Beyond axions:
The scalar case

FLASH and Resonant-Mass Detectors

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Sezione di Pisa

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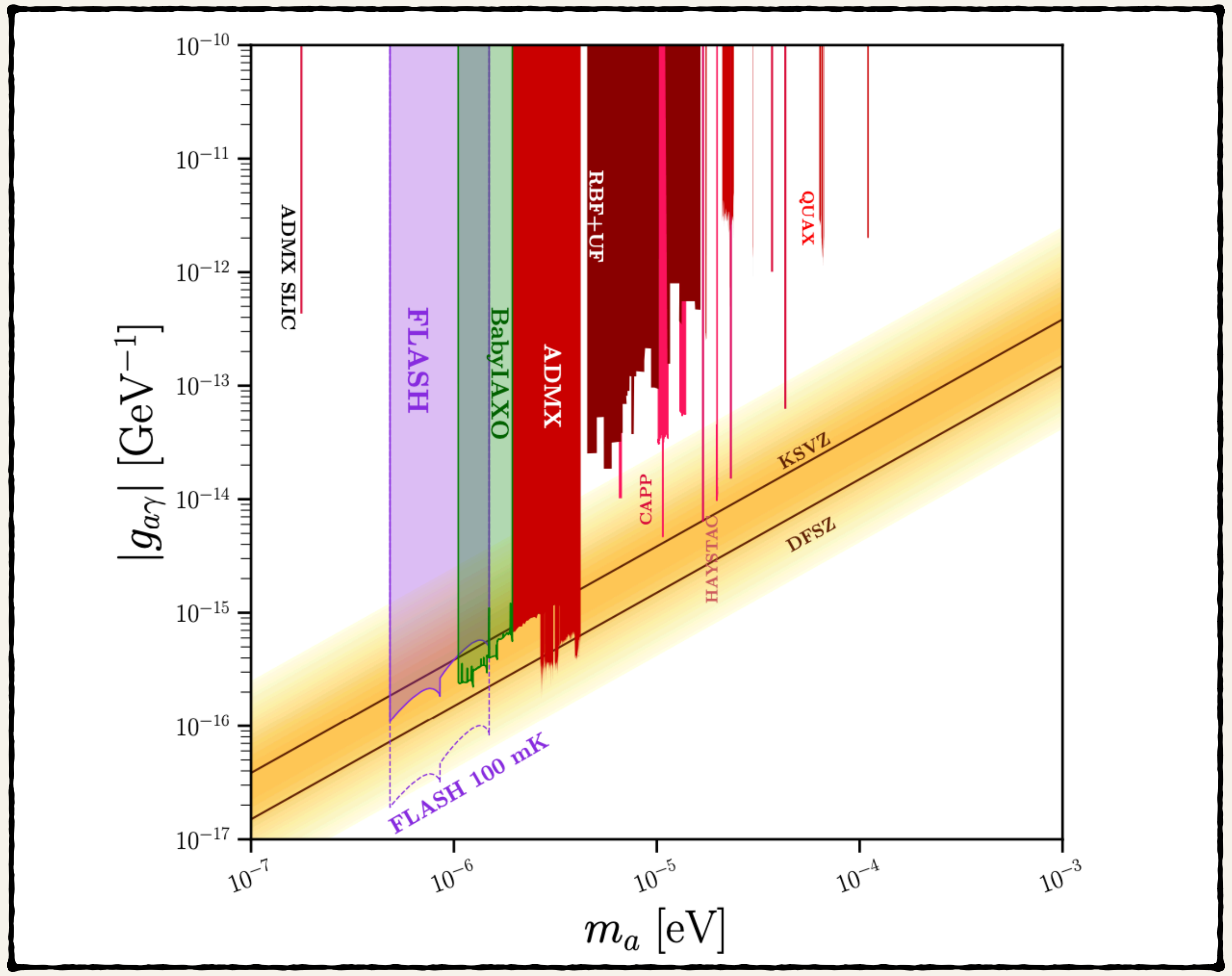
Ultra light particles

Axions



Scalars

- **DM candidate**

  $$\phi(t,x) \sim \sqrt{\rho_{DM}}/m_\phi \cos(m_\phi t + \ldots)$$

- **Dilaton models (ϕFF, ...)**
- **Constraints**
  - **ISL modifications → 5th Force (composition independent)**
  - **EP Violation Test (composition dependent)**

