Direct limits for Scalar Field Dark Matter from a Gravitational-Wave Detector

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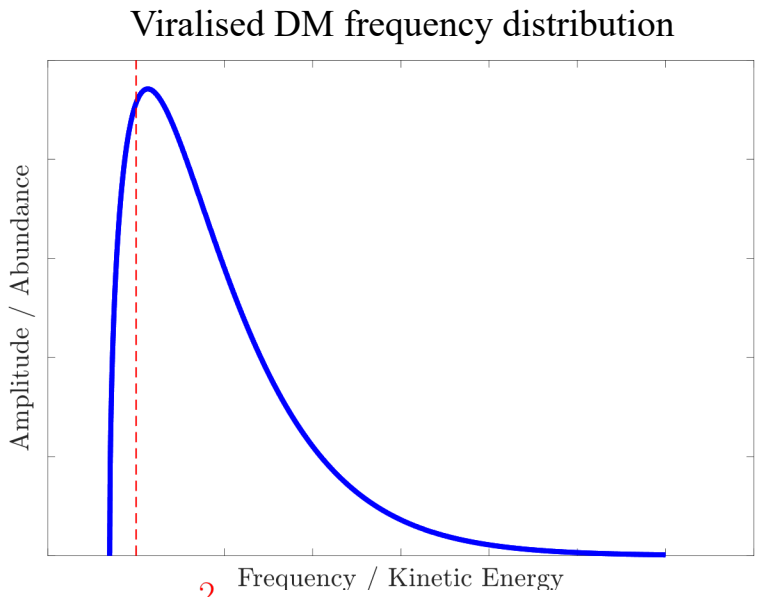
Sub-eV Scalar Field Dark Matter

(includes WISP/VULF, Dilaton, Moduli, Relaxion, …)

- Produced in early Universe by e.g. ‘misalignment mechanism’, manifests as oscillating field with local density ρ_{local}

$$\phi(t,\vec{r}) = \left[\frac{\hbar\sqrt{2\,\rho_{\mathrm{local}}}}{m_\phi\, c}\right] \cos\left(\omega_\phi\, t - \vec{k}_\phi \cdot \vec{r}\right)$$

- Trapped and virialised in gravitational potential wells of e.g. galaxies



$$\omega_\phi = \frac{m_\phi c^2}{\hbar}$$

Scalar DM changes Size and Refractive Index of Solids

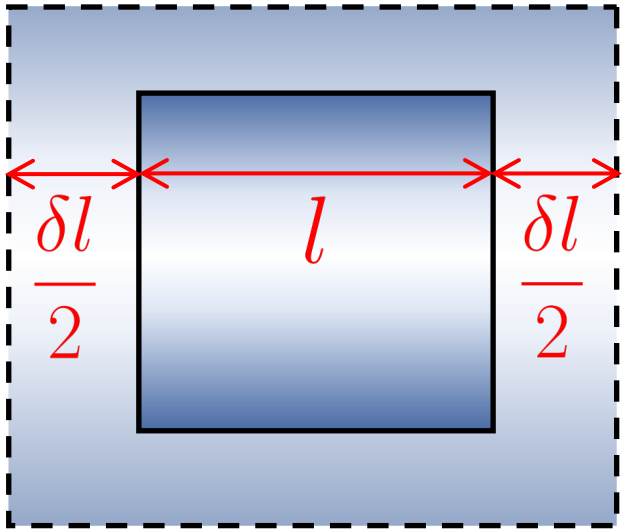
- Couples to SM photon and electron fields with coupling strength $\Lambda_{\gamma,\, e}$

$$\mathcal{L}_{\rm int} \supset \frac{\phi}{\Lambda_\gamma}\frac{F_{\mu\nu}F^{\mu\nu}}{4} - \frac{\phi}{\Lambda_e} m_e \bar{\psi}_e \psi_e$$

- Scalar DM changes electron mass m_e and fine structure constant α

$$\frac{\delta\alpha}{\alpha} = \frac{\phi}{\Lambda_\gamma} \qquad \frac{\delta m_e}{m_e} = \frac{\phi}{\Lambda_e}$$

