Condensed Matter Theory Laboratory
Chief Scientist: Akira Furusaki (D.Sci.)

(0) Research field

CPR Subcommittee: Physics

Keywords: topological phases of matter, strongly correlated electron systems, frustrated magnets, phase transitions

(1) Long-term goal of laboratory and research background

We aim to understand theoretically various properties of materials of macroscopic scale from the physical laws that govern microscopic world. Many-electron systems having infinite degrees of freedom exhibit rich physical phenomena: they can have phases with spontaneously broken symmetry and transitions among these phases. A typical example is offered by magnetism and superconductivity in strongly-correlated electron systems, such as transition metal oxides and molecular conductors, which are the main research subjects of our laboratory. Our recent research subjects include unconventional ordered states and spin liquids in strongly frustrated quantum magnets and other new kinds of quantum phases like topological insulators and topological superconductors, or symmetry protected topological phases.

(2) Current research activities (FY2019) and plan (until Mar. 2025)

Our main research subjects in FY2019 include quantum phase transitions in one-dimensional quantum spin systems, wire construction of three-dimensional models with fractional excitations, spin current generation in organic antiferromagnets, spin nematic phases in two-dimensional frustrated magnets, magnetic order and thermal Hall effect in volborthite. Among those our research outcome on the study of quantum phase transitions in one-dimensional quantum spin chains is briefly summarized below. We studied the quantum XYZ spin chain with the nearest- and next-nearest-neighbor antiferromagnetic exchange interaction and obtained its ground-state phase diagram (Figure below) using bosonization and numerical methods. When the ratio J=J2/J1 of the nearest-neighbor coupling J1 and the next-nearest-neighbor coupling J2 is large, the ground state is in the dimer phase with spontaneous dimerization, while for small J the ground state is in one of the Neel ordered phase depending on the direction of the strongest Ising anisotropy. In the dimer phase lattice translation symmetry is broken, while in the Neel phases π-rotation symmetry in the spin space as well as the lattice translation symmetry is broken. The quantum phase transition between different phases is in the U(1)-symmetric Gaussian transition with the central charge c=1, which is promoted to SU(2) symmetric transition along the blue lines in the figure.

We will continue the study of magnetism in strongly-correlated electron systems and that of topological phases in the following years. In particular, the research on the physics of topological phases is conducted also as a research project under JST CREST (2019-2025).

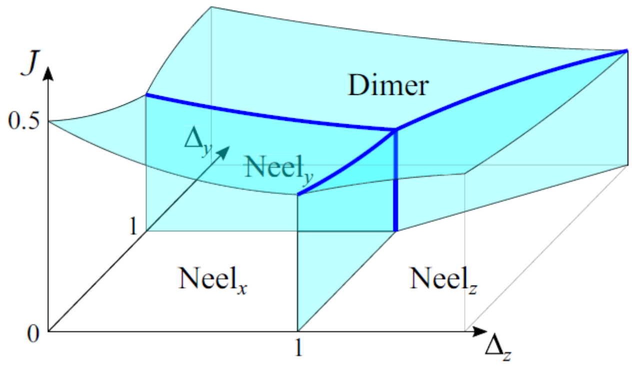

Fig.1: The phase diagram of the J_1-J_2 XYZ spin chain.

(3) Members **as of March, 2020**

(Chief Scientist)
Akira Furusaki
(Senior Research Scientist)
Tsutomu Momoi, Shigeki Onoda,
Hitoshi Seo
(Special Postdoctoral Researcher)
Shunsuke Furuya

(Junior Research Associate)
Takuya Furusawa
(Student Trainee)
Mateo Fontaine

(4) Representative research achievements

1. "Quantum phase transitions beyond Landau-Ginzburg theory in one-dimensional space revisited", C. Mudry, A. Furusaki, T. Morimoto, and T. Hikihara, Phys. Rev. B **99**, 205153 (2019).
2. "From coupled wires to coupled layers: Model with three-dimensional fractional excitations", Y. Fuji and A. Furusaki, Phys. Rev. B **99**, 241107(R) (2019).
3. "Spin current generation in organic antiferromagnets", M. Naka, S. Hayami, H. Kusunose, Y. Yanagi, Y. Motome, and H. Seo, Nat. Commun. **10**, 4305 (2019).
4. "Spin nematics in frustrated spin-dimer systems with bilayer structure", T. Hikihara, T. Misawa, and T. Momoi, Phys. Rev. B **100**, 214414 (2019).
5. "Effects of Dzyaloshinskii-Moriya interactions in Volborthite: Magnetic orders and thermal Hall effect", S. Furuya and T. Momoi, J. Phys. Soc. Jpn. **89**, 034711 (2020).

Laboratory Homepage
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