[1] *"The future search for low-frequency axions and new physics with the FLASH resonant cavity experiment at Frascati National Laboratories" [arXiv: 2309.00351]*

Flash sensitivity

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}(\partial_\mu\phi)^2 - \frac{1}{2}m_\phi^2\phi^2 + \frac{1}{4}\frac{\sqrt{4\pi}}{M_{pl}}d_e\phi F_{\mu\nu}F^{\mu\nu}$$

$$\boxed{\begin{aligned} C_{011} &= 5\times10^{-13} \\ C_{111} &= 3\times10^{-7} \end{aligned}} \longleftarrow C_\alpha = \frac{1}{B_0^2 V}\frac{|\int_V d^3\mathbf{x}e^{i\mathbf{k}\cdot\mathbf{x}}\mathbf{B}_0\cdot\mathbf{B}_\alpha|^2}{\int_V d^3\mathbf{x}\,\mathbf{B}_0\cdot\mathbf{B}_\alpha}$$

Mapping to the axion case

$\sqrt{C_{111}/C_{010}} \sim 10^{-3}$

Non vanishing B_z:TE_{011} ,TE_{111}

$Q(4\mathrm{K})_{011} = 1.3\times10^6$

$Q(4\mathrm{K})_{111} = 711\times10^3$

$$P_{sig} \propto (d_e^2\alpha_{em}^2\frac{\rho_{DM}}{\Lambda^4})\times(\nu_c Q_L B_0^2 V C_\alpha)$$

$$SNR = \frac{P_{\mathrm{sig}}}{T_{\mathrm{sys}}}\sqrt{\frac{\tau}{\Delta\nu_I}}$$

[1] "The future search for low-frequency axions and new physics with the FLASH resonant cavity experiment at Frascati National Laboratories" [arXiv: 2309.00351]

