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Microscopic approach to f-electron states

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It has been a long-standing issue to understand the mechanism of unconventional superconductivity of f-electron systems from a microscopic viewpoint. Recently this problem has attracted renewed attention due to the discovery of exotic superconductivity in filled skutterudites, which are considered as typical f^2 systems. For insulating f-electron compounds, the theory of crystalline electric field (CEF) has been established based on the LS coupling scheme to consider f^n-electron state, irrespective of the value of n. However, when f electrons begin to move around the system as heavy quasi-particles through the hybridization with conduction electrons, it is very difficult to treat f^n-electron systems with $n>1$ in the LS coupling scheme by using standard quantum field theoretical techniques, since the Wick's theorem does not hold in the scheme. Rather it is recommended to reconsider the problem based on a j-j coupling scheme, in which one f-electron state is first defined. However, it is still unclear how to include the CEF effects as well as Coulomb interactions in the j-j coupling scheme. In this presentation, we discuss how the microscopic model should be expressed in the j-j coupling scheme. Then, we provide a conventional way to include effectively both the CEF effects and Coulomb repulsions in the form of two-body interactions so as to reproduce the local f^2 state of the LS coupling scheme. Some numerical results based on the model are shown and finally, future problems of the present microscopic approach will be briefly discussed.