Title: Particle Physics Lecture - 230331

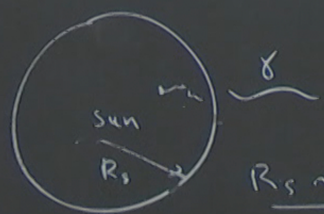
Speakers: Junwu Huang

Collection: Particle Physics (2022/2023)

Date: March 31, 2023 - 11:30 AM

URL: https://pirsa.org/23030068

Radiation from the Sun. $\quad cm = \frac{1}{10^{-4} eV}$



$R_s \sim 10^8 m$

Why is the Sun good?

$$\Gamma = n_e \sigma \sim n_e \frac{\alpha^2}{m_e^2}$$

$$d \sim \frac{1}{\Gamma} \simeq \frac{m_e^2}{\alpha^2 n_e} \simeq \frac{MeV^2}{10^{-4} \cdot 10^{23}/cm^3} \simeq \frac{MeV^2}{10^{-4} \cdot 10^{23}\, 10^{-12}\, eV^3} \simeq \frac{10^5}{eV} \simeq 0.1 m$$

$$\Gamma \sim g_{a\gamma\gamma}^2$$

$$d \sim \frac{1}{g_{a\gamma\gamma}^2}$$

(1) $\Gamma \cdot d \sim$ constant.

(2) Actual limit has $g_{a\gamma\gamma}$ that produces $d \gg R_s$.

Forces & Radiation

Axion

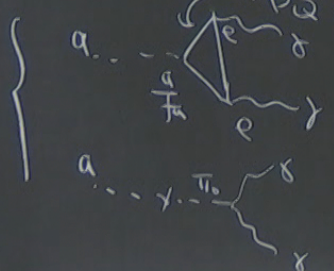
$\mu eV \lesssim m_a \lesssim meV$ $\qquad g_{a\gamma\gamma}\, a\, \boxed{F\tilde{F}} \leftarrow \vec{E}\cdot\vec{B}$

$10^{9}\,GeV \lesssim f_a \lesssim 10^{12}\,GeV$ $\qquad g_{a\gamma\gamma} \simeq \frac{\alpha_{EM}}{4\pi}\frac{1}{f_a}$

$mm \lesssim \lambda_a \lesssim meter$

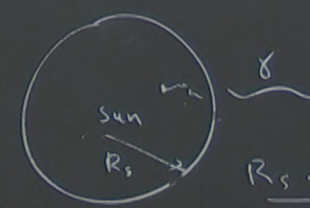
$$g_{a\gamma\gamma} \simeq \boxed{\frac{\alpha_{EM}}{4\pi}}\left(\frac{E}{N} - 1.92\right)\frac{1}{f_a}$$

PQ quanta



Radiation from the Sun.

$cm = \frac{1}{10^{-4}\,eV}$



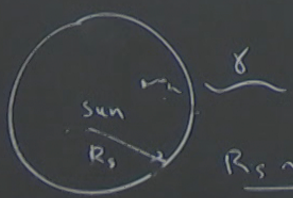
$R_s \sim 10^{8}\,m$

Why is the Sun good?

$$\Gamma = n_e\,\sigma \sim n_e \frac{\alpha^2}{m_e^2}$$

$$\ell \sim \frac{1}{\Gamma} \sim \frac{m_e^2}{\alpha^2 n_e} \simeq \frac{MeV^2}{10^{-4}\cdot 10^{23}/cm^3} \simeq \frac{MeV^2}{10^{-4}\cdot 10^{23}\, 10^{-12}\, eV^3}$$

Radiation from the Sun. $\quad cm = \frac{1}{10^{-4}\,eV}$



$R_s \sim 10^8\,m$

Why is the Sun good?

$$\Gamma = n_e \sigma \sim n_e \frac{\alpha^2}{m_e^2}$$

$$d \sim \frac{1}{\Gamma} \sim \frac{m_e^2}{\alpha^2 n_e} \simeq \frac{MeV^2}{10^{-4} \cdot 10^{23}/cm^3} \simeq \frac{MeV^2}{10^{-4} \cdot 10^{23}\, 10^{-12}\, eV^3} \simeq \frac{10^5}{eV} \simeq 0.1\,m$$

$$\Gamma \sim g_{a\gamma\gamma}^2$$

$$d \sim \frac{1}{g_{a\gamma\gamma}^2}$$

(1) $\Gamma \cdot d \sim$ constant.

(2) Actual limit has $g_{a\gamma\gamma}$ that produces $d >> R_s$.

$T_{core} >> T_{surface}$. $\quad \Gamma \propto T^4$

$g_{a\gamma\gamma} \lesssim 10^{-10}\,GeV^{-1}$.

$\Gamma \sim g_{a\gamma\gamma}^2$

$d \sim \frac{1}{g_{a\gamma\gamma}^2}$

$g_{a\gamma\gamma} \lesssim 10^{-10}\,\mathrm{GeV}^{-1}$ cooling bounds

(1) $\Gamma \cdot d \sim$ constant.

(2) Actual limit has $g_{a\gamma\gamma}$ that produces $d \gg R_S$.