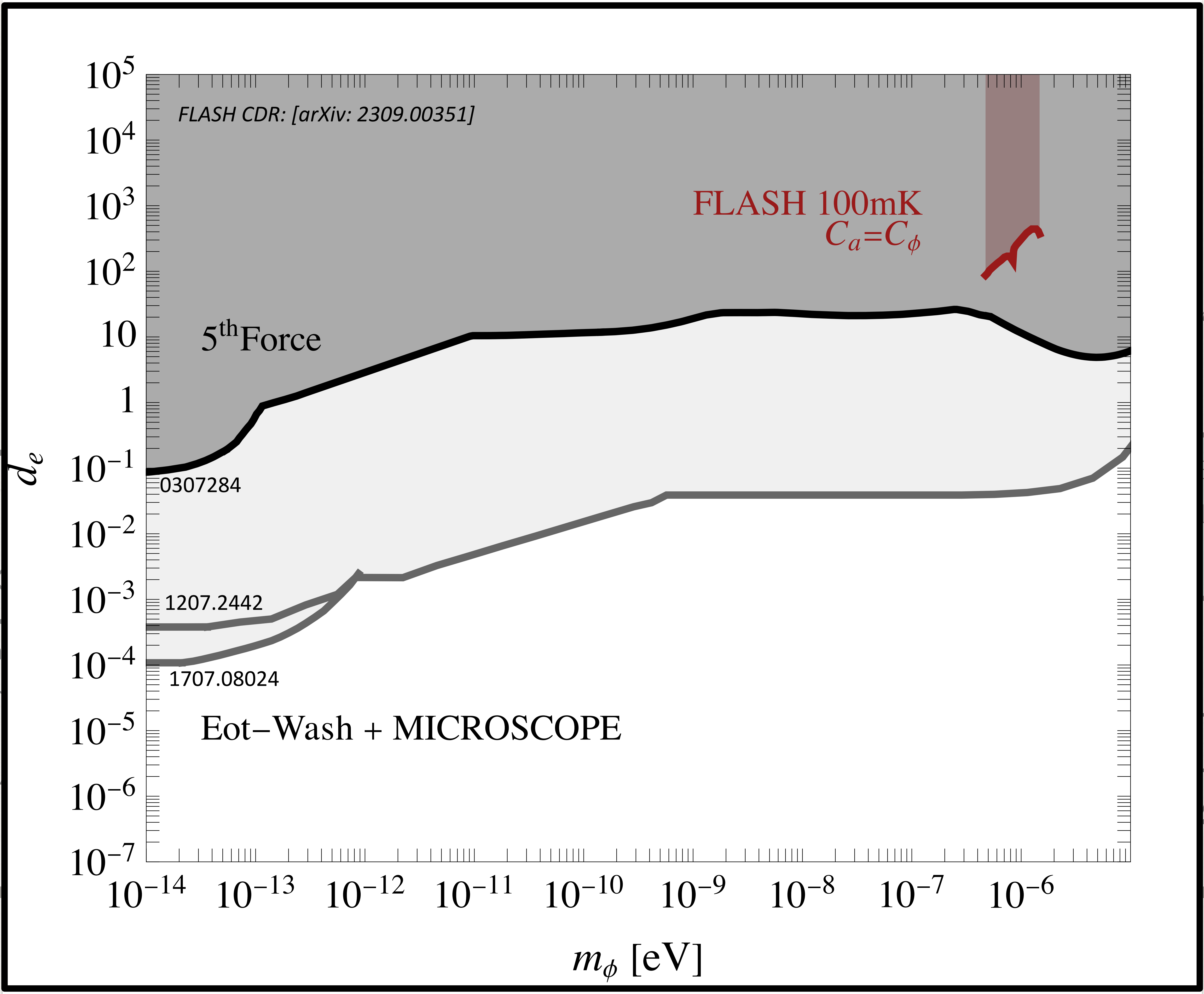
$\mathscr{L}$

$C_{011} = 5 \times$

$C_{111} = 3 \times$

Mapping to the a

$\sqrt{C_{111}/C_{010}}$



E_{011}, TE_{111}

10^6

10^3

τ

$\Delta\nu_I$

Resonant mass detectors

$$\mathscr{L} = -\frac{\sqrt{4\pi}}{M_{pl}}\phi\left(d_{m_e} m_e \bar{e}e - \frac{1}{4}d_e F_{\mu\nu}F^{\mu\nu}\right)$$

$$\phi(t, \mathbf{x}) \simeq \frac{\sqrt{2\rho_\phi}}{m_\phi}\cos[m_\phi(t - \mathbf{v}\cdot\mathbf{x} + \ldots)]$$

$$h = \frac{\sqrt{4\pi}}{M_{pl}}\frac{(d_e + d_{m_e})}{\alpha_0 m_{e,0}}\phi = -\frac{\delta\alpha}{\alpha} - \frac{\delta m_e}{m_e}$$

$$\ddot{\xi}_n + \frac{\omega_n}{Q_n}\dot{\xi}_n + \omega_n^2\xi_n = \frac{1}{\mu_n}(f_{\mathrm{dm}} + f_{\mathrm{th}})$$

$$h_{\min} \approx \sqrt{\frac{16 v_{\mathrm{vir}} T \mu_n}{Q_n q_n^2 \omega_n^{5/2}}}\tau_{\mathrm{int}}^{-1/4} \simeq 2\sqrt{S_{hh}^{th}}(\tau_{int}\tau_c)^{-1/4}$$

$$(d_{dm})_{\min} \approx \sqrt{\frac{c^2}{8\pi G\rho_{\mathrm{dm}}}}\omega_n h_{\min}$$

