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10 Miyashita Group

Research Subjects: Statistical Mechanics, Phase Transitions, Quantum Spin systems,

Quantum Dynamics, Non-equilibrium Phenomena

Member: Seiji Miyashita and Keiji Saito

1. Cooperative Phenomena and Phase Transition

Study on phase transitions and critical phenomena is one of main subjects of the statistical mechanics. We have studied various types of ordering phenomena in systems with large fluctuation. In the last year, we studied the following aspects of phase transitions. [1]

One is the phase transition in long-range Interacting systems. So far, phase transitions of spin systems have been studied mainly on the fixed lattice. However, we pointed out that difference of local lattice structure, e.g. the sizes of the high-spin (HS) and the low-spin (LS) in the spin-crossover materials causes lattice distortions. This degree of freedom of lattice deformation causes an effective long range interaction for ordering of bistable states. We have pointed out that the critical property of this type of models belongs to the universality class of the mean-field model, and also that its dynamical critical properties, such as the spinodal phenomena, are described by the corresponding mean-field theory. In the last year, in particular, we studied on the spatial ordering patterns of the system with long range interaction. In the long range interaction system with periodic boundary condition, the system does not show compact ordering cluster even at the critical point in contrast to the usual short range systems in which the correlation length diverges and infinite clusters appear. [41, 45] We studied how the correlation length changes if both short and long range interactions exists. We derived a scaling relation of the correlation length as function of the ratio of the short and long range interactions, and confirmed by a Monte Carlo simulation. We also studied how switching between the two ordered state occurs in system with open boundary condition, and found a scale-invariant property. [3, 4, 41, 45]

We also studied in which condition systems with long range interaction are described by the mean-field theory. It is known that in the cases where the interaction energy per spin diverges, where the extensivity is not satisfied and the so-called Kac procedure is necessary, the thermal properties are described by the mean-field theory if the order parameter is not conserved. We investigate the condition in detail, and confirmed this property. Moreover, we found that even in this case, the properties in a fixed value of order parameter cannot be described by the mean-filed theory in some parameter region. This indicates that the uniform configuration for the state of mean-field state becomes unstable inn such parameter region. We are studying the properties of such states. [5, 31, 39]

Hiroko Tokoro made experimental studies on novel magnetic materials in collaboration with Ohkoshi laboratory (chemistry department). [6, 58, 59]

We also studies the general structure of the so-called mixed phase which has been found in the generalized 6-state clock model with a quasi-degenerate energy structure. We found various new type phases and phase transitions. [37, 43] We also studied on the classification of the first order phase transitions in the Potts model with the so-called transparent states.

2. Quantum Statistical Mechanics

Cooperative phenomena in quantum systems are also important subject in our group. In quantum systems, they show interesting non-classical behavior. We have studied quantum phase transitions in spin systems and also itinerant electron systems. In particular, the mechanism of Nagaoka ferromagnetism provides an interesting magnetic property in system where we control the chemical potential of the itinerant electrons (Hubbard model). We proposed a system in which the transition between magnetic and non-magnetic state takes place with this mechanism and the property of the model is studied by the DMRG method. [50]

As a study on the exact solvable models, we studied the exact property of spin chain by making use of algebraic Bethe anzatz. In particular, we investigated properties of boundary states of $S = 1$ spin chain. [22, 23, 26, 27, 28, 29] We also studied a nontrivial symmetry in a one-dimensional $S = 1$ bilinear-biquadratic model by an exact diagonalization method. [57].

We also studied the dynamical properties and also response. Coherent dynamics of quantum systems has also various characteristic features, and attracts interests from the view point of quantum information processing. We have studied such novel quantum phases and quantum responses. [2] Parts of the subject are studied as an activity of the JST CREST project (Quantum-mechanical cooperative phenomena and their applications). [47]

Quantum response to external fields is one of the important subjects in our group, and we have studied resonant spectrum of interacting system by proposing a direct numerical method for the Kubo formula, and extended it to systems with dissipative dynamics.[48, 49]。In the last year, we studied the line spectrum of a spin chain with an alternative Dzyaloshinsky-Moriya interactions at high temperature limit, and analyzed it in the relation with the autocorrelation function of the spin torque which shows a deviation from the gaussian relaxation at long time. We discussed an extension of the Kubo-Tomita theory. [7]

We also studied hybridization of a spin system in the cavity and the cavity photon which attracts interests from the view point of coupling of photon information and materials. We published a paper with the related experiments[8], which has been reviwed as a possible realization of the Quantum RAM. We extended the study to detailed structure of the line shape by studying the energy structure of hybridized systems.

Moreover, we studied origins of decoherence of the Rabi oscillation which is regarded as an evidence of quantum coherence. We classified the characterization of the origins of the decoherence, e.g. the local distribution of magnetic field and the magnetic anisotropy, and the dipolar-dipolar interactions among the spins, etc. We are applying it to the related experiments.

How the equilibrium (canonical distribution) is realized is also a big topic in statistical mechanics. We have study an isolated spin system and study the dynamics explicitly, and observed how the local system approaches to a stationary state and it is resemble to the canonical distribution as a function of strength and type of the interaction between the local system and the rest system. [9]

We have studied quantum effect in the conveyance process of particle dragged by a potential well. We studied origins of the non-adiabatic transition during the process, and analyzed them from the view points of the resonant state for systems with the quantum tunneling.[56]。

We also studied dynamical properties of quantum systems under transverse field in the context of the quantum annealing. [10, 11]。

On the duality between particle and wave in quantum mechanics, we studied in what condition we can realize the wave nature in a model of particles. [12, 13]

As to the transport phenomena, we studied universal feature of the current fluctuation. We derived a generated cumulant function and examine the proposal of the additivity principle of Derrida. We also studied the AC conductance of the heat conductivity. [14, 15, 16, 17, 18, 19, 20, 52, 53, 54, 55]