PHY680-03: Quantum Hall Effect and Chern-Simons Theory

Yin-Chen He

YITP seminar room (Math 6-125), Mo-We 11:00am–12:20pm, Fall '25

Description. This course provides an introduction to the quantum Hall effect and Chern–Simons theory. The quantum Hall effect is a cornerstone of quantum-matter physics, and it is a beautiful example where real experiments, insightful theories, and formal mathematics meet. Since its discovery in the 1980s, it has remained—and continues to be—a constant source of inspiration for novel ideas in quantum matter and other fields, including topological phases, topological quantum computing, quantum field theory dualities, topological/conformal field theory and physics on non-commutative geometry.

Topics. The course will cover the following topics, in chronological order:

1. Integer quantum Hall effect: Landau levels, topological invariant, disorder, edge states.
2. Fractional quantum Hall effect: Laughlin wavefunction, composite fermion, non-Abelian quantum Hall states.
3. Chern-Simons theory: topological order, anyons, edge states (chiral CFT)
4. Field theory dualities: boson-vortex duality, duality web of gauge theories
5. Survey topics (may only select a few): bulk-boundary (TQFT-CFT) correspondence, topological phases, fractional/integer Chern insulators, topological quantum computing, non-commutative geometry, composite fermi liquid, experiments of anyon statistics and non-Abelian quantum Hall.

Prerequisites. There are no hard technical prerequisites, the major portion of the course should be accessible to anyone familiar with quantum mechanics. Some knowledge of QFT will be helpful (but not required) for the Chern–Simons theory part. If you are not yet familiar with QFT, do not be intimidated; Chern–Simons theory is solvable in a relatively simple manner and can serve as an approachable introduction to the language of QFT and gauge theories.

Course materials: The course will be mainly based on the lecture notes by David Tong on the quantum Hall effect.

Exam: Presentation on selected topics.