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METAL-INSULATOR TRANSITION - MAGNETISM AND SUPERCONDUCTIVITY

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Extended abstract

In the correlated fermion (electron) systems the kinetic (band) energy of electrons is comparable to the interaction energy among the particles [1]. In effect, the interaction cannot be treated as a perturbation of noninteracting states. This situation is called as that with *correlated electronic states*. In the cases of high-temperature and heavy-fermion superconductors the band energy is even much smaller than the Coulomb interaction, which is

customarily represented by the intraatomic part - the Hubbard interaction. In the case of orbitally degenerate 3d or 4f states, this interaction is supplemented by the Hund's rule coupling, which represents intraatomic, but interorbital, ferromagnetic interaction. In the simplest (model) situation the correlated electrons are theoretically discussed in terms of a single-narrow-band states; the role of p orbitals due to oxygen (or other elements present in concrete systems) is usually neglected or incorporated in effective hybridized states of d or f types. For such correlated narrow-band states we discuss phenomena such as the Mott-Hubbard localization, real-space pairing and unconventional quasiparticle states or strictly speaking, provide their discussion in term of those states.

Mott-Hubbard transition

First of the discussed phenomena is the instability of metallic state (the so-called *almost localized Fermi liquid*) against the formation of magnetic Mott insulator. An elementary approach to statistical thermodynamics of such system will be provided by generalizing the Gutzwiller approach to nonzero temperature. The concept of heavy quasiparticles which become infinitely heavy at the transition, is introduced. The approach explains also the Pomeranchuk effect at liquid-solid transition of condensed ^{3}He, which is also considered as an almost ideal example of the Mott-Hubbard transition. Particular emphasis is put on the appearance of Mott insulating phase when increasing temperature (cf. Fig. 1).

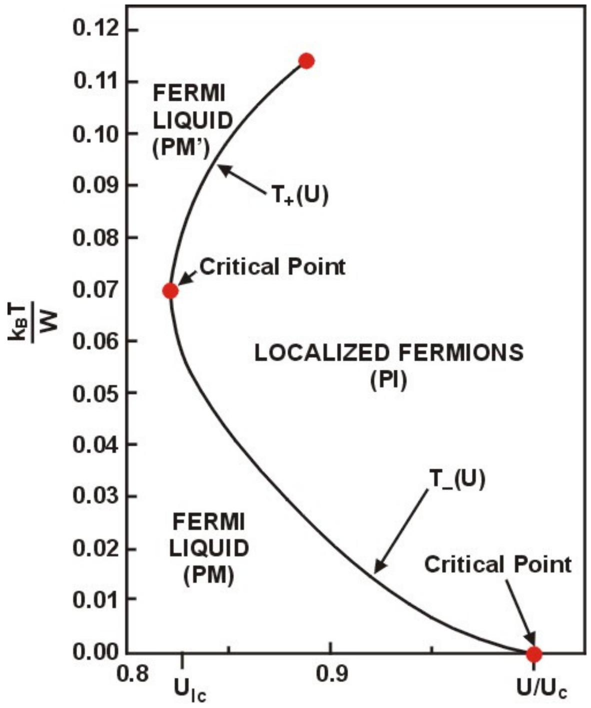

Fig.1.

In the second part of the lecture I shall discuss recent results concerning *quantum critical behavior* at the Mott-Hubbard threshold [2] and introduce, on this example, the quantum critical phenomena associated with it. As a supplement, I discuss evolution of the electronic states in the nanoscopic system on the example of a finite-size quantum wires and low-dimensional clusters [3]. In this case, one can observe a continuous evolution of the Fermi-Dirac-distribution-like function into that corresponding to atomic states at large interatomic distance (cf. Fig. 2). This last topic is raised to claim the universality of the *Mott phenomenon*. If time allows, I shall discuss briefly the transition from Kondo insulator to non-Fermi liquid [4].