- Changes size l and refractive index n of solids

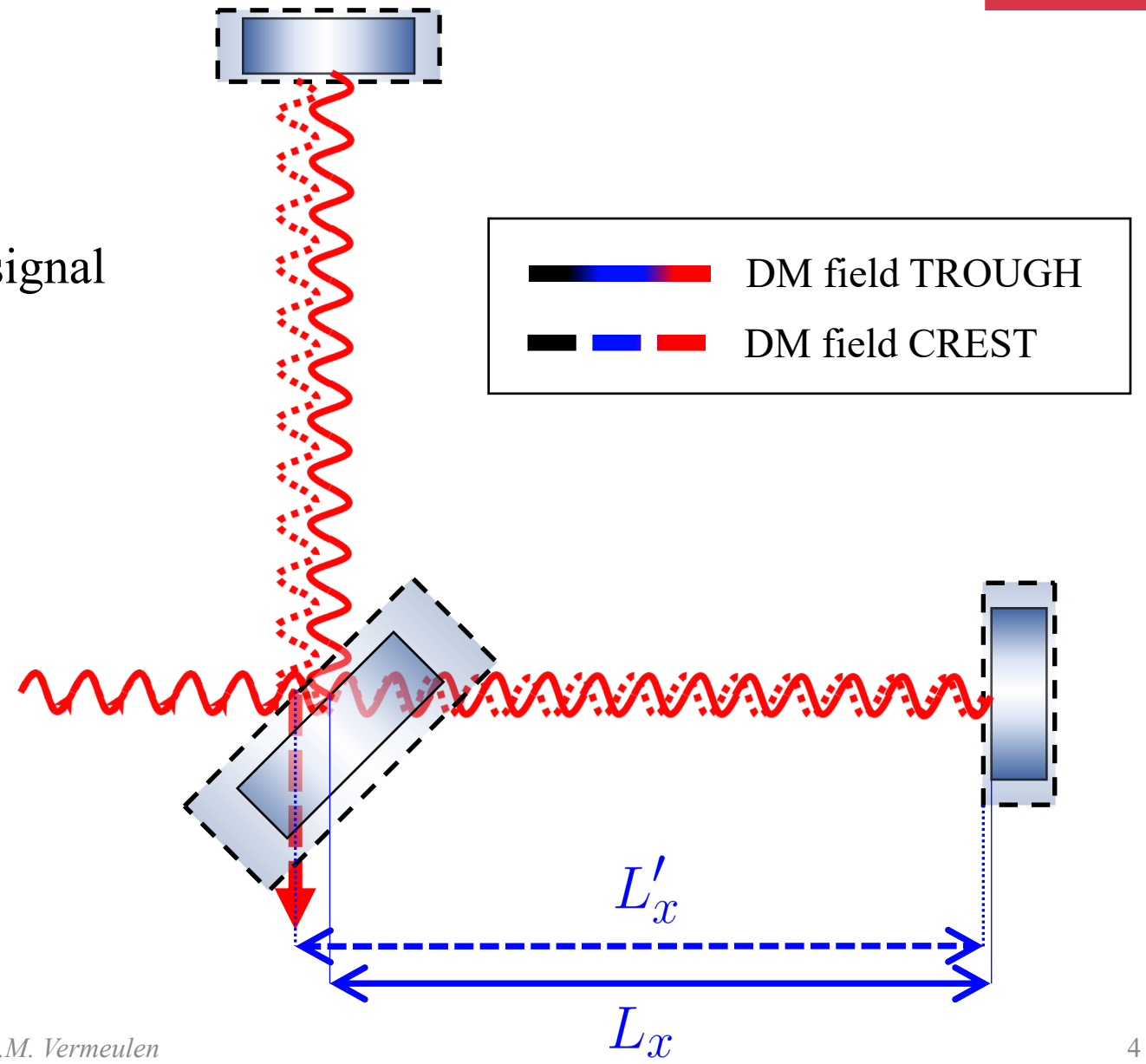


Grote & Stadnik (2019)

