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Sensitivity, quantum limits, and quantum enhancement of noise spectroscopies MORGAN MITCHELL, ICFO - The Institute of Photonic Sciences, VITO GIOVANNI LUCIVERO, Department of Physics, Princeton University, ALEKSANDRA DIMIC, Faculty of Physics, University of Belgrade, JIA KONG, RICARDO JIMENEZ-MARTINEZ, ICFO - The Institute of Photonic Sciences — We study the fundamental limits of noise spectroscopy using estimation theory, Faraday rotation probing of an atomic spin system, and squeezed light. We find a simple and general expression for the Fisher information, which quantifies the sensitivity to spectral parameters such as resonance frequency and linewidth. For optically-detected spin noise spectroscopy, we find that shot noise imposes "local" standard quantum limits for any given probe power and atom number, and also "global" standard quantum limits when probe power and atom number are taken as free parameters. We confirm these estimation theory results using non-destructive Faraday rotation probing of hot Rb vapor, observing the predicted optima and finding good quantitative agreement with a first-principles calculation of the spin noise spectra. Finally, we show sensitivity beyond the atom- and photon-number-optimized global standard quantum limit using squeezed light.

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