$T_{core} \gg T_{surface}$ $\Gamma \propto T^{\#}$

$\simeq \frac{10^5}{eV} \simeq 0.1\,\mathrm{m}$

Forces & Radiation.

Axion

$\mu eV \lesssim m_a \lesssim meV$

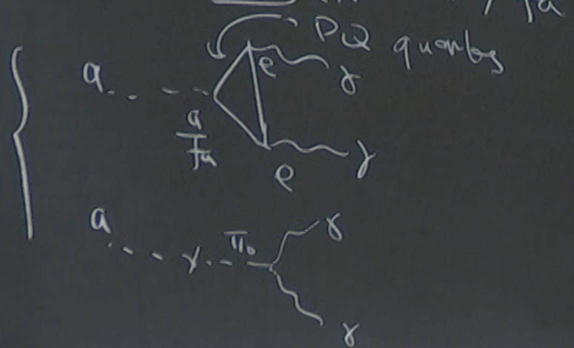
$10^9\,GeV \lesssim f_a \lesssim 10^{12}\,GeV$

$mm \lesssim \lambda_a \lesssim$ Meter

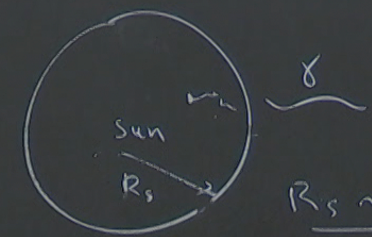
$g_{a\gamma\gamma}\, a\, \boxed{F\tilde{F}} \leftarrow \vec{E}\cdot\vec{B}$

$g_{a\gamma\gamma} \simeq \frac{\alpha_{EM}}{4\pi}\frac{1}{f_a}$

$$g_{a\gamma\gamma} \simeq \boxed{\frac{\alpha_{EM}}{4\pi}}\left(\frac{E}{N} - 1.92\right)\frac{1}{f_a}$$



Radiation from the Sun.



$R_s \sim 10^8\,m$

Why is the Sun good?

$\Gamma = n_e \sigma \sim n_e \frac{\alpha^2}{m_e^2}$

$d \sim \frac{1}{\Gamma} \sim \frac{m_e^2}{\alpha^2 n_e} \simeq \frac{MeV^2}{10^{-4}\cdot 10^{23}/cm^3} \simeq \frac{MeV}{10^{-\ldots}}$

Lecture 13. How to build an experiment.

$$\Gamma_{decay} \sim \frac{m_a^3}{f_a^2} \sim \frac{(\mu eV)^3}{(10^{12}\,GeV)^2} \simeq 10^{-60}\,eV$$

ADMX experiments (QCD axion)

