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Multipole Properties of Filled Skutterudite Compounds

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It has been gradually recognized that multipole degrees of freedom play crucial roles for understanding of exotic magnetism and unconventional superconductivity observed in filled skutterudite materials. For $PrOs_4Sb_{12}$, the existence of a quadrupole ordered state induced by a magnetic field near the superconducting phase [1] suggests a potential role of quadrupole fluctuations for Cooper-pair formation. A second-order phase transition of $PrFe_4P_{12}$ is considered to be due to antiferro-quadrupole ordering [2]. For $SmRu_4P_{12}$, signs of octupole ordering have been suggested by elastic constant measurement [3] and μSR experiment [4].

In order to develop a theory for multipole phenomena, we have proposed the construction of a microscopic model for f-electron systems based on a j-j coupling scheme [5]. On the basis of such a model, we have shown a scenario to understand magnetism and superconductivity of filled skutterudites from a microscopic viewpoint [6,7]. We have also proposed a way to calculate multipole susceptibility within the standard linear response theory [8]. However, the microscopic research on the effect of multipole fluctuations has just started [9,10]. We believe that such a study opens the door to a new stage in "multipole physics" of f-electron systems.

In this talk, first we discuss a concept of optimal multipole susceptibility to determine the multipole state in an unbiased manner. Concerning "rattling", a characteristic issue of filled skutterudites, we introduce an idea to consider "rattling" as Jahn-Teller phonon. Then, from a conceptual viewpoint, we explain non-magnetic Kondo behavior due to the dynamical Jahn-Teller effect [11]. After we briefly explain an effective way to include the crystalline electric field potential with $T_{\rm h}$ symmetry in the j-j coupling scheme [12], we show our recent results on the multipole state and the effect of dynamical Jahn-Teller phonons of Sm-based filled skutterudites.

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