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Lectures on the quantum phase transitions of metals

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Abstract

Quantum phase transitions of metals involve changes in the Fermi surface, and can be divided into three categories. The first two categories involve symmetry breaking, and lead to a distortion or reconstruction of the Fermi surface. The third category involves a change in the volume enclosed by the Fermi surface without any symmetry breaking: one phase is a Fermi liquid (FL) with the conventional Luttinger volume, while the other phase is a 'fractionalized Fermi liquid' (FL*), which has a non-Luttinger volume Fermi surface accompanied by a spin liquid with fractionalized excitations. It is a relatively simple matter to obtain a FL*-FL transition in Kondo lattice models. However, the FL*-FL transition can also be present in single-band Hubbard-like models: this is efficiently described by the 'ancilla' method, which shows that the transition is a 'flipped' Kondo lattice transition. This single-band FL*-FL transition is argued to apply to the metallic states of the hole-doped cuprates. In the clean limit, the critical properties of the quantum transitions in the three categories are distinct, but all lead to perfect metal transport in the quantum-critical regime. Impurity-induced 'Harris disorder', with spatial fluctuations in the local position of the quantum critical point, is a relevant perturbation to the clean critical points. In the presence of Harris disorder, all three categories exhibit strange metal behavior, which can be described by a universal two-dimensional Yukawa-Sachdev-Ye-Kitaev model.

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Lecture Videos on YouTube.

Contains extracts from:

- *Quantum Phases of Matter*, by S. S., Cambridge University Press (2023).
- *Strange Metals and Black Holes: Insights From the Sachdev-Ye-Kitaev Model*, S. S., Oxford Research Encyclopedia in Physics, December 2023; arXiv:2305.01001