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Numerical Renormalization Group study of quasiparticle interactions for f^2-impurity Anderson model

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Heavy fermions containing two f-electrons at each site (f^2) have attracted much attention for a decade or so. Although uranium compounds UBe_{13}, UPt_3,$\cdots$, and Pr-based skutterudites exhibit rich physics such as superconductivity, anomalous magnetism, non-Fermi liquid and so on, microscopic theory for those systems does not seem to have been fully developed. Coming to think of low temperature physics of those f^2 systems, espicially superconductivity, we need to know about the quasi-particle properties. It is important to clarify how quasi-particles of f^2 compounds interact with each other on the basis of microscopic approach. We employ numerical renormalization group method of Wilson at the level of impurity problem in the case of UPt_3 with hexagonal symmetry, because the local part of quasi-particle interaction is expected to play a dominant role. Our basic assumption is that ground state is f^2-singlet. Under this assumption, our model is almost equivalent to the f^2-singlet ground state model for dilute uranium compounds $R_{1-x}U_xRu_2Si_2$(R=Th,Y and La, x$\leq$0.07) [1]. Pt night shift experiment and magnetic succestibility of UPd_2Al_3 which has same crystal structure of UPt_3 indicate this assumption is reasonable.

This model is known to show the competition between Kondo-Yosida singlet and f^2-crystalline-electric-field singlet. There are two stable fixed points : Kondo-Yosida singlet fixed point (KYSFP) and CEF singlet one (CEFSFP). Between these two fixed points, there exists an unstable non-Fermi liquid fixed point (NFLFP). Around the stable fixed point, we can write down effective Hamiltonian from free or bare states. The parameters of the effective Hamiltonian in NRG are known to be related to the Fermi liquid parameters. Of course it is impossible to do this at NFLFP. Then we obtain quasiparticle interactions from those parameters. Our main results are :

1. Inter-orbit interactions are greater than intra one in the intermeadiate region of CEF configuration : f^2 Γ_5 magnetic doublet is located slightly above the ground state f^2 Γ_4 singlet, which corresponds to KYSFP. If Γ_5 level is lifted, NFLFP emerges by fine tuning. When Γ_5 level is lifted much more, corresponding fixed point is CEFSFP.

2. Bare interactions (Coulomb interaction) are highly renomalized and result in the shape with the symmetry only satisfying point group operations. More clearly, once f^2 ion configuration is determined, spherical Coulomb interaction is renormalized to the lower symmetry (in this case hexagonal symmetry) and especially the terms corresponding to the dominant f^2 state are much enhanced.

We speculate that intra orbit interactions play important roles in forming triplet pairing of f^2-based compounds such as UPt_3.

[1] S. Yotsuhashi et al J. Phys. Soc. Jpn. 71 (2002) 389