第 13 東北大中性子散乱物性グループワークショップ・QLC Topical Workshop

Workshop on
Quantum Magnetism and Neutron Scattering

主催：スピン量子物性研究分野
協賛：人・環境と物質をつなぐイノベーション創出ダイナミック・アライアンス 物質・デバイス領域共同研究拠点
日時：2019 年 11 月 8（金）
場所：東北大学多元物質科学研究所　西一号館（科研 S 棟）2F 大会議室

奇しくも時を同じくして量子磁性に関連する複数の第一線研究者が仙台を訪れるため、この機会に量子磁性と中性子散乱に関するワークショップを企画いたしました。皆様お誘い合わせの上ぜひ御参加くださいますようお願い申し上げます。

Program

10:00 Opening
10:10 *Spin excitations in spin-1/2 anisotropic triangular antiferromagnet*
Kazuhiro Nawa (IMRAM, Tohoku University)
10:50 *Gap function in Sr2RuO4 probed by neutron spin resonance*
Kazuki Iida (CROSS Neutron Science and Technology Center)
11:30 *Successful and not-so-much tuning magnetism with chemistry and geometry: a square and kagomé lattice example*
Maxim Avdeev (Australian Nuclear Science and Technology Organisation)
12:10 Lunch
13:30 *Magnetoelectric effects in low-dimensional magnetic systems*
Alexander Vasiliev (Moscow State University)
14:10 *Spinons, longitudinal modes, and dark magnon in f-electron metal*
Igor Zaliznyak (Brookhaven National Laboratory)
15:10 Closing

Spin excitations in spin-1/2 anisotropic triangular antiferromagnet

Kazuhiro Nawa
IMRAM Tohoku University, Sendai, Japan

Abstract:

Search for elementary excitations with fractional quantum numbers is one of intriguing topics in condensed matter physics. A spin-1/2 anisotropic triangular lattice antiferromagnet comprising two types of interactions, J and J′, is the good playground to understand the origin of the fractionalization since it relates a decoupled one-dimensional antiferromagnet (J′ /J = 0) with a triangular-lattice antiferromagnet (J′/J = 1). In the talk, I present inelastic neutron scattering spectrum on single crystalline samples of Ca3ReO5Cl2, which was reported as a new candidate spin-1/2 anisotropic triangular lattice antiferromagnet [1]. The spin excitation spectrum exhibits spinon-like continuous excitations as well as finite dispersion between chains, which is reminiscent of those observed in the prototypical compound Cs2CuCl4 [2]. Interestingly, we found that scattering intensities are enhanced at specific wavevector and energy transfer at low temperatures, which has been interpreted as spinon bound states in Cs2CuCl4 [3].

[1] D. Hirai, K. Nawa, M. Kawamura, T. Misawa, and Z. Hiroi, J. Phys. Soc. Jpn., **88**, 044708 (2019).
[2] R. Coldea, D. A. Tennant, Z. Tylczynski, Phys. Rev. B **68**, 134424 (2003).
[3] M. Kohno, O. A. Starykh, L. Balents, Nat. Phys. **3**, 790 (2007).

Gap function in Sr2RuO4 probed by neutron spin resonance

Kazuki Iida

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Abstract:

Low-energy incommensurate (IC) magnetic fluctuations in Sr2RuO4 are investigated by INS measurements and RPA calculations. Analysis of the L dependences of the low-energy IC magnetic fluctuations enables us to observe the spin resonance at Q = (0.3, 0.3, 0.5) and hw = 0.56 meV which corresponds well to the superconducting gap 2Delta = 0.56 meV. The spin resonance shows the L modulated intensity with maximum at L = 0.5. The L modulated intensity of the spin resonance and our RPA calculations demonstrate that the superconducting gaps regarding the quasi-one-dimensional alpha and beta sheets have the horizontal line nodes.

Successful and not-so-much tuning magnetism with chemistry and geometry: a square and kagomé lattice example

Maxim Avdeev
Australian Nuclear Science and Technology Organisation and University of Sydney, NSW, Australia

Abstract:

The talk will focus on experimental and DFT calculation results for two structure types: quasi-layered melilite family A2BC2O7 with square lattice and a layered kagomé (Fe,Mn)4Si2(Sn,Ge)7O16 system. The former was found well behaved and chemical substitutions on magnetic B-site and non-magnetic A- and C-sites allowed to modify the magnetic structure between G/C and collinear/non-collinear type. In contrast, the (Fe,Mn)4Si2(Sn,Ge)7O16 system, which is a curious case with stripes of 1/3 of idle spins, was found surprisingly robust with respect to changes in chemistry.

