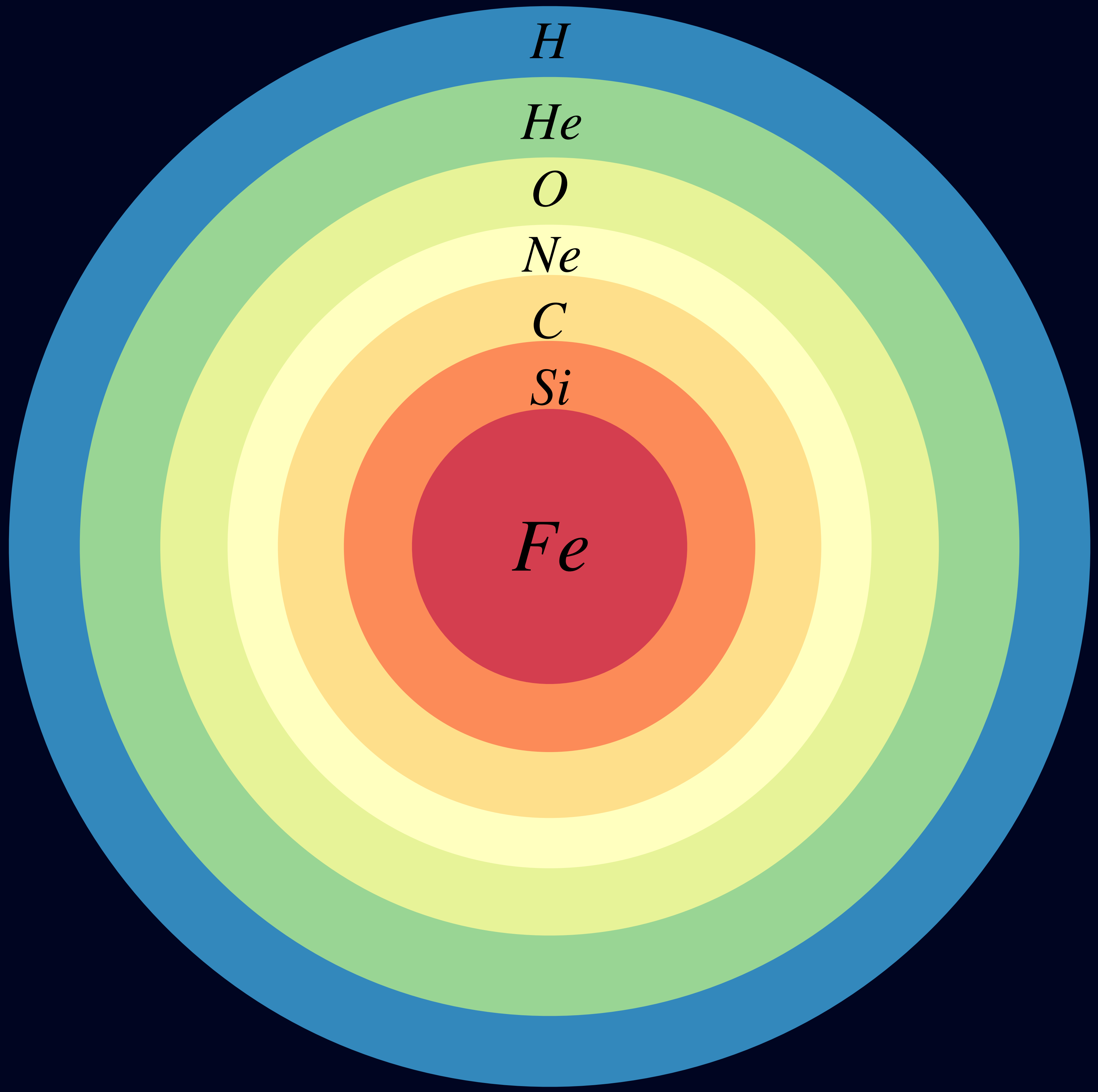
IDM, June 1^{st} 2026

Detecting light axions from nearby supernovae

Francesca Lecce
(University of Bari, INFN Bari)

Based on:
arXiv:2512.04185 with A. Lella, G. Lucente, M. Giannotti, A. Mirizzi

Core collapse Supernovae

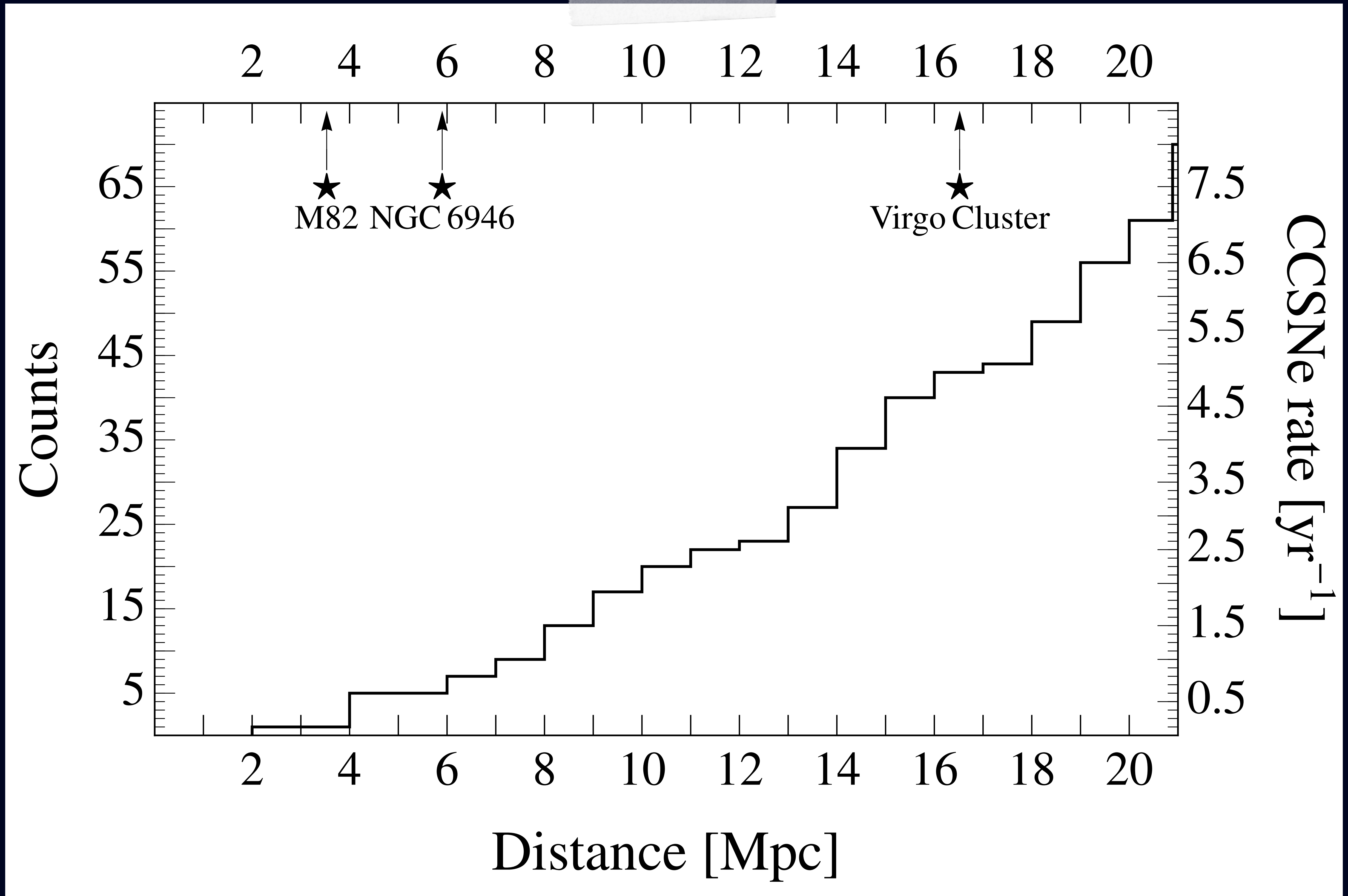


1. Thermal MeV neutrinos
2. Electromagnetic radiation
3. Gravitational waves $(10^2 - 10^3\,\mathrm{Hz})$

Galactic SNe rate: 1-2 per century

Nearby galaxies

How often do Core-Collapse Supernovae occur?



2008-2025

Meyer et al. (2020), arXiv:2006.06722

Galactic SNe rate: 1-2 per century

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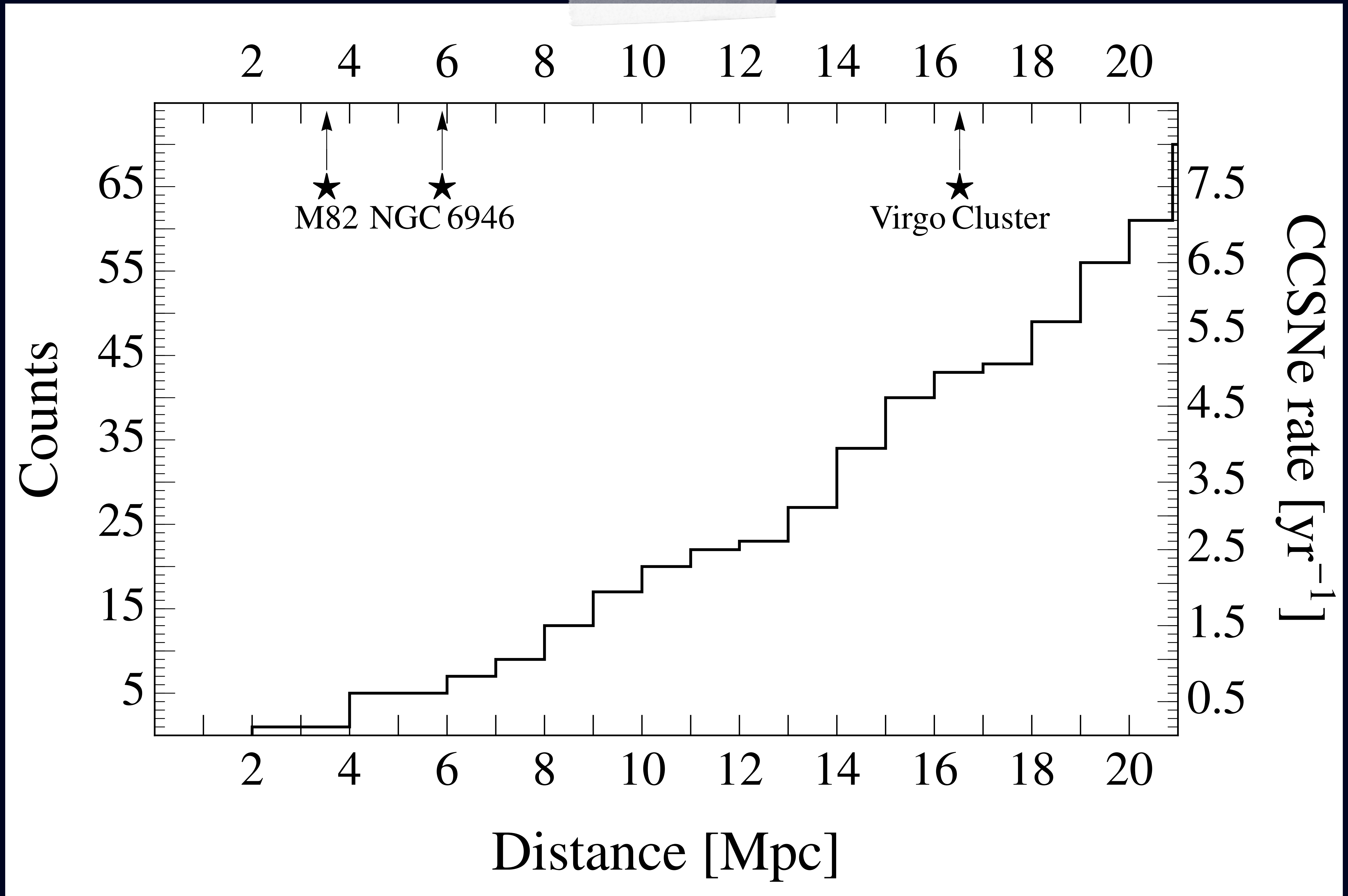
Kennicutt et al. (2008), arXiv:0807.2035

Tully et al. (2013), arXiv:1307.7213

Nearby galaxies

How often do Core-Collapse Supernovae occur?



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Galactic SNe rate: 1-2 per century

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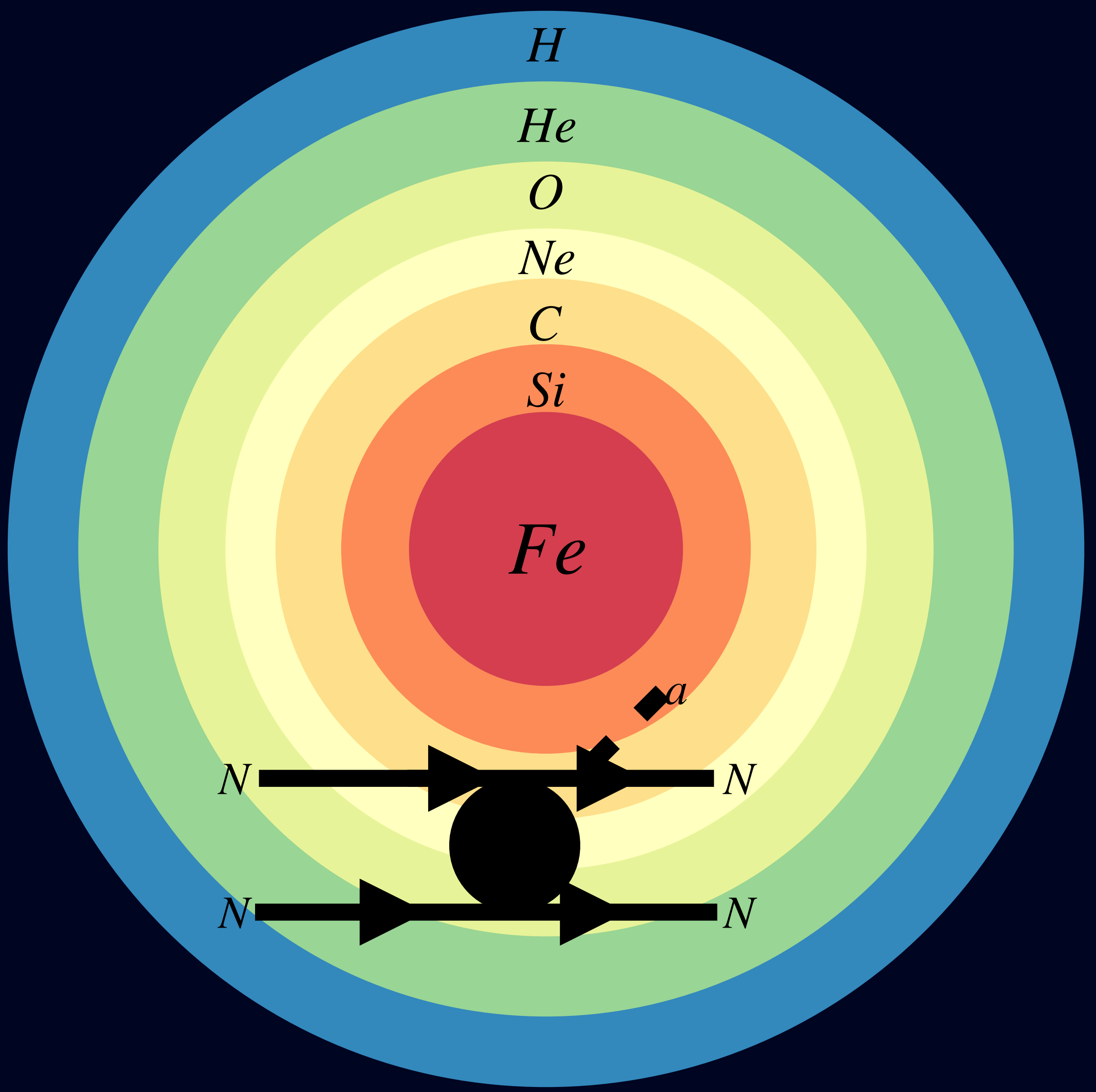
Within 20 Mpc we could see 7 CCSNe per year!

