

Experimental report

29/07/2024

Proposal: 4-05-872

Council: 4/2023

Title: Novel spin excitations in a triangular-lattice frustrated quantum magnet

Research area: Physics

This proposal is a new proposal

Main proposer: Jun ZHAO

Experimental team: Feiyang LIU
Hongliang WO
Yinghao ZHU

Local contacts: Arno HIESS
Paul STEFFENS

Samples: PrMgAl11O19

Instrument	Requested days	Allocated days	From	To
ORIENTEXPRESS	1	1	29/08/2023	30/08/2023
THALES	7	7	30/08/2023	06/09/2023

Abstract:

Quantum spin liquids are exotic quantum states that are actively sought in materials with frustrated magnetism. Recently, a new class of two-dimensional triangular lattice frustrated magnet PrMgAl11O19 was discovered, which features a perfect triangular lattice of magnetic Pr³⁺ ions. The absence of static order or spin freezing in this system and a reduced site mixing in its non-magnetic layers (as compared to YbMgGaO4) make this material a promising quantum spin liquid candidate. We synthesized high quality single crystal PrMgAl11O19, thus providing great opportunity to study the low energy spin excitations and reveal the nature of magnetism in this compound. Our results will provide further insight in this new class of rare-earth frustrated magnets.

Experiment report for 4-05-872

Scientific background

Quantum spin liquids (QSLs) are highly entangled quantum states characterized by novel fractionized excitations. These exotic states, over the years, have attracted intense research efforts because of their potential relevance to high- T_c superconductivity and topological quantum computation [1]. In magnetic systems, frustration is essential to avoid long-range order and realize theoretically predicted QSL states. As a result, QSLs are actively sought in materials with antiferromagnetic interactions on geometrically frustrating lattices, such as the pyrochlore, Kagome and triangular structures [2].

Recently, a new class of two-dimensional triangular lattice frustrated magnet $\text{PrMgAl}_{11}\text{O}_{19}$ was discovered [3]. This material features ideal 2D magnetic layers of perfect triangular lattice Pr^{3+} ions with large space intervals ($\sim 11.0 \text{ \AA}$) between them (Fig. 1). Moreover, the potential disorder effects from $\text{Mg}^{2+}/\text{Al}^{3+}$ mixing in the non-magnetic spacers are expected to be greatly reduced due to rather dilute presence of Mg^{2+} ions dictated by chemical stoichiometry [3,4]. Previous thermodynamic measurements on polycrystalline $\text{PrMgAl}_{11}\text{O}_{19}$ confirm the absence of static order and spin freezing down to 2 K [3]. Inelastic neutron scattering measurements on the polycrystalline sister compound $\text{PrZnAl}_{11}\text{O}_{19}$ revealed diffusive low-energy excitations at 7 K with no static order or spin freezing [4]. In order to unambiguously determine the nature of magnetism in this system, neutron scattering measurements of the spin excitation in single crystalline samples at millikelvin temperature are required. We have successfully synthesized high quality single crystal $\text{PrMgAl}_{11}\text{O}_{19}$, in an aim to study its magnetic excitations and provide further insight into this new class of rare-earth frustrated magnets.

Experiment result

In this experiment, we have prepared a total of 6 grams high quality $\text{PrMgAl}_{11}\text{O}_{19}$ 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 70 mK. During the measurement, the Flatcone mode has been used with a k_f of 1.4 \AA^{-1} . No magnetic Bragg peaks or dispersive spin wave dispersions can be found at base temperature. Instead, we observed broad continuum signals with a clear spin gap at 70mK (Fig. 2). 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 $\text{PrMgAl}_{11}\text{O}_{19}$. 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] Ashtar, M. et al. *J. Mater. Chem. C* **7**, 10073–10081 (2019)
- [2] Y. Shen *et al.*, *Nature* **540**, 559-562 (2016)
- [3] A. Banerjee *et al.*, *Science* **356**, 1055-1059 (2017)
- [4] Bu et al. *Phys. Rev. B* **106**, 134428 (2022)