Scalar DM Couples to an Interferometer

- GEO600 most sensitive IFO for this type of signal

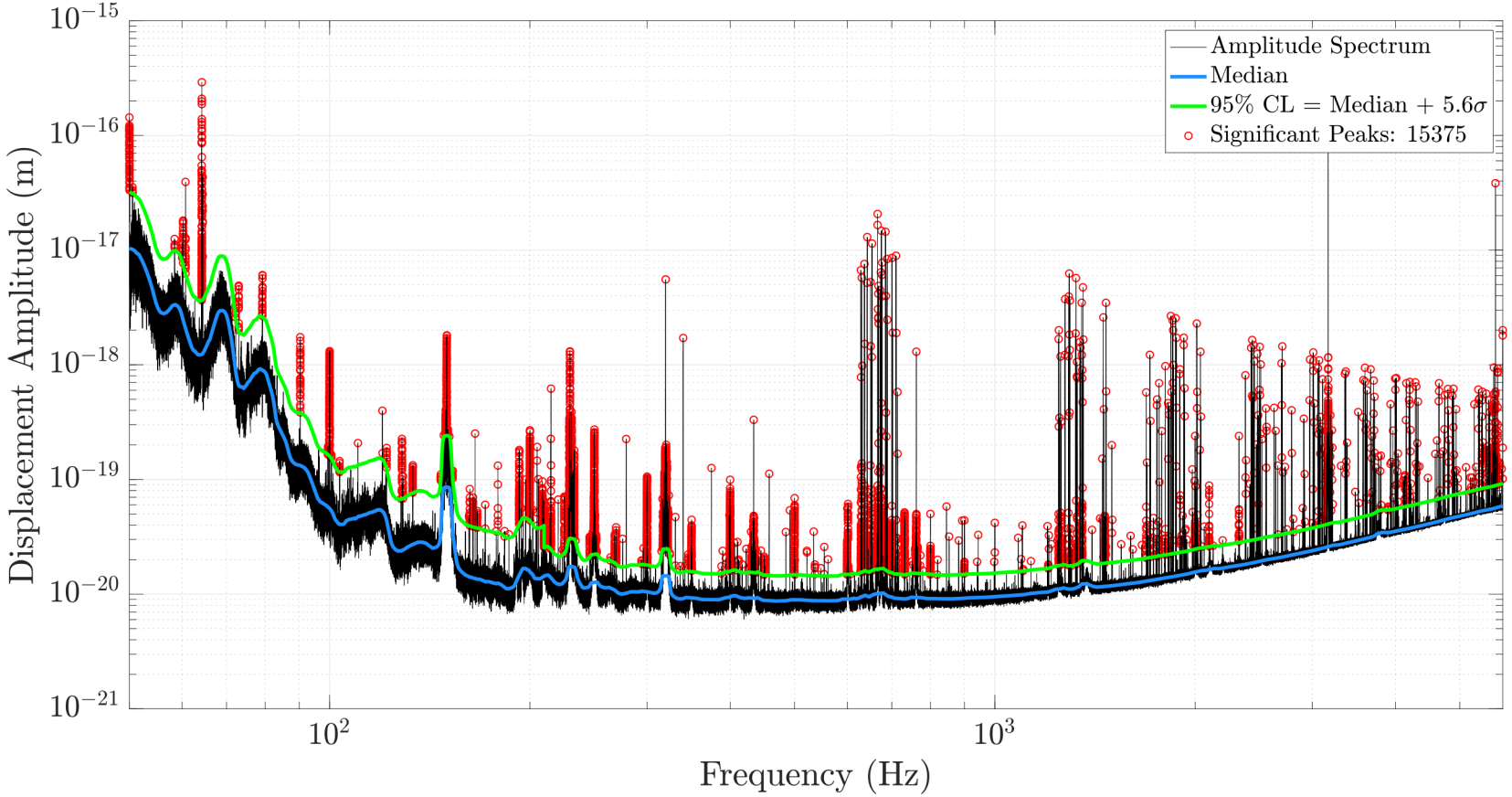
$$\delta(L_x - L_y) \approx \sqrt{2}\,(n\delta l + l\delta n)$$



