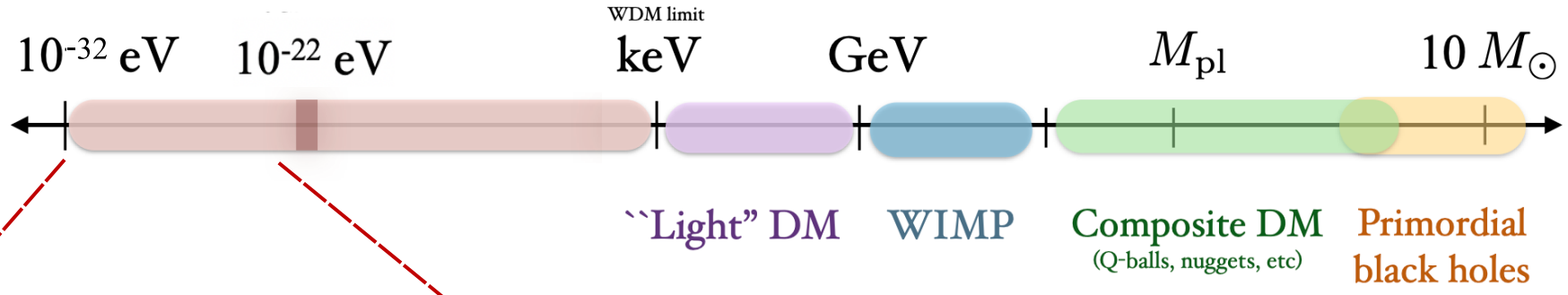
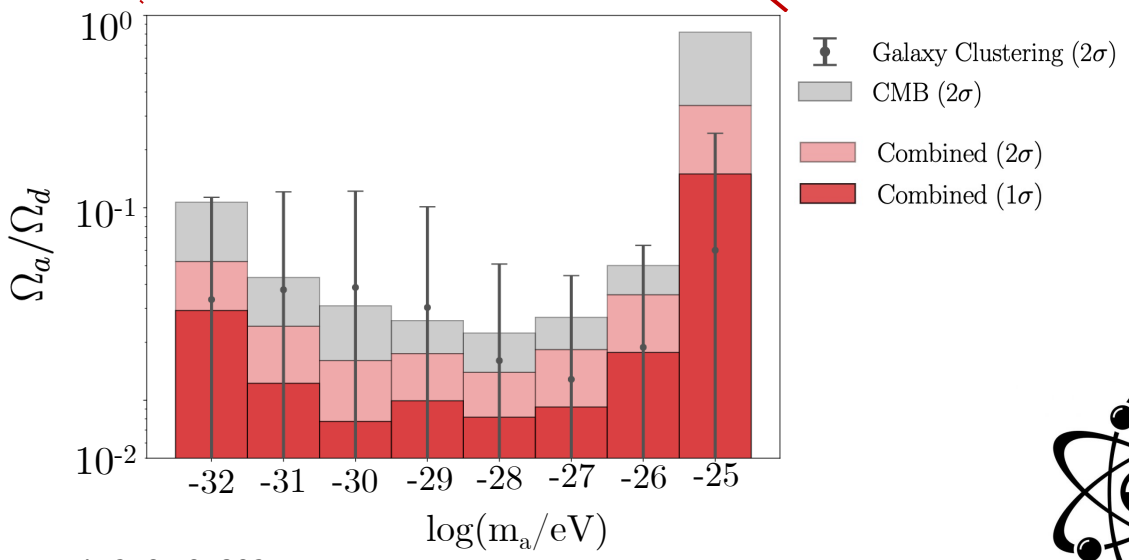
Searching For *Ultra* Ultra Light Scalars

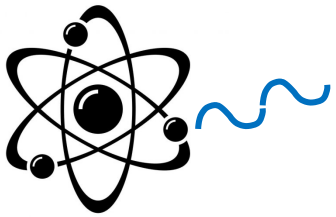




arxiv 2104.07802

Scalars can couple to many Lagrangian terms in the Standard Model (through dimensionful couplings):

$$\mathcal{L}_\phi = \kappa\phi\left[+ \frac{d_e}{4e^2}F_{\mu\nu}F^{\mu\nu} - \frac{d_g\beta_3}{2g_3}G^A_{\mu\nu}G^{A\mu\nu} - d_{m_e}m_e\bar{e}e - \sum_{i=u,d}(d_{m_i} + \gamma_{m_i}d_g)m_i\bar{\psi}_i\psi_i\right]$$



