

# Probing spin-fluctuations in dense alkali-metal media

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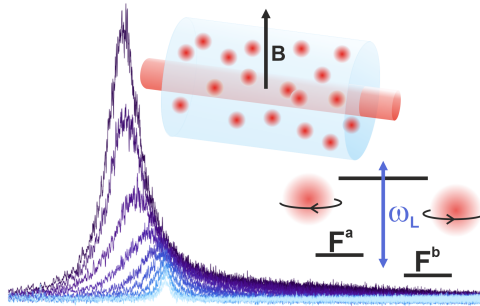
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SERF regime in alkali-metal ensembles is powerful but hard to analyze because intra-atomic (hyperfine), inter-atomic (spin-exchange collisions), and environmental (Zeeman) effects compete to define the spin dynamics. We study the quantum spin noise in this scenario by considering the mean field evolution combined with Ornstein-Uhlenbeck dynamics. We derive the full two-time spin covariance matrix and the observable noise spectra in Faraday rotation experiments, from the deep-SERF to deep-spin-exchange regimes [1]. These predict partial cancellation of quantum noise in relevant scenarios, which suggest for SERF magnetometers an “ultimate sensitivity” better than what is found by simpler models. We find good agreement between the new modeling and spin noise spectroscopy in a  $^{87}\text{Rb}$  vapor [2] as well as in a dual-species experiment  $^{87}\text{Rb} - ^{133}\text{Cs}$  [3]. If time allows, extension of the results to spin-polarized states will be discussed [4].



**Figure 1.** Overview of spin-noise spectroscopy. Spin-noise spectra in the SERF regime. Spin-exchange collisions create strong correlations between  $\mathbf{F}^a$  and  $\mathbf{F}^b$  in the ground state.

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[2] K. Mouloudakis\*, J. Kong\*, A. Sierant, E. Arkin, M. Hernández Ruiz, R. Jiménez-Martínez and M. W. Mitchell, Anomalous noise spectra in a spin-exchange-relaxation-free alkali-metal vapor, *Phys. Rev. A Letter*, **109**, L040802 (2024).

[3] K. Mouloudakis, et.al., Interspecies spin-noise correlations in hot atomic vapors, *Phys. Rev. A* **108**, 052822 (2023).

[4] K. Mouloudakis, V. Koutrouli, I. K. Kominis, M. W. Mitchell, G. Vasilakis, Spin projection noise and the magnetic sensitivity of optically pumped magnetometers, arXiv, 2402.10746, (2024)