Observing spin fluctuations by neutrons; recent development of neutron inelastic spectroscopy

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In this talk, I will briefly overview the present status of the neutron inelastic spectroscopy in Japan. As the construction of the new spallation neutron source J-PARCC/MLF has completed, a number of powerful inelastic neutron spectrometers are online. In addition, after roughly 20 years of operation, the research reactor JRR-3 is now fully equipped with matured inelastic spectrometers; recent development of neutron optics enables much efficient experiments at the reactor spectrometers. The combination of the inelastic spectrometers at the stead-state and pulsed neutron sources will provide novel opportunities for condensed matter sciences in this country.

The neutron inelastic scattering is an unparalleled technique for detecting spin fluctuations in quantum magnets, since it can observe the Q and $\hbar\omega$ dependence of the generalized magnetic susceptibility. In this talk I would try to exemplify the uniqueness of the neutron magnetic inelastic scattering technique, and to foresee its future direction, by using our recent research outcomes.

The first one is the role of the spin fluctuations in the Fe-based superconductors. The Fe-based superconductors were discovered in 2008, and now has the second highest superconducting transition temperature, next to the cuprates, and thus is actively investigated by many researchers all over the world. A close relation between the antiferromagnetic fluctuations and the high-Tc superconductivity was inferred from the beginning. To experimentally confirm the relation, we have performed neutron inelastic scattering experiments on the $BaFe_2As_2$ parent (antiferromagnetic) compound, and its superconducting phases realized by electron doping ($Ba(Fe,Co)_2As_2$) [1]. We have confirmed that the spin fluctuations are significantly suppressed in the overdoped region, where the superconductivity is also suppressed, evidencing the close relation between the antiferromagnetic spin fluctuations and the superconductivity.

Secondly, I will talk on the formation of the valence-bond-solid (VBS) state in the quantum kagome antiferromagnet [2]. Ground state of the s=1/2 quantum kagome antiferromagnet has been studied intensively for decades. Nevertheless, it is still controversial if there is a gapless resonating-valence-bond (RVB) state, or its solidified kind VBS, is realized or not. Using the single-crystalline sample of the deformed kagome compound $Rb_2Cu_3SnF_{12}$, we have unambiguously confirmed that the pinwheel VBS state is stabilized. This confirmation can be only obtained by inelastic neutron spectroscopy, since the ground state has no detectable spins. This way, the neutron inelastic spectroscopy is the key tool to study the quantum coherent state of the antiferromagnetically coupled systems.

[1] K. Matan, S. Ibuka, R. Morinaga, S. Chi, J. W. Lynn, A. D. Christianson, M. D. Lumsden, and T. J. Sato, Doping dependence of spin dynamics in electron-doped Ba(Fe1-xCox)2As2, Phys. Rev. B 82 (2010) 054515-1-5.
[2] K. Matan, T. Ono, Y. Fukumoto, T. J. Sato, J. Yamaura, M. Yano, K. Morita, and H. Tanaka, Pinwheel valence-bond solid and triplet excitations in the two-dimensional deformed kagome lattice, Nature Phys. 6 (2010) 865-869.