Dilaton Searches With Cosmological Probes

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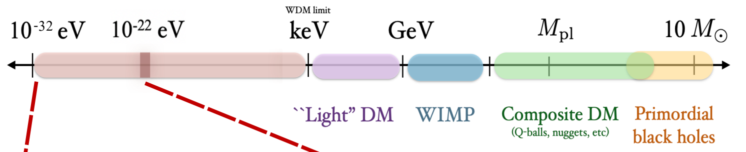
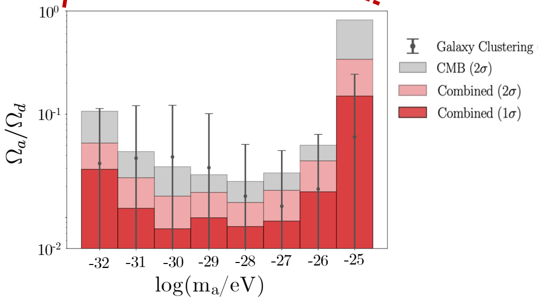
1 – Ultra-Ultralight cosmology



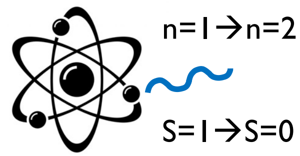
Klein-Gordon equation:

$$\ddot{\phi} + 3H\dot{\phi} + m_\phi^2\phi = 0$$



- Bounds on dilaton relic density exist from CMB lensing and galaxy clustering
- We generate 3D synthetic UVES SQUAD data at each dilaton mass
- Use axionCAMB for structure formation: structure surpressed at smallest dilaton masses

2 - Couplings



- Dilatons can couple to many Lagrangian terms in the Standard Model (through dimensionful couplings)
- This leads to variations of "constants" of nature such as the fine structure constant or fermion masses

$$\Delta E_{\mathrm{Ly}\alpha} = \frac{3}{4}\mathrm{Rydberg} = \frac{3m_e\alpha^2}{8} \qquad \Delta E_{21\mathrm{cm}} = \frac{4}{3}g_e g_p \alpha^2 \frac{m_e}{m_p}\mathrm{Ry}$$

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

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

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

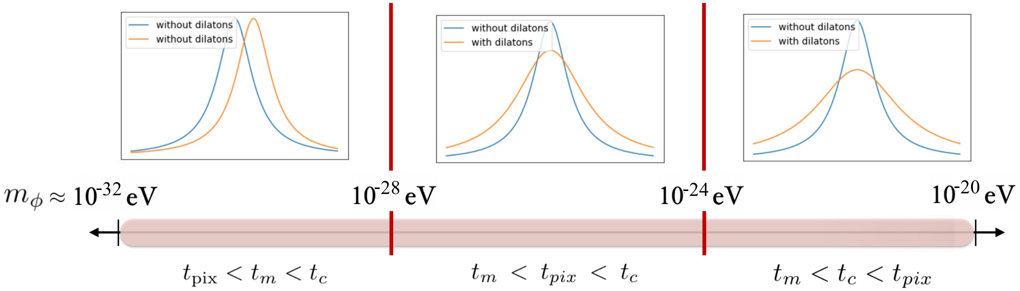
3 – Generalized Voigt Profile

- Absorption is modeled by Voigt profile, a convolution of a Gaussian and a Lorentzian.
- Oscillating variation of the absorption wavelength requires another convolution. Final convolution comes from averaging over Rayleigh distribution (models decoherence)

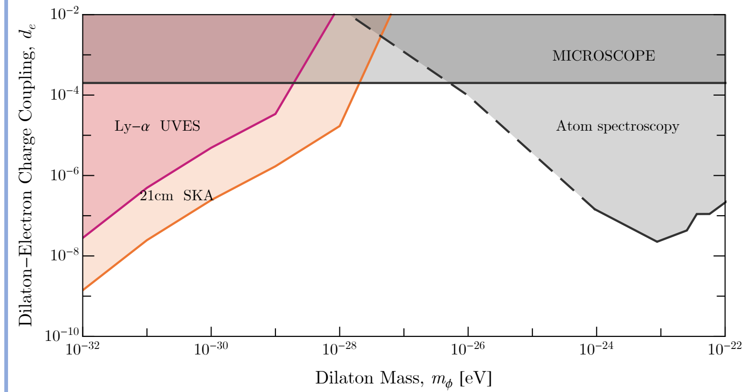
Timescales:

$$t_c \approx \frac{\lambda_{\rm dB}}{v_\phi} = \frac{2\pi}{m_\phi v_\phi^2}$$

$$t_m \approx m_\phi^{-1}$$



4 - Sensitivities



- SKA 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
- 21cm bounds can be extended to bounds quark mass couplings and gluon coupling

- Electron mass coupling also a constrained up to 4 orders of magnitude (cf presentation)

References:
[1] D.Marsh *et al.* (2021) – [2] T.Damour, J.Donoghue (2010)
– [3] MICROSCOPE (2017) – [4] K.Van Tilburg, J.Huang, A.Arvanitaki