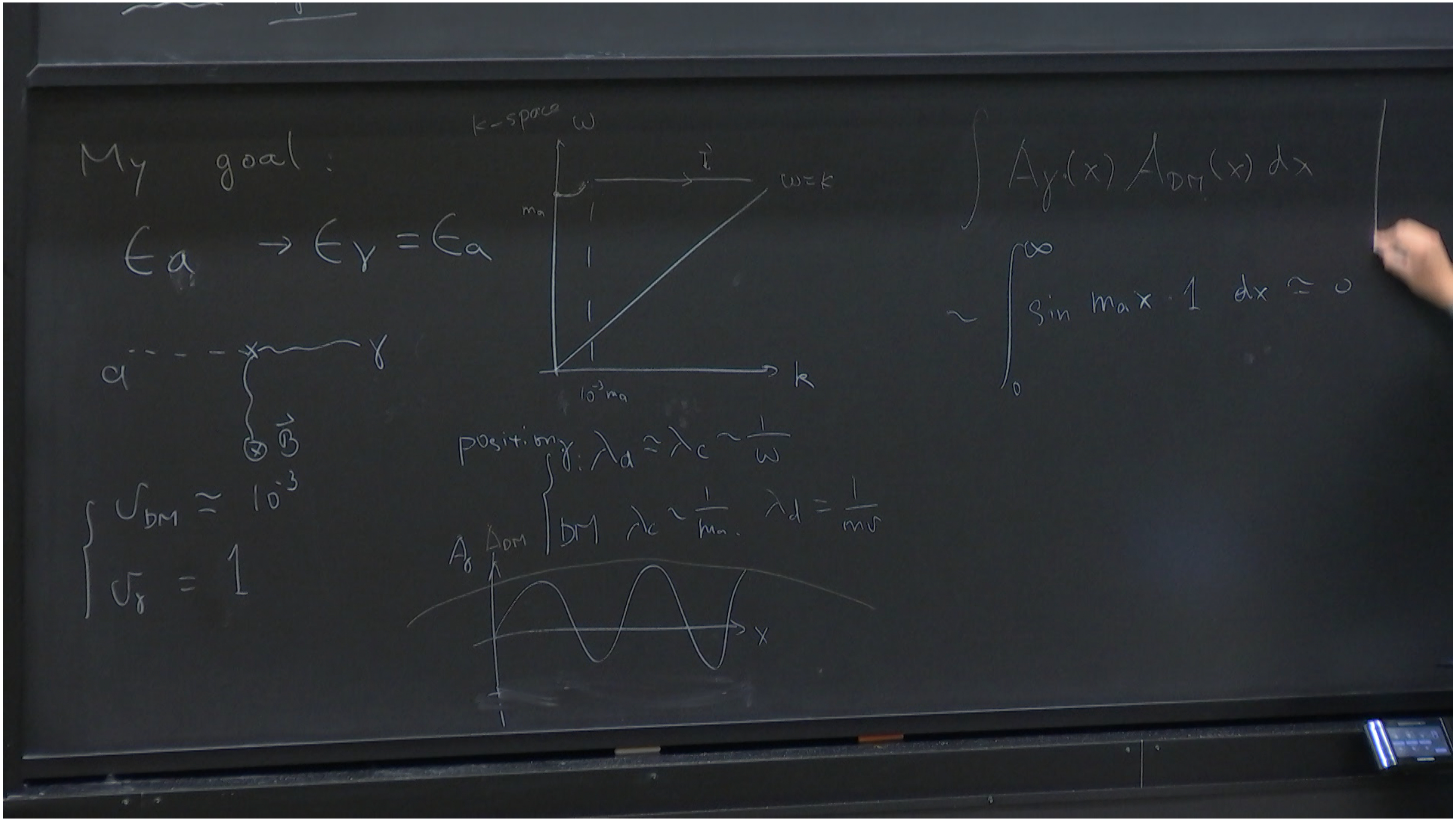
Energy Comes From

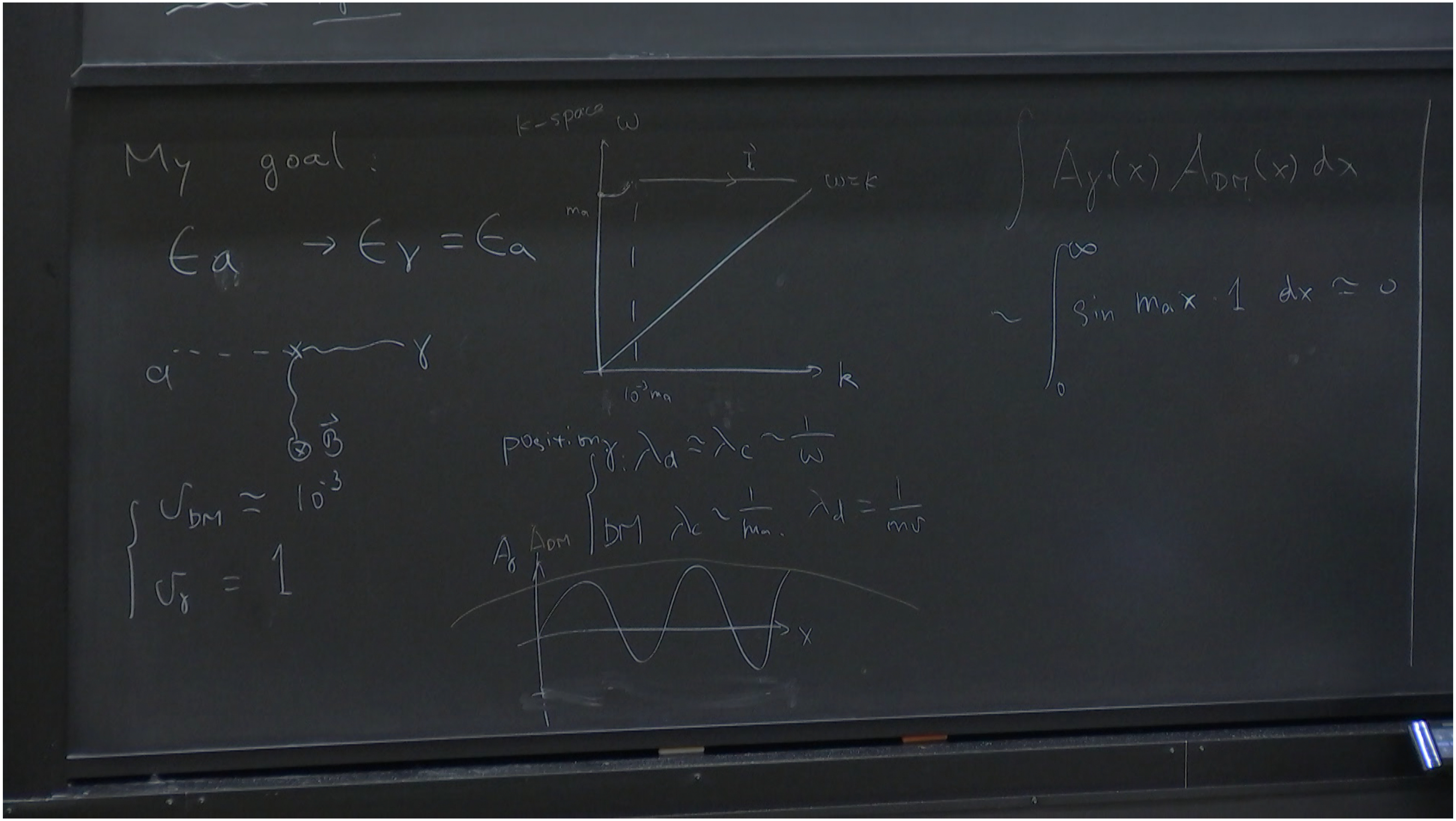
1. WIMP. Kinetic. Scattering

2. Axion. $E \sim m$ Absorption. $(\delta E \to \delta T)$

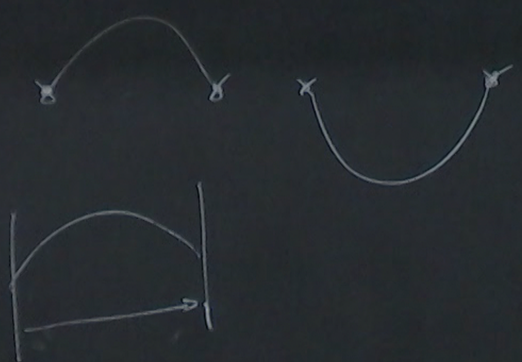
3. ADMX $\frac{E = m}{E_\gamma = E_a}$ Conversion.

My goal:


My goal:
$\epsilon_a \to \epsilon_\gamma = \epsilon_a$
a
γ
$\vec{B}$
$v_{DM} \simeq 10^{-3}$
$v_\gamma = 1$
k-space
ω
m_a
$\omega = k$
k
$10^{-3} m_a$
position γ: $\lambda_a \simeq \lambda_c \sim \frac{1}{\omega}$
DM $\lambda_c \sim \frac{1}{m_a}$. $\lambda_d = \frac{1}{mv}$
A_γ A_{DM}
x
$\int A_\gamma(x) A_{DM}(x)\, dx$