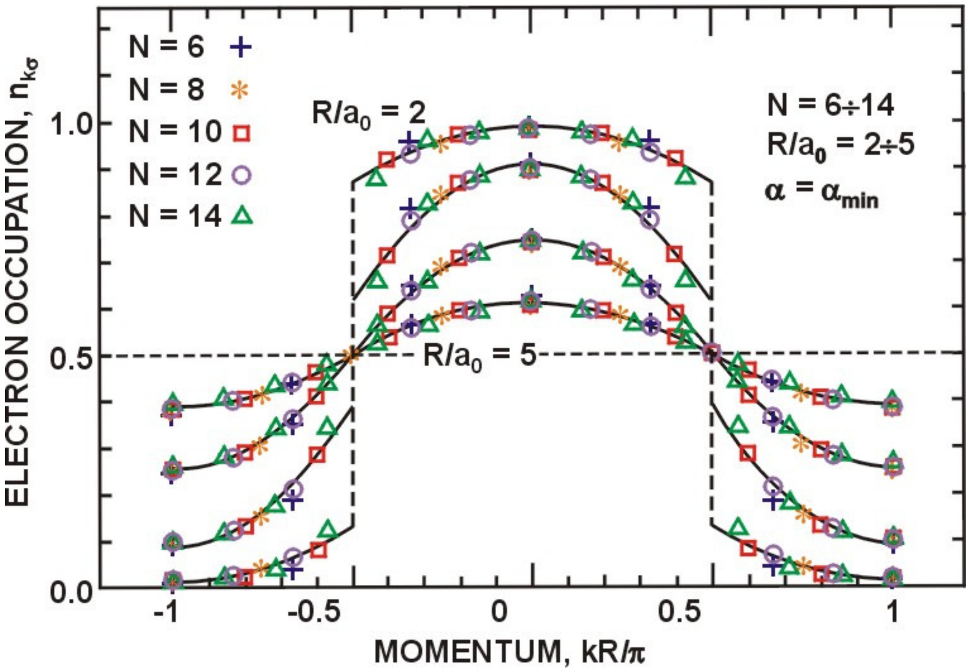

Fig. 2

Real space pairing as the source of unconventional superconductivity

In this part we are moving to the extreme limit of strongly correlated systems when the kinetic energy of electrons is essentially smaller than the Hubbard interaction. In that limit, a specific type of interaction called the *kinetic exchange appears among the correlated particles* [5] in the Mott antiferromagnetic insulator. In the doped Mott insulator another transition to the metallic state takes place as a function of the doping (this time to superconducting phase). The corresponding model with the antiferromagnetic interactions (the t-J model) is transformed to the representation with real-space pairing and is supposed to catch the essential physics of the high-temperature superconductivity [6]. I shall detail only few aspects of the description within the mean-field-type solution.

In this second part of my lectures, I shall address the related phenomenon of heavy-fermion superconductivity which I describe as induced by the Kondo-type correlations. The quasiparticles forming the Cooper pairs in those superconductors have unusual properties: their effective mass depends on their spin direction (in the spin-polarized state) and a specific field induced by the correlations is generated in those systems [7]. Such characteristics produce, among others, new superconducting states observed only in those strongly correlated systems, e.g. the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state with moving Cooper pairs (an exemplary phase diagram is exhibited as Fig. 3).

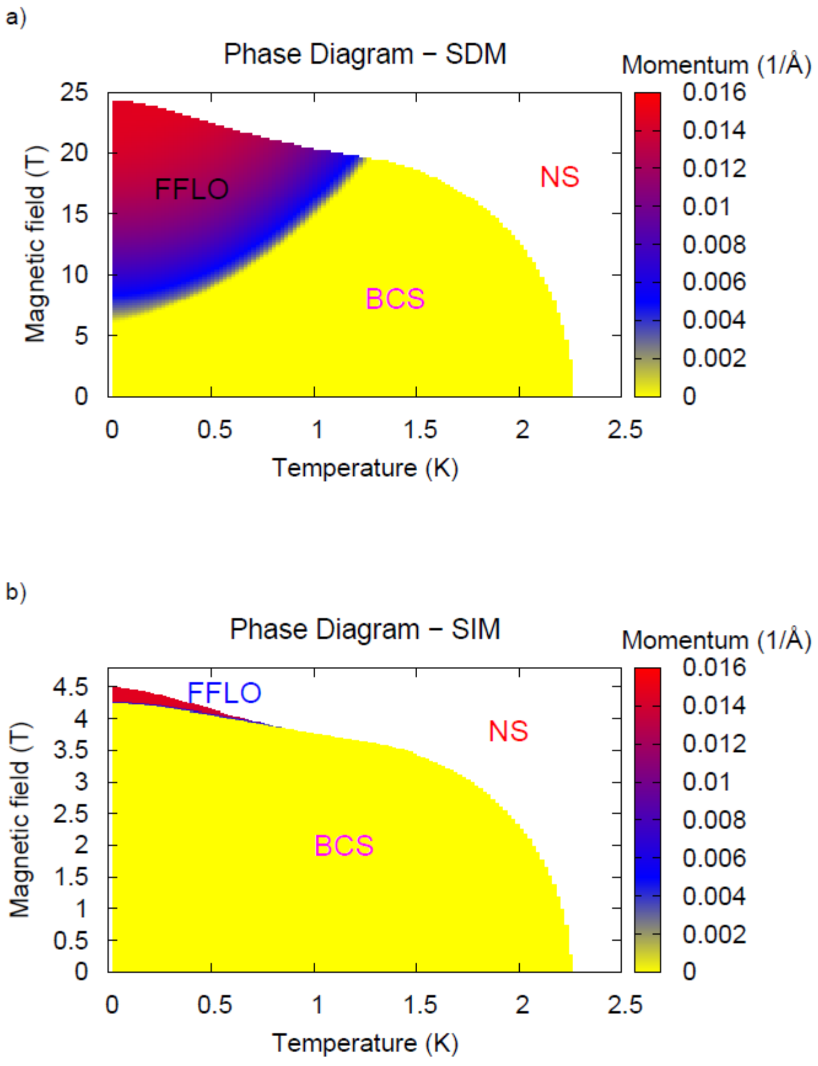

Fig. 3.

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