11220PHYS474500
強相關電子系統(Strongly Correlated Electronic Systems)

Brief course description

This course aims at building a bridge between undergraduate physics study and contemporary condensed matter research. Strongly correlated electron systems (SCES) are solid-state systems in which the interactions among the macroscopic number of electrons create new phenomena beyond the single-particle description. Notable examples include high-temperature superconductivity, charge and spin density waves, heavy fermion materials, and exotic magnetism. SCES (typically metals) and topological materials (typically semiconductors or semimetals) form the two pillars of quantum materials research. This course will cover a wide range of topics in current SCES research and the course participants will be introduced to all branches of SCES and develop an understanding of the current state of the art.

In the first two weeks, concepts in the Landau-Fermi liquid theory, Ginzburg-Landau theory of phase transitions, and macroscopic quantum coherent phenomena (superconductivity, superfluidity and Bose-Einstein condensate) that have wide-ranging applications in SCES studies will be introduced. In the following weeks, a recent research paper will be chosen as the vantage point to introduce one topic of the current SCES agenda, including:

- Unconventional superconductivity
- Heavy fermion systems
- Quantum spin liquids
- Strange metals
- Quantum phase transitions

The discussion of course material will be focused on experimental discoveries made in representative materials systems, complemented by the introduction of essential theoretical concepts for their understanding.

Evaluations will be based on an oral presentation of a current research paper (mid-term; 50%), a written report on a prospective research project (final; 50%), and course participation (bonus).

The language of this course is English.
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Syllabus

Theoretical concept

- Landau’ s Fermi liquid theory
- Ginzburg-Landau theory
- Theory for superconductivity

Quantum states of matter

- Unconventional superconductivity
- Metal-insulator transitions
- Heavy-fermion systems
- Quantum magnetism
- Spin-orbit coupling in solids
- Non-trivial topology of electronic band
- Strong correlations in 2D materials
- Quantum phase transitions and criticality
- Strange metals and anomalous criticality

Advanced experimentation

- Low-temperature physics
- Research in large-scale facilities