Neutron diffraction study on the $Yb_3Ru_4Al_{12}$ itinerant kagome antiferromagnet

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Geometrically frustrated spin systems have been studied extensively for decades because of many intriguing phenomena, exemplified by the non-magnetic quantum disordered states. Despite a large number of both experimental and theoretical studies, the ground states and excitations in geometrical frustrated quantum magnets are still largely unrevealed. This is the case for kagome compounds where even theoretically the ground state is controversial with gapped (such as Z2 spin liquid) or gapless (U(1) Dirac spin liquid) states. Experimentally, on the other hand, due to the small number of model compounds, the work is further less conclusive, and much efforts have been devoted to find out new model materials possessing the geometrically frustrated lattices. Recently, a new direction has been taken to discover new frustrated systems in Yb^{3+} rare-earth ions; several reports indicate quantum nature of the Yb^{3+} rare-earth magnetism, such as spinon continuum in quasi-one-dimensional Yb_4As_3 [1] and Yb_2Pt_2Pb [2]. The key ingredient of such quantum spin formation is doubly degenerated ground states (pseudo spin 1/2) made of strongly coupled L and S. Hence, there now appears a chance to study geometrically frustrated quantum magnetism using Yb-based compounds. The present proposer group found a Yb^{3+} based compound $Yb_3Ru_4Al_{12}$ [3], which has an archetypal frustrated lattice, called breathing kagome lattice. This compound shows intriguing low-dimensional frustrated behavior [3], and hence, we have investigated microscopic magnetism using powder neutron diffraction.

A polycrystalline alloy of $Yb_3Ru_4Al_{12}$ was prepared by crushing the single crystals. The neutron powder diffraction experiment has been performed using the high-resolution powder diffractometer ECHIDNA installed at the OPAL reactor, Australian Nuclear Science and Technology Organisation [4]. For most of the magnetic diffraction measurement, neutrons with $\lambda = 2.4395$ Å was selected using the Ge 311 reflections, whereas for the structure analysis, to obtain reflections in a wide Q-range, we select $\lambda = 1.622$ Å using the Ge 335 reflections. The sample was set in the ϕ4 mm Cu sample can, and then set to the cold head of the ^{3}He one-shot-type refrigerator with the base temperature 0.37 K. For the high-T (6.5 K), base-T and intermediate-T ($T_{\rm set} = 1.6$ K) scans, the total data acquisition time was 15 hours.

Figure shows the comparison of the diffraction patterns in the 2θ-range of $10 < 2\theta < 60$ degrees observed at the three temperatures. Clearly, magnetic signal develops at $2\theta \simeq 15^\circ$ and 18.5° at low temperatures. We note that $2\theta \simeq 15^\circ$ corresponds to the (0,0,1) (forbidden) nuclear reflection position, indicating that the magnetic structure is antiferromagnetic along the c-axis. The 18.5° peak corresponding to the (1,0,0) position. While magnetic signal was clearly observed in the low temperature phase, the nature of the intermediate phase is still unclear, but some hints may be obtained by carefully analyzing the present dataset. Magnetic structure analysis of the base-temperature phase is in progress, while we look for a way to elucidate nature of the intermediate phase, too.

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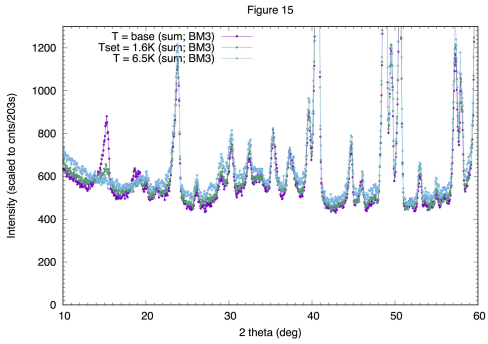

Fig. 1. Neutron diffraction patterns at the base temperature, 1.6 K and 6.5 K obtained at ECHIDNA. The temperatures are the "set" temperatures, and actual temperatures were slightly lower.