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Axion Dark Matter Detection Using Atomic Clocks

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Axions are a promising dark matter candidate as well as a compelling solution to the strong charge-parity problem. Axion dark matter can be modelled as a background, classical field, whose interactions with Standard Model particles and forces give rise to observable effects. Although there are many experiments that search for these axion-induced experimental observables, given the mystery of dark matter, it is vital to develop new experiments.

We propose a novel detection scheme using atomic clocks to detect axion dark matter. The interaction between the axion field and the electron axial vector current can produce time-dependent mixing of opposite-parity states in atomic systems, resulting in an oscillating electric dipole moment (EDM). In the presence of an external electric field, this EDM induces an oscillating Stark shift which can be detected using atomic clocks.

In this work, we estimate the achievable axion mass-coupling parameter space given current atomic clock performance. Preliminary order of magnitude calculations shows promising sensitivity of axion mass-coupling parameter space beyond current astrophysical and laboratory limits. We report on the optimal experimental parameters, including electric field configurations and clock species, that maximise sensitivity while alleviating systematic error.

This new detection scheme has the potential to either detect axions, demonstrating a novel application of atomic clocks in the search for dark matter, or constrain physical axion parameters, in the case of non-detection.

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