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Placing constraints on the time-variation of fundamental constants using atomic clocks

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Optical atomic frequency standards, such as those based on a single trapped ion of $^{171}\mathrm{Yb}^{+}$, now demonstrate systematic frequency uncertainties in the $10^{-17} - 10^{-18}$ range. These standards rely on the principle that the unperturbed energy levels in atoms are fixed and can thus provide absolute frequency references. A frequency standard's uncertainty is therefore limited by the uncertainty in realising the idealized unperturbed environment. There exists the possibility however that the unperturbed level spacing is not fixed. Some theories that go beyond the Standard Model involve a time-variation of the fundamental "constants" - such as the fine structure constant - which determine these energy levels. Measurements of spectral lines in radiation emitted from distant galaxies around 10^{10} years ago are inconclusive, with some results suggesting the existence of a time-variation, and others observing nothing. By virtue of their very small measurement uncertainty atomic-clock experiments can, in timescales of only a few years, perform tests of present-day variation that are complementary to astrophysical data. Comparisons of frequency measurements between two or more atomic "clock" transitions that have different sensitivities to these constants enables us to directly measure any present-day time-variation. Combining recent results from the NPL $^{171}\mathrm{Yb}^{+}$ clock with measurements from other experiments worldwide places upper limits on the present-day time-variation of the proton-to-electron mass ratio μ and the fine-structure constant α of $\dot{\mu}/\mu = 0.2(1.1) \times 10^{-16}\ \mathrm{yr}^{-1}$ and $\dot{\mu}/\mu = -0.7(2.1) \times 10^{-17}\ \mathrm{yr}^{-1}$.