The Kondo-vs.-RKKY quantum box

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Nanoscale systems of metal atoms antiferromagnetically exchange coupled to several magnetic impurities are shown to exhibit an unconventional re-entrant competition between Kondo screening and indirect magnetic exchange interaction. Depending on the atomic positions of the magnetic moments, the total ground-state spin deviates from predictions of standard Ruderman-Kittel-Kasuya-Yosida (RKKY) perturbation theory. This quantum-box effect shows up in the weak-coupling limit on an energy scale larger than the level width induced by the coupling to the environment.

The strong-coupling limit and the crossover from weak to strong coupling is studied by means of exact diagonalization, density-matrix renormalization, strong-coupling perturbation theory and real-space dynamical mean-field theory. It is shown that impurity moments strongly coupled to the metallic nano system may confine the conduction-electron motion due to scattering at almost localized Kondo singlets. This leads to local-moment formation in the conduction-electron system and to a novel "inverse" indirect magnetic exchange coupling mediated by the Kondo singlets. Its distance dependence is oscillatory and induces robust magnetic long-range order in one- and two-dimensional multi-impurity structures. This new mechanism for magnetic ordering is different from but related to RKKY-induced ferromagnetism, to flat-band ferromagnetism and to Lieb's ferromagnetism.