Grote & Stadnik (2019)

Spectral Analysis

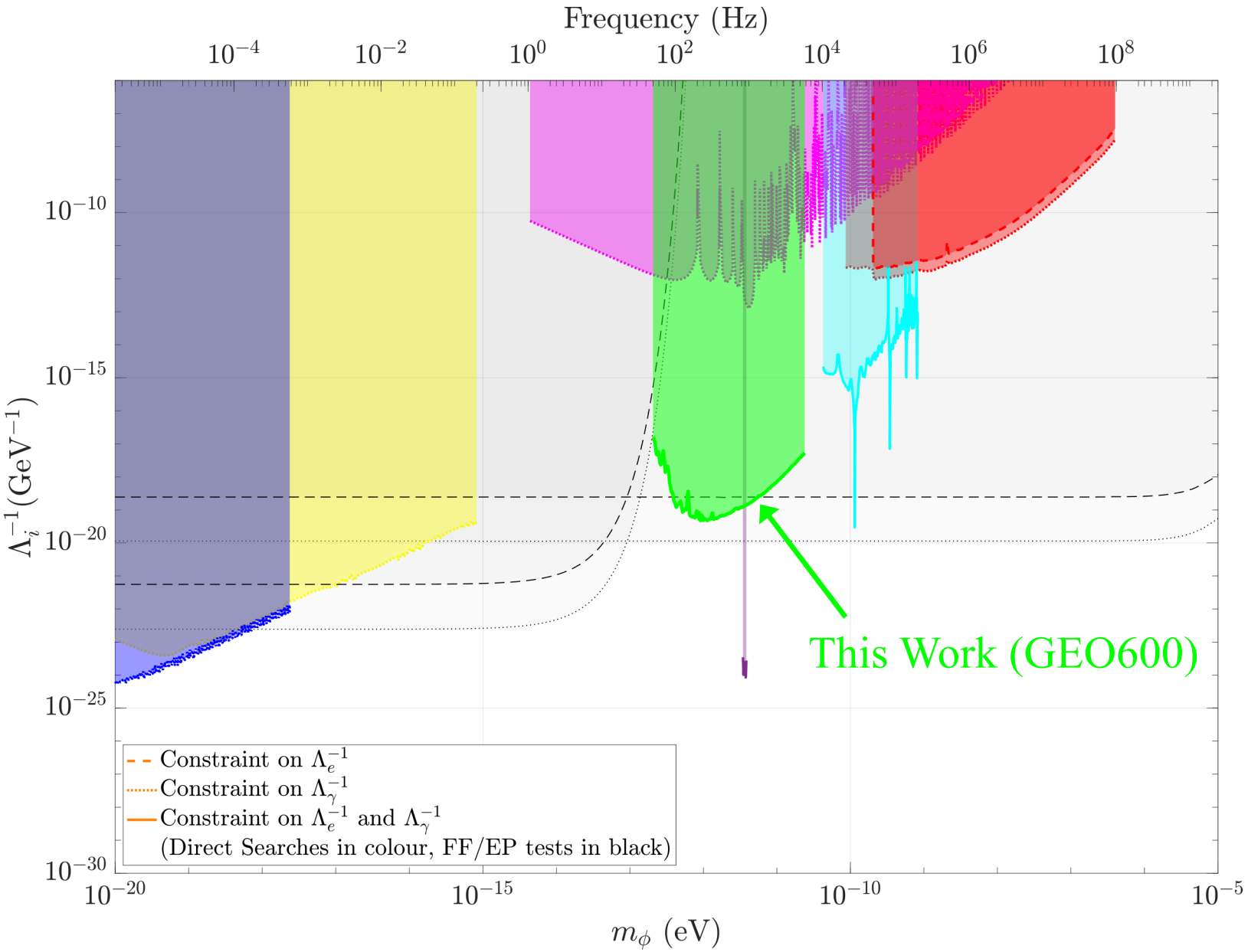
- Optimal SNR: Bin width = DM linewidth



→ Check persistence and frequency stability of candidate signals

All candidate signals rejected → Set constraints on DM parameters

New Constraints on Scalar Field DM



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