Experimental report

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Proposal: **4-05-648** **Council:** 4/2016

Title: Fractionalized spinon excitations in quantum spin liquid YbMgGaO4

Research area: Physics

This proposal is a new proposal

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Samples: YbMgGaO4

Instrument	Requested days	Allocated days	From	To
IN3	1	1	15/06/2016	16/06/2016
THALES	7	5	15/06/2016	20/06/2016

Abstract:

YbMgGaO4 is a recently discovered quantum spin liquid material with S = 1/2 Yb3+ ions arranged in a perfect triangular lattice. This configuration gives rise to strong frustration and prevents the formation of magnetic order down to 50 mK in spite of effective antiferromagnetic exchange interaction of J/kB = -4 K. We propose to measure its spin exchange interactions and the fractionalized magnetic excitations called spinons.

Experimental Report of Proposal 4-05-648

Fractionalized spinon excitations in quantum spin liquid $YbMgGaO_4$

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A conclusive experimental confirmation of a quantum spin liquid (QSL) remains an outstanding issue in condensed matter physics in spite of a variety of theoretical predictions. In QSL state, strong frustration leads to highly degenerated ground states, in which interacting spins show no static ordering but are highly entangled with one another. One of the most intriguing features is the existence of fractionalized spin excitation called spinon excitation in which spin carries $S = 1/2$ in contrast with magnon excitation where $S = 1$ [1, 2]. Very recently, a newly synthesized antiferromagnet, $YbMgGaO_4$, has been found to be a promising 2D-QSL candidate. With $S = 1/2$ Yb^{3+} ions arranged in a perfect triangular lattice, $YbMgGaO_4$ forms an ideal 2D magnetic interaction of great frustration (Fig. 1b, c). No static order is present to the lowest measuring temperature, 50 mK, in spite of effective antiferromagnetic exchange interaction of $J/k_B = -4$ K, indicating an excellent realization of 2D-QSL [3, 4].

In this experiment, we propose to search for spinon excitations in $YbMgGaO_4$ single crystals. We co-aligned three pieces of single crystals with total mass of 5 grams in *ab* plane. The FWHM of the Bragg peak is around 1 degree indicating the high quality of the sample and the good alignment. First, we use single detector mode with small E_f to get resolution high enough to distinguish if there is a small spin gap at low energy. No obvious gapped mode is detected at different wave vectors, consistent with previous proposal that this compound is a gapless QSL.

After that, we change the instrument configuration into Flatcone mode to probe the diffusive spinon excitation. Constant energy mappings at different energies were measured which show clear continuum-like signals covering a wide region of the Brillouin zone (Fig. 1a-e). Such continuum is rather different from what one can expect from spin wave excitation but instead it is thought to be a unique feature of fractional spinon excitation.

To further elucidate the characteristic of spinon excitation here, we made detailed measurement of its structure factor along several high symmetric points. Clear continuum is revealed and diffusive spinon excitation persists at the lowest measured energy. At the same time, a clear upper excitation edge is shown with intensity near Γ point strongly suppressed (Fig. 2). All these features are consistent with model accounted by the particle-hole excitation of a spinon Fermi surface (Fig. 1f, g).

In conclusion, we have used inelastic neutron scattering to study QSL candidate YbMgGaO4 single crystals and clear diffusive spinon excitations have been revealed with indication of the existence of spinon Fermi surface. Our results therefore identify a QSL in a perfect spin-1/2 triangular lattice occurring in the original proposal by Anderson.

The data has been published on Nature (doi:10.1038/nature20614) [5].

1. L. Balents, *Nature* **464**, 199–208 (2010).
2. M. Mourigal *et al.*, *Nature Phys.* **9**, 435-441 (2013).
3. Y. S. Li *et al.*, *Sci. Rep.* **5**, 16419 (2015).
4. Y. S. Li *et al.*, *Phys. Rev. Lett.* **115**, 167203 (2014).
5. Yao Shen *et al.*, *Nature*, doi:10.1038/nature20614 (2016).

