GeV^{-1}

ALP conversion into photons

The Galactic magnetic field will convert into photons both the DSNALPB and the point-like ALP flux from SN1987A (white dot)

D. Horns *et al.*, Phys. Rev. D **86** (2012), 075024



Conversion probability for $m_a \ll E = 50\,\mathrm{MeV}$, $g_{a\gamma} = 3 \times 10^{-13}\,\mathrm{GeV}^{-1}$

SN1987A bound

The $\gamma-$ray flux must be smaller than $0.6\,\mathrm{cm}^{-2}$ measured by the Gamma-Ray Spectrometer

The bound on $g_{a\gamma}$ for $m_a < 4 \times 10^{-10}\,\mathrm{eV}$ is strongly improved by the nucleon coupling

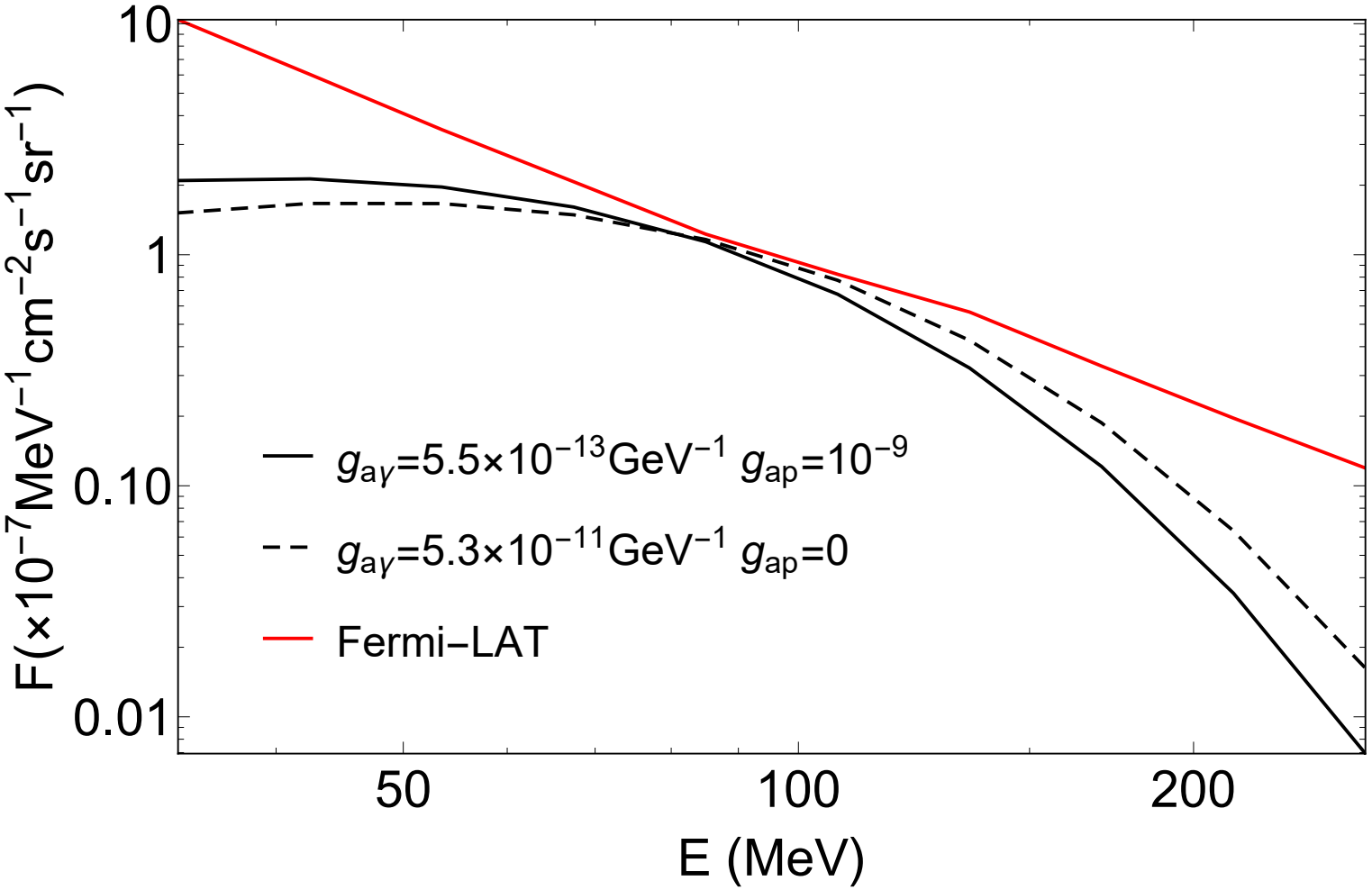
- $g_{ap} = 0$: $\quad g_{a\gamma} < 5.3 \times 10^{-12}\,\mathrm{GeV}^{-1}$
- $g_{ap} = 1.2 \times 10^{-9}$: $\quad g_{a\gamma} < 3.4 \times 10^{-15}\,\mathrm{GeV}^{-1}$

