Experimental report

13/02/2019

Proposal: **4-05-682** **Council:** 4/2017

Title: Spin excitations in the geometrically frustrated triangular lattice rare-earth selenide

Research area: Physics

This proposal is a new proposal

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Samples: KTmSe2

Instrument	Requested days	Allocated days	From	To
THALES	7	5	05/04/2018	10/04/2018

Abstract:

Frustrated magnetism has attracted tremendous research interests because it presents an excellent proving ground in which to discover new states and properties of matter. A variety of novel spin excitations have been predicted in frustrated magnetic systems. The recognition and proper understanding of these novel spin excitations have become a fundamental issue. However, due to the lack of ultra-clean materials, most of the possible states predicted by theory remain largely unexplored at the experimental level. Here we propose to study the novel spin excitations in a geometrically frustrated triangular lattice rare-earth selenide compound which is a clean system with highly frustrated magnetic interactions.

Experiment report for 4-05-682

Scientific background

Rare earth frustrated magnets are attracting more and more research interest due to the various exotic quantum phases they can realize [1-4], which is closely related to the single ion ground states of rare earth elements. Such single ion ground states are determined by the strong spin-orbit coupling together with the crystal field splitting which depends on the local ligand environment. The recently synthesized $KTmSe_2$ gives us a great opportunity to expand our knowledge on this field (Fig. 1a). The spin-orbital coupling and crystal field results in a non-Kramers doublet of Tm^{3+}. On the other hand, the no-symmetry-protected non-Kramers doublet will further split into two singlets under subtle perturbation. In the recent studying on $TmMgGaO_4$ with a similar structure, a quasi-doublet formed by these two low-lying singlets has been suggested to be the ground state [4]. Nevertheless, the nature of the magnetic ground state in $KTmSe_2$ is still unraveled.

$KTmSe_2$ crystallizes in space group R-3m and Tm^{3+} ions form a perfect two-dimensional triangular lattice without site mixing in the non-magnetic layers (Fig. 1a). The local ligand environment and spin-orbital coupling results in an effective S=1/2 non-Kramers doublet of Tm^{3+}. The susceptibility measurement on our $KTmSe_2$ sample suggests that the Tm^{3+} moments have strong antiferromagnetic correlations with a Curie-Weiss temperature Θ_w= -10.9 K (Fig. 2a). The specific heat measurements show no signature of long range order down to T = 50 mK but a broad hump, which is evidence for the existence of strong magnetic frustration (Fig. 2b). Thus, the inelastic neutron scattering experiment is proposed to be used to reveal the spin excitations in $KTmSe_2$ to fully understand the magnetic ground state in this material.

Experiment result

In this experiment, we have prepared a total of 3 grams high quality $KTmSe_2$ single crystal in order to measure the spin excitations (Fig. 1b). The sample has been mounted in the dilution refrigerator to reach a base temperature of 70mK. During the measurement, the Flatcone mode has been used with a k_f of 1.5$Å^{-1}$. Although no magnetic Bragg peaks can be found at base temperature, we observed no continuum signal expected for spinon excitations neither. Instead, a sharp and dispersive spin excitation has been clearly observed at 70mK (Fig. 3). This spin excitation survives to 20K with the intensity weakened and the feature broadened (not shown). The absence of static magnetic order and the observation of such spin excitation indicates an exotic magnetic ground state in $KTmSe_2$. Theoretical analysis of the excitation with different models is being performed, with which we hope to elucidate the nature of the magnetism in this newly found rare earth triangular lattice magnet.

References

[1] K. A. Ross *et al.*, Phys. Rev. X 1, 021002 (2011).
[2] Y. Shen *et al.*, Nature 540, 559-562 (2016).

[3] J. A. M. Paddison *et al.*, Nat. Phys. 13, 117-122 (2017).
[4] Y. Li et al., arXiv: 1804. 00696 (2018).