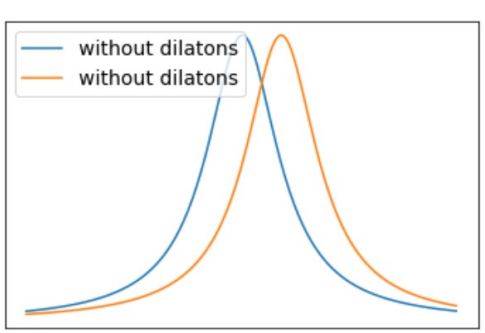
$$\alpha(\phi) = (1 + d_e\kappa\phi)\alpha = (1 + d_e\varphi)\alpha.$$

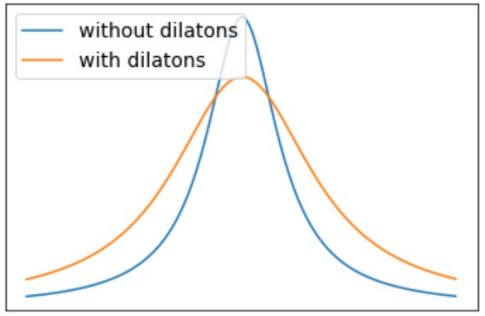
$$m_i(\phi) = (1 + d_{m_i}\kappa\phi)m_i = (1 + d_{m_i}\varphi)m_i,\ (i = e, u, d).$$

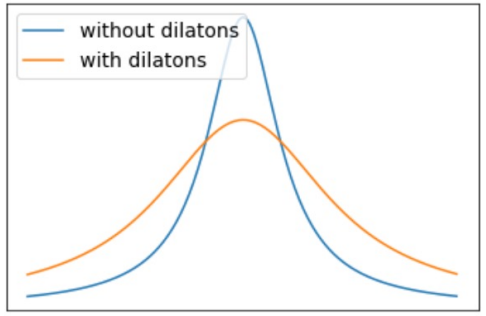
Generalized Voigt Profile

- Accounting for oscillating variation of the absorption wavelength requires another convolution. Final convolution comes from averaging over Rayleigh distribution (models decoherence):

$$\mathcal{V}(v_H(x,z), b_T(x,z), \gamma) = \frac{\gamma}{\pi^{5/2} b_T} \int_{-1}^{1} \int_{0}^{\infty} \int_{-\infty}^{\infty} \frac{e^{-\frac{v'^2}{b_T}} \left(\frac{2\phi_r}{\langle \phi_r \rangle} e^{-\frac{\phi_r^2}{\langle \phi_r \rangle^2}} \right)}{(\gamma^2 + (v_H(x,z) - v' - 2c\kappa d_i \phi_r \phi_m)^2) \sqrt{1-\phi_m^2}} d\phi_m d\phi_r dv'$$



