Strongly correlated system on frustrated lattices: The flat-band scenario and beyond

Johannes Richter
Institut für Theoretische Physik, Universität Magdeburg, Germany

Frustration in magnetic and electronic systems may lead to dispersionless (flat) one-particle bands which have a strong influence on the many-body physics of strongly correlated quantum systems. Thus, flat-band systems are receiving a great deal of attention right now, in particular with view of realizing new many-body phases there. In my talk I will give an overview on the low-temperature physics of flat-band Heisenberg spin systems and Hubbard electrons.

Interestingly for a large variety of such strongly correlated quantum systems a class of exact many-body eigenstates can be constructed. Examples are the 1D sawtooth and kagomé chains, the 2D kagomé and checkerboard lattices, and the 3D pyrochlore lattice. The exact many-particle eigenstates consist of independent magnons (electrons) localized on finite areas of the lattice and become ground states for certain values of total magnetization (electron concentrations).

The correlated quantum systems having localized eigenstates exhibit a highly degenerate ground-state manifold at the saturation field h_{sat} (at a characteristic value of the chemical potential μ_0) for magnons (electrons). The degeneracy grows exponentially with the system size and leads to a finite residual entropy. By mapping the localized magnon (electron) degrees of freedom onto a classical hard-core lattice gas one may find explicit analytical expressions for the low-temperature thermodynamics in the vicinity of h_{sat} (μ_0). Though the scenario of localized eigenstates is similar for spin and electron systems, the different statistics of spins and electrons leads to different construction rules for the localized eigenstates and, as a result, to a different hard-core lattice gas description.

For electrons the scenario of localized eigenstates is related to the so-called flat-band ferromagnetism. For spin systems the localized many-body states lead to some spectacular features in strong magnetic fields, such as zero-temperature magnetization plateaus and jumps, magnetic-field driven spin-Peierls lattice instabilities, an extra peak in the specific heat at low temperatures as well as to an enhanced magnetocaloric effect.

In real systems typically the ideal flat-band geometry ist distorted and the above ilustrated features are modified. However, for small distortions the basic low-temperature features are still present which is relevant for the experimental access to the physical properties related to the flat band.