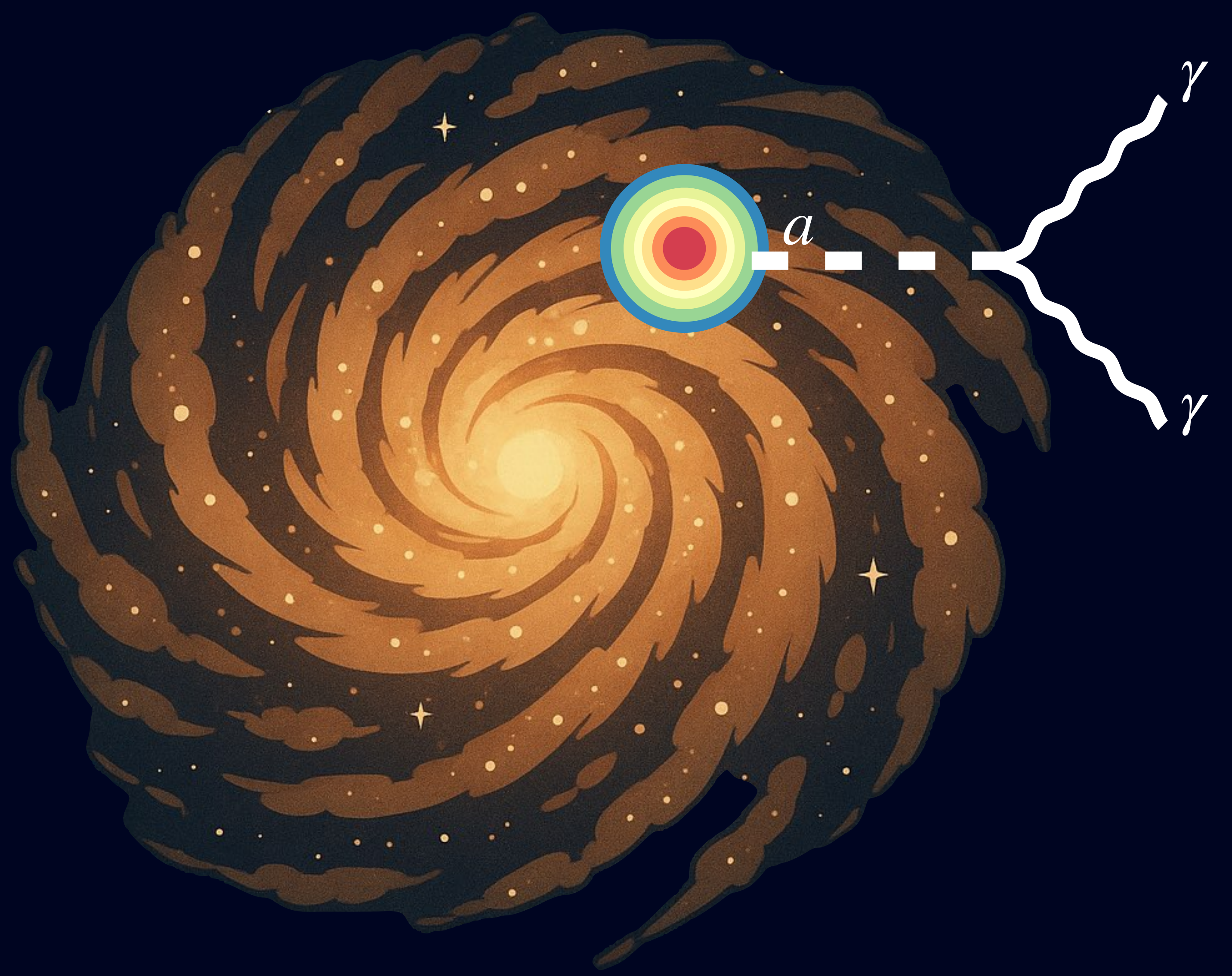
Nearby galaxies

From Supernova Axions to Gamma-Ray Signals

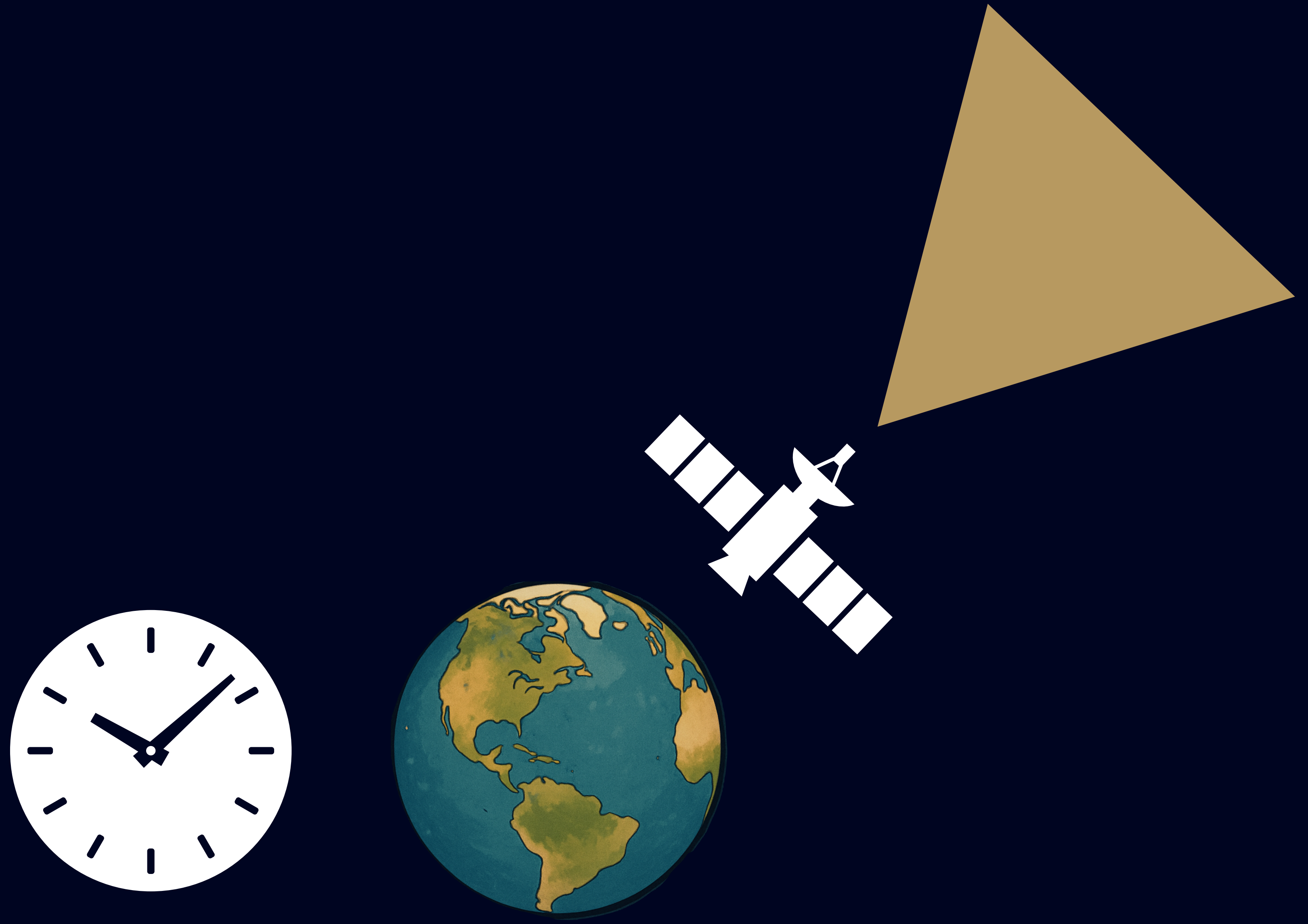


Production in CCSNe

Carenza et al. (2019), arXiv:1906.11844



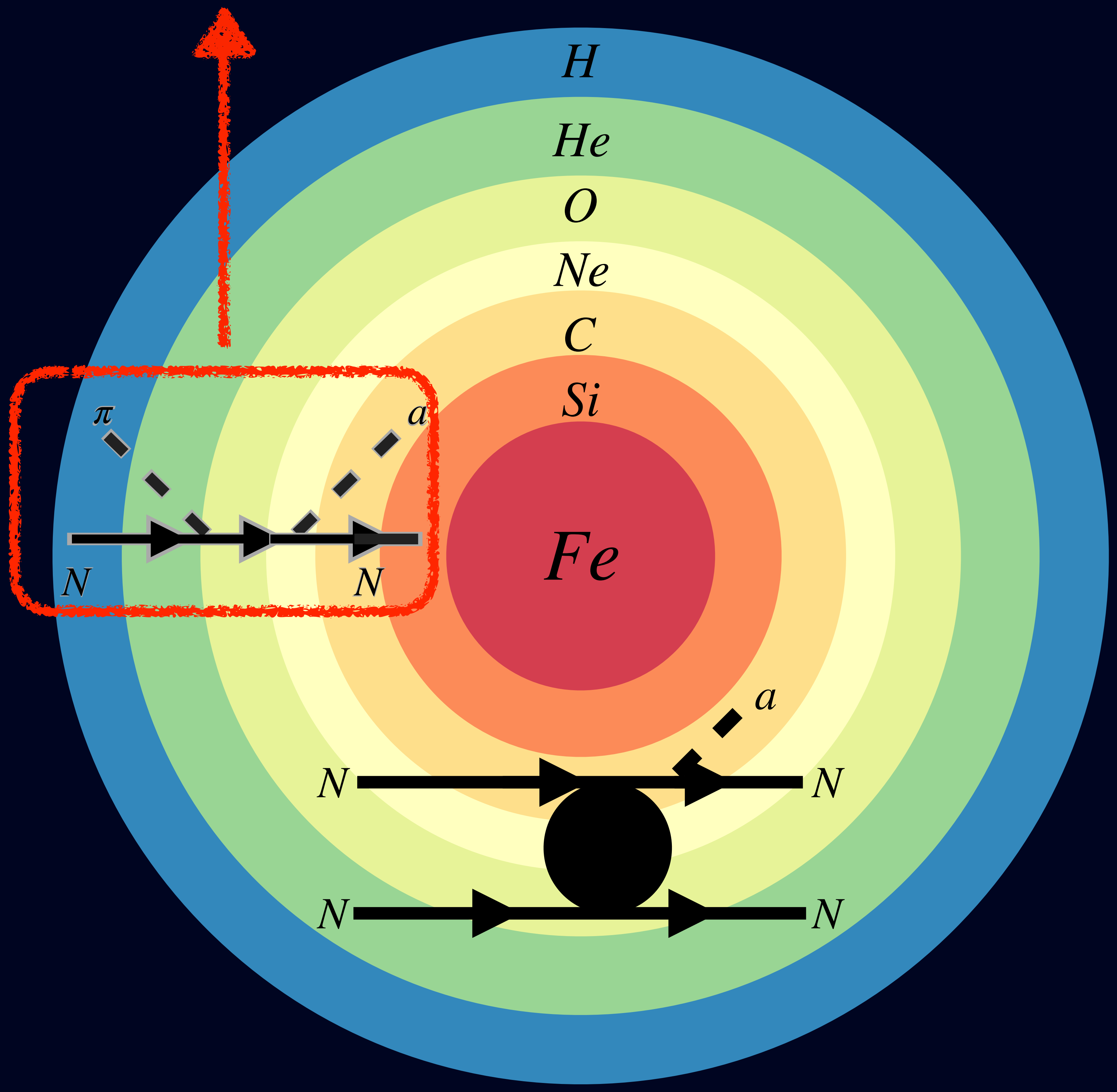
Conversion in the host magnetic field

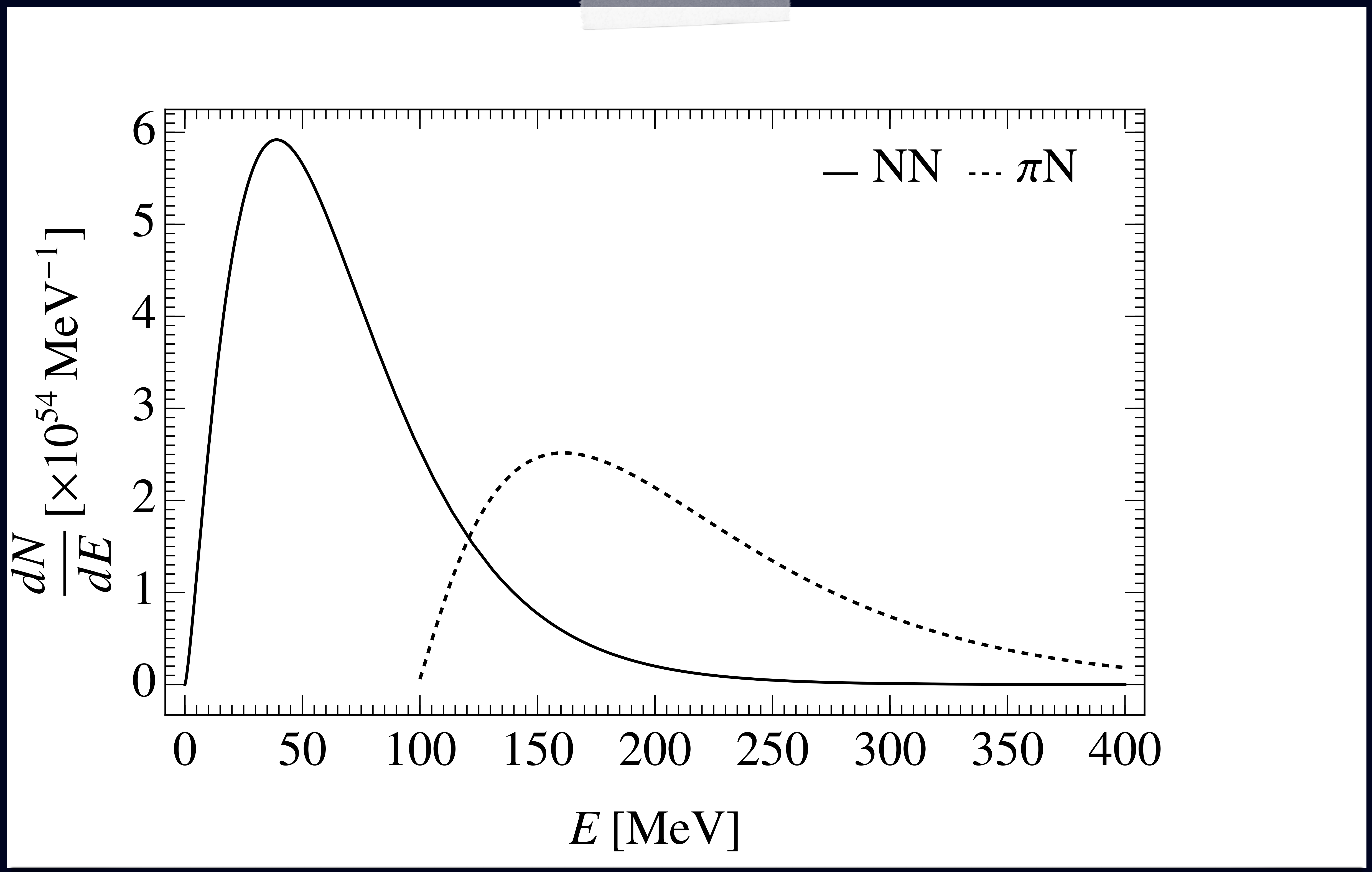


Time tagged detection of the ALP-photon induced signal

Nearby galaxies
ALP Production

Not included Fiorillo et al. (2025), arXiv:2509.13322

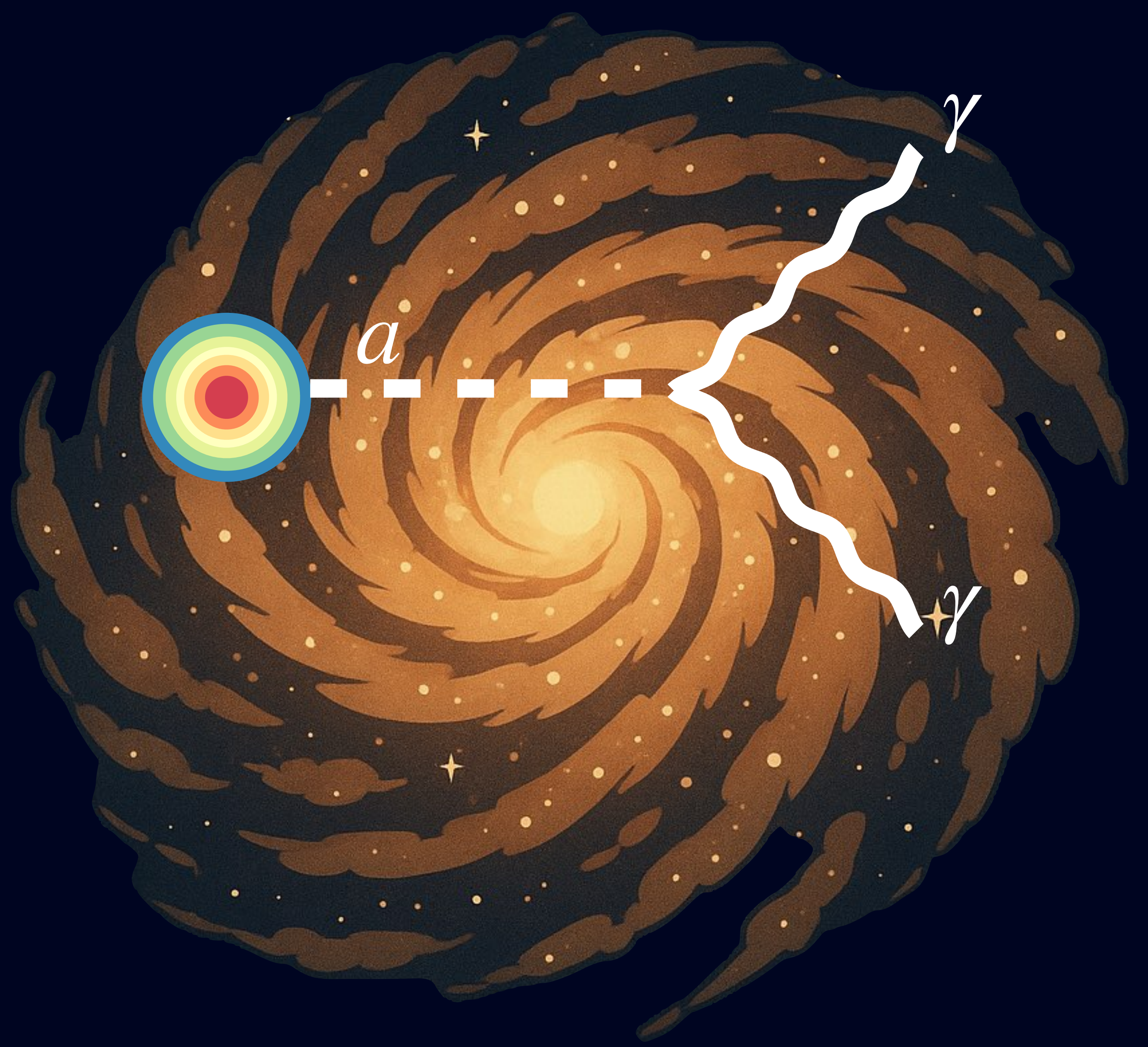




ALP production spectra from SFHo − s18.8 model

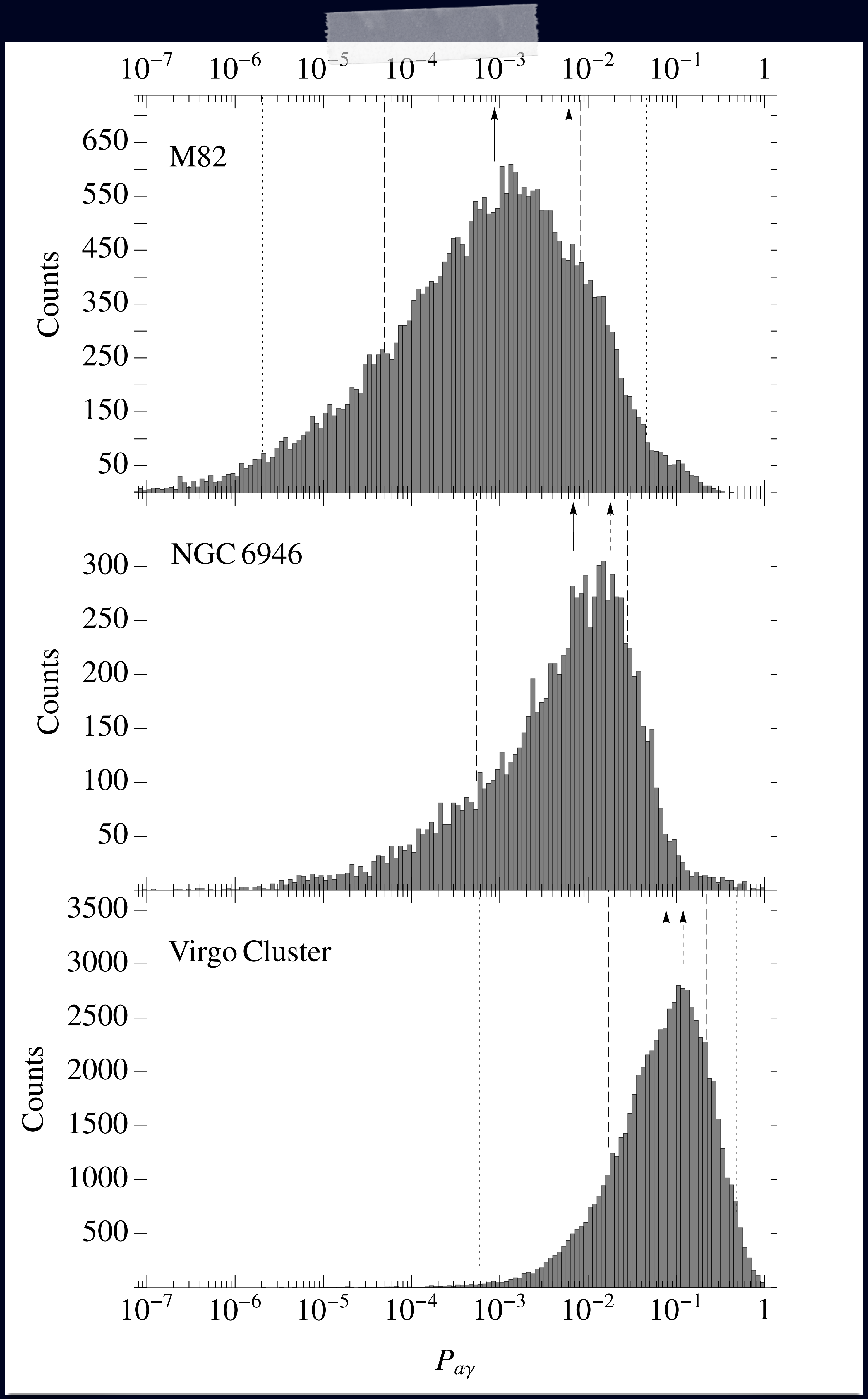
Nearby galaxies

ALP-photon conversion



IllustrisTNG

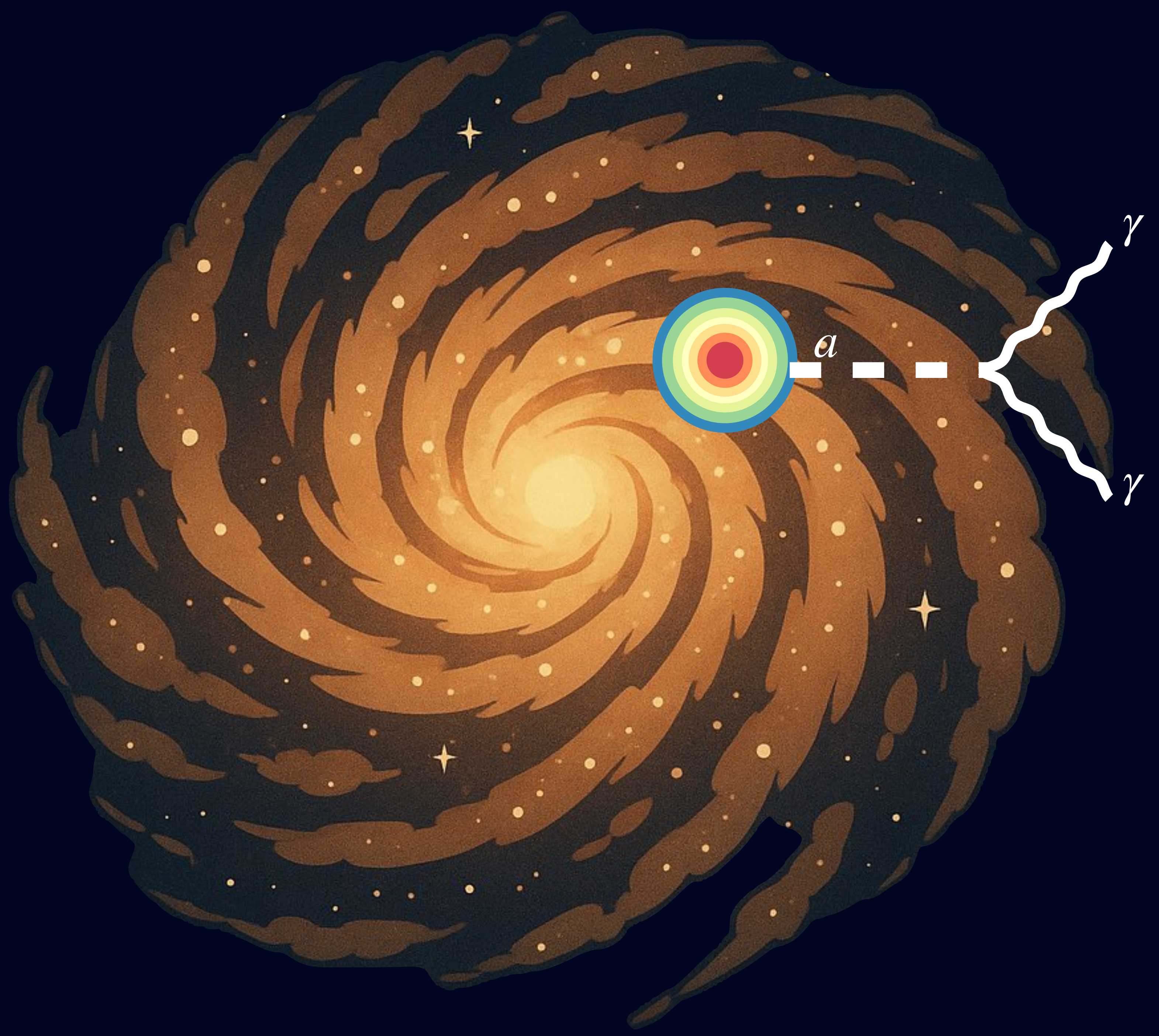
https://www.illustris-project.org



Distribution of conversion probabilities along 10^4 random directions in the various subhalo for host environments

Nearby galaxies