$f_{dm} = \ddot{h} q_n$

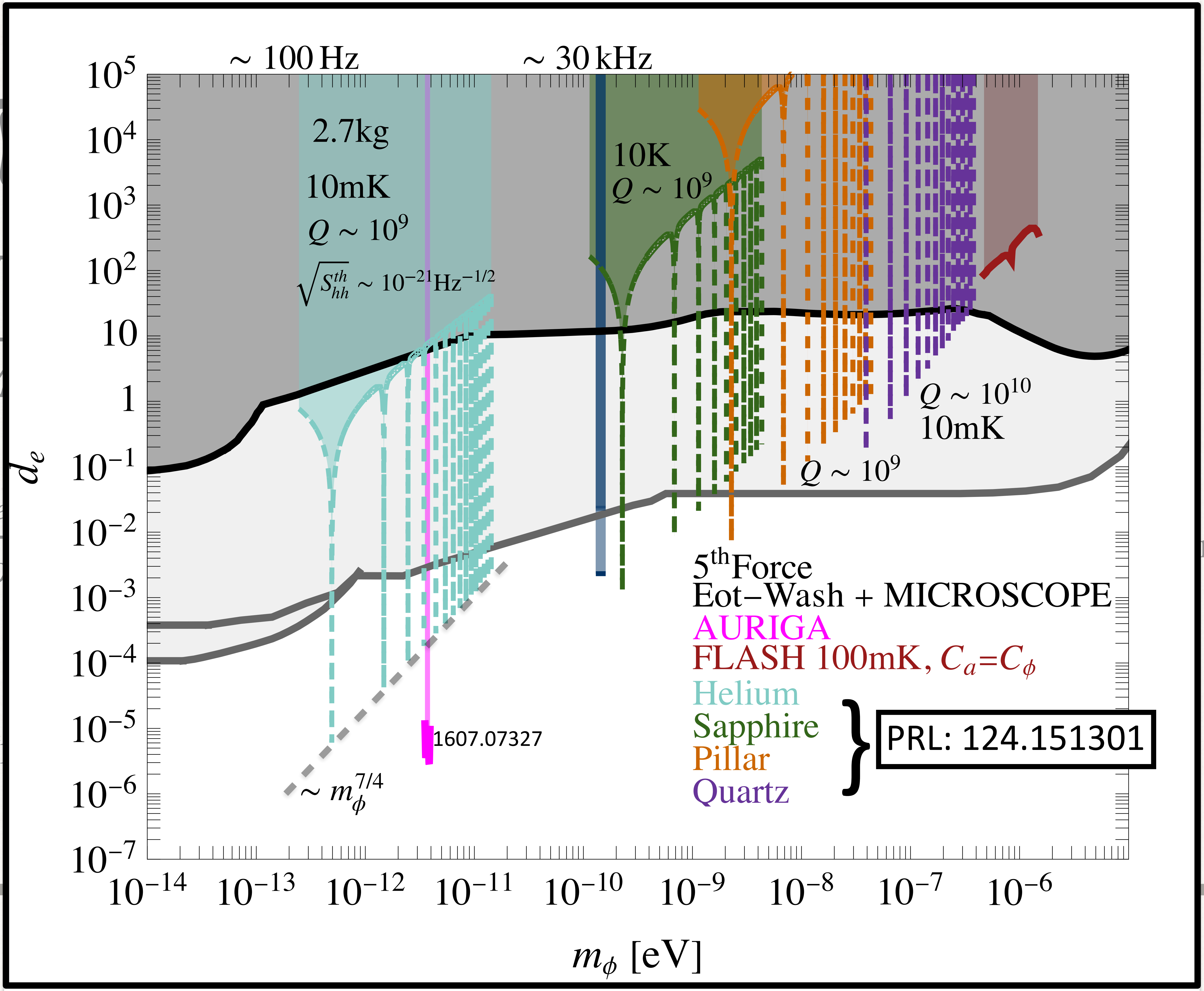
$v_{vir} \sim 10^{-3}$

$\tau_c = [v_{vir}^2 \omega_{DM}]^{-1}$

[1] A. Arvanitaki, S. Dimopoulos, and K. Van Tilburg, Physical Review Letters 116 (2016), 10.1103/phys-revlett.116.031102.
[2] J. Manley, D. J. Wilson, R. Stump, D. Grin, and S. Singh, Physical Review Letters 124 (2020),10.1103/physrevlett.124.151301.

