Universal Cause of High-Tc Superconductivity and Anomalous Behavior of Heavy Fermion Metals

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It is widely believed that unusual properties of the strongly correlated liquids observed in the high-temperature superconductors, heavy-fermion (HF) metals, 2D 3He and etc., are determined by quantum phase transitions. Therefore, direct experimental studies of relevant quantum phase transitions are of crucial importance for understanding the physics of the high-temperature superconductivity and strongly correlated systems. In case of the high-temperature superconductors, these experiments are difficult to carry out, because at low temperatures the corresponding critical point is occupied by the superconductivity. On the other hand, experimental data on the behavior of strongly correlated Fermi liquids, such as the electronic system of HF metals, can help to illuminate both the nature of this point and the nature of the phase transition. Therefore, it is of crucial importance to carry out simultaneously studies of both the high-Tc superconductivity and the anomalous behavior of HF metals.

The main features of fermion condensation quantum phase transition (FCQPT), which are distinctive in several aspects from that of conventional quantum phase transition (CQPT), are considered. We show that in contrast to CQPT, whose physics in quantum critical region is dominated by thermal and quantum fluctuations and characterized by the absence of quasiparticles, the physics of a Fermi system near FCQPT or undergone FCQPT is controlled by the system of quasiparticles resembling the Landau quasiparticles. Contrary to the Landau quasiparticles, the effective mass of these quasiparticles strongly depends on the temperature, magnetic fields, density, etc. This system of quasiparticles having general properties determines the universal behavior of the Fermi system in question [1].

Using the theory of the high temperature superconductivity based on the fermion condensation quantum phase transition [2], we show that neither the d-wave pairing symmetry, nor the pseudogap phenomenon, nor the presence of the Cu-O_2 planes are of importance for the existence of the high-Tc superconductivity [3]. We show that at low temperatures the normal state recovered by the application of a magnetic field larger than the critical field can be viewed as the Landau Fermi liquid induced by the magnetic field. In this state, the Wiedemann-Franz law and the Korringa law are held and the elementary excitations are the Landau Fermi liquid quasiparticles. Contrary to what might be expected from the Landau theory, the effective mass of quasiparticles depends on the magnetic field [4]. The recent experimental verifications of the Wiedemann-Franz law in heavily hole-overdoped, overdoped and optimally doped cuprates and the verification of the Korringa law in the electron-doped copper-oxide superconductor strongly support the existence of fermion condensate in high-Tc metals. The behavior of quasiparticles in the superconducting state is considered. This behavior coincides with the behavior of Bogoliubov quasiparticles, whereas the maximum value of the superconducting gap and other exotic properties are determined by the presence of the fermion condensate [2,3,4]. All these observations are in good agreement with recent experimental facts. The main features of a room-temperature superconductor are considered.

The behavior of the electronic system of HF metals is considered. We show that the behavior of the system can be also understood within the framework of theory based on FCQPT. At finite temperatures T, the system demonstrates the anomalous, or non-Fermi liquid behavior, which can be converted into the Landau Fermi liquid behavior by the application of magnetic fields B. We demonstrate that the effective mass diverges at the very point that the Neel temperature goes to zero. The B-T phase diagram of the electron system is studied. We demonstrate that this B-T phase diagrams has a strong impact on the main properties of heavy-fermion metals such as the magnetoresistance, resistivity, specific heat, magnetization, volume thermal expansion, etc [5].

Analyzing recent experimental data on the high temperature superconductivity and heavy fermion metals, we show that these facts can be understood within the theory of strongly correlated electron liquid based on FCQPT. Thus, FCQPT can be viewed as a universal cause of the high-temperature superconductivity and the anomalous behavior of heavy fermion metals. Finally, our general consideration suggests that FCQPT and the emergence of novel quasiparticles at FCQPT and behind FCQPT and resembling the Landau quasiparticles are qualities intrinsic to strongly correlated substances.

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