Spin-gravity coupling limits based on ultra-low-field NMR comagnetometer

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The advent of zero-to-ultra-low-field nuclear magnetic experiments enabled by the optically pumped magnetometers (OPMs) gave rise to number of searches for "exotic physics" (axion-like dark matter, long range spin couplings, spin-gravity interactions) with the liquid state coomagnetometers [1]. In these experiments, nuclear-spin evolution is investigated with the use of OPM under the influence of ultra-low magnetic field ($\sim$100 nT), in otherwise magnetically-shielded environment. Long coherence times achievable under such conditions lead to high spectral resolution enabling detection of minute changes of nuclear evolution, which may be i.e. caused by exotic interactions. Measurements of such small effects requires limitation of contribution from the magnetic field typically orders of magnitude stronger than any postulated exotic coupling. This can be done by measuring a ratio of evolution frequencies of two nuclear systems, while use of single species samples can strongly suppress systematic effects [2].

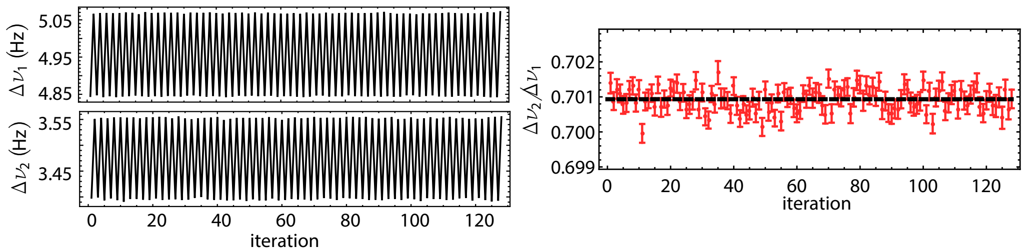

Figure 1: Magnetic line splittings (right) track imperfect field reversals in an exemplary spin-gravity measurement. The splitting ratio (right) is not sensitive to magnetic-field changes, enabling searches for non-magnetic couplings.

Here we present our initial experimental results using a single-species liquid-state nuclear-spin comagnetometer. We measure near zero-field signal with the reversal of magnetic field oriented along gravitational field, which can be used to establish new limits for hypothetical spin-gravity couplings to protons. Experimental apparatus and measurement procedures will be presented and current statistical and systematic uncertainties will be discussed.

References

[1] Ledbetter, M. P., et al. "Liquid-state nuclear spin comagnetometers." Physical Review Letters 108.24 (2012): 243001.

[2] Wu, T., et al. "Nuclear-spin comagnetometer based on a liquid of identical molecules." Physical Review Letters 121.2 (2018): 023202.