Experimental Report

15/01/2014

Proposal: **5-53-228** **Council:** 4/2012

Title: Approaching the bond-nematic quantum critical region in 2D square lattice magnets

This proposal is continuation of: 5-53-91

Researh Area: Physics

Main proposer: **SKOULATOS MARKOS**

Experimental Team: SKOULATOS MARKOS

Local Contact: NILSEN Goran

Samples: BaCdV(1-x)Ti(x)O(PO4)2 with x=0 and 0.05

Instrument	Req. Days	All. Days	From	To
D7	14	10	05/11/2012	15/11/2012

Abstract:

We have discovered a new class of J1-J2 system with ferromagnetic J1 and antiferromagnetic J2. We have generalized the theoretical J1-J2 model to include ferromagnetic interactions where new spin-liquid and bond-nematic phases are predicted. Our previous polarized neutron studies of Pb2VO(PO4)2 and SrZnVO(PO4)2 on D7 showed that this is an experimental realization of this system. We are able to tune J1 and J2 by cationic substitution, and we believe that BaCdVO(PO4)2 is close to the new bond-nematic phase. We therefore propose to investigate the spin correlations in the paramagnetic phase for BaCdVO(PO4)2 using XYZ polarization analysis on D7. In conjunction with the thermodynamic measurements already performed, this will allow us to determine J1 and J2 unambiguously. Furthermore, we propose to look at the nature of the quantum fluctuations in the spin diluted system BaCdV0.95Ti0.05O(PO4)2.

EXPERIMENTAL REPORT

EXPERIMENT N°: 5-53-228 INSTRUMENT: D7

DATES OF EXPERIMENT: 5-15/11/2012

TITLE: Approaching the bond-nematic quantum critical region in 2D square lattice magnets

EXPERIMENTAL TEAM:
M. Skoulatos[1], Ch. Rüegg[1,2] and J.P. Goff[3]

[1]LNS/NUM, Paul Scherrer Institut, CH
[2]Department of Condensed Matter Physics (DPMC), University of Geneva, CH
[3]Royal Holloway University London – Dept. Physics, UK

LOCAL CONTACT: G. Nilsen

The frustrated square-lattice (FSL) S=1/2 Heisenberg antiferromagnet with nearest-neighbour (NN) exchange constant J_1 and next-nearest-neighbour (NNN) exchange J_2, has long served as a paradigm for two-dimensional frustrated magnetism [1]. The so-called J_1-J_2 model first came to prominence due to its connection to the high-temperature superconducting cuprates. The more recent discovery of high-T_C superconductivity in pnictides [2,3] has increased interest in this model, since it may play a key role for the magnetism on the square Fe sublattice [4,5]. The frustrated square-lattice model is characterized by the frustration ratio α=J_2/J_1, and the energy scale is given by $J_c = \sqrt{J_1^2 + J_2^2}$. When the exchange constants are antiferromagnetic (AF) and $\alpha \approx 0.5$ the ground state is believed to be a valence bond solid in which spins form tightly bound singlets on nearest-neighbour bonds [6]. On the other hand, calculations for ferromagnetic (FM) J_1 and AF J_2 predict d-wave bond-nematic order for $\alpha \approx -0.5$ [7,8].

There are now several experimental realisations of spin-1/2 magnets on a square lattice where both J_1 and J_2 interactions play an important role [9], however only one material is known lying close to the so called spin-nematic region: $BaCdVO(PO_4)_2$ [10].

Bulk measurements alone cannot determine the ground state, but rather suffer from a sign problem, hence not differentiating between a columnar AF (CAF) or a Neel AF (NAF). Our D7 measurements of the ground state enabled us to uniquely place this compound in the CAF phase. As shown in Fig. 1, a CAF model shows good agreement, whilst a NAF would produce the strongest peak at a Q which experimentally shows no Bragg intensity. In combination with bulk susceptibility measurements, we were also able to extract extra information and get a good estimate of the exchange couplings. It turns out that the sample lies extremely close to the spin-nematic phase, just on the border in fact. This is also evidenced by Fig. 1, which shows purely magnetic scattering, isolated by employing *XYZ* polarisation analysis. The reduced ordered moment and the observation of diffuse scattering down to base temperature indicates the presence of disorder at low temperature. Most of the scattering is diffuse, with an ordered moment ~0.15 μ_B giving weak sharp magnetic peaks.

