

フラストレーションのある系での相転移

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Phase transitions in frustrated systems

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Competition among interactions which is called 'FRUSTRATION' causes various interesting characteristics of the phase transition. I will give a brief overview on them. The idea of frustration was introduced in the study of the spin glass by Toulouse. Then, the effects of frustration was studied in the regularly frustrated system. First, the effect is mainly studied in the Ising model, such as the triangular antiferromagnets and the Villain model. Frustration causes macroscopic degeneracy and these models have nonzero entropy in the ground state and do not have a phase transition at finite temperatures. Because of this highly degenerate situation, however, these models exhibit various types of phase transitions according to types of perturbation. When we add the ferromagnetic second nearest neighbor interaction which enhances the sublattice order (Mekata model), the system shows successive phase transitions. That is, the paramagnetic phase (P), the partially disorder phase (PD) three-sublattice sublattice phase (3FR), and the two-sublattice ferrimagnetic phase (2FR). The two-dimensional version of this model has been studied extensively. It has known that the model has three phases between which two Kosterlitz-Thouless phase transitions exist. The physical nature of the intermediate phases in three dimensions were not clear until recently. Recently, the idea of incomplete order was introduced in the generalized six-state clock model and the understanding on PD has progressed.

When we add interactions of the transverse components of the spin, i.e., the XY interaction, the system also shows successive phase transitions. In this case, the z -component and xy -components order separately. Furthermore, because of the continuous degree of freedom the macroscopic degeneracy is suppressed. On the other hand the system has non-collinear structure of the ground state. Thus the order parameter has a rich structure of the symmetry and new types of phase transitions appear. For example, when the interaction of the xy -components is stronger, then the order parameter consists of the 120° structure which has two-fold discrete symmetry besides the original rotation symmetry. This system has strong Ising-like phase transition. In three dimensions, the new symmetry causes new set of critical indices. Magnetization process in frustrated system is also an interesting problem. Generally system shows various types of 'metamagnetic' behavior.

Frustration also causes so-called reentrant phase transition. That is, When ordering structures are competing due to the frustration, a structure which is not energetically most stable may appear at finite temperatures if this phase is entropically favorable. For example, we have demonstrated that some system has a ferromagnetic phase at finite temperature while its ground state is the antiferromagnetic phase, and that various entropy-induced intermediate phases appear in a

weakly XY-like Heisenberg antiferromagnet in the triangular lattice in the magnetic field.

It is known that the effect of frustration is more serious in the corner-sharing model such as kagome lattice, where even the models with continuous degree of the freedom (XY, or Heisenberg model) has macroscopically degenerate ground state. The ordering pattern in such systems is one of the topics. The exception is the Ising-like (not Ising and not Heisenberg) case, where the ground state consist of two-fold macroscopic degenerate states and a nontrivial phase transition (Ising universality class) takes place. The ground state is a kind of ferromagnetic order but the magnon is localized.

Quantum effect on the ordering of frustrated systems is one of the biggest recent subjects. However, only little is known in definite sense. Does the long range order exist in the ground state of the $S = 1/2$ Heisenberg antiferromagnets in the triangular lattice? Does the $S = 1/2$ Heisenberg antiferromagnets in the kagome lattice has double peaks in the specific heat? Recently according to the new developments on the oxide quantum magnets, various new type of 'quantum spin systems' are discovered, including a new types of frustrated model such as the Shastry-Sutherland model.

References will be completed by the seminar.

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