Search for Ultralight Dark Matter with Spectroscopy of Radio-Frequency Atomic Transitions
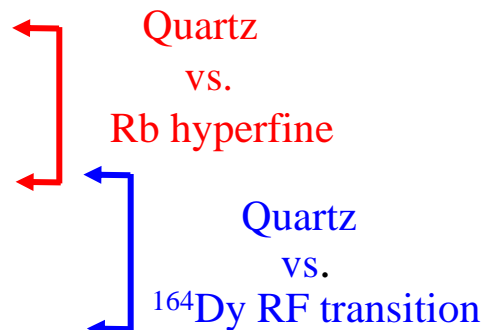
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Introduction

1. Dark matter (DM) may consist of light particles (mass range: 10^{-22} – 10 eV).

2. DM behaves like a wave oscillating at the Compton frequency f_c of the DM particle.

3. If DM particles have scalar couplings to the standard model matter, fundamental constants (FCs) oscillate at frequency f_c.

How to look for oscillations in the 'constants'?

Compare the frequency of systems which have different sensitivities to the FCs

- Hyperfine transition: $f \propto m_e \alpha^4 \left(\frac{m_e}{m_p} \right)$

- Mechanical mode frequency $f \propto m_e \alpha^2 \left(\frac{m_e}{m_N} \right)^{1/2}$

- ^{164}Dy 754 MHz RF transition $f \propto m_e \alpha^{2.6 \times 10^6}$

Quartz vs. Rb hyperfine

Quartz vs. ^{164}Dy RF transition

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$$m_e \alpha^2 \left(\frac{m_e}{m_N}\right)^{1/2} \qquad f \propto m_e \alpha^{2.6 \times 10^6}$$

vs

Quartz   **^{164}Dy RF transition**

&

$$m_e \alpha^2 \left(\frac{m_e}{m_N}\right)^{1/2} \qquad m_e \alpha^4 \left(\frac{m_e}{m_p}\right)$$

vs

Quartz   **Hyperfine transition**

Exclusion plots