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Spectroscopy of Spontaneous Spin Noise for Probes of Spin Dynamics and Magnetic Resonance SCOTT CROOKER, National High Magnetic Field Laboratory-Los Alamos

Not all noise in experimental measurements in unwelcome. Certain fundamental noise sources contain valuable information about the system itself – a notable example being the small, inherent fluctuations of electrical current (current shot noise), which both demonstrates the discrete nature of the current carriers, and also directly yields the electron charge. In magnetic systems, fundamental noise can exist in the form of random spin fluctuations. As pointed out by F. Bloch in 1946, stochastic fluctuations of N paramagnetic spins will generate measurable noise of order \sqrt{N} spins, even in zero magnetic field. As such, the relative amplitude of the noise signature compared with the signal from spins driven into saturation scales as $1/\sqrt{N}$, which approaches unity in the single-spin limit. In this work we address precisely these same \sqrt{N} spin fluctuations, using off-resonant Faraday rotation to passively "listen" to the magnetization noise in an equilibrium ensemble of paramagnetic rubidium or potassium atoms near room temperature [1]. These random spin fluctuations generate measurable spontaneous spin coherences, which precess and decay with the same characteristic energy and time scales as the macroscopic magnetization of an intentionally polarized or driven ensemble. Spin-spin correlation spectra of the measured noise reveals g-factors, nuclear spin, isotope abundance ratios, hyperfine splittings, nuclear moments, and spin coherence lifetimes – without having to excite, optically pump, or otherwise drive the system away from thermal equilibrium. These noise signatures scale inversely with interaction volume, suggesting routes towards non-perturbative, sourceless magnetic resonance of small systems containing few spins. [1] S.A. Crooker, D.G. Rickel, A.V. Balatsky, D.L. Smith, Nature **431**, 49 (2004).