ALP-photon conversion



Host Environment	Observed SNe (2008-2025)	$\langle B_T \rangle$ (μG)	L (kpc)	d (Mpc)	$P_{a\gamma}$	$g_{ap} \times g_{a\gamma}$ ($\times 10^{-24}$ GeV^{-1})
M82	SN 2008iz	1.4	13.9	3.5	8.8×10^{-4}	2.2
NGC 6946	SN 2008S,SN 2017eaw	5.8	9.3	5.9	6.8×10^{-3}	1.3
Virgo Cluster	SN 2012cc, SN 2014L, SN 2020oi, SN 2019ehk	1.1	10^3	16.4	7.6×10^{-2}	1.1

$$P_{a\gamma} \simeq \left(\frac{1}{2} g_{a\gamma} < B_T > L\right)^2$$

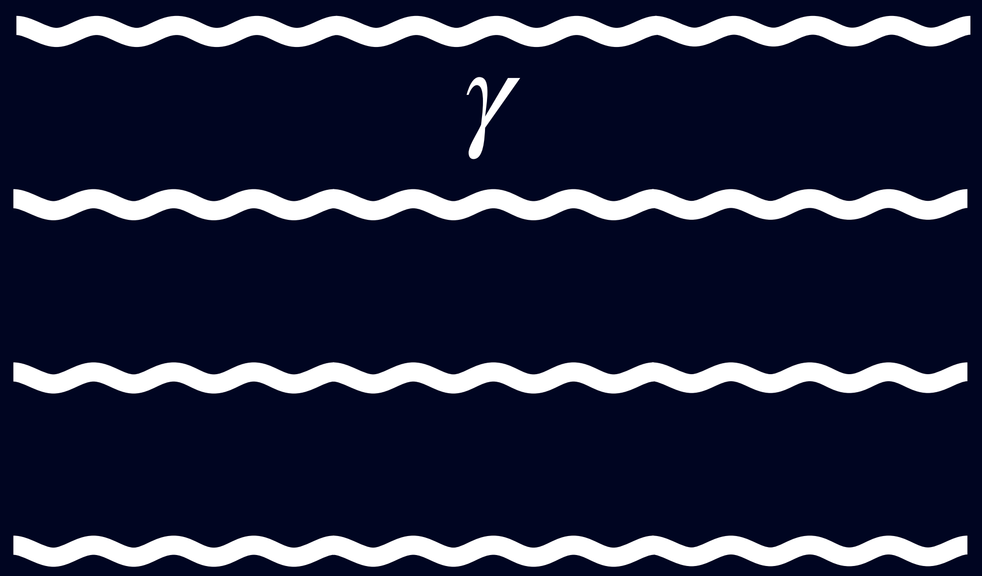
Calore et al. (2024), arXiv:2306.03925

$< B_T >_{MW} \approx 0.5 \mu G$ and $L \approx 20$ kpc

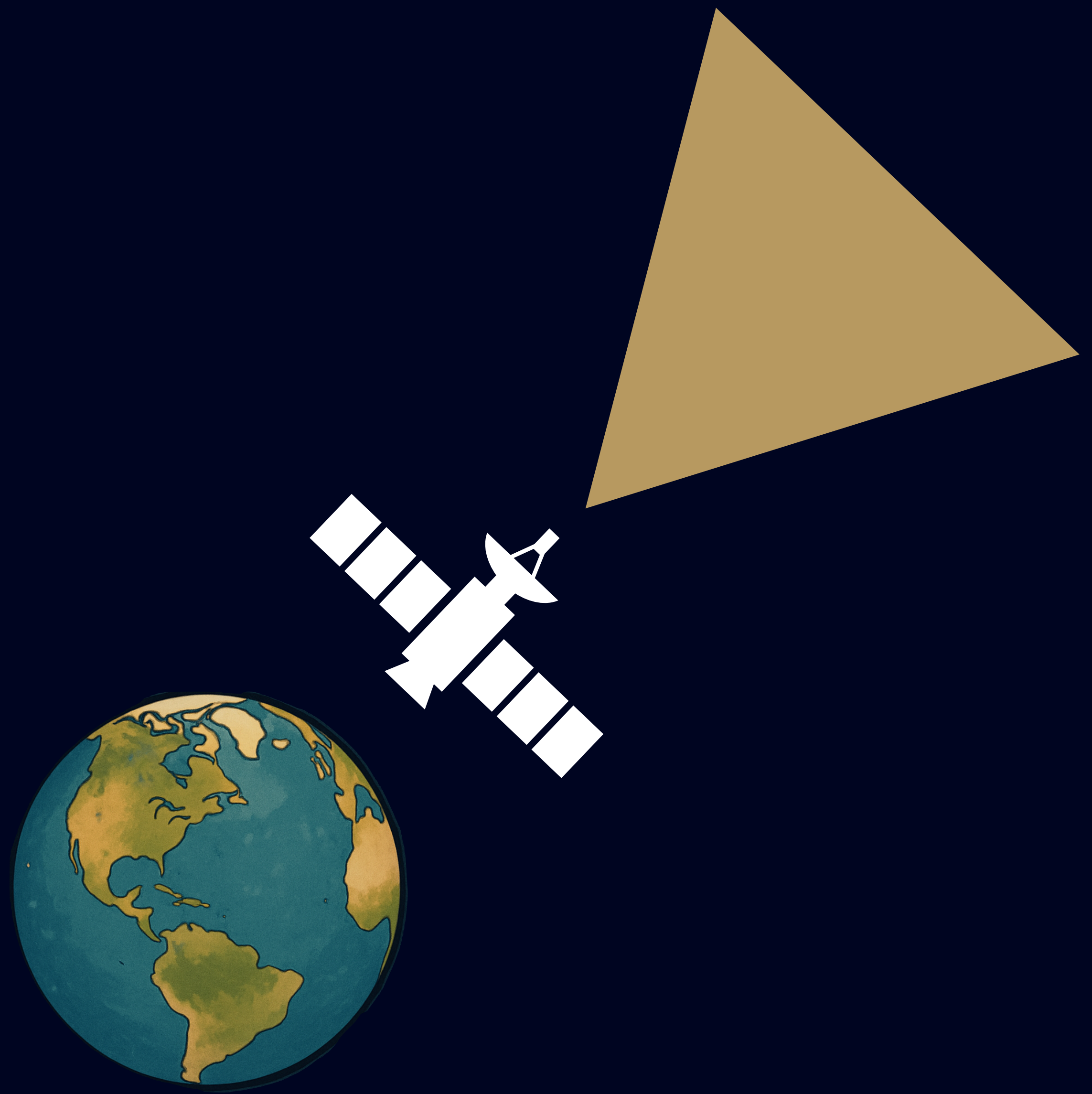
$P_{a\gamma} \sim 10^{-5} \quad g_{a\gamma} = 10^{-12}\,\mathrm{GeV}^{-1}$

Detection signatures

Why timing matters more than sensitivity

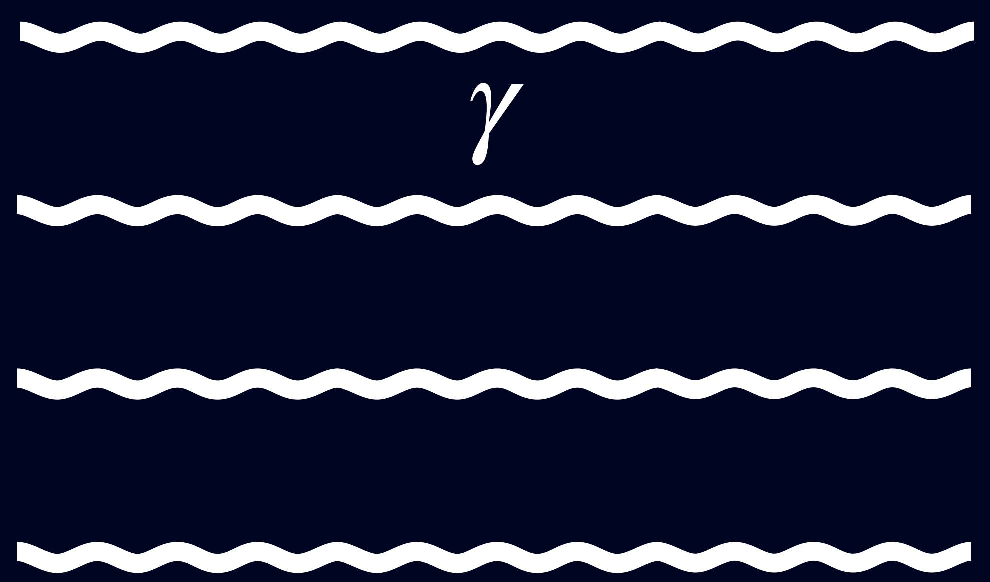


$$\frac{d\phi_\gamma}{dE}(E, L) = \frac{1}{4\pi d^2}\frac{dN}{dE}(E)\, P_{a\gamma}(E, L)$$