$\sim \int_0^\infty \sin m_a x \cdot 1 \; dx \simeq 0$

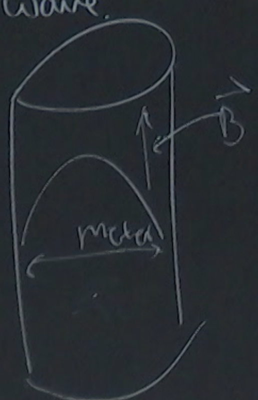

My goal:
$\epsilon_a \to \epsilon_\gamma = \epsilon_a$
k-space
ω
m_a
$\omega = k$
k
$10^{-3} m_a$
a
γ
$\vec{B}$
$v_{DM} \simeq 10^{-3}$
$v_\gamma = 1$
position γ: $\lambda_d \simeq \lambda_c \sim \frac{1}{\omega}$
DM $\lambda_c \sim \frac{1}{m_a}$. $\lambda_d = \frac{1}{mv}$
A_γ A_{DM}
x
$\int A_\gamma(x) A_{DM}(x)\, dx$
$\sim \int_0^\infty \sin m_a x \cdot 1 \; dx \simeq 0$

We want light to stop



Standing wave.

ADMX



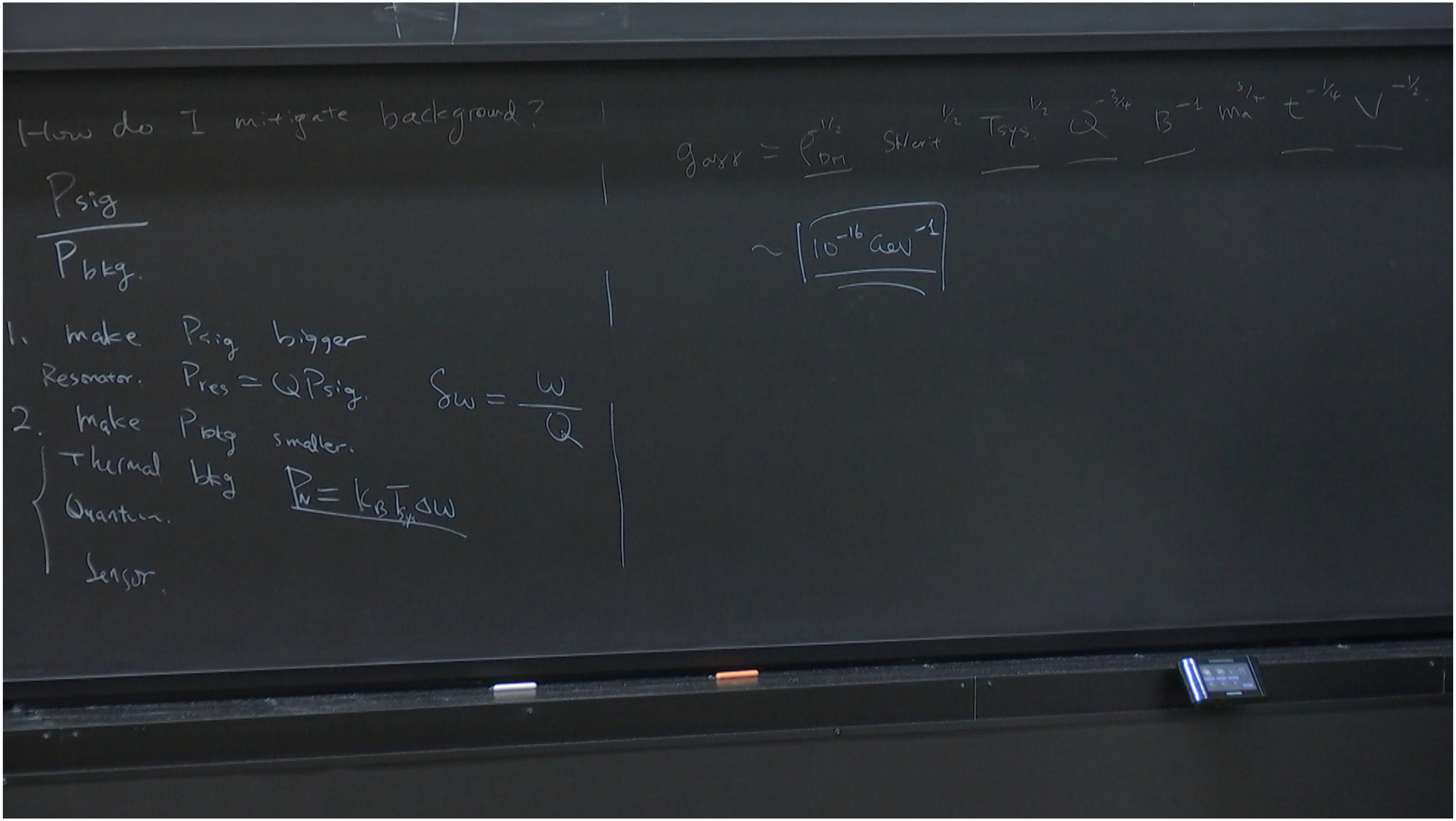
$$P_{a\to\gamma} = \left(g_{a\gamma\gamma} B\right)^2 \cdot \rho_{DM} \cdot V \cdot \frac{1}{m_a}$$