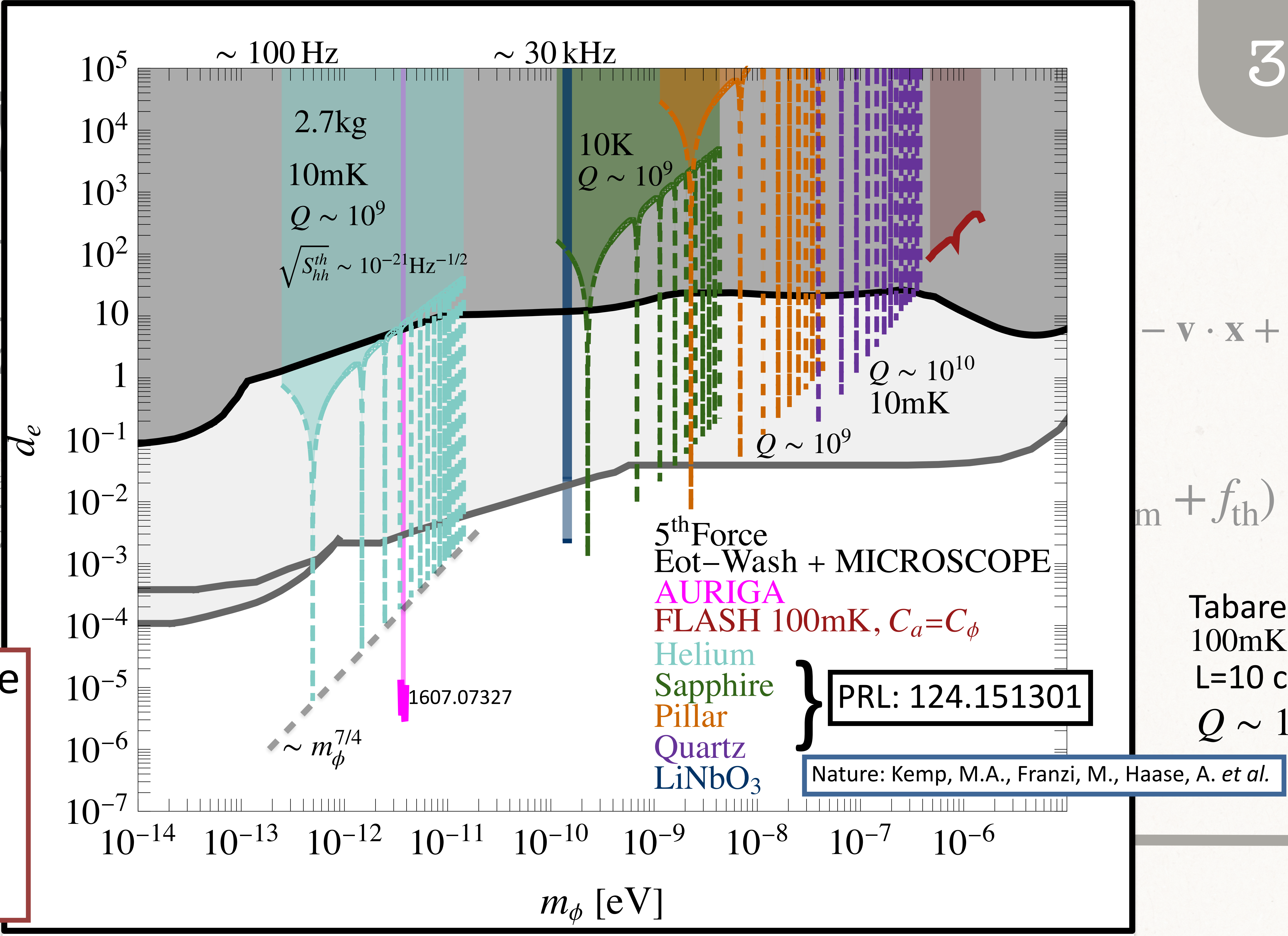
$\mathscr{L} = -\frac{\sqrt{\ }}{M}$ … $-\mathbf{v}\cdot\mathbf{x}+\ldots)]$

$h = \frac{\sqrt{4\pi}}{M_{pl}}\frac{(d_e}{\ }$ … $_{m} + f_{\rm th})$



$\mathscr{L} = -\frac{\sqrt{\ }}{M} \ldots - \mathbf{v}\cdot\mathbf{x} + \ldots)]$