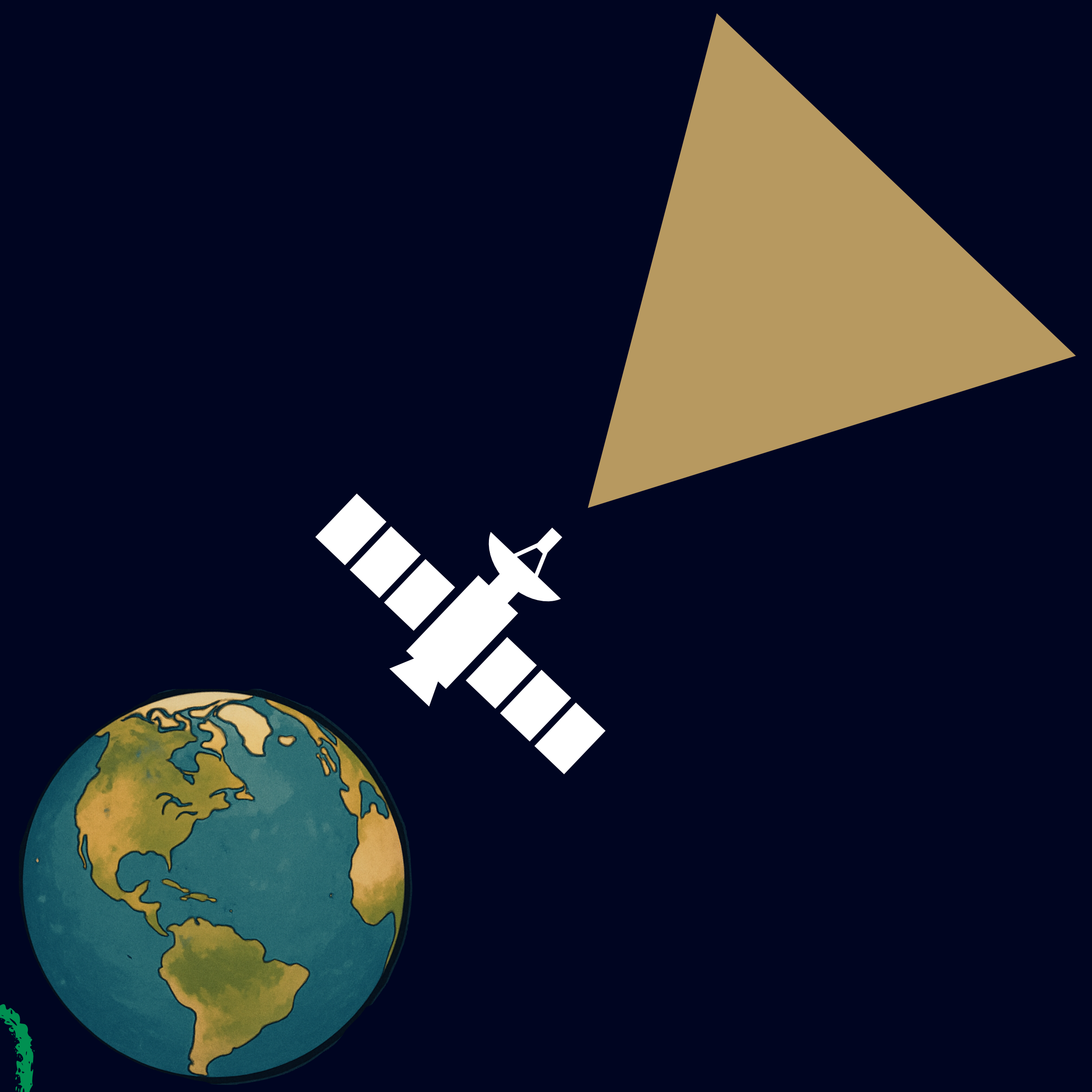


Detection signatures

Why timing matters more than sensitivity



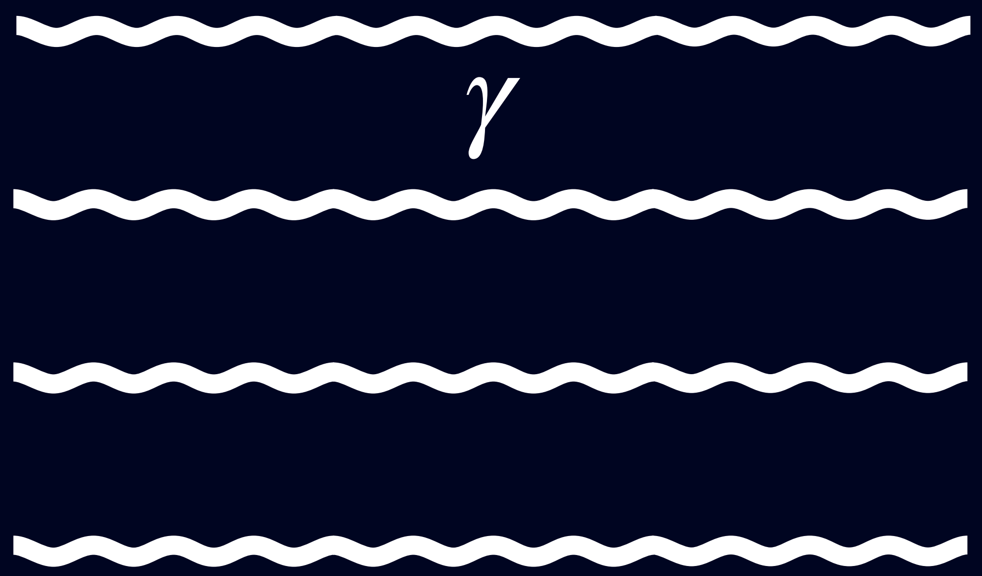
$d \gtrsim$ few Mpc



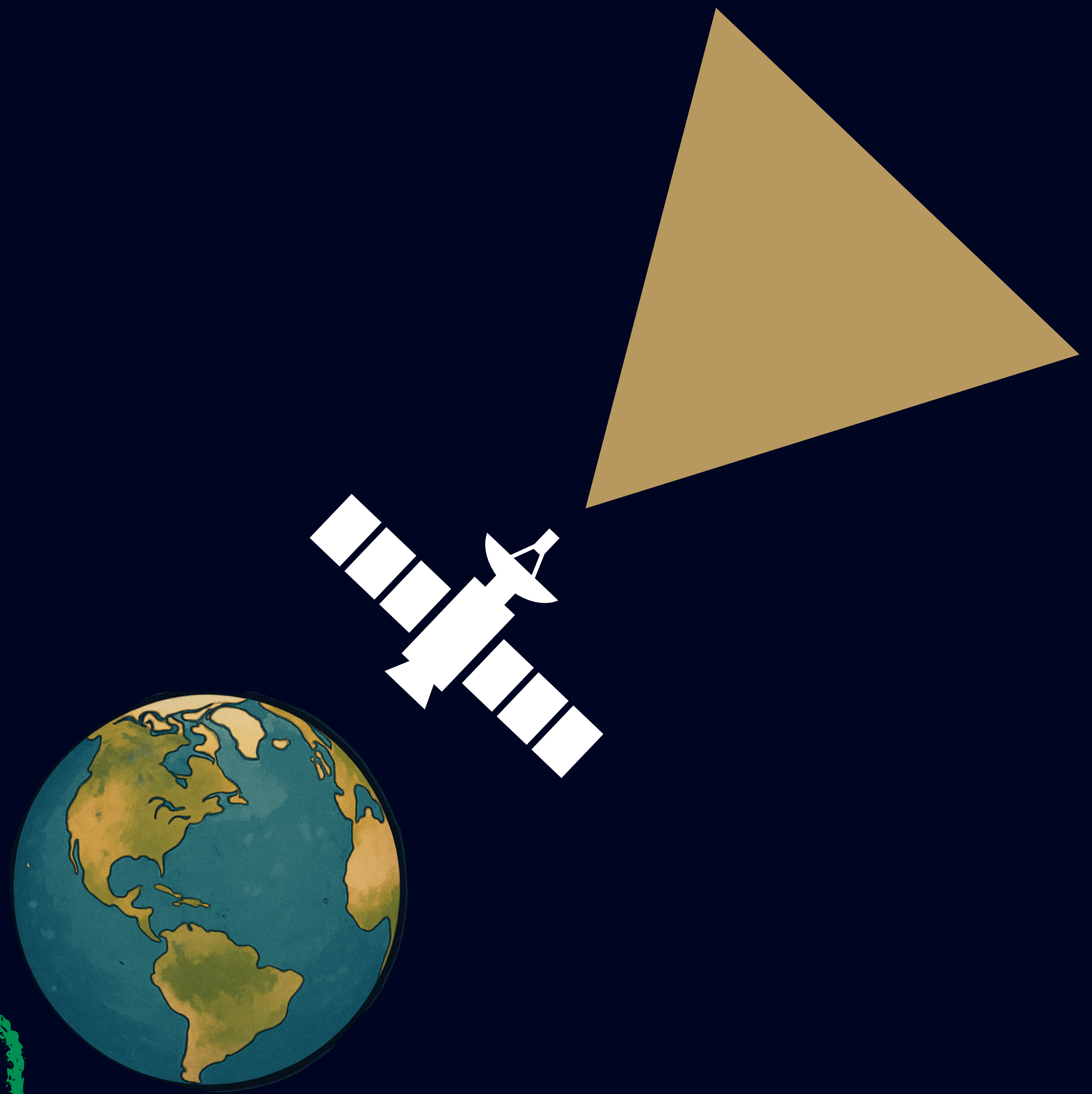
- ⭐ Current optical surveys (ASAS-SN,DLT40) $\Delta t = 1\,\mathrm{d}$
- ⭐ Future optical surveys (LSST) $\Delta t = 1\ \mathrm{h}$
- ⭐ Next-generation deci-hertz Gravitational Wave observatories (DECIGO,BBO) $\Delta t = 10\,\mathrm{s}$

Detection signatures

Why timing matters more than sensitivity



$d \gtrsim \text{few Mpc}$



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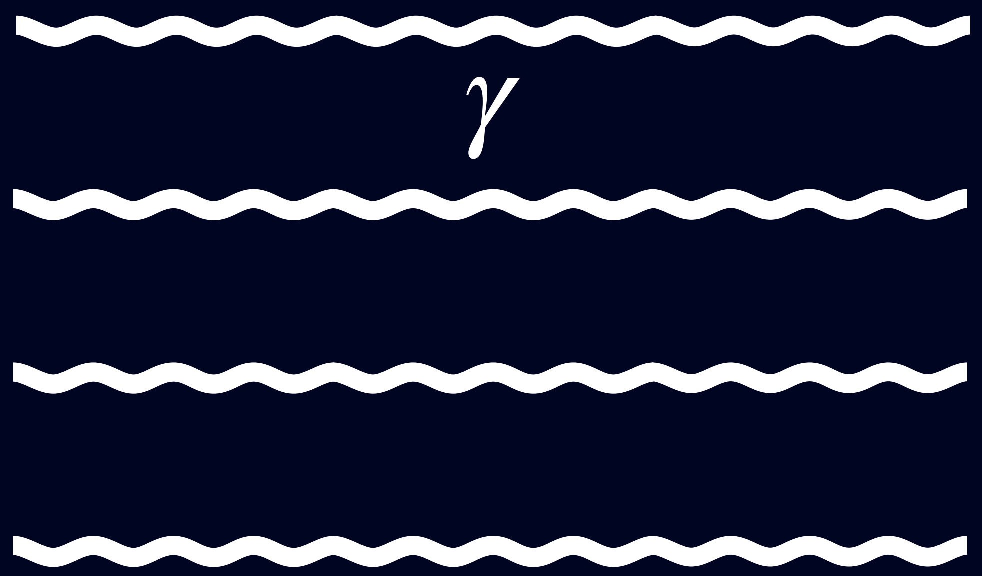
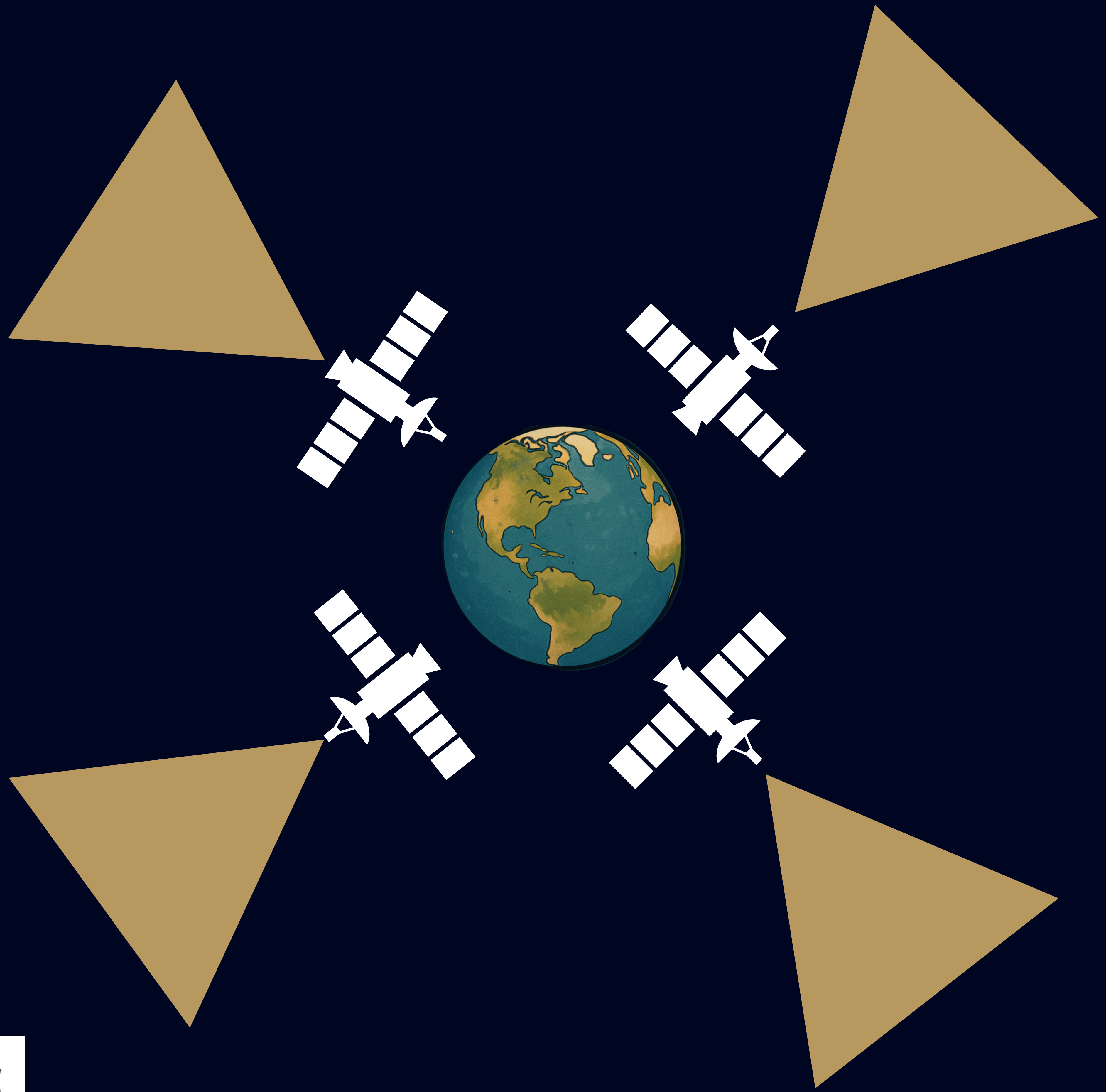
The probability of Fermi-LAT to detect SN at any distance is $20\,\%$.

Detection signatures

Why timing matters more than sensitivity





GALactic AXion Instrument for Supernova (GALAXIS)

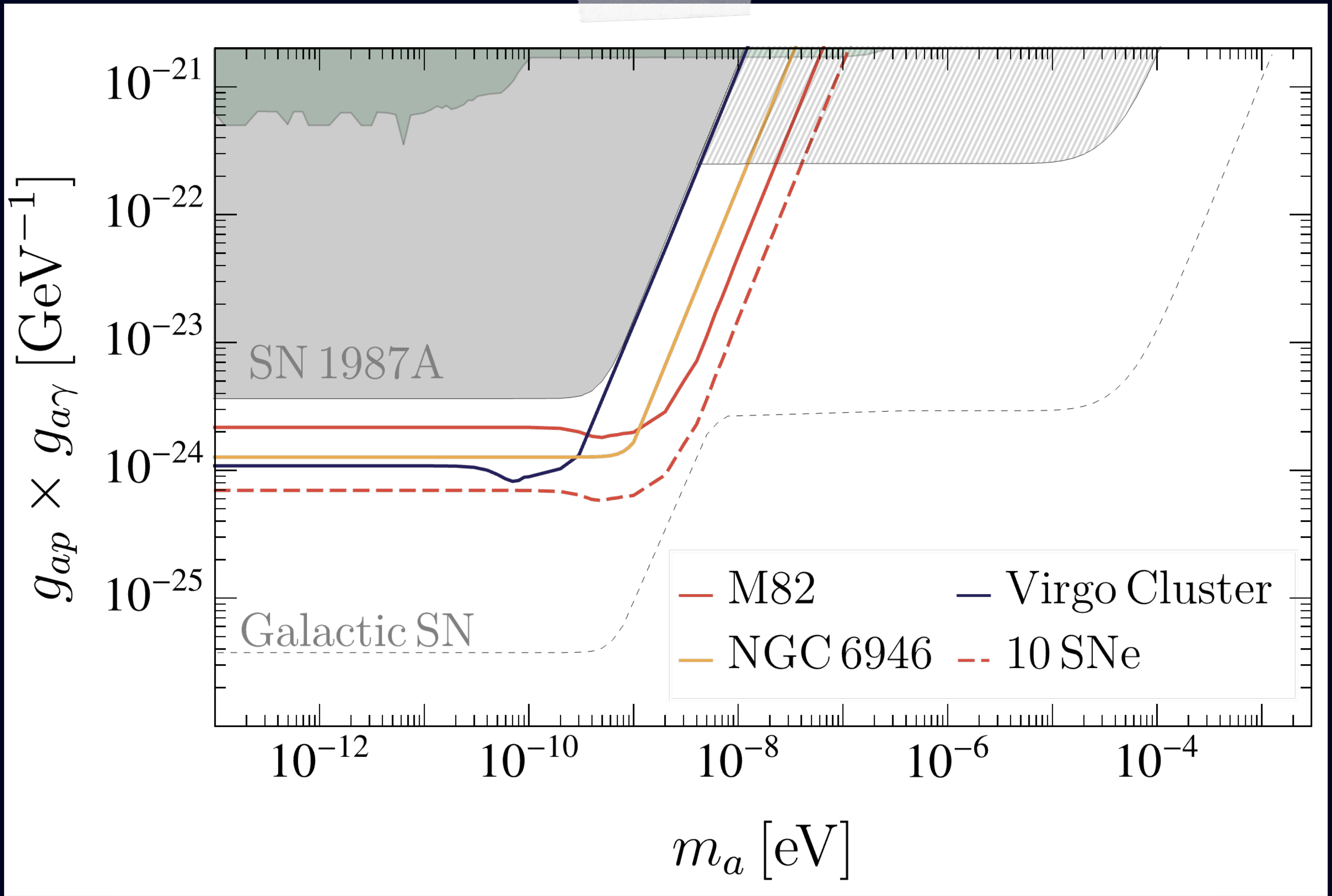
Supernova Axions Convert to Gamma Rays in Magnetic Fields of Progenitor Stars