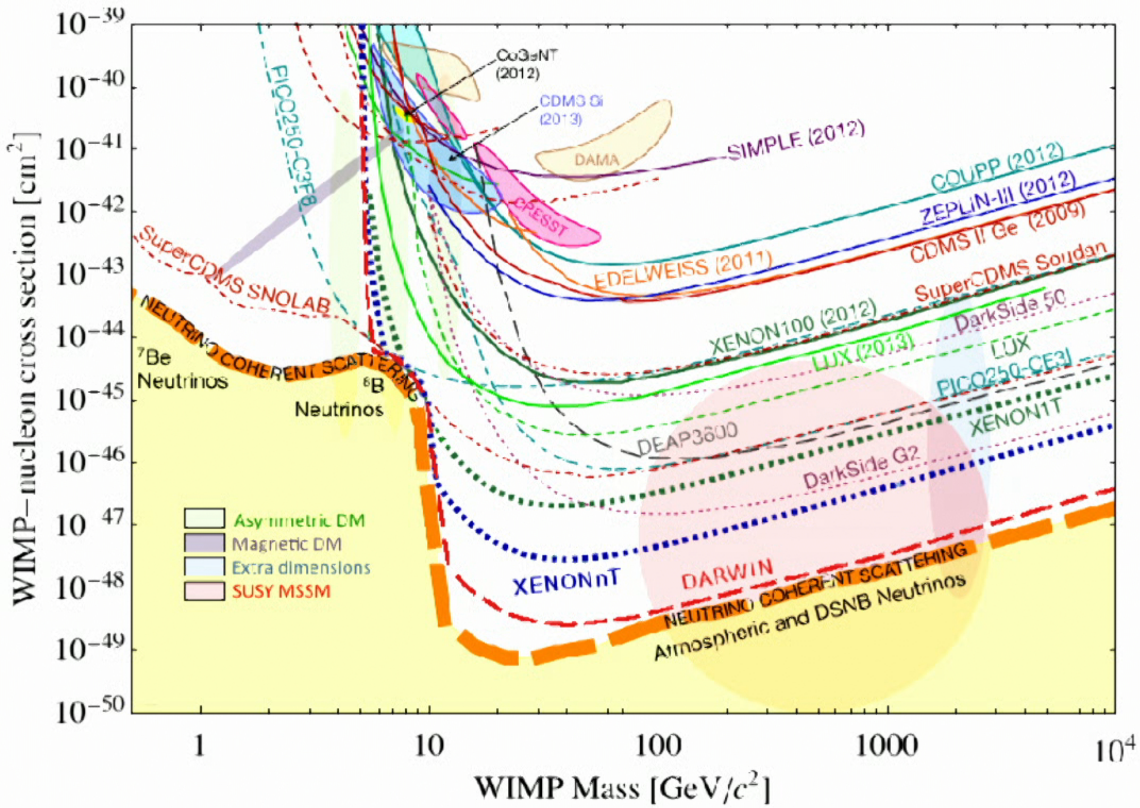
$$\boxed{N = \#\left(\frac{g_{a\gamma\gamma} B}{m_a}\right)^2 \rho_{DM}\, V\, t}$$

interaction strength.

