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Innovating quantum technologies

"Listening" to spin & magnetization noise

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working at the NHMFL in Los Alamos ever since, on various magneto-optical spectroscopies.

Not all noise in experiments is unwelcome. Certain types of fundamental noise contain extremely valuable information about the system itself – a classic example being the inherent voltage fluctuations across any resistor (i.e., Johnson noise), from which temperature can be determined. In magnetic systems, fundamental noise can exist in the form of random spin fluctuations. For example, statistical fluctuations of N independent spins should generate small noise signals of order sqrt(N) spins, even in zero magnetic field. In accordance with the Fluctuation-Dissipation Theorem, the spectrum of these fluctuations – if experimentally measurable -- can reveal the important dynamical properties (such as spin decoherence times and g-factors), but without ever driving, exciting, or perturbing the system away from thermal equilibrium. This talk will describe how we measure spin & magnetization dynamics by passively "listening" to stochastic noise signals, using methods based on sensitive optical Faraday rotation magnetometry. This approach, applied originally to atomic alkali vapors [1], has since been used to detect electron spin noise in semiconductors [2], valley fluctuations in 2D semiconductors [3], and "magnetic monopole" noise in artificial spin ice materials [4]. Interestingly, noise-based approaches also allow to circumvent certain restrictions of linear response theory. Moreover, because fluctuations are recorded directly in the time domain, nontrivial higher-than-second-order spin correlations can also be directly evaluated from the noise data. This talk will highlight recent developments in spin noise spectroscopy and will discuss how these techniques can be further improved and applied to an even broader range of material systems.

[1] Nature 431, 49 (2004); [2] PRL 104, 036601 (2010); [3] Science Adv. 5, eaau4899 (2019); [4] arXiv:2008.08635.