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New Atomic Methods for Dark Matter Detection

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Synopsis We calculate the parity and time-reversal violating effects that are induced in atoms, nuclei, and molecules by their interaction with various background cosmic fields, such as axion dark matter or dark energy.

We present our recent proposals to exploit the parity and time-reversal violating effects in atoms, nuclei, and molecules to search for evidence of various background cosmic fields, and to constrain the interaction strengths of these fields with fermions.

Candidates for such background fields include dark matter (e.g. axions) and dark energy, and also are motivated by various Standard Model extensions. Certain interactions of static and dynamic background cosmic fields would lead to the mixing of opposite parity states in atoms and molecules. This would, in turn, give rise to observable parity and time-invariance violating effects. The measurement of such effects would shed light on the interactions that gave rise to them.

Of particular interest is the interaction of a dynamic pseudoscalar field with atomic/molecular electrons and nuclei. Such a field could describe axions, a hypothetical pseudoscalar particle invoked to solve the strong CP problem from QCD, now also a leading cold dark matter candidate. We perform calculations of the parity and time-invariance violating effects that such a field would induce in atoms [1, 2], and demonstrate a potential very large enhancement of the effects in diatomic molecules.

Axion-induced nuclear Schiff moments were considered theoretically in [3], and a thorough experimental proposal to exploit this effect to search for axions was proposed in [4]. We note that nuclear magnetic quadupole moments are also generated via the interaction with axions [5]. Such moments may have significant advantages over nuclear Schiff moments.

Crucially, all the effects we consider here are linear in the small parameter that quantifies the interaction strength between the dark matter particles and ordinary matter particles; most current dark matter and axion searches rely on effects that are proportional to quadratic and higher powers of this parameter.

Oscillating electric dipole moments have the potential to be measured with very high accuracy, and experimental techniques in this field are evolving fast, making this a particularly exciting area for potential discovery in the near future. Pairs of closely spaced opposite parity levels that are found in diatomic molecules may also lead to a significant enhancement in these effects [2, 5, 6].

We are also interested in a possible explanation for the anomalous DAMA dark matter detection results. Our calculations may provide a possible mechanism for dark matter induced ionisation modulations that are not ruled out by other experiments. Alternatively, they could further reduce the available parameter space for certain dark matter models.

References

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