The case $g_{ap} = 0$ agrees with A. Payez *et al.*, JCAP **02** (2015), 006

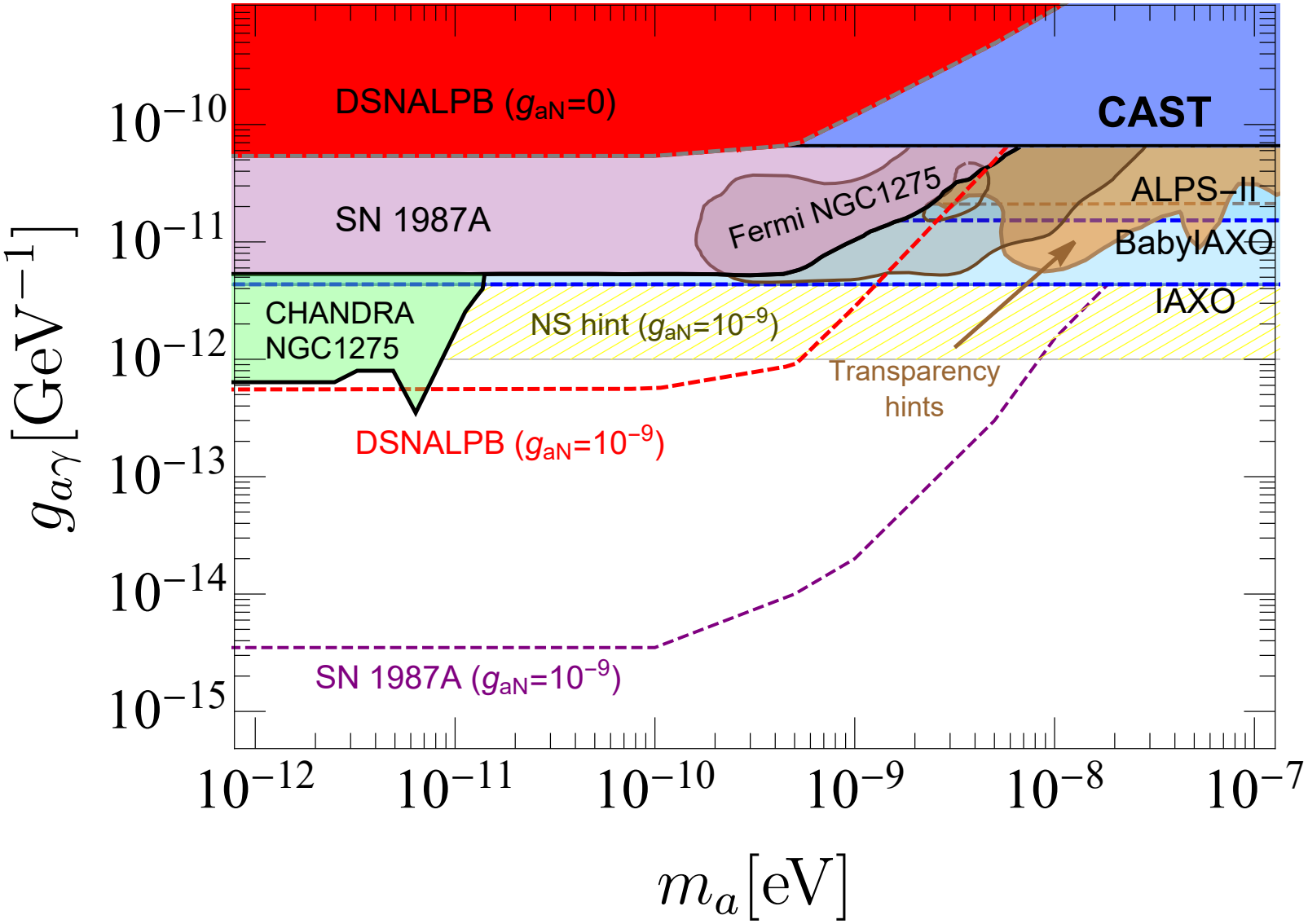
DSNALPB bound

The converted DSNALPB must be smaller than the diffuse $\gamma-$ray background measured by Fermi-LAT

