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Competition between crystal-field and Kondo effects due to multipoles in orbitally degenerate electron systems like Pr-based skutterudite compounds

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A singlet-triplet configuration is the common structure of the Pr lowest-lying crystal-field states of Pr-based skutterudites. A variety of multiorbital Kondo effect can be expected by controlling the crystal-field levels experimentally, although no Kondo-like behavior has been observed other than $PrFe_4P_{12}$.

We recently studied theoretically competing crystal-field and Kondo effects that reflect, for instance, in enhancement of a local field. The following two cases are shown here:

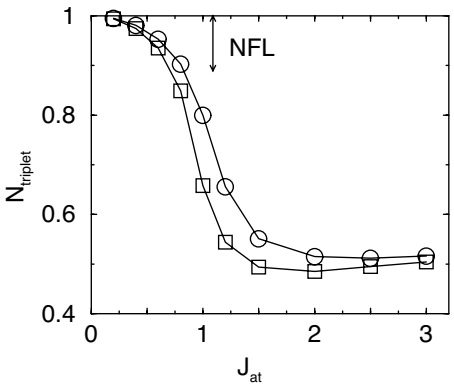
1. Local singlet-triplet configuration coupled to both a_u and t_u electrons [1]

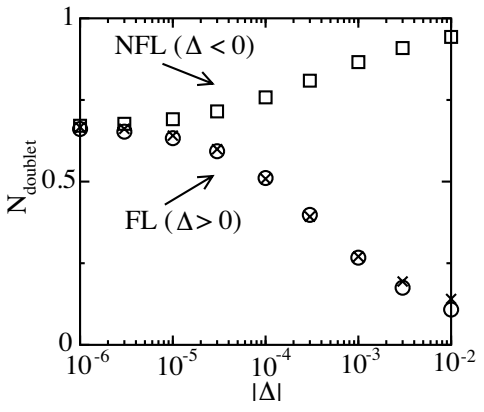
   The a_u and t_u molecular orbitals come from pnictogen cages surrounding each Pr ion and hybridize the f orbitals with the conduction band. The Kondo effect due to the local triplet stabilizes a non-Fermi liquid (NFL) state, while the local singlet favors a Fermi liquid (FL). In the figure, the charge redistribution $N_{\rm triplet}$ in the triplet represents a local hexadecapolar field renormalized at low temperatures. J_{at} is a coupling constant of a_u-t_u exchange interaction with the local singlet-triplet interchange that stabilizes the FL.

2. Local singlet-doublet configuration coupled to Γ_8 fourfold degenerate electrons [2]

   A quadrupolar exchange interaction stabilizes the non-Kramers doublet, leading to an NFL that competes with a singlet dominant FL. Both FL and NFL phases are separated by a critical-point NFL. This NFL is stabilized just when the local singlet and doublet states are degenerate. In the same manner with the first case, the charge redistribution $N_{\rm doublet}$ in the doublet represents a renormalized quadrupolar field as shown in the figure. Here Δ is an energy level of the doublet measured from the singlet.

The enhancement of local multipoles by such FL vs. NFL competition is found as a universal feature in the multiorbital Kondo effect. We will also apply the same argument to an orbitally degenerate Anderson model considering various types of interaction between the f electrons.





[1] M. Koga and M. Matsumoto: J. Phys. Soc. Jpn. **76** (2007) 074714.
[2] M. Koga and M. Matsumoto: Phys. Rev. B **77** (2008) 094411.