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Theory for anomalous properties due to multilevel Kondo effect

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We discuss the following three aspects: (1) It will be discussed that the origin of heavy fermion state of $SmOs_4Sb_{12}$ can be understood as multilevel Kondo effect due to rattling degrees of freedom of Sm ions in the cage of Sb_{12} [1]. (2) The effect of higher excited levels of ionic motions in the two-level Kondo model is discussed on the poor man's scaling method. (3) A plan for discussing transport properties, the temperature dependence of the resistivity and superconducting mechanism, due to the renormalized rattling motion of ions will be briefly shown.

In this abstract, only the first subject is summarized. As a model for rattling motion of Sm ion between off-center stable positions, we first investigate the four-level Kondo model (in which an ion is tunneling among four-stable points and interacting with surrounding conduction electrons) both by the Wilson numerical renormalization group (NRG) method and the two-loop perturbational renormalization (PRG) method. We find the result that purely orbital Kondo effects occur at low temperatures in these systems which are direct generalizations of the Kondo effect in the so-called two-level system. This result offers a good explanation for the enhanced and magnetically robust Sommerfeld coefficient observed in $SmOs_4Sb_{12}$ and some other filled-skutterudites as shown in the figure below [1]. Since NRG and PRG of two-loop order give essentially the same fixed point in the case of four-level Kondo model [1], we investigate the six-level Kondo model (which is considred to simulate some filled-skutterudite compounds) by PRG method and we find that the strong coupling fixed point is possible for reasonable strength of parameters [2].

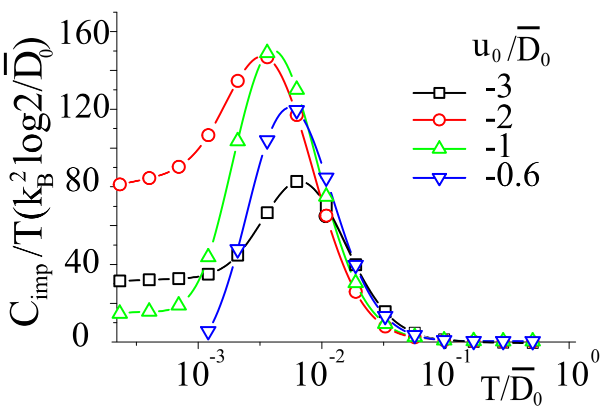

Figure 1: $C_{\rm imp}/T$ vs. T, C being the impurity specific heat. The parameter set used is: $\Delta = -0.0169\bar{D}_0$, $k_F a = 0.8$ and $k_F\sigma = 0.42$ (we obtain similar results for $u_0 > 0$ cases). For the bare bandwidth $\bar{D}_0/k_{\rm B} = 100$K, $C_{\rm imp}/T \simeq 57 \times$ (scale of ordinate) mJ/K$^2 \cdot$ mol. The definitions of parameters will be explained in the talk, or please refer to the ref. [1].

References

[1] K. Hattori and K. Miyake: J. Phys. Soc. Jpn. **74** (2005) 3306.

[2] K. Hattori, Y. Hirayama and K. Miyake: J. Phys. Soc. Jpn. Suppl. **75** (2006), in press.