Experimental report

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Proposal: **4-01-1511** **Council:** 4/2016

Title: Spin dynamics in the high-field phases of the triangular lattice antiferromagnet with XY anisotropy

Research area: Physics

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Samples: $RbFe(MoO_4)_2$

Instrument	Requested days	Allocated days	From	To
THALES	6	6	17/11/2016	23/11/2016

Abstract:

Two-dimensional triangular lattice antiferromagnets (TLA) with field applied in the plane have a complex phase diagram in which fluctuations, both thermal and quantum, play a role in the stabilization of spin orders. $RbFe(MoO_4)_2$ is an excellent realization of such model with XY anisotropy. A magnetization plateau at 1/3 of the saturation is observed in this compound, as expected for TLA, but it exists on a larger field range than what is predicted. It is believed that quantum fluctuations are responsible for the extended stabilization of this phase. We propose to investigate the quantum effects on the spin dynamics in the field-induced phase of $RbFe(MoO_4)_2$. The experiment would search for possible deviations from classical spin wave theory, such as finite lifetime of the excitations and renormalization of the magnon branch.

Spin dynamics in the high-field phases of the triangular lattice antiferromagnet with XY anisotropy

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Abstract

The experiment 4-01-1511 on ThALES was performed from November 17th to 23rd, 2016. The magnetic excitations of the triangular lattice system $RbFe(MoO_4)_2$ were measured for magnetic fields $H = 0.02$, 7 and 13.5 T applied along the (001) direction at $T = 40$ mK. In zero field, the inelastic spectra is in very good agreement with the spin wave calculations based on the previously reported Hamiltonian. At $H = 7$ and 13.5 T, the dispersion is also in good agreement with the model but a broadening of the excitation peak widths is observed away from the Brillouin zone boundary. We interpret this broadening as the signature of quantum fluctuations reducing the excitations lifetime by opening new decay channels.

Quantum fluctuations are expected to have significant effects on the spin dynamics in two dimensional antiferromagnets [1, 2]. For non-collinear ground state such as the 120° structure in the triangular lattice, cubic terms in the expansion of the Holstein-Primakoff expression are allowed and can create significative deviation from the linear spin wave theory [3]. These deviations are expected to be strongest for $S = \frac{1}{2}$ and larger spins should behave more classically. Nevertheless, single-magnon breakdown has been observed in $S = 2$ system, as evidenced by renormalization of the magnon branch and linewidth broadening in hexagonal $LuMnO_3$ [3]. It is also predicted that these effects are stronger in fields near the saturation field H_S [1].

$RbFe(MoO_4)_2$ is an excellent realization of the two-dimensional triangular lattice antiferromagnet with XY anisotropy with moments $S = 5/2$ [4]. We have investigated the magnetic excitations to verify if quantum fluctuations play a significant role in this system. Single crystals with a total mass of 40 mg were coaligned in the hk plane and inserted in dilution refrigerator in a 15 T vertical magnet and mounted on the ThALES triple-axis spectrometer. The measurements where performed with fixed analyzer wavevector $k_f = 1.3$ Å^{-1} at $T = 40$ mK. A small field of $H = 0.02$ T was applied to suppress the superconductivity of the aluminum sample holder and have good thermalization of the sample. The spin waves were measured in the triangular plane and the results for $H = 0.02$ T are shown in Fig. 1b, in comparison with the spin wave model convoluted with the instrumental resolution function in Fig. 1a. The very good agreement confirms the validity of the proposed model by White *et al.* [4]. No evidence for deviations from the model are observed, indicating that quantum fluctuations do not play a significant role in zero field.

Measurements have also been taken at $H = 7$ and 13.5 T. The results $H = 13.5$ T are presented in Fig. 2b in comparison with the model in Fig. 2a. While the general dispersion agrees well with the model, the excitation peaks are broader than the energy resolution of the instrument. This indicates that the excitation have finite lifetimes and suggest the presence of decay channels of the magnetic excitations. Quantum fluctuations due to the non-collinearity of the field-induced magnetic structure could be responsible for this. Therefore, our results strongly support the presence of quantum fluctuations for a $S = 5/2$ triangular magnet in large magnetic fields. More experimental and theoretical work will be needed to clarify the precise mechanism leading to excitations finite lifetime away from the Brillouin zone boundary.