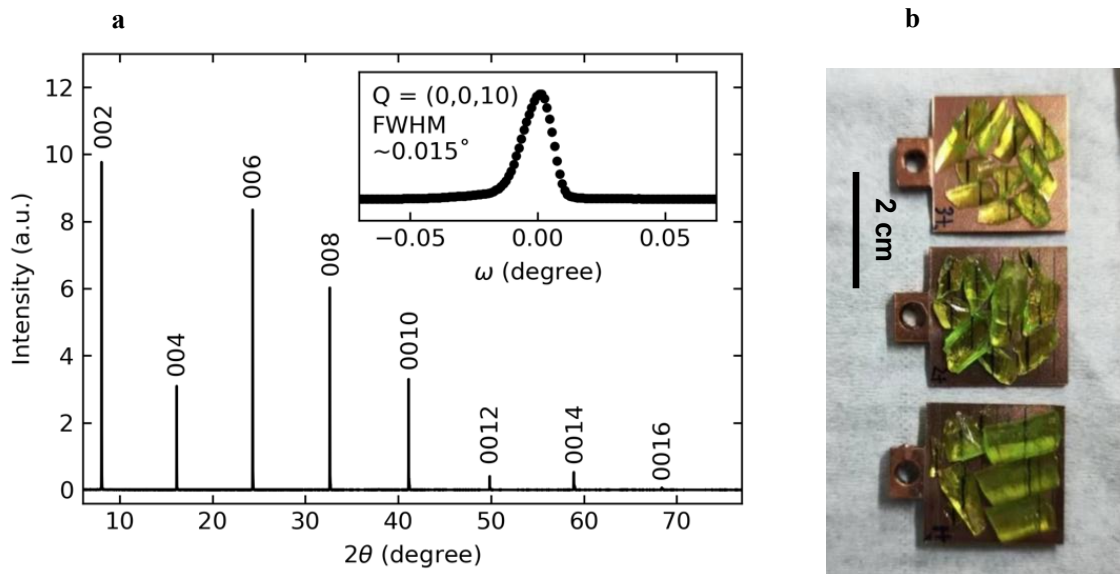


Figure 1. (a) X-ray diffraction pattern of PrMgAl₁₁O₁₉ single crystal. The insets show the rocking curve of (0010) peak. **(b)** Photo of a PrMgAl₁₁O₁₉ single crystal.

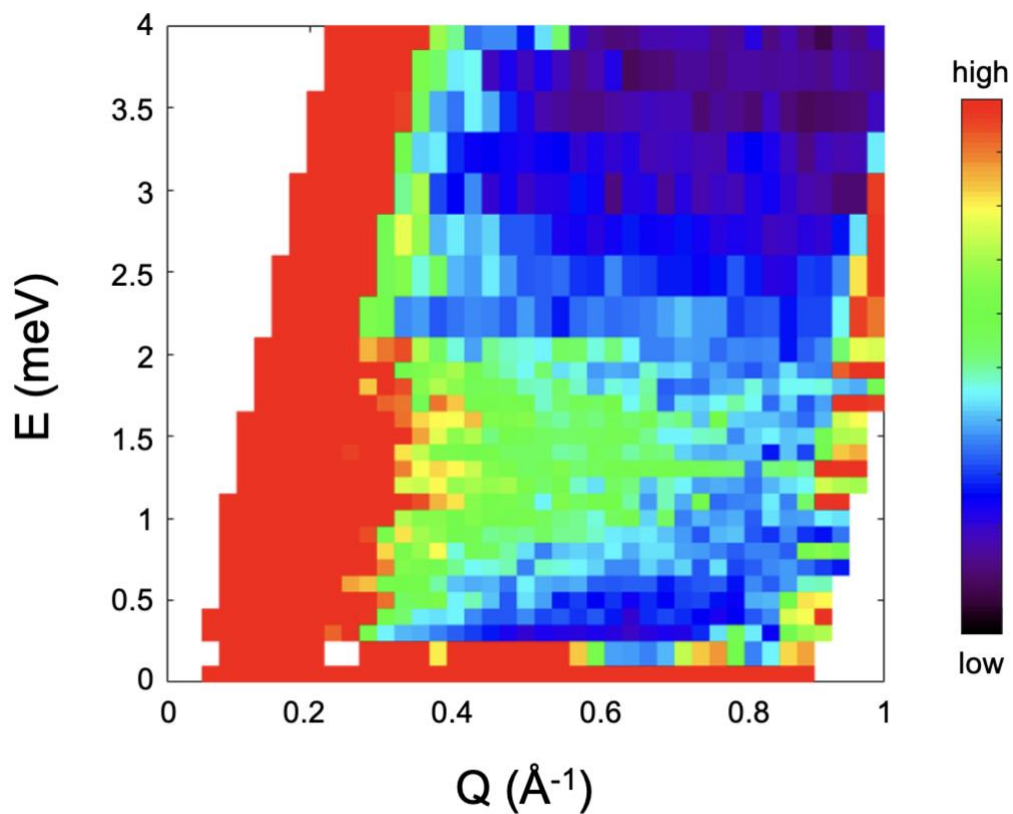


Figure 3. The broad continuum spin excitations observed at 70mK.