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Multiple energy scales of strongly correlated electrons as revealed by the thermoelectric transport data

V. Zlatić[1], S. Burdin[2]

[1] *Institute of Physics, Bijenička c. 46, 10001 Zagreb, Croatia*
[2] *Max Planck Institute for Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Strasse 38, 01187 Dresden, Germany*

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The heavy fermions and valence fluctuators with Ce, Eu, and Yb ions can exhibit completely different behaviors, depending on temperature, pressure or magnetic field. Typically, we distinguish the local moment (LM) regime, characterized by the Kondo scale T_K, and the Fermi liquid (FL) regime, characterized by an energy scale T_0.

The LM–FL crossover is characterized by the reduction of entropy, an enhancement of the low-energy effective mass, the change of the susceptibility from Curie-Weiss to Pauli like, and the change of the transport coefficients from logarithmic to simple power laws. The question is, can we understand the crossovers induced by temperature, pressure, doping, or the field, explain the anomalies observed in the FL and LM phase, and relate T_0 and T_K to each other?

We address these problems by representing the $4f$ systems by the periodic Anderson model with infinite $f-f$ correlation. Close to the ground state, the properties are obtained by the Fermi liquid theory, with the FL scale T_0 taken from the dynamical mean field approximation (DMFT) or from the experiment. The high-temperature properties are calculated by the diagrammatic expansion which provides the Kondo scale T_K and explains most of the experimental features observed for $T \geq T_K$. However, in a stoichiometric compound, the crossover proceeds differently than in a dilute alloy and cannot be described by a single impurity model.

To infer the overall behavior of intermetallic compounds with $4f$ ions we solve the periodic Anderson model in the slave-boson approximation and derive an approximate relationship between T_0 and T_K. We show that the value of the ratio T_0/T_K and the nature of the crossover ("fast" or "slow" with respect to the single impurity case) depends very much on the shape of the conduction electrons density of states around the chemical potential. An understanding of the crossover allows us to interpolate between the LM and the FL solutions. Using these results we explain the anomalies found in the experimental data on thermoelectric transport. We show that the thermopower is particularly well suited for estimating the characteristic energy scales of strongly correlated systems.