**5-1952**

# Microscopic Theory of Multi-stage Fermi Surface Reconstruction in Higher-rank Moment Quantum Materials

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Classification and understanding of quantum phase transitions and critical phenomena in itinerant electron systems are outstanding questions in quantum materials research. Recent experiments on heavy fermion systems with higher-rank multipolar local moments provide a new platform to study such questions. In particular, experiments on $Ce_3Pd_{20}(Si,Ge)_6$ show novel quantum critical behaviors via two consecutive magnetic field-driven quantum phase transitions. At each transition, the derivative of the Hall conductivity jumps discontinuously, which was attributed to sequential Fermi surface reconstructions. Motivated by this discovery, we consider a microscopic model of itinerant electrons coupled to local dipolar, quadrupolar, and octupolar moments arising from $Ce^{3+}$ ions. Using renormalization group analyses, we demonstrate that numerous transitions can occur depending on which multipolar moments participate in the Fermi surface and which other moments are decoupled via Kondo destruction, and identify order parameters consistent with experiments. Our work offers a new theoretical framework for understanding multipolar quantum materials.

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