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11 Miyashita Group

Research Subjects: Statistical Mechanics, Phase Transitions, Quantum Spin systems, Quantum Dynamics, Non-equilibrium Phenomena

Member: Seiji Miyashita and Keiji Saito

1. Novel Quantum States, Excited States, and Quantum Dynamics

In strongly interacting quantum systems, various interesting phases appear in the ground state. The coherent motion of quantum mechanics exhibits various characteristics which would play important roles in control of quantum information processing. We have studied such novel quantum phases and quantum responses. Parts of the subject are studied as an activity of the JST CREST project (Quantum-mechanical cooperative phenomena and their applications).

We studied the properties of the super-solid state. We performed quantum Monte Carlo simulation (stochastic series expansion method) on the soft-core Hubbard model in a three-dimensional lattice (simple cubic), and observed successive phase transitions of the solid order and of the super-fluidity at finite temperatures. We also studied the ground state phase diagram as a function of the density of the particles. We found that the super-solid phase exists in a less-filled region, which has been denied in two-dimensional systems.

We study the magnetism of itinerant electron system on a lattice by using the Hubbard model. When an electron is removed from the half-filled state, the total spin of the system changes from zero to the maximum value if the lattice satisfies a certain condition (Nagaoka-ferromagnetism). We demonstrated an adiabatic change of this transition. Moreover we studied magnetic states of itinerant systems with larger spins, e.g. $S = 1$ (Boson) and $3/2$ (Fermion), etc. These new magnetic phenomena could be realized in the optical lattice of the laser cooled atom systems.

We also studied nontrivial degeneracy of eigen-energies as a function of the transverse field in uniaxial large spins with terms of the single-ion type anisotropy which are models for single-molecular magnets. This degeneracy has been interpreted as an interference of the Berry phase. We showed that this degeneracy can be attributed to a parity symmetry of terms for the anisotropy. We also studied the distribution of the degenerate points in the parameter space of higher order terms for the anisotropy.

We studied the dynamics of magnetization under swept-field in the transverse Ising model, and found a kind of quantum spinodal decomposition phenomena with a collaboration of Professor Hans De Raedt of Groningen University and Professor Bernard Barbara of the Louis N´eel laboratory. In order to explain the size-independence of the magnetization process in fast sweepings, we introduced a new perturbation scheme for fast swept systems.

The transverse field is used in the quantum annealing to find the ground state of complicated systems. We studied the relation between the quantum fluctuation and the thermal fluctuation.

Besides the above topics, we studied control of photon state in micro-cavity with atom beams by studying a time-dependent Jaynes-Cummings model, and investigated the effect of observation on the photon state. We also studied generalized Yang-Baxter relation in large spin system with uniaxial anisotropy.

2. Phase Transition in Spin-Crossover Materials

We pointed out that the difference of the sizes of the high-spin (HS) and the low-spin (LS) states causes lattice distortions which interact through the elastic interaction. We found that the critical property of this model belongs to the universality class of the mean-field model. We also found that its dynamical critical properties are described by the corresponding mean-field theory (i.e., in the long-range interaction model) as well as the static critical property. We studied the excitation process from LS state to HS state at a low temperature by photo-irradiation. We found a threshold of the strength of the irradiation, below which the system stays in LS state and above which it jumps up to HS state. This threshold behavior can be regarded as a kind of spinodal phenomena. In short range model, the spinodal phenomenon is a crossover because the nucleation process smears a sharp transition in the relaxation time even in the infinite lattice. On the other hand, the present model exhibits threshold behavior as a true critical dependence. In order to analyze the scaling property of this singularity we studied the spinodal phenomena in a long-range-interaction system and obtained a finite scaling formula.

3. Formulations of Non-equilibrium Statistical Physics

We studied the formulism of time-evolution equation in contact with the thermal bath, and pointed out that the reduced density matrix of the equilibrium state of the total system gives the steady state of the reduced time-evolution equation. However, we also pointed out that the steady state of the quantum master equation obtained by the perturbation agrees with the reduced density matrix of the equilibrium state of the total system only in the leading order of the perturbation. That is, it only guaranties the zero-th order in the diagonal element, and the second order in the off-diagonal elements.

We also constructed concrete formula for the complex admittance which expresses the line shapes of the electron spin resonant (ESR). We also studied fundamental mechanisms and statistical properties of the heat conductivity.

12 Ogata Group

Research Subjects: Condensed Matter Theory

Member: Masao Ogata, Youichi Yanase

We are studying condensed matter physics and many body problems, such as strongly correlated electron systems, high-T_c superconductivity, Mott metal-insulator transition, magnetic systems, low-dimensional electron systems, mesoscopic systems, organic conductors, unconventional superconductivity, and Tomonaga-Luttinger liquid theory. The followings are the current topics in our group.

- High-T_c superconductivity
  The t-J model as a mechanism for the oxide high-T_c superconductors.[1]
  Mott metal-insulator transition and superconductivity.
- New superconductor: Iron-pnictide
  New mechanism for iron-pnictide superconductivity, "unscreening" effect of Coulomb interaction.[2]
  Normal-state spin dynamics of five-band model for iron pnictides.[3]
- Organic conductors
  Dimensional crossover and superconductivity in quasi-one-dimensional organic conductors.[4]
  Novel spin-liquid state in an organic system induced by one-dimensionalization.
  Static nonequilibrium state of the competing charge orders under an electric field.[5]
- Theories of anisotropic superconductivity
  Superconductivity and antiferromagnetism in a non-centrosymmetric system.[6]
  FFLO superconductivity near an antiferromagnetic quantum critical point.[7]
  Anderson localization and superconductivity fluctuation in an impurity band.[8]
- Interband effects of magnetic field on Hall effects for Dirac fermion systems. [9]
- Electronic and spin states in frustrated systems
  Four-state classical Potts model with a novel type of frustrations as a model for rattling.
  Ground states of the frustrated quasi-two-dimensional Hubbard model.[10]
- Kondo effect and heavy fermion systems
  Fermi surface reconstruction with Kondo screening at quantum critical point.[11]
- Two-dimensional ^{3}He system on graphite
  A new quantum liquid realized in the two-dimensional t-J-K model with ring-exchange interaction.[12]
- Microscopic theory for the magnetic domain wall driving.[13]

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