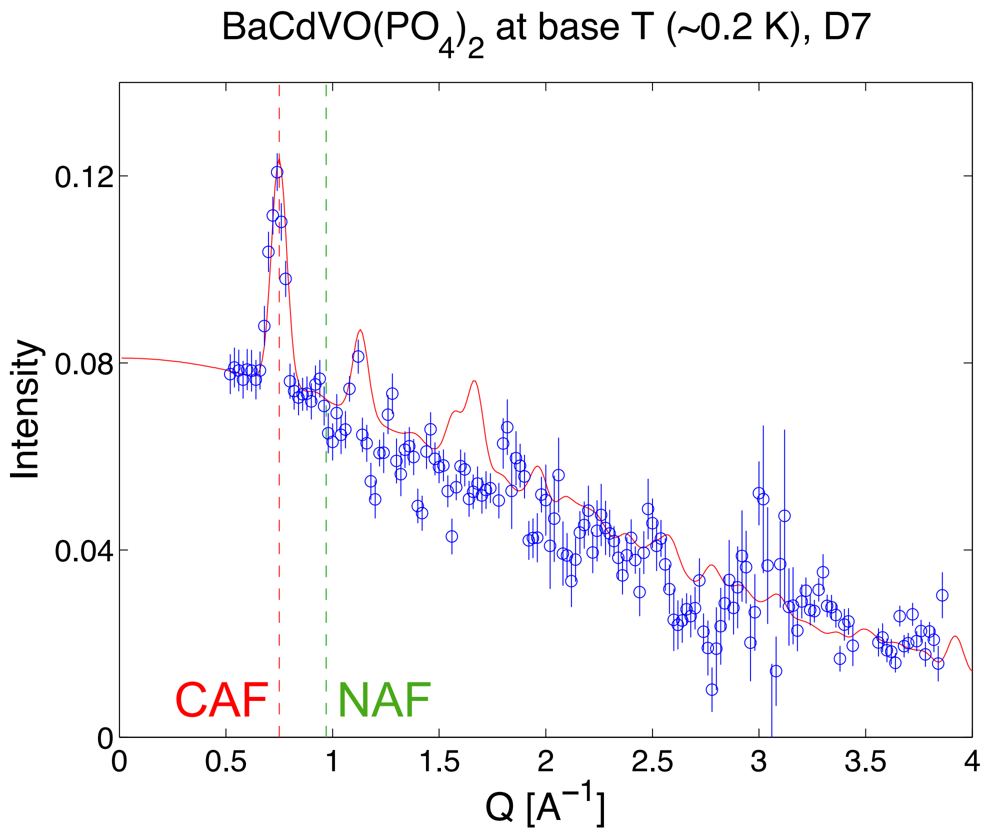

Fig. 1: Magnetic diffraction pattern of $BaCdVO(PO_4)_2$, isolated by using *XYZ* polarisation analysis on D7. Most of the intensity exists as diffuse background due to short range correlations, while a small part of the moment is ordered, giving rise to weak, sharp magnetic peaks (~0.15 μ_B). The CAF model gives reasonable agreement, while the NAF model would give its largest peak at a *Q* value with no Bragg intensity (second dashed line). The system is quantum disordered down to the lowest temperature and lies on the border of the CAF – spin-nematic phase.

References:

[1] Misguich G. and Lhuillier C., Frustrated Spin Systems, edited by Diep H. T. (World Scientific, Singapore) 2004. [2] Y. Kamihara, T. Watanabe, M. Hirano and H. Hosono, J. Am. Chem. Soc. **130**, 3296 (2008). [3] X. Chen, T. Wu, G. Wu, R. Liu, H. Chen and D. Fang, Nature **453**, 761 (2008). [4] Q. Si and E. Abrahams, Phys. Rev. Lett. **101**, 076401 (2008). [5] A. Smerald and N. Shannon, Eur. Phys. Lett. **92**, 47005 (2010). [6] H. Schulz, T. Ziman and D. Poilblanc, J. Phys. I **6**, 675 (1996). [7] N. Shannon, B. Schmidt, K. Penc and P. Thalmeier, Eur. Phys. J. B **41**, 599 (2004). [8] N. Shannon, T. Momoi and P. Sindzingre, Phys. Rev. Lett. **96**, 027213 (2006). [9] M. Skoulatos, J.P. Goff, C. Geibel, E.E. Kaul, R. Nath, N. Shannon, B. Schmidt, A.P. Murani, P.P. Deen, M. Enderle and A.R. Wildes, Eur. Phys. Lett. **88**, 57005 (2009). [10] R. Nath, A.A. Tsirlin, H. Rosner and C. Geibel, Phys. Rev. B **78**, 064422 (2008).