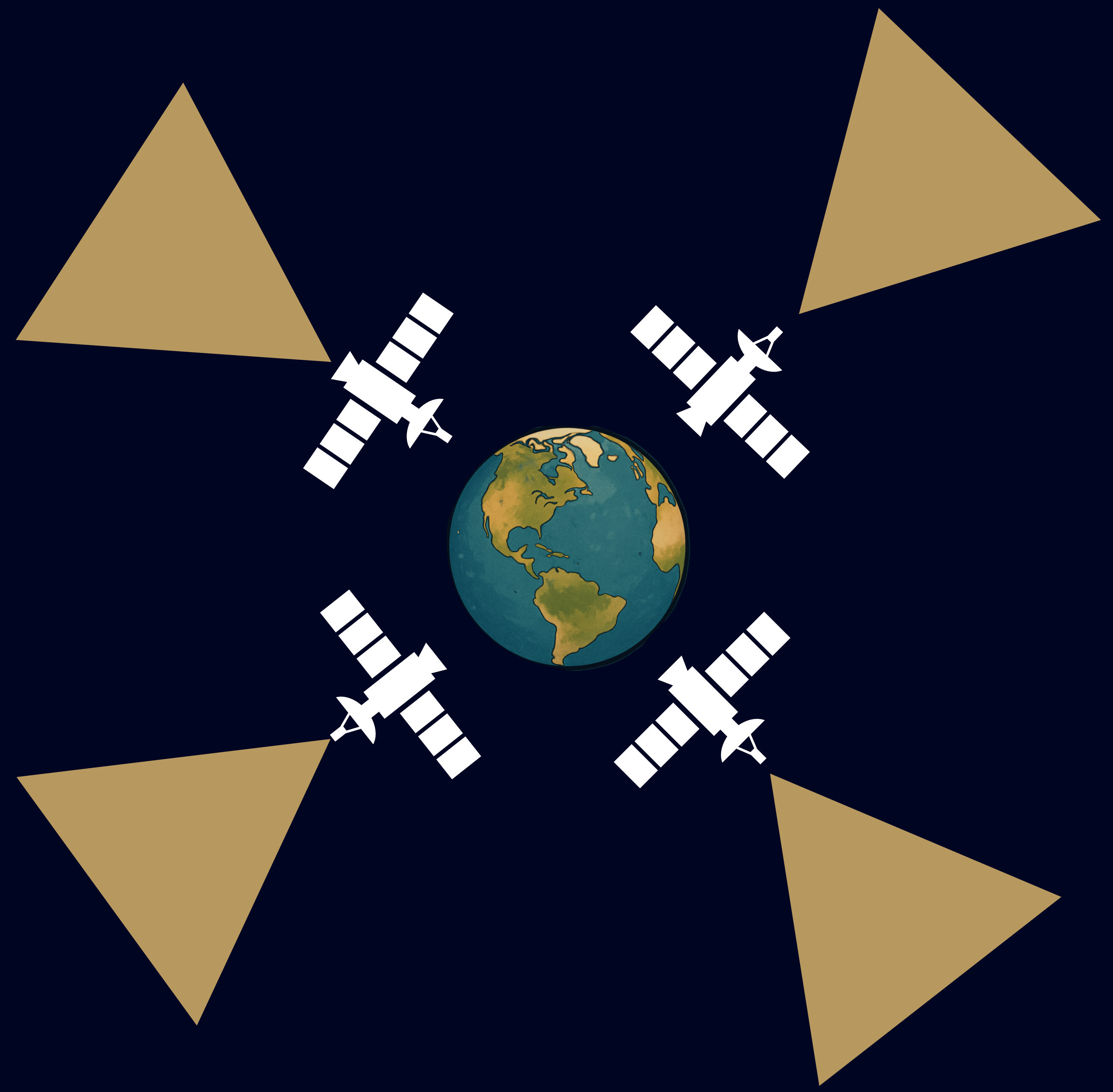
Claudio Andrea Manzari, Yujin Park, Benjamin R. Safdi, and Inbar Savoray

Detection signatures

Sensitivity to Supernova axions

$\Delta t = 10\,\mathrm{s}$





$N_{\mathrm{ev}} > 3$

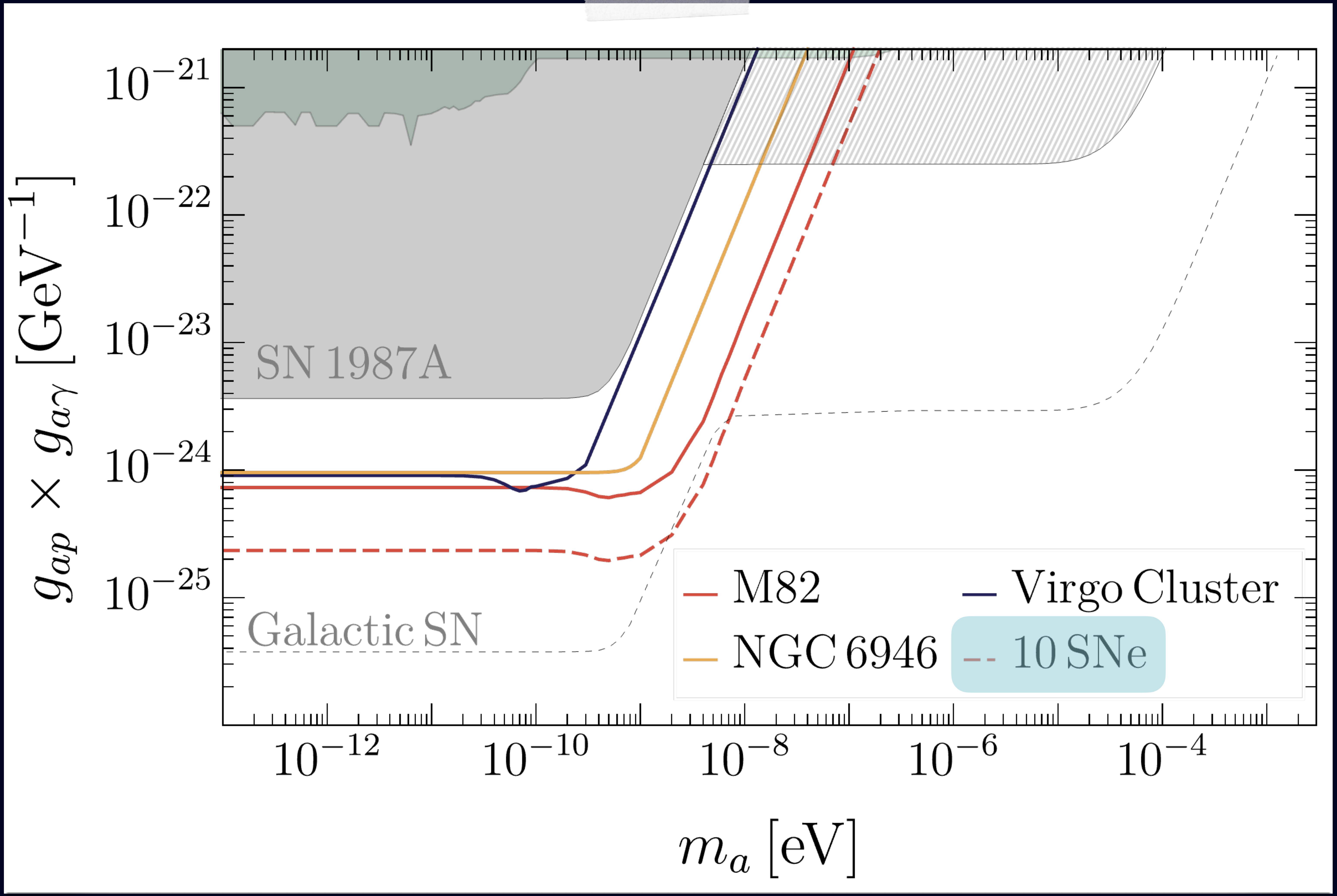
Feldman et al. (1997), arXiv:physics/9711021

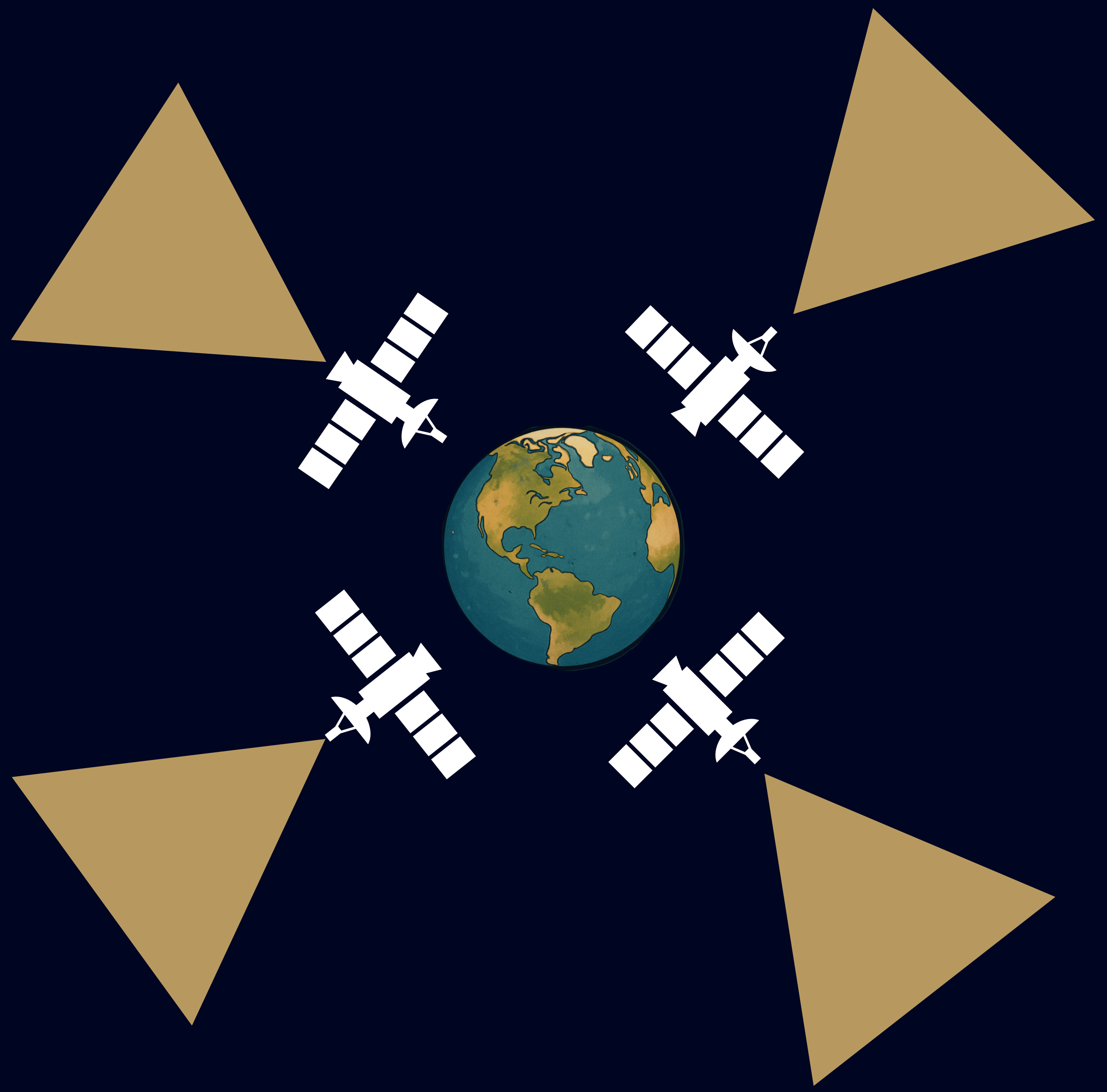
Comparable sensitivities regardless the host environment

