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Searching for dark matter and exotic bosons with atoms, molecules and ultracold neutrons

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We propose new schemes for the direct detection of dark matter and exotic bosons in experiments involving atoms, molecules and ultracold neutrons. Dark matter, which consists of low-mass bosons (such as axions, pseudoscalars or scalars), can readily form an oscillating classical field that survives to reside in the observed galactic dark matter haloes if these particles have sufficiently low mass and are sufficiently feebly interacting.

An oscillating classical dark matter (axion or pseudoscalar) field can give rise to a number of oscillatory spin-dependent effects in the laboratory. These effects include the precession of polarised spins about Earth's direction of motion though galactic dark matter [1-3], and induced oscillating electric dipole moments of atoms, molecules and nucleons [3-5]. We are currently working with the nEDM collaboration to search for these oscillatory spin-dependent effects using a dual neutron/^{199}Hg co-magnetometer [6].

An oscillating classical dark matter (scalar) field can produce both 'slow' cosmological evolution and oscillating variations in the fundamental constants [7], which can be sought for in astrophysical phenomena and in the laboratory. Using data pertaining to Big Bang nucleosynthesis, as well as atomic spectroscopy measurements in the laboratory [8,9], we have derived limits on interactions of dark matter with Standard Model particles that improve on existing constraints by up to 15 orders of magnitude [7]. In the laboratory, we can also use laser and maser interferometry as another high-precision platform to search for dark matter via the effects of variation of fundamental constants [10].

Exotic scalar fields may also be sourced by massive bodies. Using atomic spectroscopy measurements in the laboratory, we have derived limits on the interactions of such scalar particles with Standard Model particles, including constraints on combinations of interaction parameters which cannot otherwise be probed with traditional anomalous-force measurements [11]. We suggest further measurements to improve on the current level of sensitivity [11].

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Summary

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