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Nonlocal Effects of Local Nonmagnetic Impurities in Metals near AF-QCP

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In nearly antiferromagnetic (AF) metals, a single nonmagnetic impurity frequently causes nontrivial widespread modification of the electronic states. To elucidate this issue, we study a single impurity problem in a large size Hubbard model (with 64×64 sites). In general, it is not easy to obtain an appropriate solution for this model because two different kinds of strong interactions have to be taken into account on the same footing. To overcome this difficulty, we develop the GV^I-method, which is a powerful method of calculating the electronic states in real space [1].

Based on the GV^I-method, we find that (i) both the local susceptibility and the AF correlation are strongly enhanced around the impurity, which is observed by NMR measurements in high-Tc superconductors [2]. By this reason, (ii) the quasiparticle lifetime around the impurity is strongly suppressed, which causes an approximate T-independent “huge residual resistivity” beyond the s-wave unitary scattering limit [3]. In addition, (iii) only a few percent of impurities can causes the insulating behavior of resistivity when the system is very close to the AF quantum critical point (QCP). Similar insulating behavior is actually observed in various under-doped systems [4,5]. The present study based on the Fermi liquid theory near AF-QCP naturally explains the main impurity effects on high-Tc cuprates, heavy fermion systems and organic superconductors, which had been a long-standing problem for years.

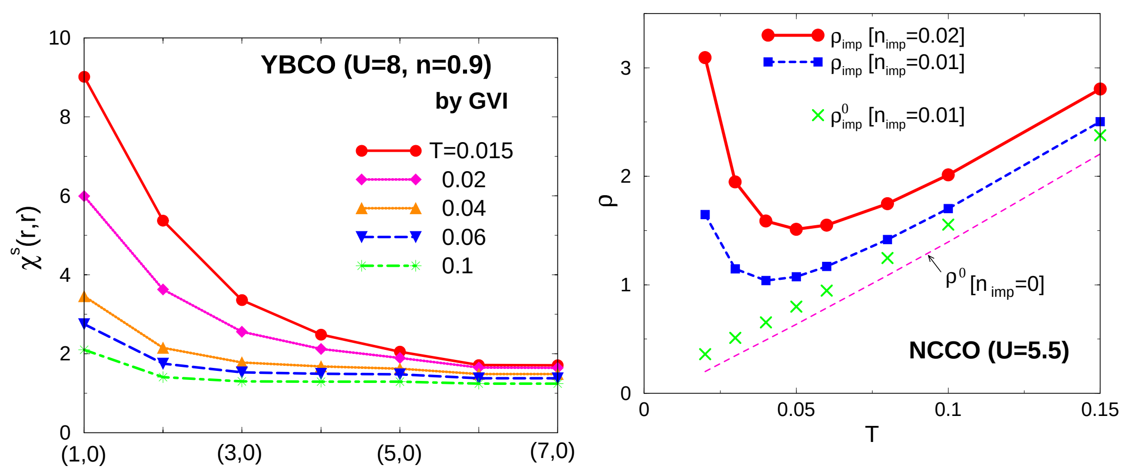

Figure 1: **(left)** Local spin susceptibility $\chi^{Is}(\mathbf{r},\mathbf{r})$ given by the GV^I-method around the impurity site (at $(0,0)$) along the x-direction. It increases drastically as T decreases near the impurity site. **(right)** Obtained T dependence of ρ with dilute impurities. At higher T, a huge parallel shift of ρ ($\Delta\rho$) is caused by impurities, far beyond the s-wave unitary scattering value. The “Kondo-like upturn” at lower T is caused by extremely short quasiparticle lifetime around impurities. $T = 0.1$ corresponds to 400K in high-Tc cuprates.

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