Experimental report

14/02/2018

Proposal:	**4-05-651**	**Council:**	4/2016
Title:	The effect of magnetic field on the quantum spin liquid state of Tb\$_{2+x}\$Ti\$_{2-x}\$O\$_{7+y}\$		
Research area:	Physics		

This proposal is a new proposal

Main proposer:	**Bjorn FAK**
Experimental team:	Bjorn FAK Hiroaki KADOWAKI
Local contacts:	Martin BOEHM

Samples: Tb2+xTi2-xO7+y

Instrument	Requested days	Allocated days	From	To
THALES	7	5	28/09/2016	03/10/2016

Abstract:

We have shown, using inelastic single crystal neutron scattering on IN5, that the frustrated pyrochlore magnet Tb2+xTi2-xO7+y (TTO) for x<-0.0025 has a quantum spin liquid (QSL) ground state with short-range spin-fluctuations centered at Q=(1/2,1/2,1/2). In order to better understand these fluctuations and their role in the proximity of the quantum critical point to a hidden ordered state for x>-=0.007, which is possibly a planar (anti-)ferropseudospin state, we propose to study these fluctuations in a vertical magnetic field on the cold triple-axis spectrometer Thales. We expect that a field along [1,-1,0] will decouple the three-dimensional (3D) QSL state into one-dimensional (1D) QSL chains and polarized magnetic chains. Such a dimensional control from 3D to 1D will provide important information for understanding the QSL state in TTO.

Geometrically frustrated magnets have been actively studied in recent years [1]. These include classical and quantum spin systems on two-dimensional triangle [2] and kagomé [3] lattices, and three-dimensional pyrochlore-lattice systems [4]. For classical systems, prototypes of which are the trianglar-lattice antiferromagnet and the spin ice [5], many investigations have been performed for several decades using a number of theoretical and experimental techniques [1]. Possibilities of quantum spin liquid (QSL) states in frustrated magnets, which date back to the theoretical proposal of the RVB state [6], are recently under hot debate. Highly-entangled many-body wave functions without magnetic long-range order (LRO), anticipated in QSL states, provide theoretically challenging problems [7]. Experimentally, investigations of QSL states using present-day available techniques, which are not well optimized for studying QSL states, have been challenging quests, e.g. [8].

A non-Kramers pyrochlore system $Tb_2Ti_2O_7$ (TTO) has attracted much attention since interesting reports of absence of magnetic LRO down to 0.1 K [9], which could be interpreted as a QSL candidate or quantum spin ice. In addition to to this QSL state, we recently showed that depending on off-stoichiometry parameter x of $Tb_{2+x}Ti_{2-x}O_{7+y}$ the ground state of TTO becomes an electric quadrupole ordered state ($x > x_c \sim -0.0025$) [10].

In this work, we used a single crystal sample of $Tb_{2+x}Ti_{2-x}O_{7+y}$ in the QSL range ($x < x_c$) [11] and investigated a magnetic field effect on the QSL state. By applying magnetic fields along [1,-1,0], one can expect that TTO behaves as decoupled magnetic quantum chains and polarized magnetic chains. A good point of this expectation is that one can simplify the difficult three-dimensional (3D) quantum problem to a simpler one-dimensional (1D) quantum problem.

Measurements were performed at low temperatures $0.1 < T < 1$ K and under vertical magnetic fields $0 < H_{\parallel[1,-1,0]} < 0.3$ T. The spectrometer Thales was operated with a k_i fixed mode with $k_i = 1.1$ Å^{-1}. In Fig. 1 we show typical Q-scans through (1/2, 1/2, 3/2), where a magnetic 3D short-range-ordered (SRO) peak appears. These were measured at 0.1 K in several magnetic fields. One can evidently see that this 3D SRO is suppressed by weak magnetic fields of the order 0.1 T. In this field of H = 0.1 T, we searched Q-space for magnetic scattering related to the expected 1D magnetic SRO. However, contrary to the initial expectation, no 1D magnetic scattering was found. This experimental fact seems to indicate that another possible scenario works in TTO: since electric quadrupole interactions are stronger than magnetic interactions, 1D quadrupole SRO develops instead of 1D magnetic SRO. To pursue this possibility we are performing analyses by using exact diagonalization techniques.

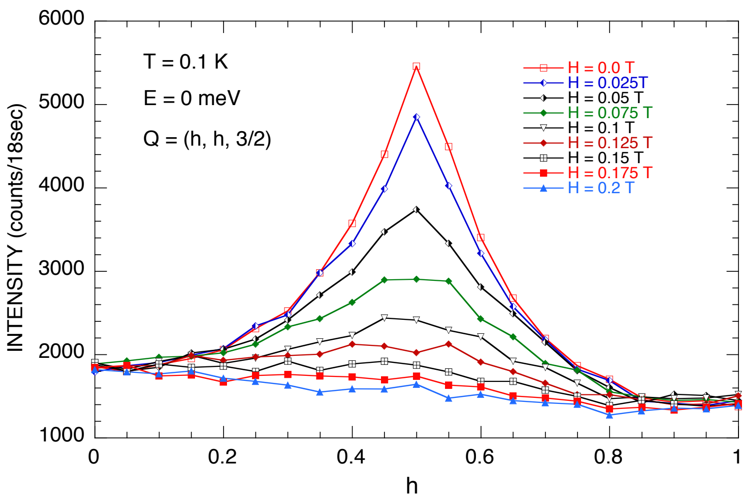

Fig. 1: Q-scans through (1/2, 1/2, 3/2) along $(h, h, 0)$ direction.

References

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