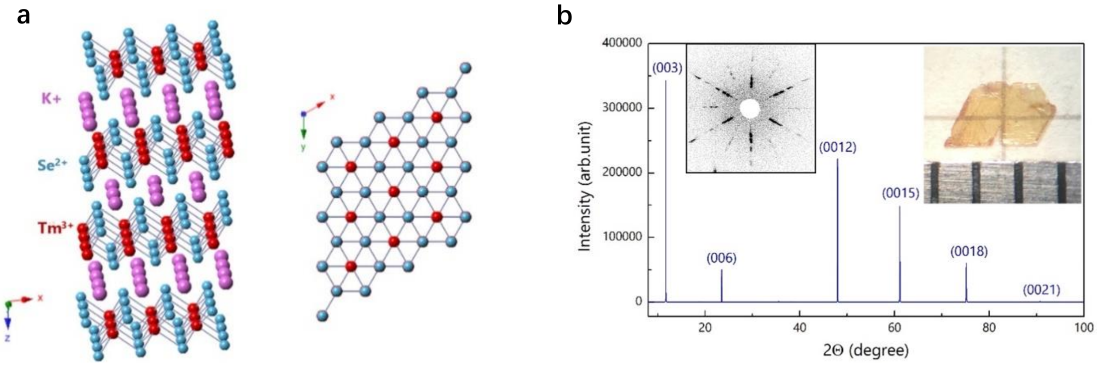

Fig. 1. **a**, The schematic of the crystal structure of $KTmSe_2$. **b**, The photo of a typical $KTmSe_2$ single crystal, with the Laue pattern and the X-ray single crystal diffraction pattern.

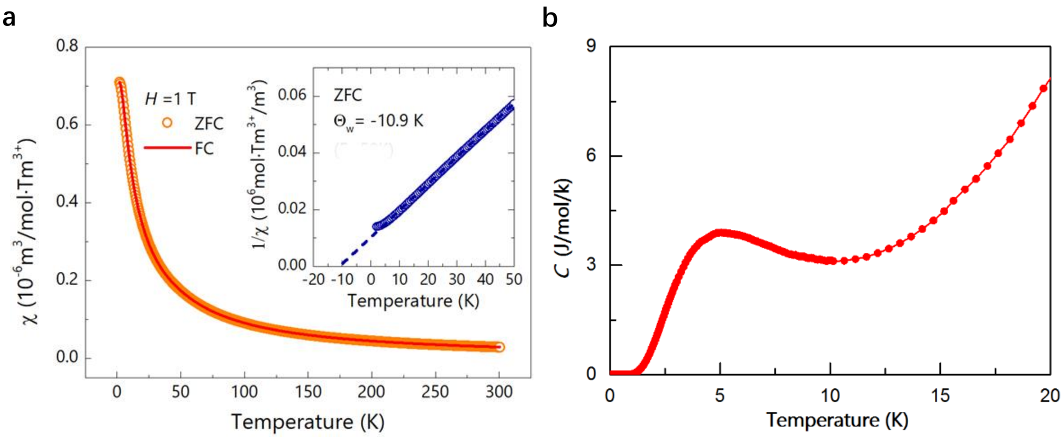

Fig. 2. **a**, Temperature dependence of magnetic susceptibility of $KTmSe_2$. **b**, Specific heat measurement on $KTmSe_2$ single crystal.

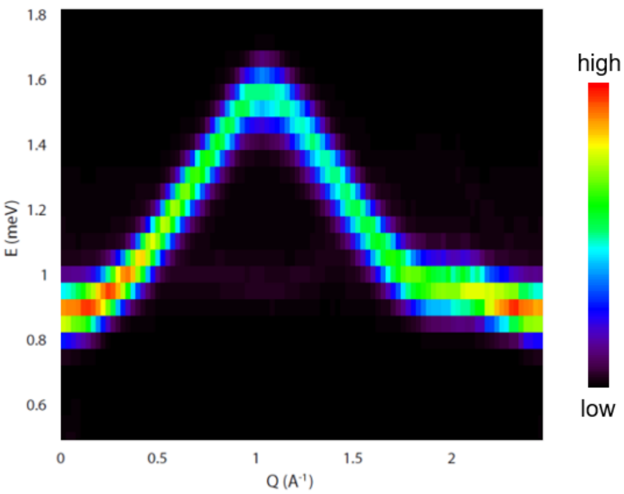

Fig. 3, The dispersive spin excitation observed at 70mK.