$h = \frac{\sqrt{4\pi}}{M_{pl}} \frac{(d_e}{d} \ldots {}_m + f_{\mathrm{th}})$



1 Year exposure
10 mK (Pisa)
High Q factors
$1/\sqrt{NT\tau}$ rule

Tabarelli p.c.
100mK
L=10 cm
$Q \sim 10^5$

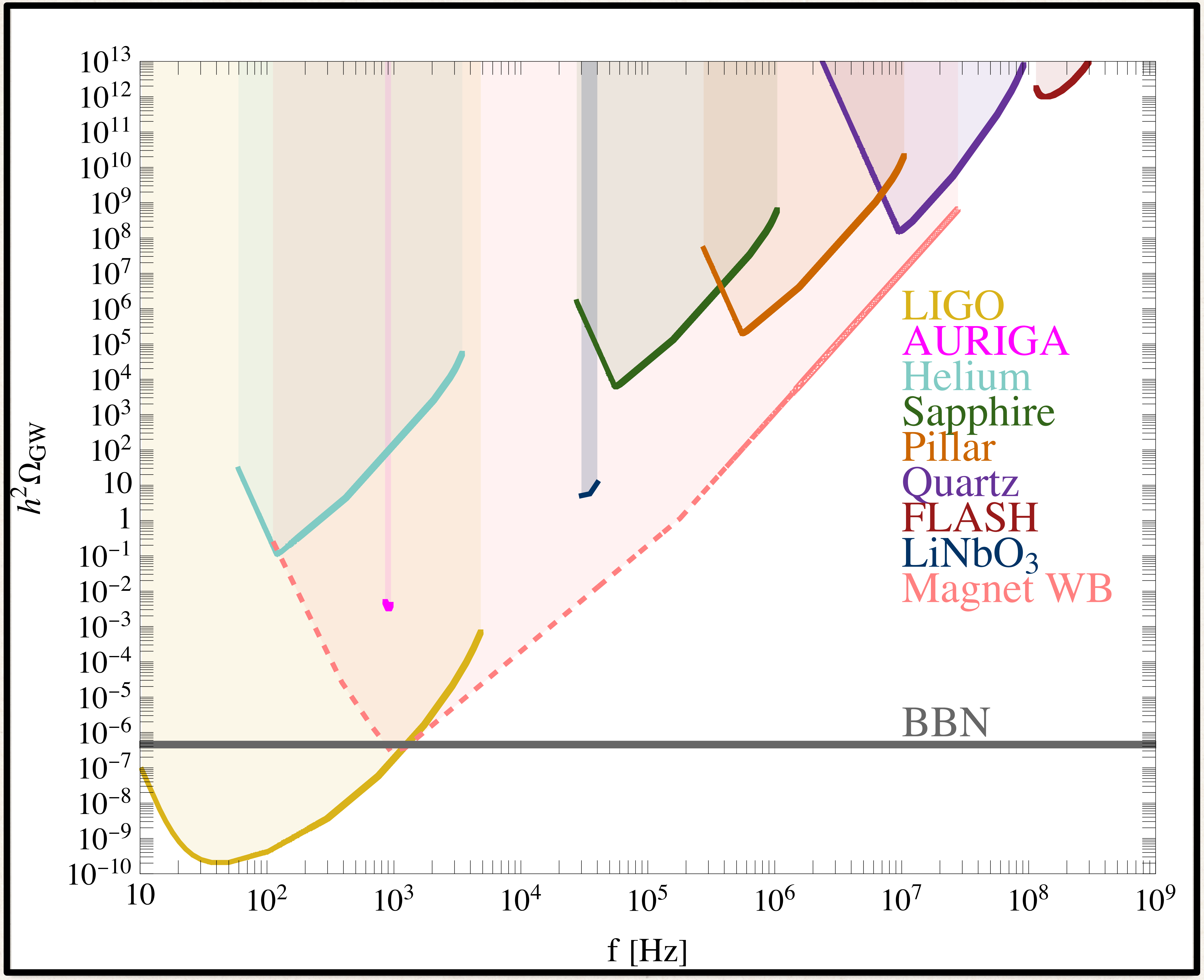
Conclusion

- Flash (Ultra-dream) probes a parameter space already excluded by **unavoidable 5th force bounds**
- Resonant mass detectors seems to be promising.

  High Q-factor, low mechanical losses, cm size $\rightarrow N \gg 1$
- Nothing new! Just providing orientation within the existing literature.
- GW?

thank you

Questions?



LIGO
AURIGA
Helium
Sapphire
Pillar
Quartz
FLASH
$LiNbO_3$
Magnet WB
BBN
$h^2\Omega_{GW}$
f [Hz]
10^{13}
10^{12}
10^{11}
10^{10}
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
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10
10^2
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