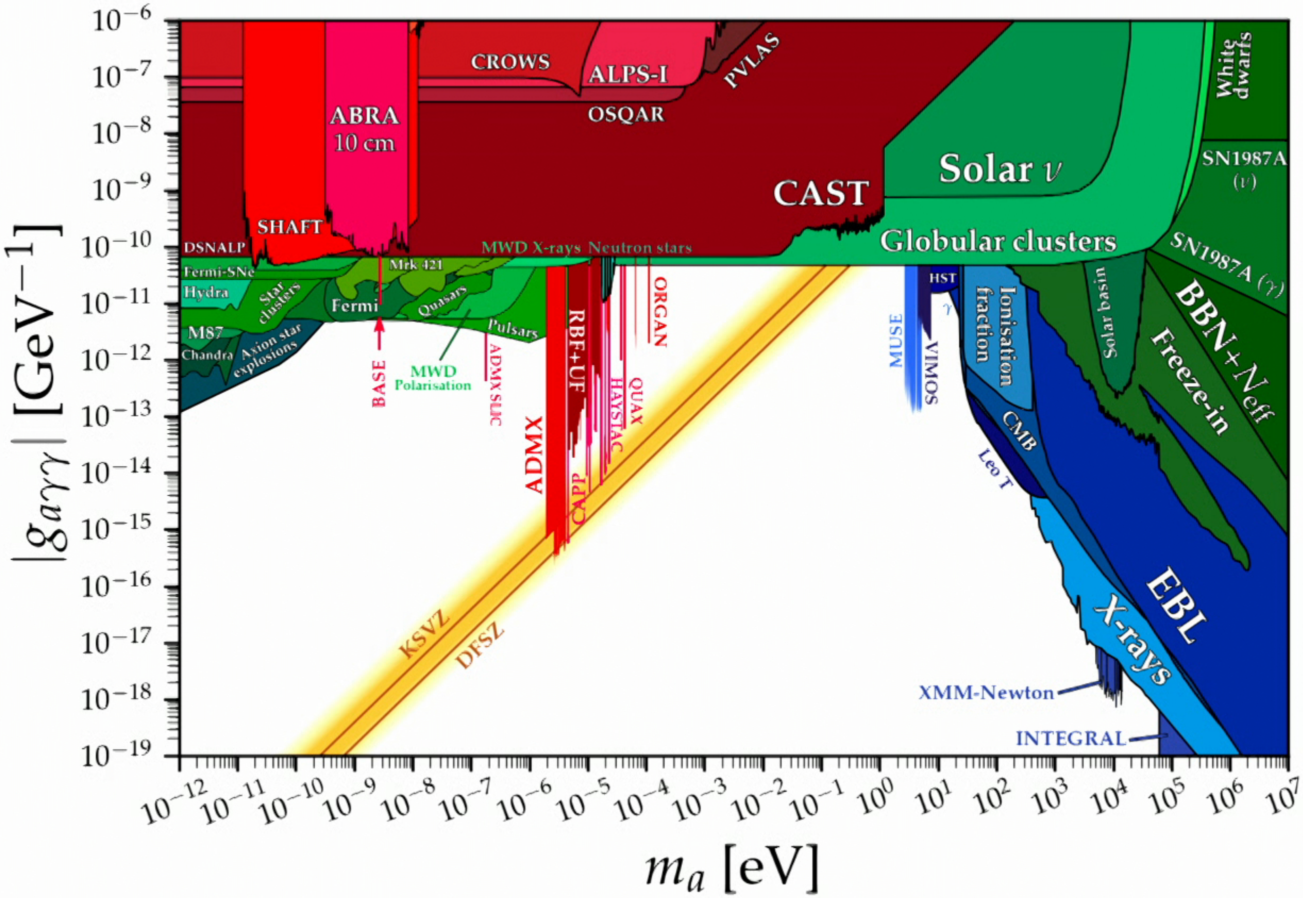
ADMX $B \sim 8T$. $\rho_{DM} = 0.3\,\mathrm{GeV/cm^3}$. $V = 0.1\,m^3$. $t = 10^8\,s$.

