Microscopic Origin of Fully Gapped s-wave Superconductivity against Strong Coulomb Interaction and Quadrupole order in Heavy Fermion System.

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Superconductivity

Recent experiments have revealed that s-wave superconductivity without any sigh-reversal emerges near the AFM-QCP in heavy fermion system $CeCu_2Si_2$. However, microscopic origin of the s-wave superconductivity (SC) against the strong Coulomb interaction and AFM fluctuation has not been understood by conventional Migdal theory. Here, we study the s-wave SC mechanism on the basis of periodic Anderson model. [1,2] Due to the higher-order many body effects, s-wave state is realized near the AFM phase. The origin of s-wave SC is cooperation between el-ph interaction, electric fluctuation and magnetic fluctuation near AFM-QCP. In particular, the significant contributions come from the Aslamazov-Larkin process which represent the strong orbital-spin interference.

Multipole ordering

In CeB_6, AF quadrupole order with $q=(\pi,\pi,\pi)$ occurs at T_Q=3.2K, and magnetic order appears at T_N = 2.4K. However, the microscopic origin of these phase diagram is still unsolved. Here, we focus on the multipole degrees of freedom due to strong spin-orbit interaction(SOI) and analyze a periodic Anderson model. As a result, various types of electric and magnetic fluctuation develop cooperatively and AF quadrupole (O_{xy}) order is induced by the strong "inter-multipole coupling" driven by higher-order many-body effects. Strong interference among different quantum critical fluctuation lead to the emergence of AF quadrupole phase. The present theory naturally explains AF quadrupole order in CeB_6.

[1] R. Tazai et al., JPSJ, **88**, 6, 063701 (2019). [2] R. Tazai et al.,PRB, **98**, 205107 (2018). [3] R. Tazai et al., arXiv: 1901.06213.

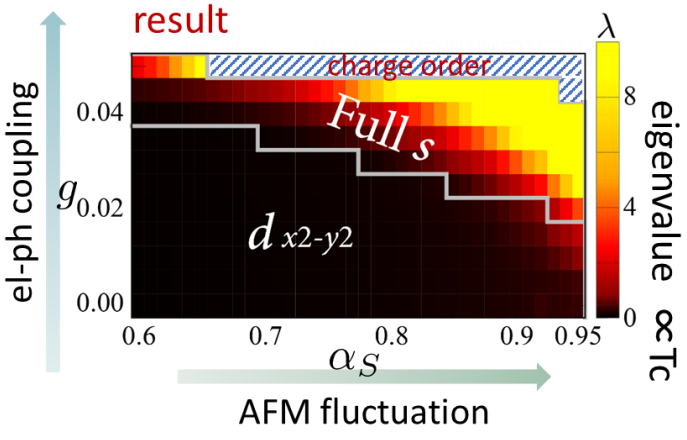

Figure: Obtained phase diagram. Fully gapped s-wave SC appears near AFM-QCP due to the cooperation of el-ph and AFM