Magnetoelectric effects in low-dimensional systems

Alexander Vasiliev

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Abstract:

Magnetoelectric multiferroics can be divided in two classes: type-I multiferroics with a ferroelectric Curie point higher than the magnetic ordering temperature, and type-II (or improper) multiferroics with a magnetically induced electric polarization appearing below magnetic Curie or Neel temperature. The magnetoelectric coupling is an intrinsic feature of the improper multiferroics.
Specific heat C, thermal conductivity κ, dielectric permittivity ε, electric polarization P, and Raman scattering experiments are performed on $Cu_3Bi(SeO_3)_2O_2X$ (X = Br, Cl) single crystals. The Cl compound undergoes a structural phase transition at $T^* \sim 115K$ evident in C(T), $\varepsilon(T)$, and $\kappa(T)$ and accompanied by the appearance of unique phonon lines in Raman scattering. No evident structural changes are detected in the Br compound. At $T < T^*$, a very weak polarization loop with a $P \parallel c$ axis is observed in the Cl compound. Both compounds order antiferromagnetically at comparable temperatures $T_N \sim 25K$ marked by sharp lambda-type singularities. For $T < T_N$, an intensive mode of magnetic origin appears in both compounds. At the lowest temperatures, the energy of this mode is in good agreement with both the magnon excitation observed in infrared spectroscopy and the spin gap found recently in inelastic neutron scattering of the Cl compound [1].
The mixed spin chain compound, $LiCuFe_2(VO_4)_3$, reaches a magnetically ordered state in two steps at $T_{N2} = 9.8$ K and $T_{N1} = 8.2$ K detected in magnetic-susceptibility χ and specific-heat C measurements. Dielectric permittivity ε evidences these transitions by a sharp peak at T_{N2} and a steplike anomaly at T_{N1}, both easily suppressed by an external magnetic field. These features in permittivity are preceded by a frequency-dependent relaxation-type anomaly at T* insensitive to the magnetic field. Mossbauer spectroscopy reveals a wide distribution of a hyperfine field between T_{N2} and T_{N1} while the first-principles calculations provide values of magnetic-exchange-interaction parameters. For Cu, the orbital moment aligned in the same direction as the spin moment is substantial. This large orbital moment is important in driving the polarization through an inverse Dzyaloshinksii-Moriya interaction in a situation where the spatial symmetry gets broken in the magnetic structure. The data obtained suggest the spin-order-induced ferroelectricity inherent for improper multiferroics [2].
Among various low – dimensional magnetic systems recently studied in Moscow State University $Cu_3Bi(SeO3)_2O_2Cl$ exhibit properties of type I multiferroics and $LiCuFe_2(VO_4)_3$ evidences properties of type II multiferroic. NaCuFe2(VO4)3 is a “hidden” multiferroic of type II due to presumably non-uniform distribution of mobile alkali ions in the channels of howardevansite structure.

1. V. Gnezdilov, Yu. Pashkevich, P. Lemmens, V. Kurnosov, P. Berdonosov, V. Dolgikh, E. Kuznetsova, V. Pryadun, K. Zakharov, and A. Vasiliev, Lattice and magnetic instabilities in $Cu_3Bi(SeO_3)_2O_2X$ (X = Br, Cl). Phys. Rev. B 96, 115144 (2017).
2. A.V. Koshelev, K.V. Zakharov, A.P. Pyatakov, L.V. Shvanskaya, A.A. Shakin, O.S. Volkova, D.A. Chareev, S. Kamusella, H.-H. Klauss, K. Molla, B. Rahaman, T. Saha-Dasgupta, and A.N. Vasiliev, Spin-Order-Induced Ferroelectricity and Magnetoelectric Effect in $LiCuFe_2(VO_4)_3$. Phys. Rev. Appl. 10, 034008 (2018).

Spinons, Longitudinal Mode, and Dark Magnon in f-electron metal

Igor Zaliznyak
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Abstract:

Quantum states with fractionalized excitations, such as spinons in one-dimensional chains, are commonly viewed as belonging to the domain of S=1/2 spin systems. However, recent experiments on the quantum antiferromagnet Yb_2Pt_2Pb, part of a large family of R_2T_2X (R=rare earth, T=transition metal, X=main group) materials spectacularly disqualify this opinion [1-3]. The results show that spinons can also emerge in an f-electron system with strong spin-orbit coupling, where magnetism is mainly associated with large and anisotropic orbital moments. Here, the competition of several high-energy interactions – Coulomb repulsion, spin-orbit coupling, crystal field and the peculiar crystal structure lead to the emergence, at low energy, of an effective spin-1/2, purely quantum Hamiltonian. Consequently, it produces unusual spin-liquid states and fractional excitations enabled by the inherently quantum mechanical nature of the moments [1,3]. The emergent quantum spins bear the unique birthmark of their unusual origin in that they only lead to measurable longitudinal magnetic fluctuations, while the transverse excitations such as spin waves remain invisible in scattering experiments. Similarly, "hidden" would be transverse magnetic ordering, although it would have visible excitations. The rich magnetic phase diagram of Yb_2Pt_2Pb is suggestive of the existence of hidden-order phases [1-3], while the recent experiments reveal the gapless dispersive longitudinal mode and "dark magnon", a hidden excitation in the saturated ferromagnetic (FM) phase of Yb_2Pt_2Pb [4]. Unlike copper-based spin-1/2 chains, where the magnon in the FM state accounts for the full spectral weight of the zero-field spinon continuum, in the spin-orbital chains in Yb_2Pt_2Pb it is 100 times, or more, weaker. It thus presents an example of "dark magnon matter", whose Hamiltonian is that of the effective spin-1/2 chain, but whose coupling to magnetic field, the physical probe at our disposal, is vanishingly small. It can be revealed, though, via its coupling to "visible" electronic matter [4].

[1] L. S. Wu *et al.*, Science, **352**, 1206 (2016).
[2] W. Miiller *et al.*, Phys. Rev. B **93**, 104419 (2016).
[3] W. J. Gannon *et al.*, Nature Communications, 10, 1123 (2019).
[4] I. A. Zaliznyak *et al.*, unpublished (2019).