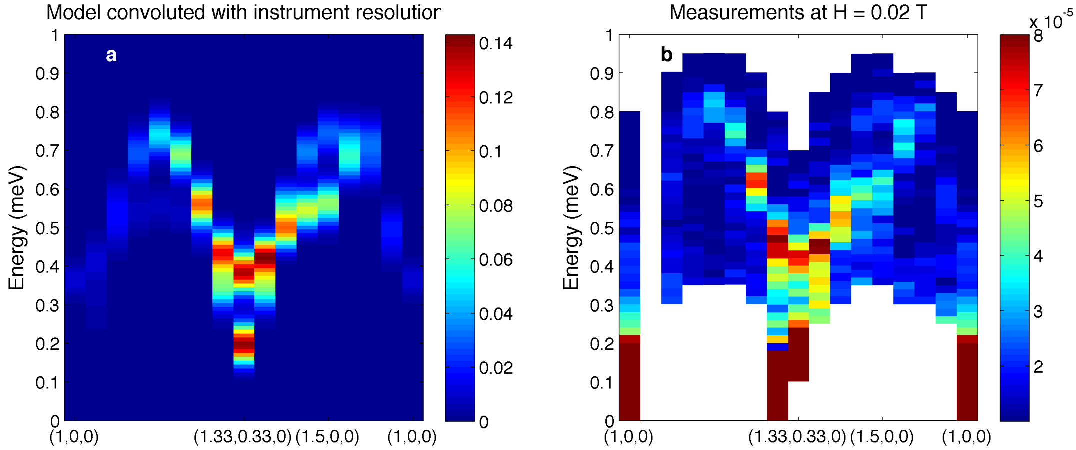

Figure 1: (a) Calculated spin wave spectra at $H = 0$ T convoluted with the instrumental resolution of the ThALES spectrometer. (b) Measurements of the inelastic spectra of $RbFe(MoO_4)_2$ at $H = 0.02$ T and $T = 40$ mK.

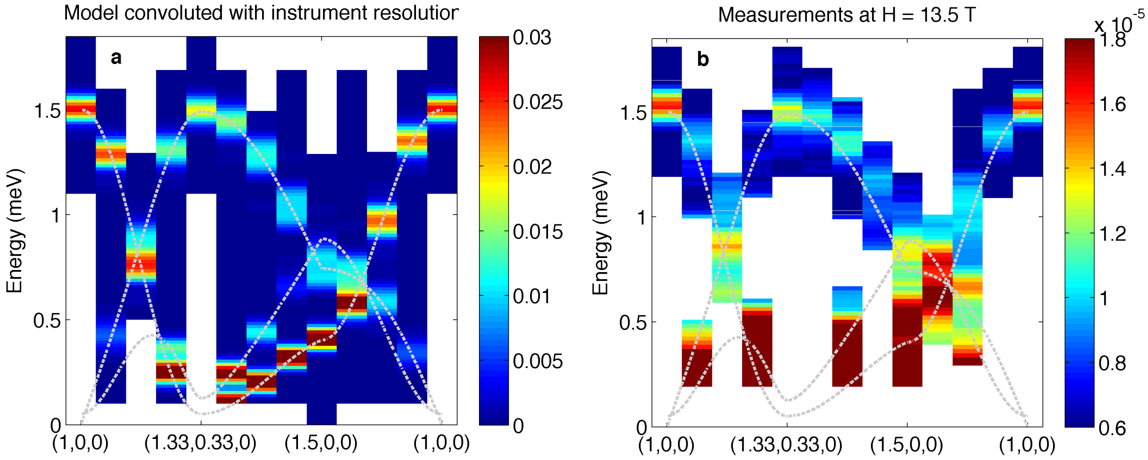

Figure 2: (a) Calculated spin wave spectra at $H = 13.5$ T convoluted with the instrumental resolution of the ThALES spectrometer. (b) Measurements of the inelastic spectra of $RbFe(MoO_4)_2$ at $H = 13.5$ T and $T = 40$ mK. The dashed lines represent the spin wave dispersion.

References

[1] W. T. Fuhrman *et al.*, Phys. Rev. B **85**, 184405 (2012).

[2] M. Mourigal *et al.*, Phys. Rev. B **88**, 094407 (2013).

[3] J. Oh *et al.*, Phys. Rev. Lett. **111**, 257202 (2013).

[4] J. S. White *et al.* Phys. Rev. B **88**, 060409(R) (2013).