Detection signatures

Sensitivity to Supernova axions

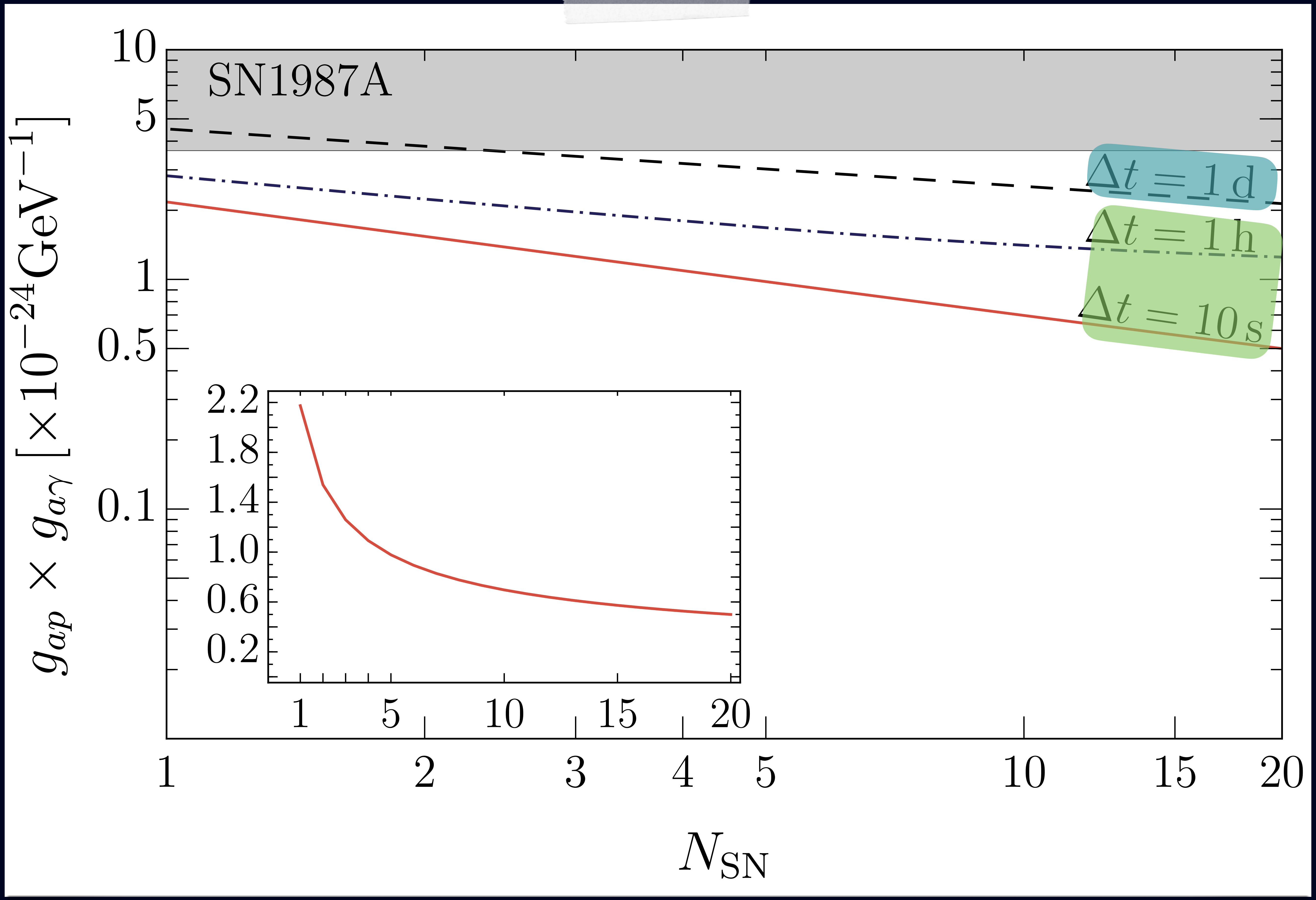
$\Delta t = 10\,\mathrm{s}$

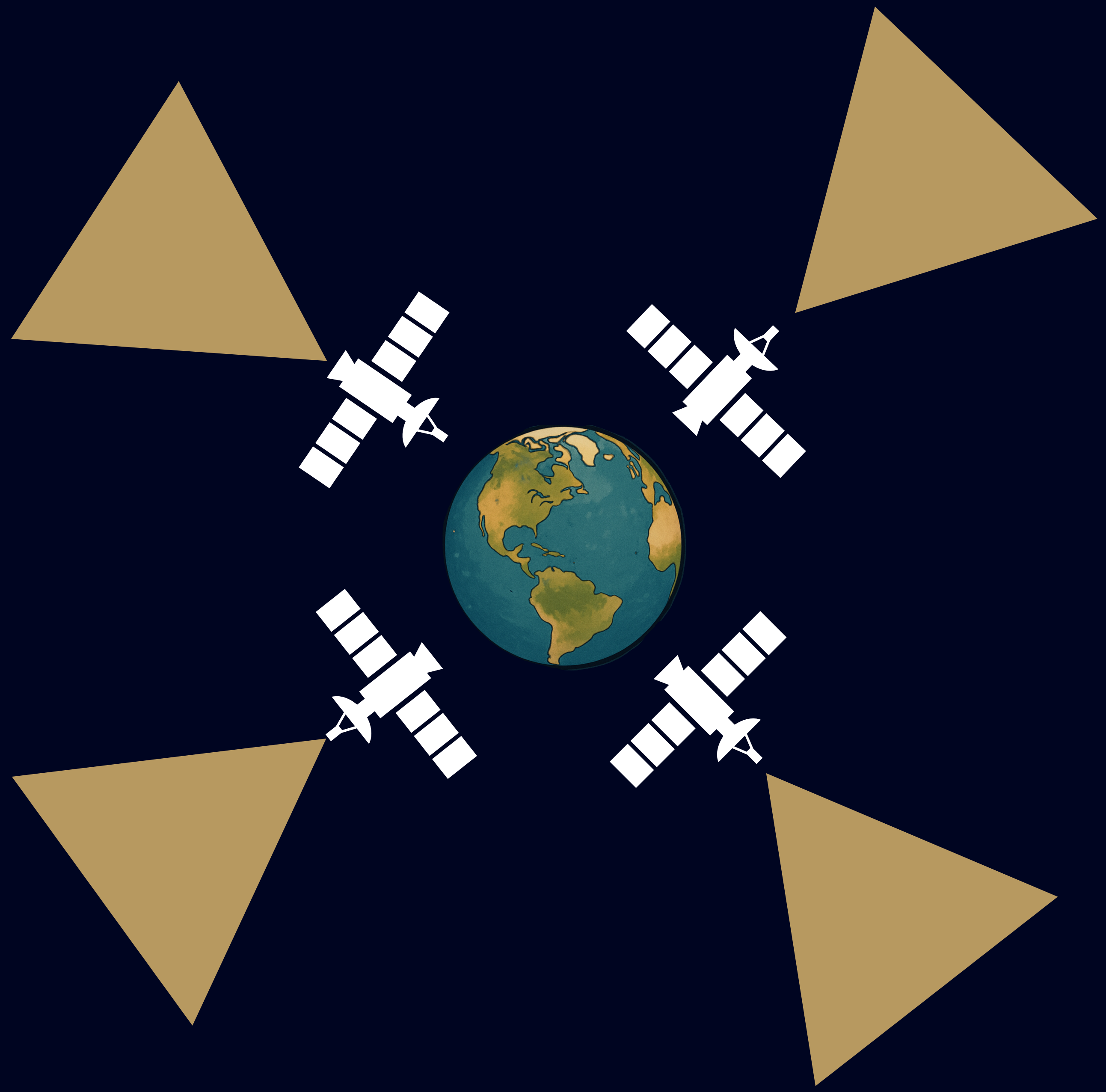




Detection signatures

Sensitivity scaling with stacked supernovae



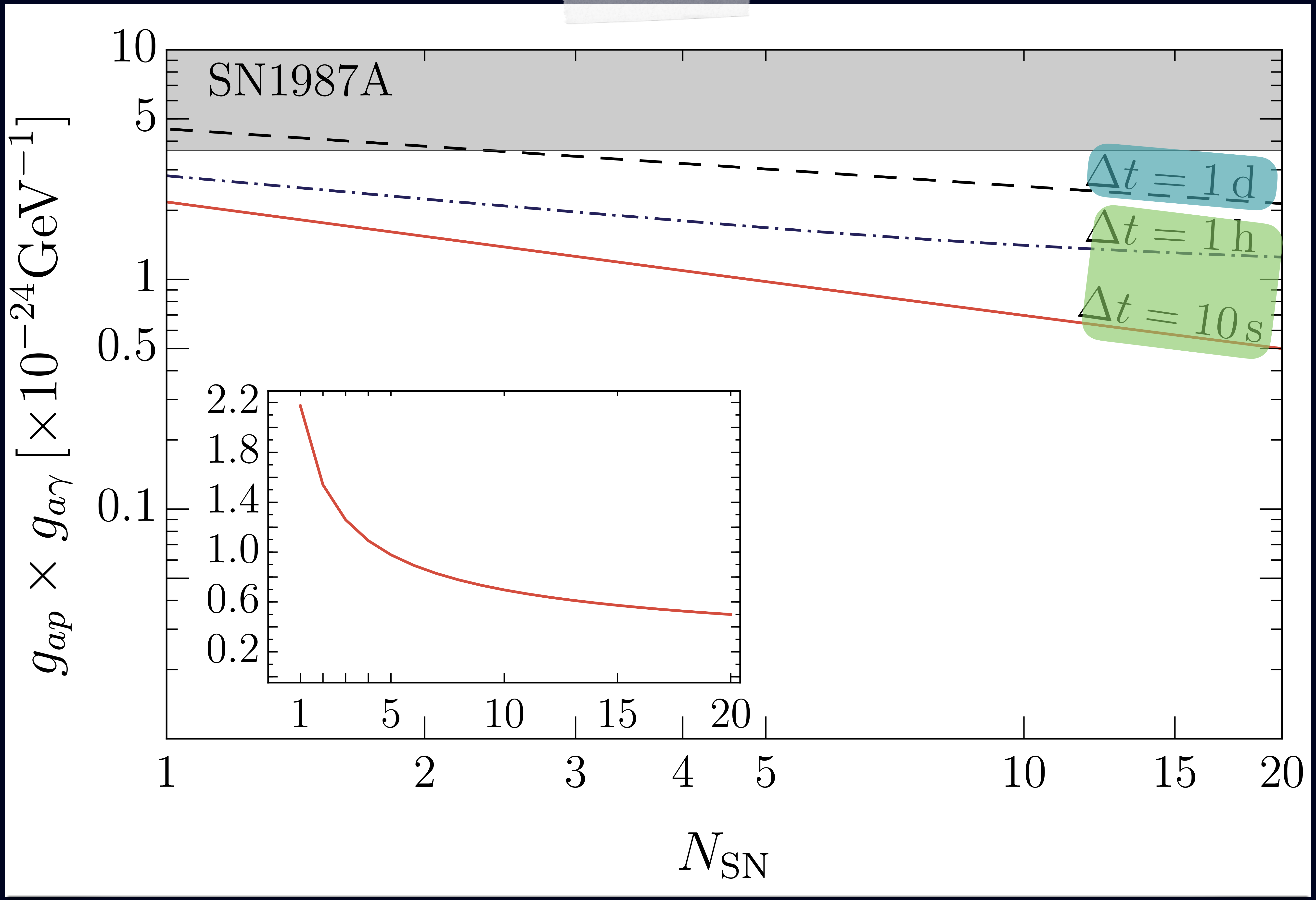


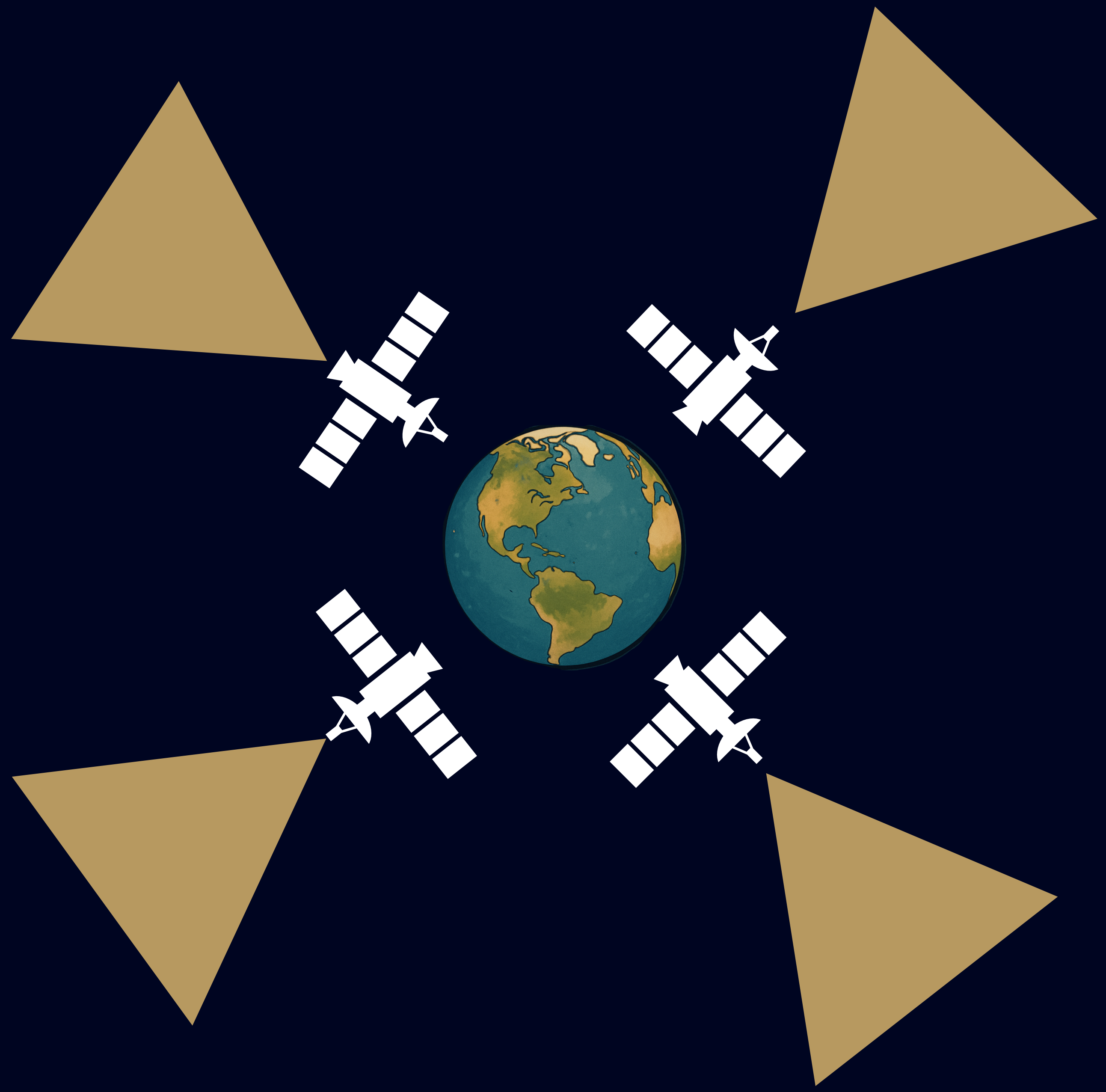
$N_{\rm SN}N_{\rm ev} > 1.64\sqrt{N_{\rm SN}N_{\rm bkg}}$ $\quad g_{\rm ap} \times g_{a\gamma} \propto N_{\rm SN}^{-1/4}$

$N_{\rm SN}N_{\rm ev} > S_{\rm CL}$ $\quad g_{\rm ap} \times g_{a\gamma} \propto N_{\rm SN}^{-1/2}$

Detection signatures

Sensitivity scaling with stacked supernovae





$N_{\mathrm{SN}} N_{\mathrm{ev}} > 1.64\sqrt{N_{\mathrm{SN}} N_{\mathrm{bkg}}}$ $\quad g_{\mathrm{ap}} \times g_{a\gamma} \propto N_{\mathrm{SN}}^{-1/4}$

$N_{\mathrm{SN}} N_{\mathrm{ev}} > S_{\mathrm{CL}}$ $\quad g_{\mathrm{ap}} \times g_{a\gamma} \propto N_{\mathrm{SN}}^{-1/2}$

We just need 10 SNe

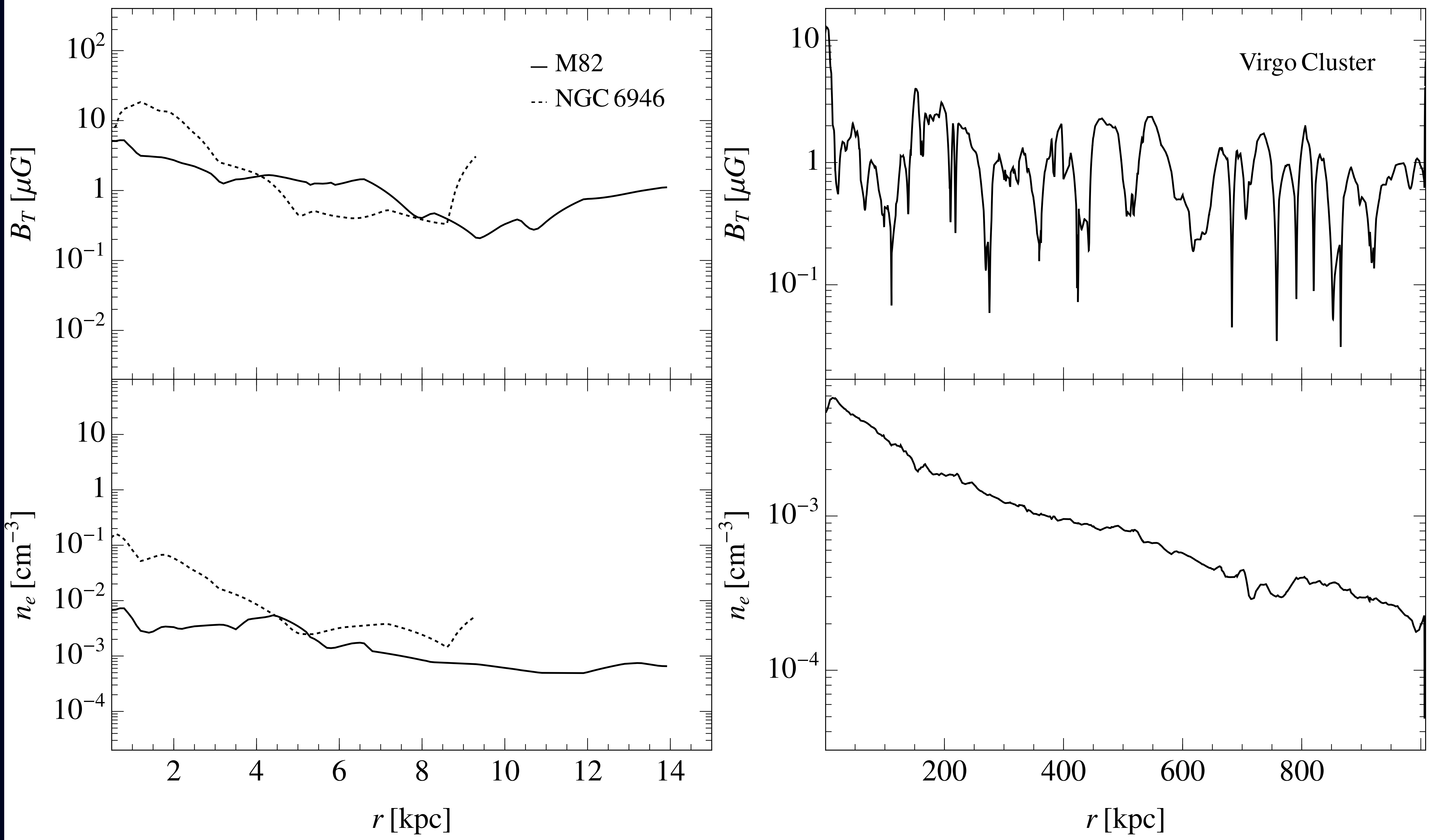
The Milky Way may be quiet, but the Universe is not , we just have to look up.

Francesca Lecce, June 1^{st} 2026

francesca.lecce@ba.infn.it

Nearby galaxies

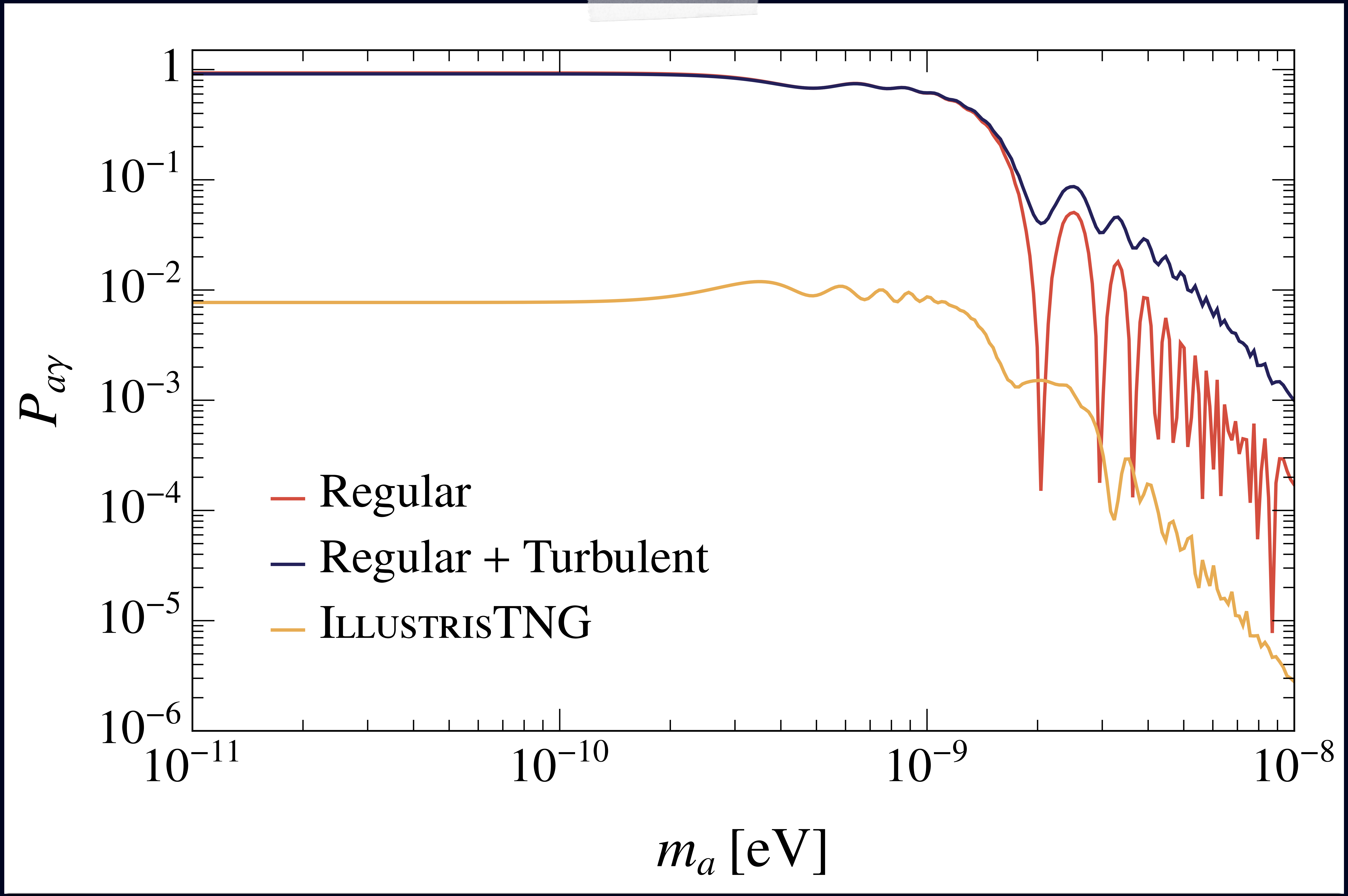
Magnetic field and n_e



Nearby galaxies

M82 models

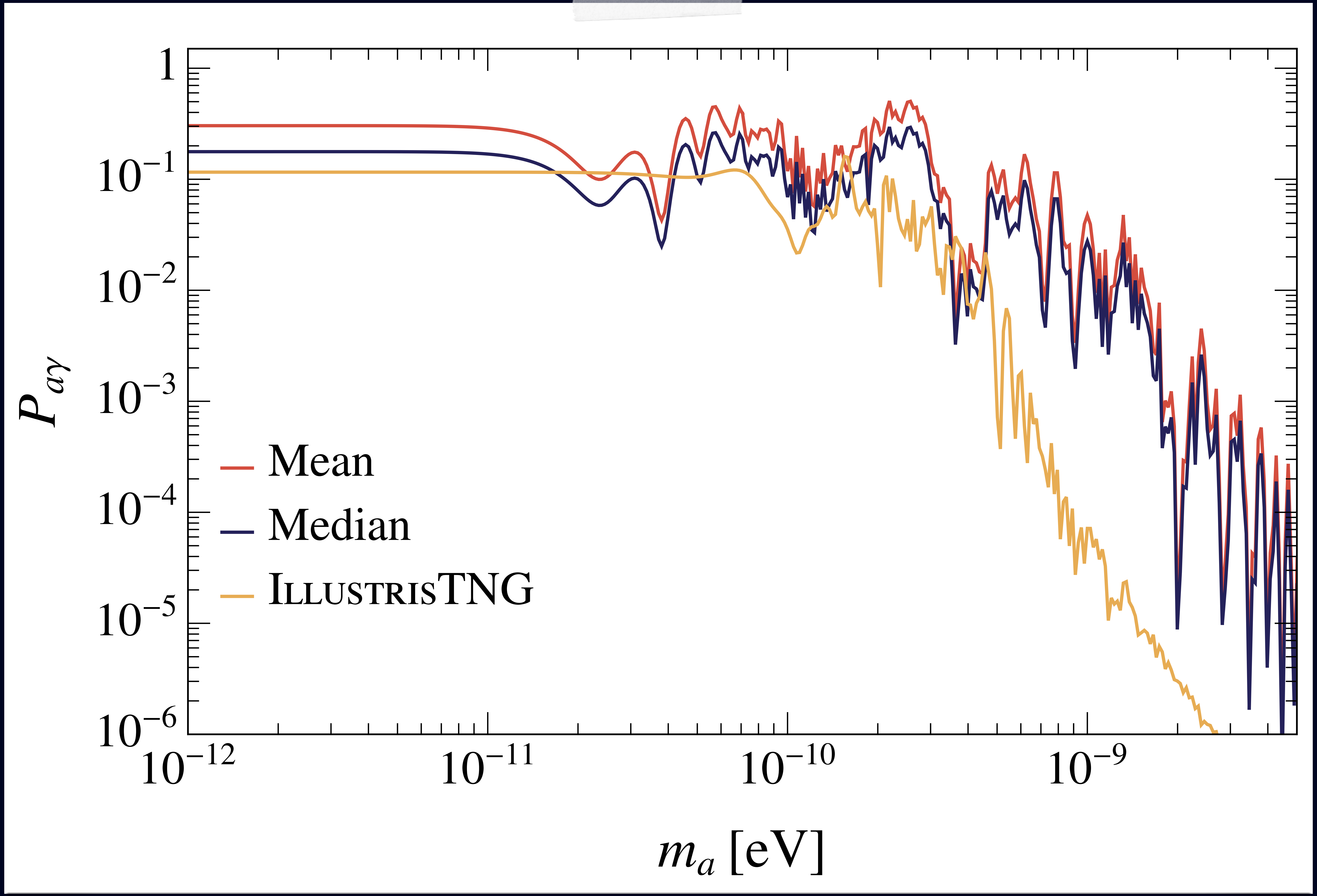
Lopez-Rodriguez (2021), arXiv:2102.03362