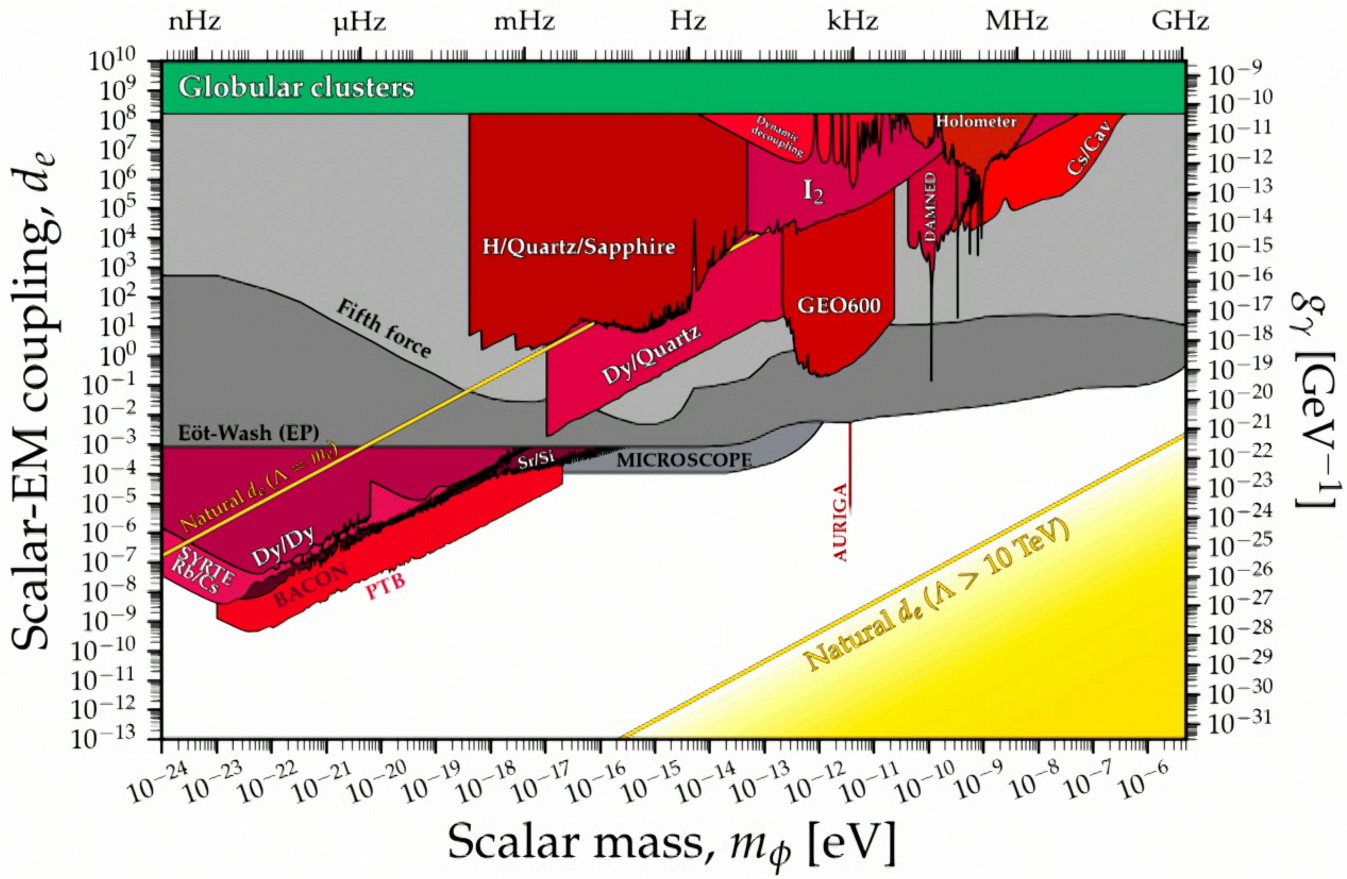
$$g_{a\gamma\gamma} \sim 10^{-17}\,\mathrm{GeV}^{-1}$$

