Award Abstract #1404325

Precision Measurements with Nuclear Spins

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ABSTRACT

In this project scientists will search for new, very weak forces between atoms. The current understanding of physics and cosmology allows for the possibility that in addition to the four known fundamental forces there may be additional weak forces due to the existence of new particles. To search for such forces the group supported by the present grant will perform very sensitive experiments on atoms using a variant of the technique that underlies MRI medical scanners (nuclear magnetic resonance). In the proposed experiments the group will orient the nuclear spins of atoms using lasers and watch how the spin orientation changes with time. They expect to improve the sensitivity by several orders of magnitude compared with earlier experiments. In addition to allowing the scientists to search for new forces between atoms, the proposed experiments will also have practical applications for very sensitive measurements of magnetic fields and for precision navigation.

The proposal describes a program of precision measurements based on high-sensitivity nuclear spin magnetometers. In one part of the program an existing alkali-metal noble-gas co-magnetometer will be used to set new limits on several hypothetical spin interactions. A possible interaction between spin and mass can be mediated by axions or other light pseudo-scalar particles. However, existing laboratory experiments searching for this effect have not yet reached a sensitivity that is competitive with astrophysical limits. One of the proposed experiments will improve these limits by more than 3 orders of magnitude and reach, for the first time, an unexplored range of parameter space. Another type of interaction that can be mediated by hypothetical light particles is a non-magnetic spin-spin interaction. Recent limits on such electron spin interactions can be improved by 1 or 2 orders of magnitude using already existing experimental

apparatus. Another part of the program is focused on development of a new type of spin co-magnetometer, using two noble gas nuclear spin species and an alkali-metal readout with a Ramsey pulse interrogation. It is designed to have a higher accuracy as well as better precision compared with existing approaches. The sensitivity of the new co-magnetometer is already sufficient to realize a search for spin-gravity interaction with energy sensitivity at the Planck scale. The group's efforts will focus on the control of systematic effects in this experiment.