Contribution ID: **88** Type: **Hot Topic Talk**

New limits on variations of the fine-structure constant and ultralight dark matter

Tuesday, 26 September 2023 15:05 (20 minutes)

The 171Yb+ ion features two narrow optical transitions: an electric octupole (E3) transition as well as an electric quadrupole (E2) transition. Because they have a large differential sensitivity to the fine structure constant α, its possible variations can be probed by comparing the transition frequencies at various positions in spacetime. We find improved bounds on a linear temporal drift of α, as well as its coupling to the gravitational potential of the sun, from a long-term optical clock comparison [1,2].

Additionally, the couplings of so-called ultralight bosonic dark matter (m « 1 eV/cˆ2) to standard model particles would lead to coherent oscillations of constants, with an oscillation frequency corresponding to the Compton frequency of the dark matter mass [3]. We conduct a broadband dark-matter search by comparing the frequency of the E3 transition to that of the E2 transition, and to that of the 1S0 ↔ 3P0 transition in 87Sr. We find no indication for significant oscillations in our experimental data. Consequently, we put limits on oscillations of the fine-structure constant and thus improve existing bounds on the scalar coupling of ultralight dark matter to photons for dark-matter masses of about 1E−24 to 1E−17 eV/cˆ2 [2]. Couplings to quarks and gluons can also be investigated with optical frequency ratio measurements by considering the effect an oscillating nuclear charge radius would have on electronic transitions [4].

[1] Lange et al., Phys. Rev. Lett. 126, 011102 (2021).
[2] Filzinger et al., Phys. Rev. Lett. 130, 253001 (2023).
[3] Arvanitaki et al., Phys. Rev. D 91, 015015 (2015).
[4] Banerjee et al., arXiv:2301.10784 (2023).

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Session Classification: Tuesday Hot Topics