Theory of Optical Measurements Quantum

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Skyrmions in frustrated magnets have nanoscale dimensions, making them promising for quantum applications, such as as qubits [1]. While quantum dynamics of skyrmions has been theoretically analyzed at length, direct experimental evidence of their non-classical behaviour remains an open challenge. On the other hand, Brillouin light scattering (BLS) is a well-established tool to study classical magnons with a high spatio-temporal resolution. In this work [2], we propose that BLS could also be an apt method to probe quantum skyrmions. We analyze classical and quantum BLS by skyrmions in a frustrated magnet. We show that, for a specific geometry, classical skyrmions produce symmetric sidebands in the BLS spectrum, whereas quantum skyrmions exhibit a distinct asymmetry arising from vacuum fluctuations of their rotation. By studying the photon-skyrmion interaction, we calculate the BLS spectrum using a quantum master equation and show that sideband asymmetry serves as a robust witness of energy level quantization. We find that this asymmetry is pronounced at low temperatures, and can be controlled by input laser power (as the figure shows). These findings establish a concrete protocol for the optical detection of non-classical features in spin textures, paving the way for exploring their role in quantum applications.

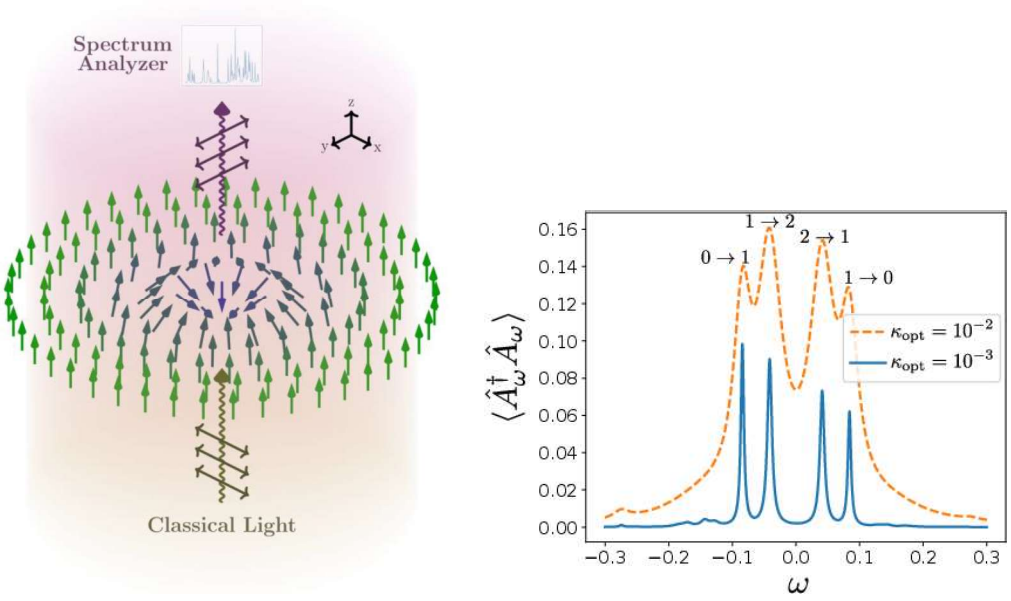

Figure 1: *The setup analyzed here involves scattering of light by a nanoscale skyrmion. The right figure shows the spectrum dependent on input power* $\propto \kappa_{\rm opt}$*, with quantum asymmetries.*

References:

[1] Christina Psaroudaki and Christos Panagopoulos, Skyrmion Qubits: A New Class of Quantum Logic Elements Based on Nanoscale Magnetization, Phys. Rev. Lett. 2021
[2] Sanchar Sharma and Christina Psaroudaki, Optical signatures of quantum skyrmions, arXiv 2025.