Nearby galaxies

Virgo Clusters models

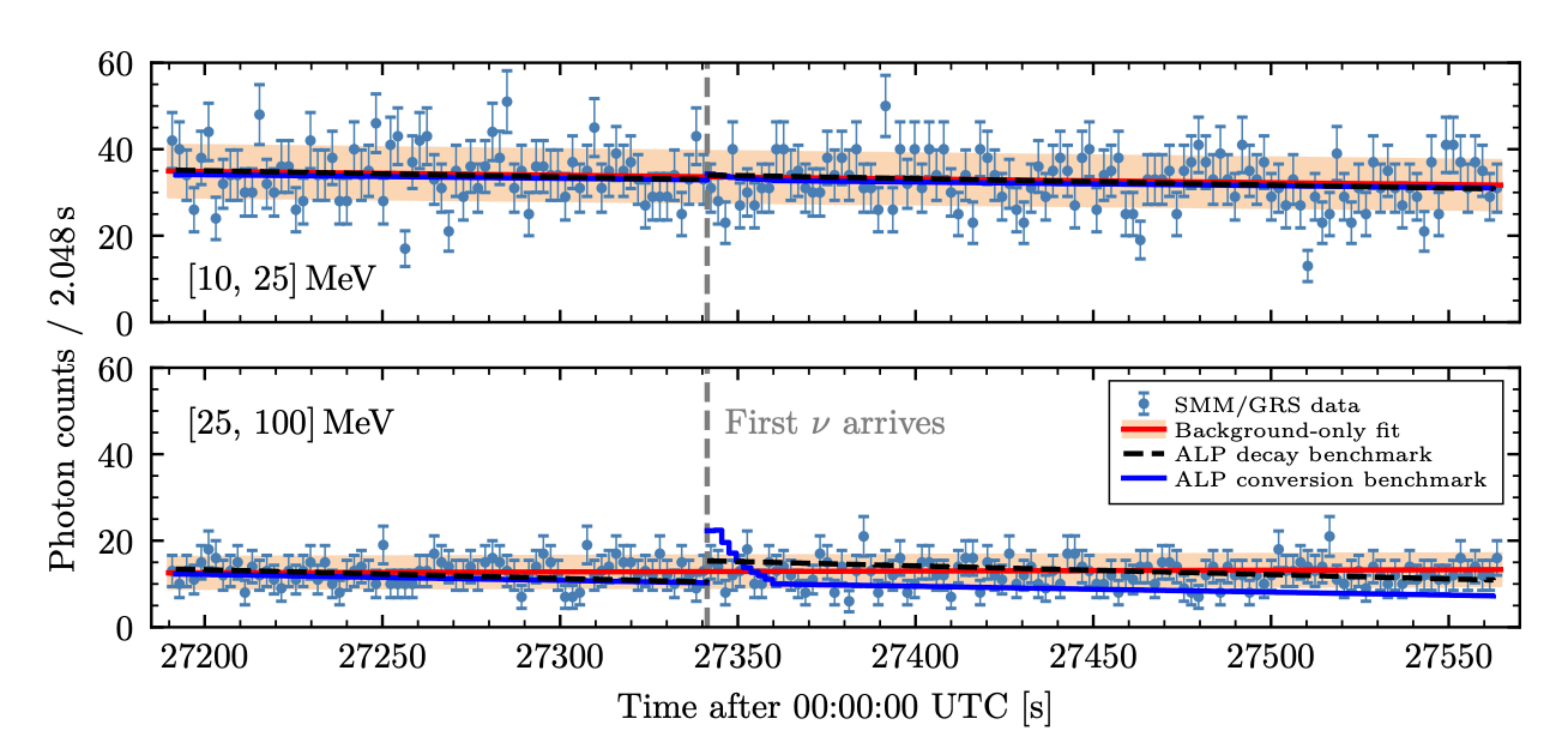
Marsh (2017), arXiv:1703.07354



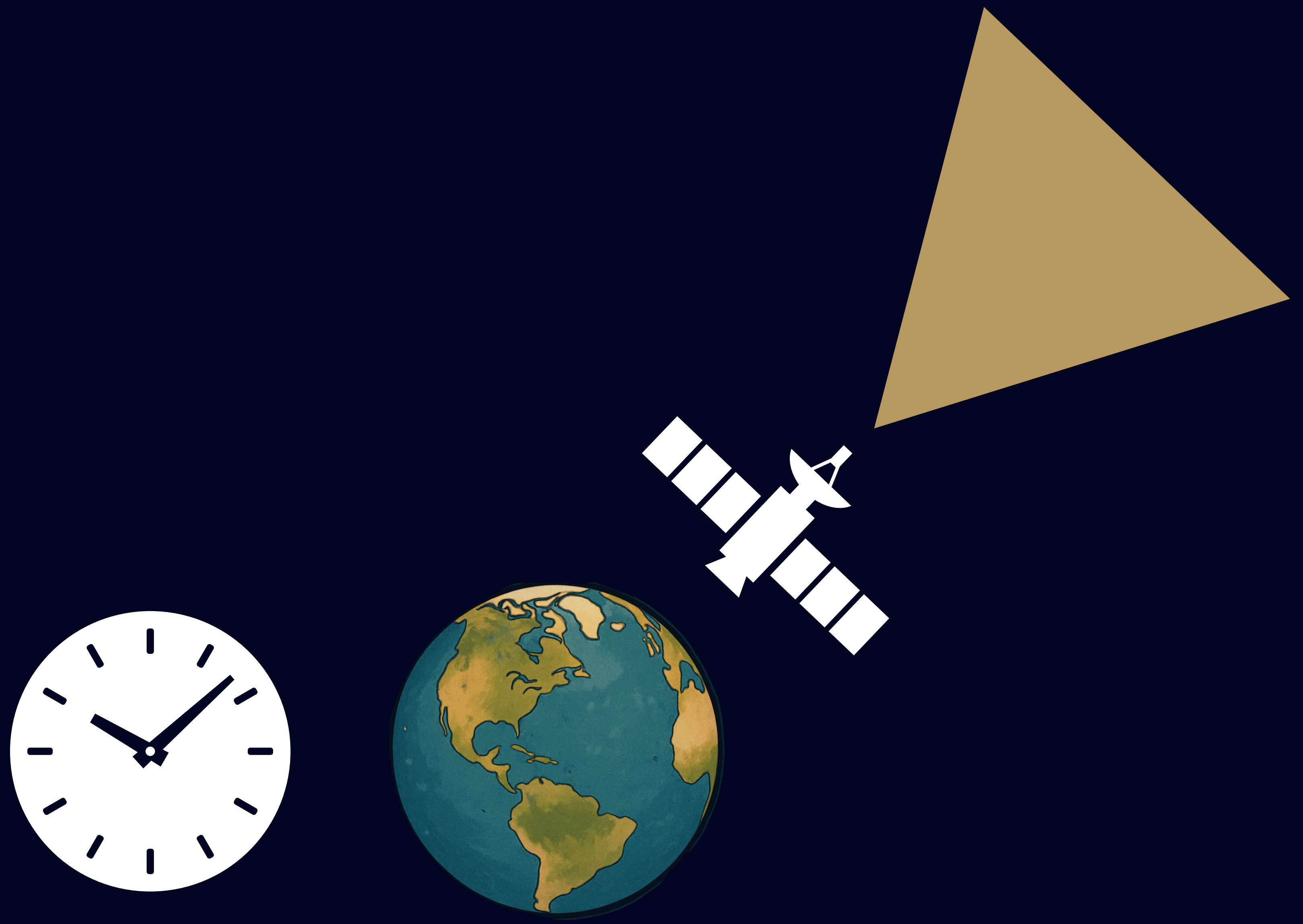
Detection signatures

Why timing matters more than sensitivity

$d \lesssim$ few Mpc



Hoof et al. (2023), arXiv:2212.09764

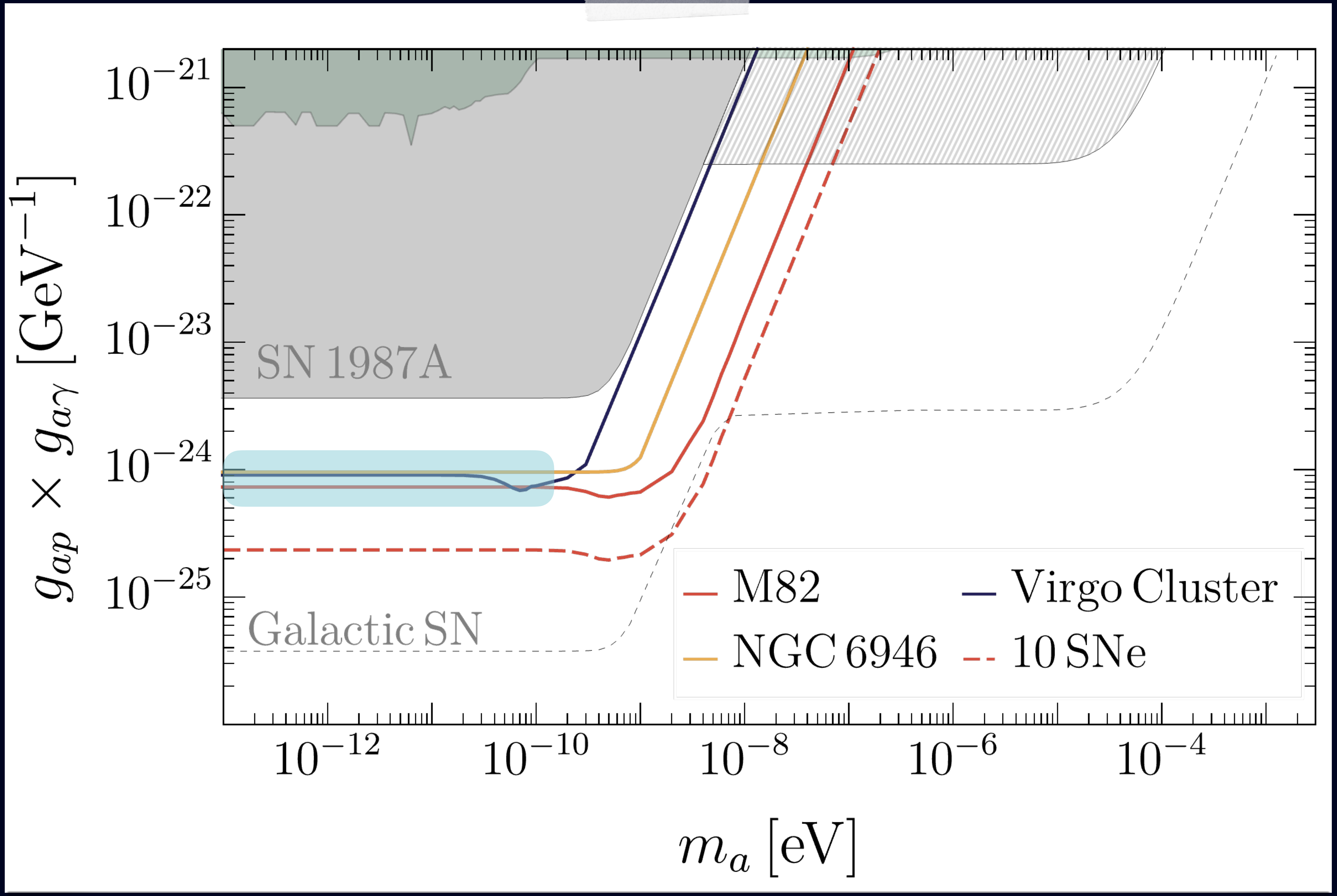


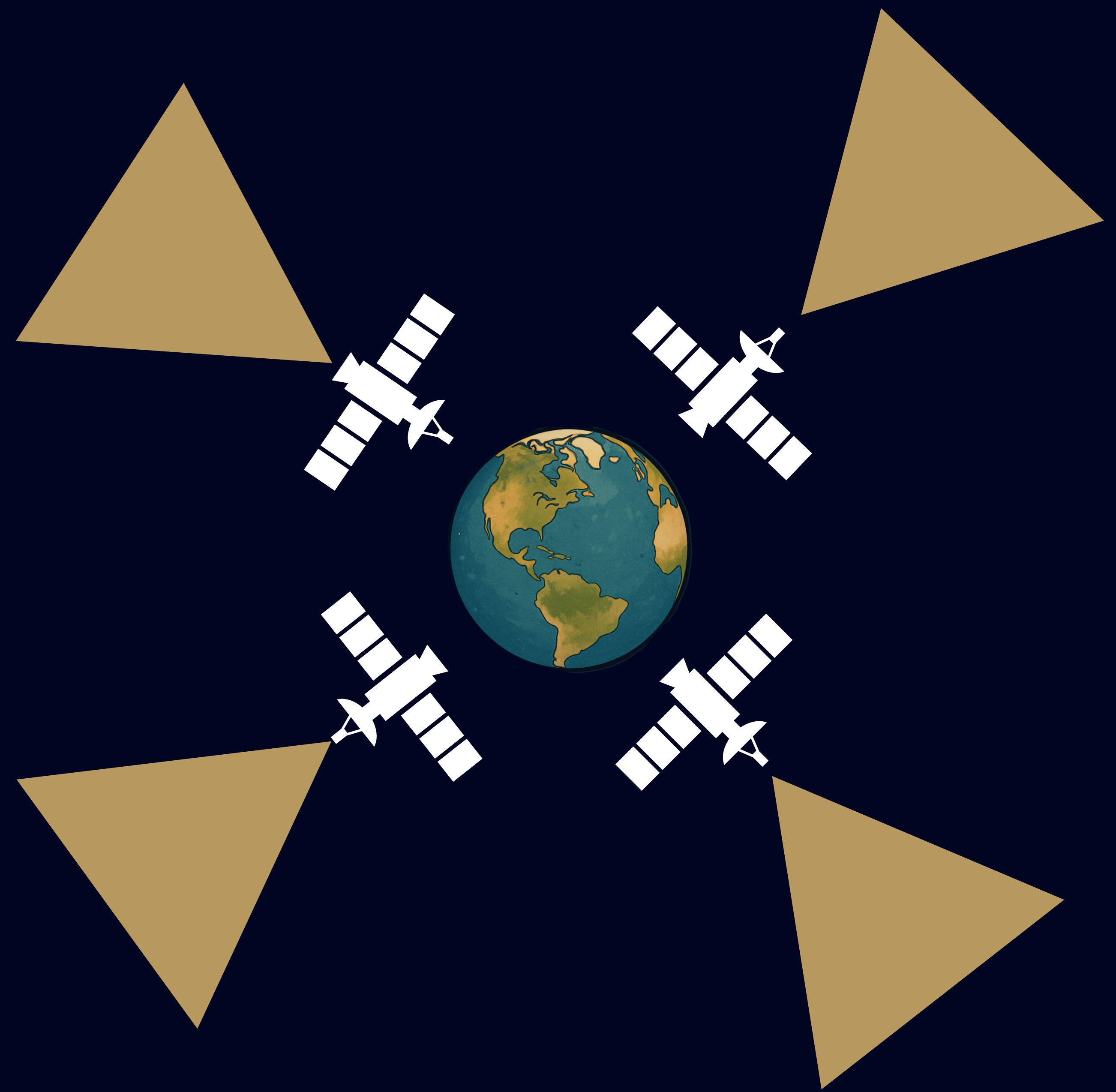
Time tagged detection of the ALP-photon induced signal

