Experimental report

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Title: Magnetic interactions in a triangular lattice quantum spin liquid

Research area: Physics

This proposal is a new proposal

Main proposer: **Jun ZHAO**

Experimental team: Qisi WANG
Yao SHEN
Helen WALKER

Local contacts: Martin BOEHM

Samples: YbMgGaO4

Instrument	Requested days	Allocated days	From	To
THALES	7	5	09/02/2017	14/02/2017
IN3	1	1	08/02/2017	09/02/2017

Abstract:

A quantum spin liquid (QSL) is a new state of matter in which spins show no magnetic order down to zero temperature but are highly entangled. Elucidating the magnetic interactions of a QSL is essential to understanding the microscopic mechanism underlying this exotic state. Recently, our neutron scattering experiments on a quantum spin liquid (QSL) candidate YbMgGaO4 have revealed clear spinon excitation at zero temperature limit (70 mK), which is a hallmark of a QSL state. Hamiltonian combining XXZ model and spin-orbital coupling induced anisotropic interactions has been proposed to explain the stabilization of QSL state in this compound. Here, we propose to measure YbMgGaO4 single crystals with in-plane magnetic field to probe and determine the anisotropic interactions to help understand the origin of QSL state in triangular lattice.

Experimental Report of Proposal 4-05-658

Magnetic interactions in a triangular lattice quantum spin liquid

Yao Shen,[1] H. C. Walker,[2] P. Steffens,[3] M. Boehm,[3] and Jun Zhao[1]

[1]*State Key Laboratory of Surface Physics and Department of Physics, Fudan University, Shanghai 200433, China*

[2]*ISIS Facility, Rutherford Appleton Laboratory, STFC, Chilton, Didcot, Oxon OX11 0QX, United Kingdom*

[3]*Institut Laue-Langevin, 71 Avenue des Martyrs, 38042 Grenoble Cedex 9, France*

Ever since the proposal of quantum spin liquid (QSL), great progress has been made in theoretical study, while the experimental confirmation of a quantum spin liquid (QSL) remains controversial [1]. For the recently found triangular-lattice QSL candidate $YbMgGaO_4$, no symmetry breaking is presented in a variety of measurements down to 30 mK, including magnetic susceptibility, heat capacity, μSR and neutron diffraction, in spite of effective antiferromagnetic exchange interaction of J/k_B = -4 K [2-5]. Our inelastic neutron scattering measurements on ThALES have revealed dispersive spinon excitations with a clear upper excitation edge in $YbMgGaO_4$, which can be naturally accounted by the particle-hole excitations of a spinon Fermi surface [5]. However, recent theoretical research claims that $YbMgGaO_4$ is actually deep in the ordered stripe phase in the J_1-J_2 diagram, far away from the QSL regime [6]. Therefore, they argues that the continuum observed in zero field is not spinon excitations but just a result of stripe-type magnon excitations with orientational spin disorder [6].

In this experiment, we propose to study the magnetic interactions by measuring the spin wave dispersion in $YbMgGaO_4$ single crystals under high field. We used the same crystal as we used in last experiment (co-aligned three pieces of single crystals with total mass of 5 grams in *ab* plane) [5]. We checked the alignment on IN3, revealing the FWHM of the Bragg peak around 0.6 degree, indicating the high quality of the sample and that the good alignment was preserved. The sample was then attached to the dilution insert and loaded in a vertical magnet, which can provide magnetic field up to 10 T.

First, we use single detector mode with small E_f to measure the energy dependence of the spin excitations at several high symmetry points under field from 0 to 9.5 T. After that, we change the instrument configuration into Flatcone mode to map out the spin excitations in a large range. After measuring the spin excitations under 2.5 T, we focus our measurement on the spin wave dispersions under 9.5 T at which the compound has transited from QSL state into the polarized state. Constant energy mappings at different energies were measured which show clear spin wave dispersion with a large field-induced spin gap (Fig. 1). Such dispersion is different from the continuum we observed at zero field, indicating that the diffusive signal at zero field is not from spin wave excitations but instead can serve as a unique feature of fractional spinon excitation.

To further elucidate the spin interactions in $YbMgGaO_4$, we fitted the high field data using a Hamiltonian with anisotropic terms and next-nearest interactions [7]. We found interactions of J_2/J_1~0.1, which makes $YbMgGaO_4$ lying inside the QSL regime in the phase diagram. In that case, the diffusive signals observed in $YbMgGaO_4$ are more likely to have QSL origin instead of a feature of disordered stripe state, inconsistent with recent theoretical report [6].

In conclusion, we have used inelastic neutron scattering to study the polarized state of QSL candidate $YbMgGaO_4$ single crystals under high magnetic field and clear spin wave excitations have been revealed with spin interactions of J_2/J_1~0.1. This result indicates that $YbMgGaO_4$ is close to the QSL regime in the phase diagram. Our results therefore provide another evidence for the existence of QSL state in $YbMgGaO_4$.

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2. Y. S. Li *et al.*, *Sci. Rep.* **5**, 16419 (2015).
3. Y. S. Li *et al.*, *Phys. Rev. Lett.* **115**, 167203 (2015).
4. Y. S. Li *et al.*, *Phys. Rev. Lett.* **117**, 097201 (2016).
5. Y. Shen *et al.*, *Nature* **540**, 559-562 (2016).
6. Z. Zhu *et al.*, Preprint at <http://arxiv.org/abs/1703.02971> (2017).
7. J. A. M. Paddison *et al.*, *Nat. Phys.* **13**, 117-122 (2017).

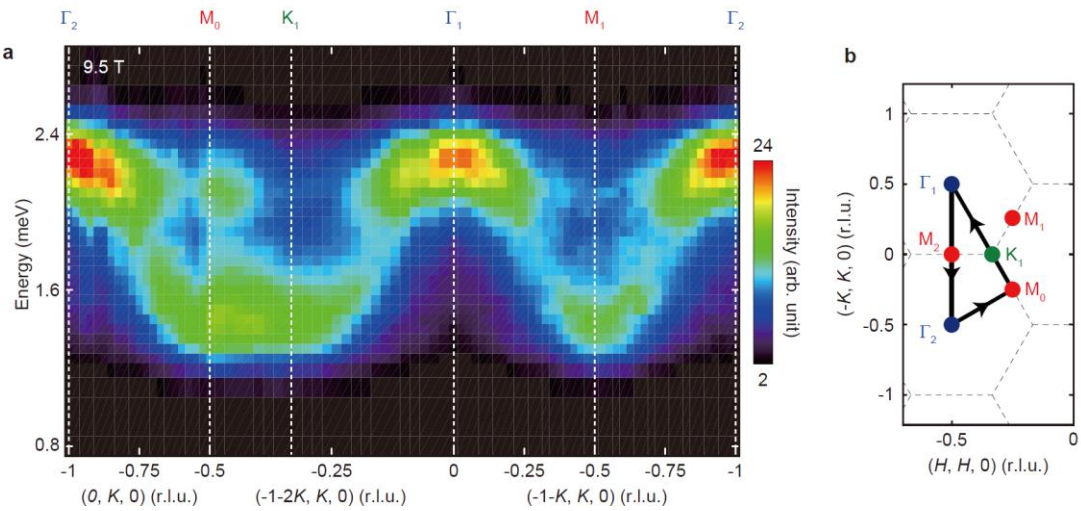

Figure 1: a, Intensity contour plot along the high symmetry directions as illustrated in b. Vertical dashed lines represent the high-symmetry points. The measurement was done at 70 mK under 9.5 T. **b,** Sketch of reciprocal space. Dashed lines indicate the Brillouin zone boundaries.