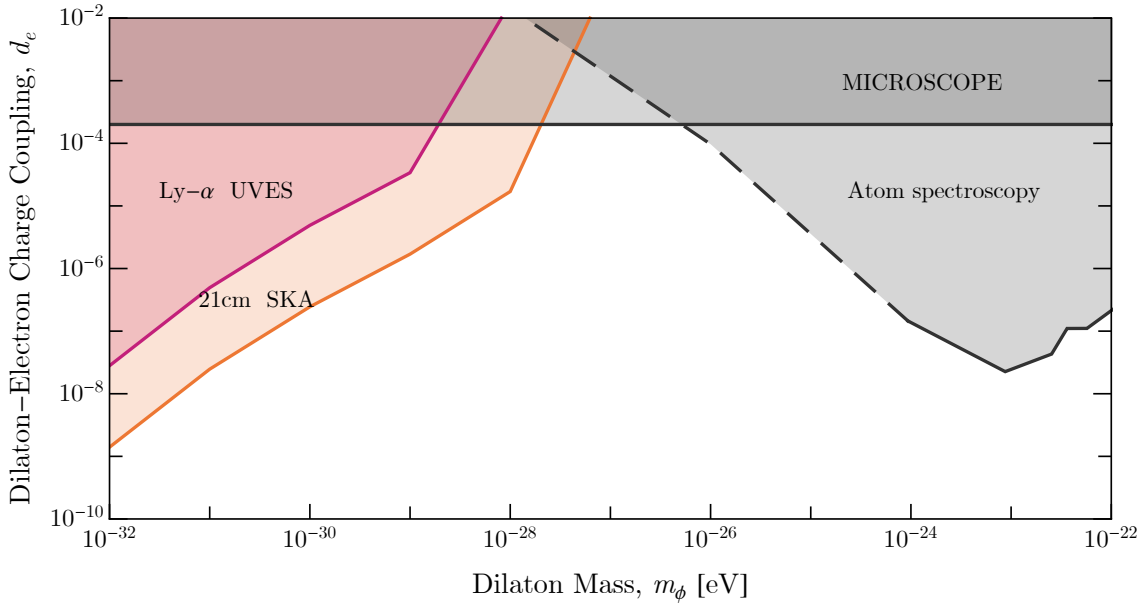


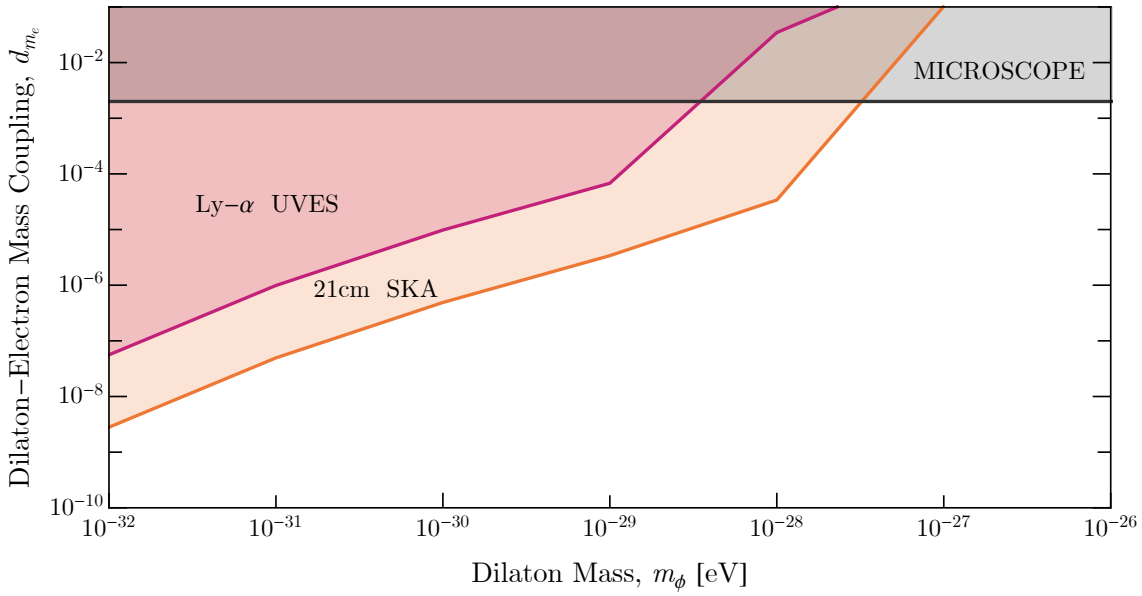


$m_\phi \approx 10^{-32}$ eV $\quad 10^{-28}$ eV $\quad 10^{-24}$ eV $\quad 10^{-20}$ eV

$t_{\rm pix} < t_m < t_c \qquad t_m < t_{pix} < t_c \qquad t_m < t_c < t_{pix}$

New Bounds!





- SKA-like and UVES SQUAD data can improve bounds. Results scale differently for $t_{\rm pix} < t_m < t_c$
- Competing bounds limited by integration time (e.g. atomic clocks, equivalence principle tests)
- 21cm bounds can be extended to bounds on quark mass couplings and gluon coupling:

$$\Delta E_{21\rm cm} = \frac{4}{3} g_e g_p \alpha^2 \frac{m_e}{m_p} \mathrm{Ry}$$