STRONGLY CORRELATED ELECTRON SYSTEMS

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1 - Overview of strongly correlated electron systems

We recall the description of electronic states in solids with the independent electron approximation and show its limitations and failures. We introduce localized orbitals and narrow bands and discuss examples of strongly correlated electron systems with focus on the metal-insulator transition in transition metal oxides and the formation of heavy quasi-particles in *f* electrons systems.

2 – Kondo effect and heavy fermion systems [1,2]

The physics of heavy fermion systems will be treated in more details in order to illustrate competitive effects in strongly correlated electron systems. Here the antagonist effects are the formation of Kondo singlet and the tendency of magnetic ordering through RKKY interactions. This will be illustrated by elements of the spin dynamics of canonical heavy fermion systems showing both local and collective excitations. We will introduce the spin fluctuation theory in itinerant electron magnetism.

3 - Quantum critical point [3,4]

Many intriguing properties of strongly correlated electron systems occur in the vicinity of their quantum critical points. This point corresponds to a phase transition for which the critical temperature is tuned to zero Kelvin by applying pressure, magnetic field or varying chemical composition. We will highlight the differences between quantum phase transitions and classical finite temperature phase transitions and discuss the specificity of the spin dynamics at a quantum critical point and how it influences thermodynamics and transport properties.

3 - Competition/coexistence between magnetism and superconductivity [5]

The topic of unconventional superconductivity is common to many magnetic materials with strong correlations (cuprates, heavy fermions, new iron-based superconductors). We will introduce typical features of such systems for which it is believed that magnetic fluctuations participate in the formation of Cooper pairs. We will present the feedback of the superconductivity on the magnetic excitation spectrum. And finally we will introduce the exciting topics of ferromagnetic superconductors and field induced antiferromagnetism in superconducting materials.

[1] Y. Kuramoto and Y. Kitaoka, Dynamics of Heavy Electrons, Oxford University Press, 2000.

[2] T. Moriya, Spin Fluctuations in Itinerant Electron Magnetism, Springer Verlag 1985.

[3] S. Sachdev, Quantum Phase Transitions, Cambridge University Press, 2011.

[4] M. Continentino, Quantum Scaling in Many Body Systems, World Scientific 2001.

[5] M.R. Norman, Science 332 (2011) 196.