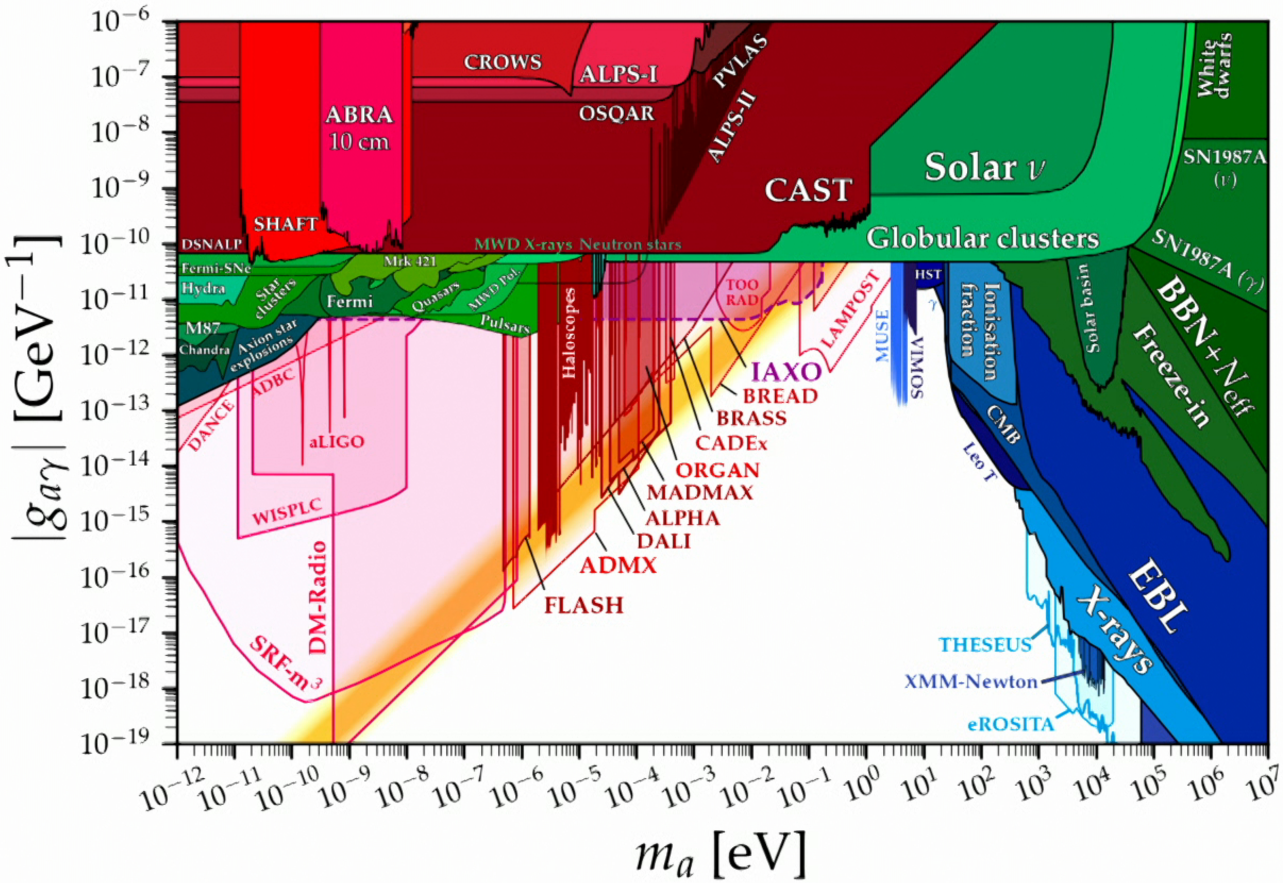

How do I mitigate background?
Psig / Pbkg.
1. make Psig bigger
Resonator. Pres = Q Psig.
δω = ω / Q
2. make Pbkg smaller.
Thermal bkg
PN = kB Tsys Δω
Quantum.
Sensor.
gaγγ = ρDM^1/2 SNRcrit^1/2 Tsys^1/2 Q^-3/4 B^-1 ma^3/4 t^-1/4 V^-1/2
~ 10^-16 GeV^-1



WIMP–nucleon cross section [cm^2]
WIMP Mass [GeV/c^2]
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
SuperCDMS Soudan
CRESST
EDELWEISS (2011)
PICO250-C3F8
SuperCDMS SNOLAB
XENON100 (2012)
LUX (2013)
DarkSide 50
LUX
PICO250-CF3I
XENON1T
DEAP3600
DarkSide G2
XENONnT
DARWIN
^{7}Be Neutrinos
^{8}B Neutrinos
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
Asymmetric DM
Magnetic DM
Extra dimensions
SUSY MSSM


CROWS
ALPS-I
OSQAR
PVLAS
ABRA
10 cm
SHAFT
CAST
Solar ν
Globular clusters
DSNALP
Fermi-SNe
Hydra
M87
Chandra
Star clusters
Fermi
Mrk 421
Quasars
Pulsars
MWD X-rays
Neutron stars
MWD Polarisation
BASE
ADMX SLIC
ADMX
RBF+UF
CAPP
HAYSTAC
QUAX
ORGAN
KSVZ
DFSZ
MUSE
VIMOS
HST
Ionisation fraction
CMB
Leo T
Solar basin
White dwarfs
SN1987A
SN1987A (γ)
BBN+N_{eff}
Freeze-in
EBL
X-rays
XMM-Newton
INTEGRAL
$|g_{a\gamma\gamma}|$ [GeV^{-1}]
m_a [eV]


nHz
μHz
mHz
Hz
kHz
MHz
GHz
Globular clusters
Dynamic decoupling
Holometer
I_2
DAMNED
Cs/Cav
H/Quartz/Sapphire
GEO600
Fifth force
Dy/Quartz
Eöt-Wash (EP)
Sr/Si
MICROSCOPE
AURIGA
Natural d_e ($\Lambda = m_\phi$)
Dy/Dy
SYRTE Rb/Cs
BACON
PTB
Natural d_e ($\Lambda > 10$ TeV)
Scalar-EM coupling, d_e
g_γ [GeV^{-1}]
Scalar mass, m_ϕ [eV]


CROWS
ALPS-I
PVLAS
ABRA
10 cm
OSQAR
ALPS-II
Solar ν
White dwarfs
SN1987A (ν)
CAST
SHAFT
DSNALP
MWD X-rays Neutron stars
Globular clusters
SN1987A (γ)
Fermi-SNe
Hydra
Star clusters
Mrk 421
Fermi
Quasars
MWD Pol.
Pulsars
M87
Chandra
Axion star explosions
Haloscopes
TOO RAD
LAMPOST
MUSE
HST
VIMOS
Ionisation fraction
Solar basin
BBN+N_{eff}
Freeze-in
IAXO
BREAD
BRASS
CADEx
ORGAN
MADMAX
ALPHA
DALI
ADMX
FLASH
DANCE
ADBC
aLIGO
WISPLC
DM-Radio
SRF-m^3
CMB
Leo T
EBL
X-rays
THESEUS
XMM-Newton
eROSITA
$|g_{a\gamma}|$ [GeV^{-1}]
m_a [eV]