Simulating spin noise in magnetically ordered structures

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In recent years, spin noise spectroscopy has emerged as an experimental tool to investigate material properties in solid state physics [1]. Here, we investigate spin noise from a theoretical point of view in an antiferromagnetically ordered orthoferrite.

The material of interest is $Sm_{0.7}Er_{0.3}FeO_3$, which undergoes a second order magnetic reorientation transition at approximately room temperature. On the basis of the classical Heisenberg model and the stochastic Landau-Lifshitz-Gilbert equation of motion we numerically compute the time evolution of a four-sublattice system, resembling the subsystem of iron atoms in $Sm_{0.7}Er_{0.3}FeO_3$, on a timescale from picoseconds up to one nanosecond and investigate the thermal fluctuations of the magnetization. By means of competing anisotropies the second order reorientation transition is realized. Moreover, a Dzyaloshinskii-Moriya interaction, mediated by the oxygen atoms, induces a canting of the magnetic moments, leading to a finite magnetization and making the system a weak ferromagnet. Furthermore, it characterizes the magnetization as an order parameter.

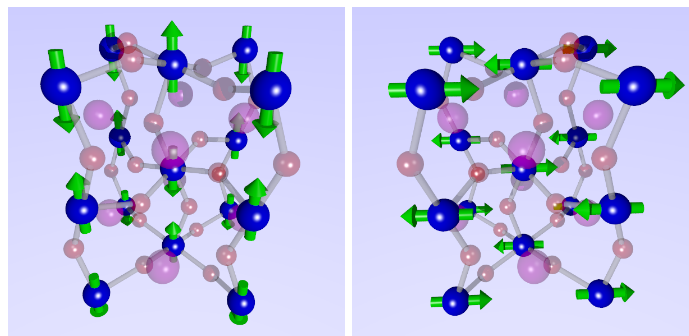

Fig. 1: *Reorientation transition of the magnetic moments of the iron atoms in $ErFeO_3$ from the low temperature regime (left) to the high temperature regime (right).*

By Fourier-transforming the time dependent magnetization it is found that the spectral noise power density comprises resonances. With the help of linear spin-wave theory those resonances can be assigned to the magnetic eigenmodes of the system. The autocovariance, calculated via the Wiener-Khinchin theorem, unveils critical fluctuations at the critical temperatures of the reorientation transition in the time domain and thus marks the reorientation transition in the noise of the magnetization. In addition, the system shows a random two-level switching process on a picosecond timescale close to the critical temperatures of the reorientation transition.

The theoretical findings are in good agreement with experimental spin noise measurements [2], which is a promising result for future characterizations of antiferromagnets based on spin noise spectroscopy.

References:

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[2] Marvin A. Weiss et al., "Ultrafast spontaneous switching in an antiferromagnet", *arXiv:2301.02006* (2023)