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Magnetic fluctuations in unconventional superconductors: The onset of superconducting phase transition

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We explore how antiferromagnetic spin fluctuations lead to the onset of unconventional superconducting phase transition in the Cu-based, Fe-based and heavy fermion superconductors. Realizing that electron has both the spin and the charge degrees of freedom, we will pay special attention to both the spin and the charge dynamics in line with the magnetic spin susceptibility and the optical conductivity respectively. This study helps us understand how common features (universal scaling behaviors) are revealed in the measurements of the unconventional superconductors. In this regard we first examine the observed phase diagrams of the Cu-based superconductors in light of interplay between the two degrees of freedom, based on our earlier proposed gauge theoretic approach (Ref. 1) to the slave-boson represented t-J Hamiltonian. This theory consistently provided qualitative agreements with all other measurements including optical conductivity and neutron scattering. We discuss that the onset of superconductivity is caused by the coupling of the spin (spinon) pairing order with the charge (holon) pairing order, thus revealing the interplay between the spin and the charge degrees of freedom. Further we explain the universal scaling behaviors of the linear increase of magnetic spin resonance peak energy with the antiferromagnetic coupling energy J and that of the mid-infrared peak location energy with J, for both of which the interplay of the two degrees of freedom is found to play a major role.

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