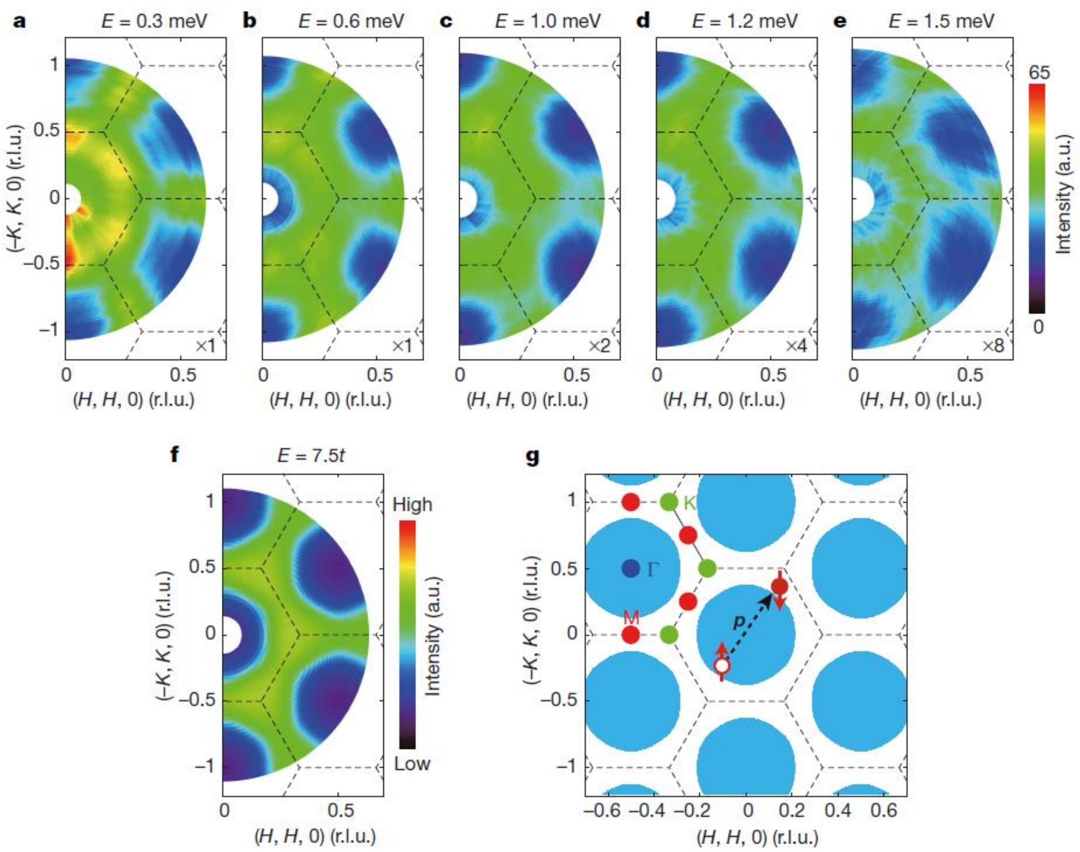

Figure 1 a-e, Constant energy image at indicated energies collected on ThALES using the Flatcone detector. **f,** Calculated momentum dependence of the spinon excitations. **g,** Calculated spinon Fermi surface. The black arrow indicates a spinon particle-hole excitation, and dashed lines indicate the Brillouin zone boundaries. High symmetry points M, K and Γ are labelled by red, green, and blue solid circles, respectively [5].

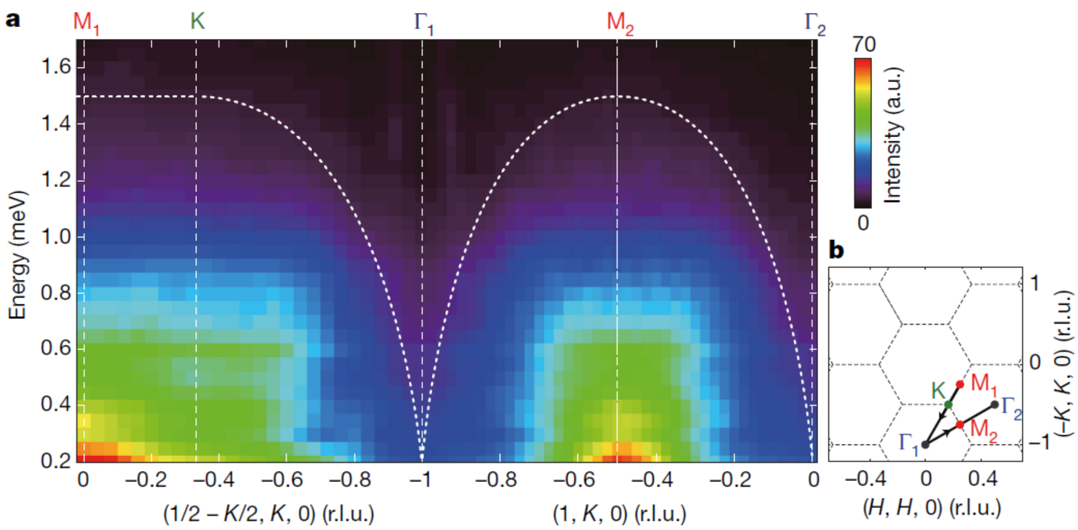

Figure 2: a, Intensity contour plot along the (1/2-*K*/2, *K*, 0) and (1, *K*, 0) directions as illustrated in b. Vertical dashed lines represent the high-symmetry points, and dotted lines indicate the upper bounds of spin excitation energy. **b,** Sketch of reciprocal space. Dashed lines indicate the Brillouin zone boundaries.