Detection signatures

Sensitivity to Supernova axions

$\Delta t = 10\,\mathrm{s}$

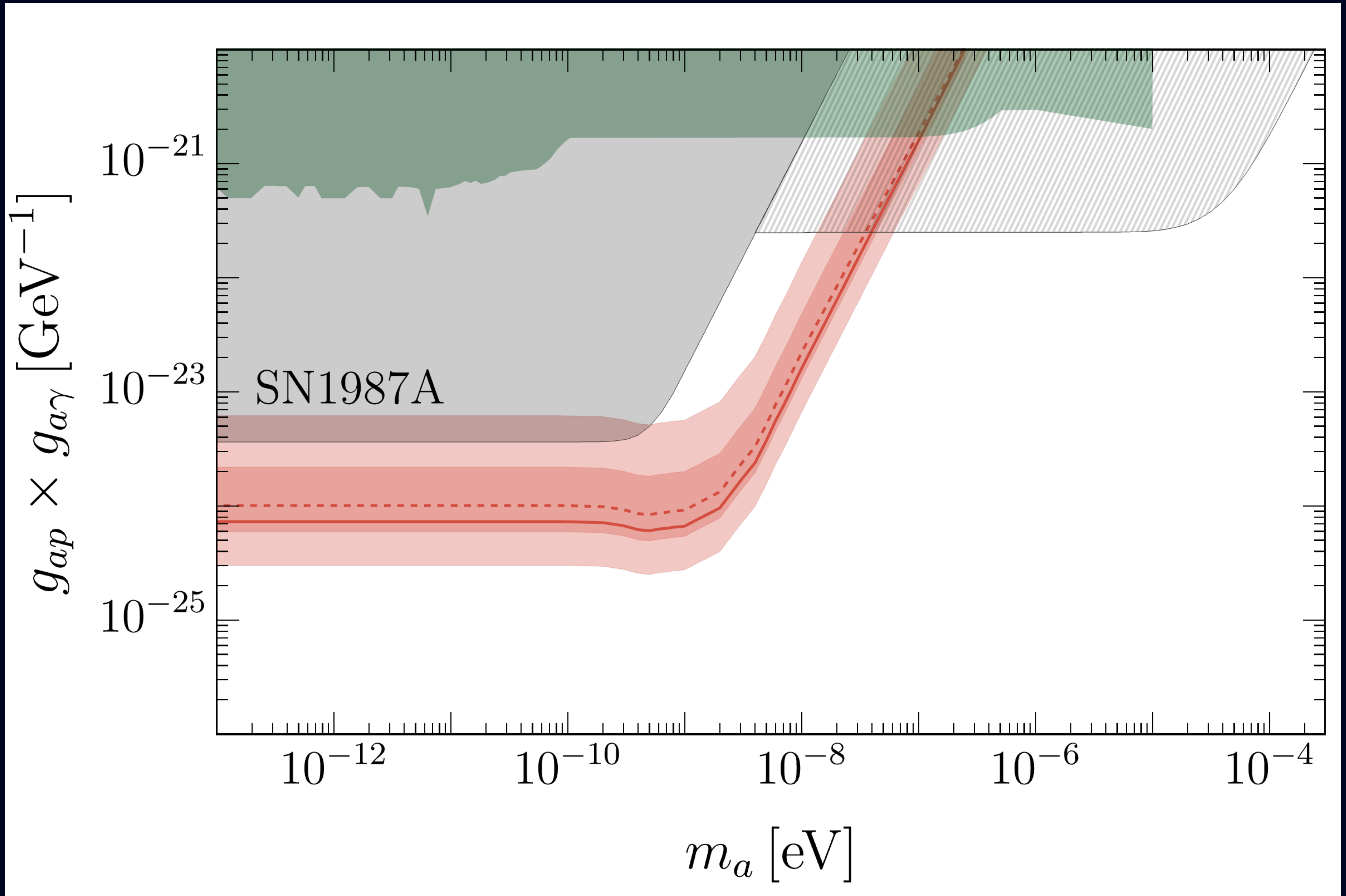


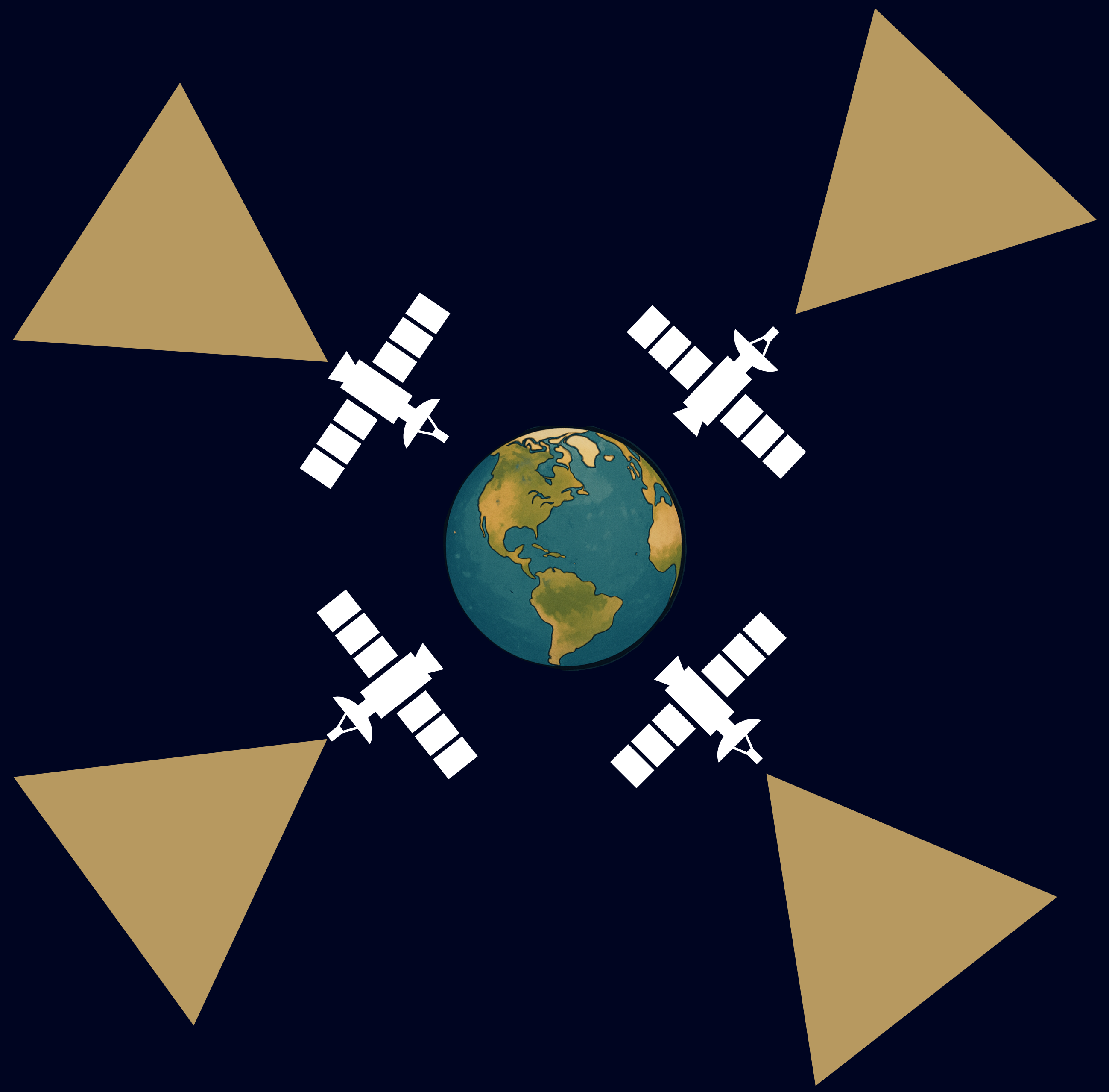


What is the variability of these results?

Detection signatures

Variability band



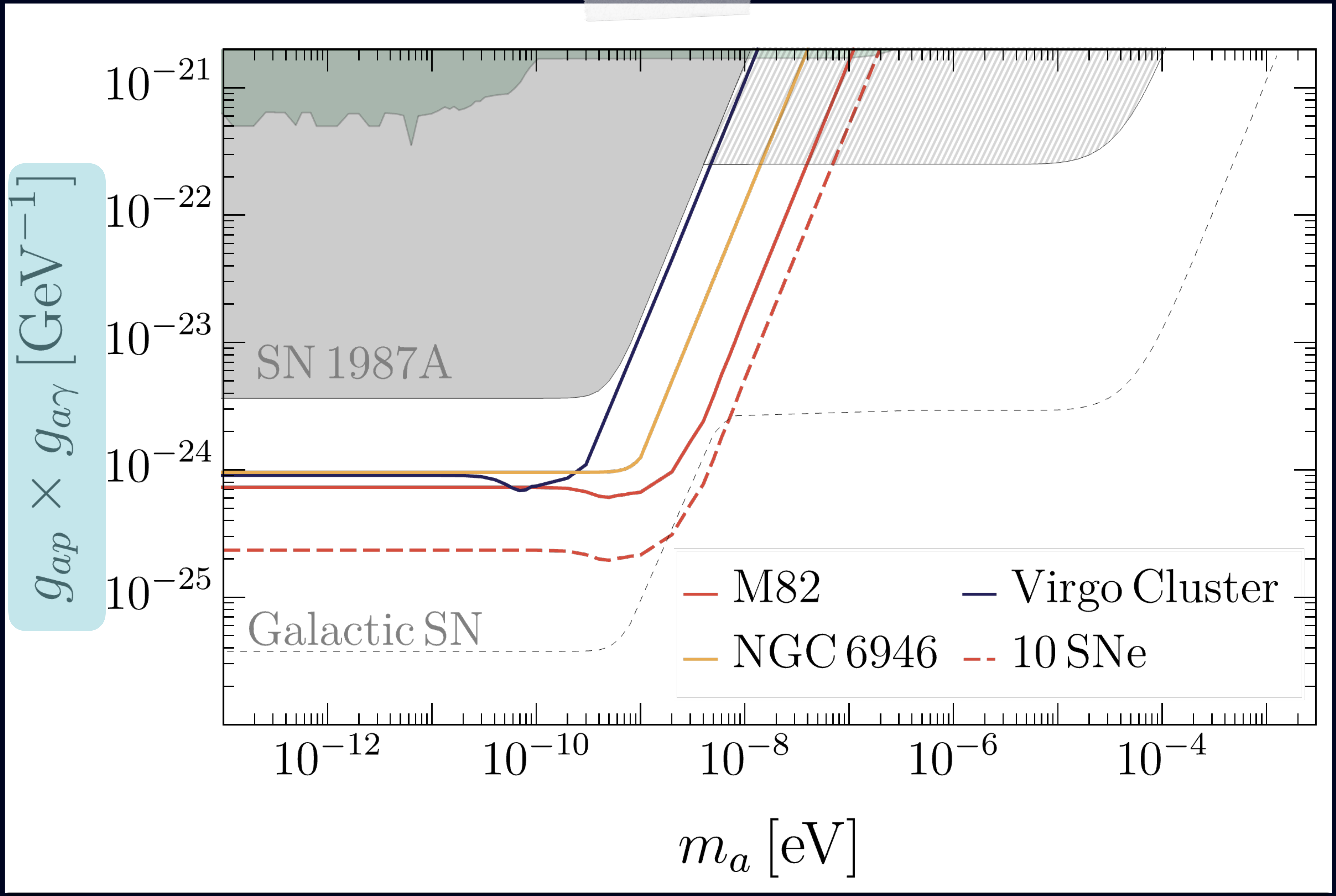


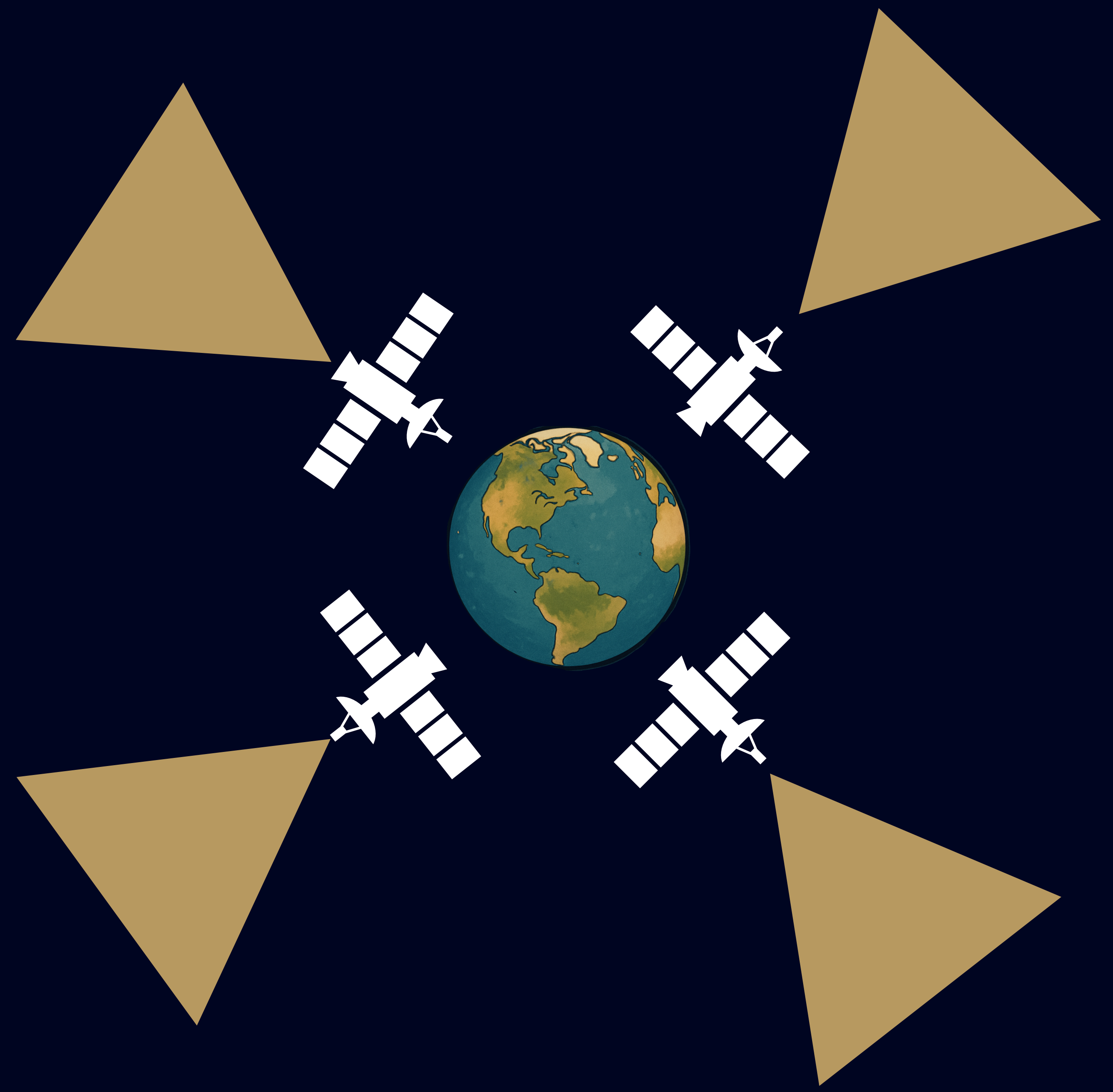
Variability band with $68\,\%\,CL$ and $95\,\%\,CL$

Detection signatures

Sensitivity to Supernova axions

$\Delta t = 10\,\mathrm{s}$

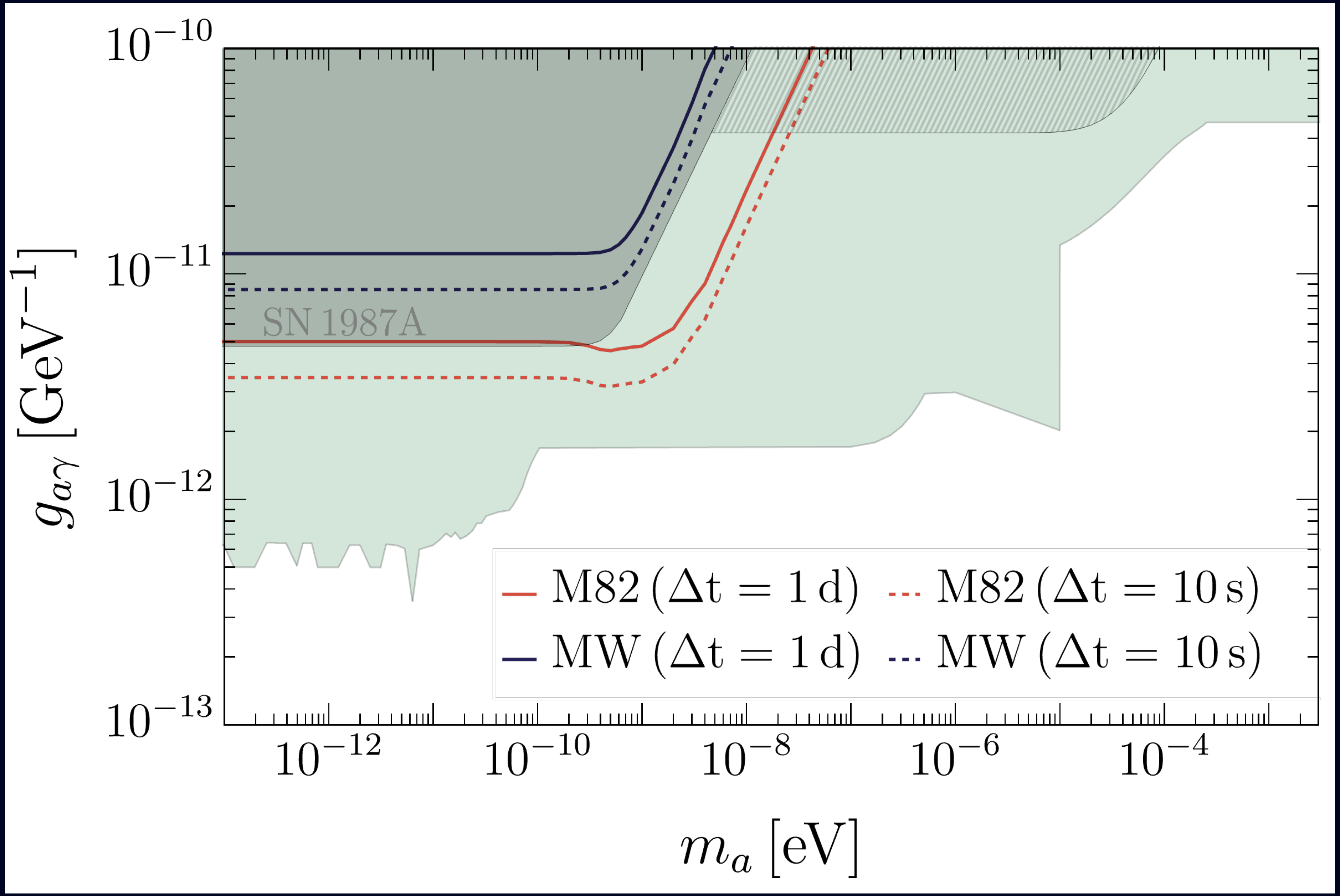




What happens in the $m_a \times g_{a\gamma}$ parameter space?

Detection signatures

Sensitivity to Supernova axions



Production via Primakoff

Conversions in the MW are comparable to

Meyer et al. (2020), arXiv:2006.06722

Pion processes