M. Ackermann *et al.* [Fermi-LAT], Astrophys. J. **799** (2015), 86



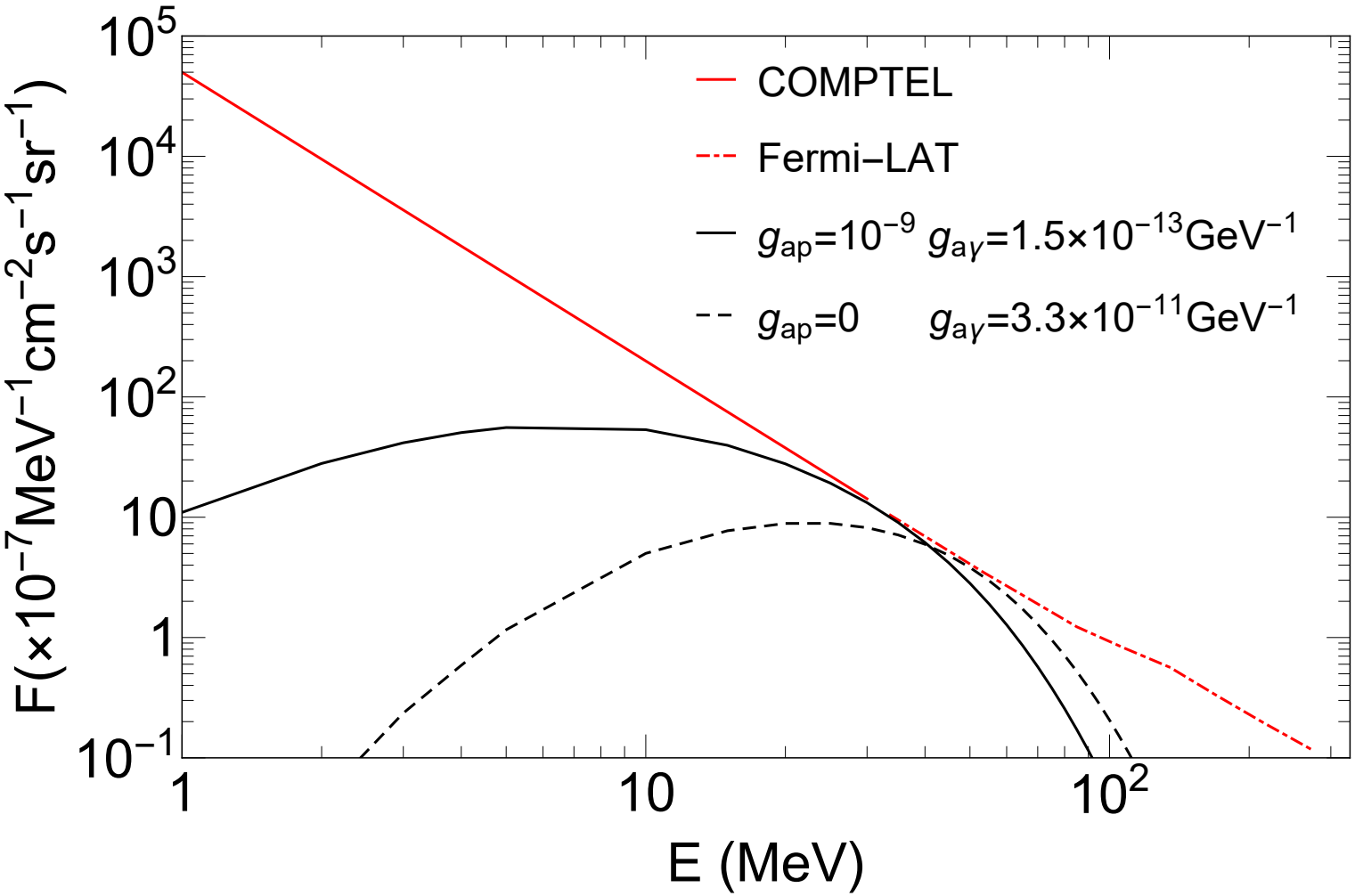
Overview plot



DSNALPB for massive ALPs

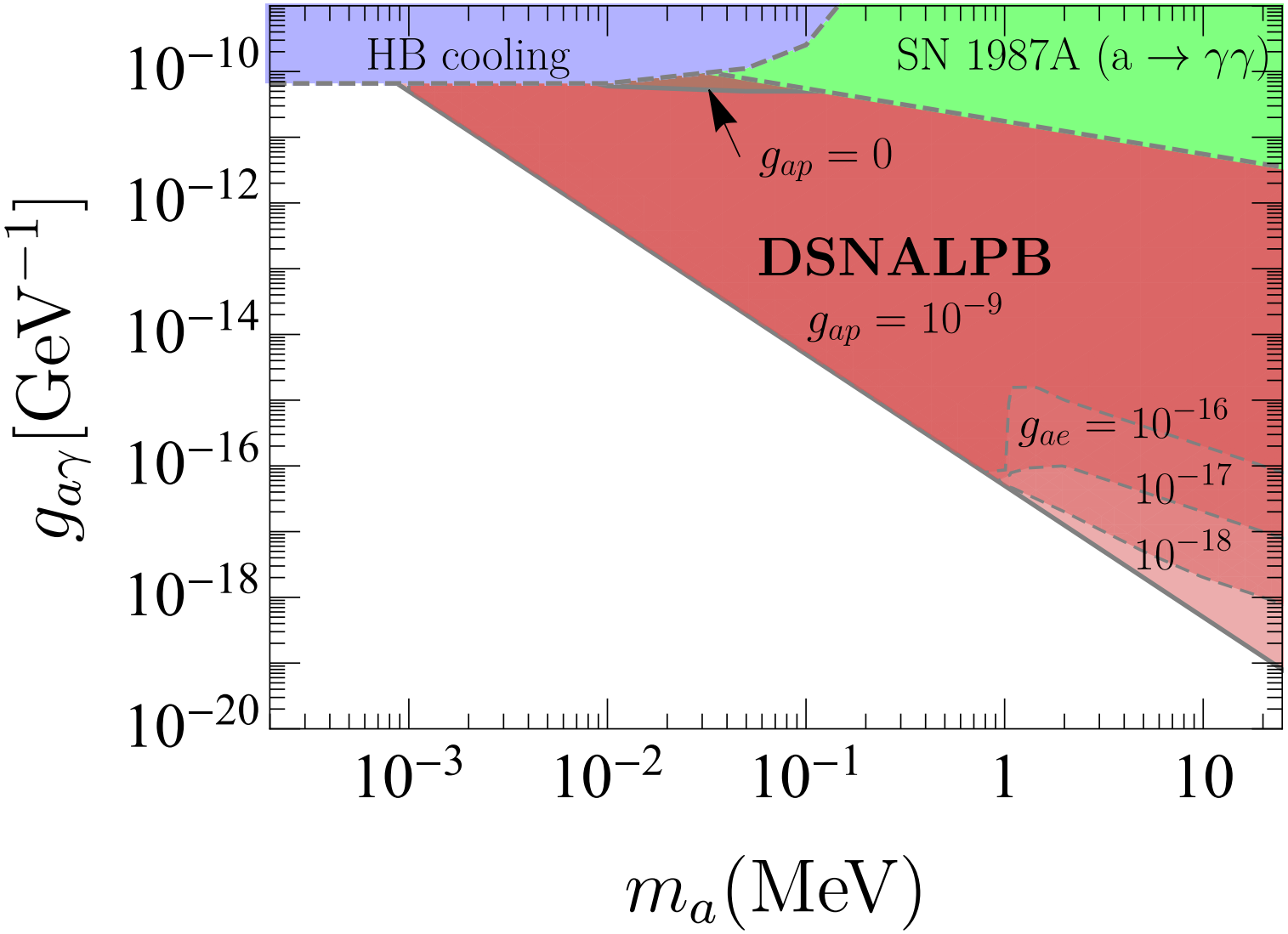
The DSNALPB produces a $\gamma-$ray background by decaying ALPs constrained by Fermi-LAT and COMPTEL ($m_a = 5\,\text{keV}$ in the plot)

S. C. Kappadath, PhD thesis (U. of New Hampshire, 1998)



Coupling with electrons

If ALPs decay into e^+e^-, the $\gamma-$ray background is reduced



Conclusions

- We computed the DSNALPB for ALPs coupled to photons and nucleons
- Bounds for $m_a < 10^{-7}$ eV related to conversion in the Galactic magnetic field
- Bounds for $m_a >$ keV related to decay into photons
- The bound could be improved by eASTROGAM in the high mass region

THANKS FOR YOUR ATTENTION