Physics 525 Advanced Condensed Matter Physics:
Quantum Dynamics, Transport Dynamics and Hydrodynamics near Quantum Critical Points
Tues, Thur 12:30-2:00pm

Part I: General Discussions on quantum criticality

0) Basic ideas of Phase transitions and critical phenomena: Fluctuations and interactions

1) Scale symmetry and Wilson-Fisher strong coupling fixed points

2) Concept of Quantum phase transitions and Quantum critical points (regimes)

3) Standard approach to quantum criticality via quantum field theories

4) Celebrated examples of Quantum critical points (QCPs)

Part II: Dynamics near Quantum critical points (QCPs)

1) Kimble-Zurek mechanism near QCPs and applications to quenched many-body dynamics

2) Universal Transport phenomena near strongly coupling QCPs

3) Planckian transport in a few strongly interacting condensed matter systems

4) Hydrodynamics near QCPs: nearly perfect quantum liquids

5) Quantum dynamics near QCPs with dynamic critical exponent z=2:
SO(2,1) conformal symmetry a) Weak and strong coupling fixed points;
b) The issue of bulk and shear viscosity; c) Quantum Boltzmann breathers.

Part III: More recent applications: QCPs in Quantum topological Matter

1) Beyond-Landau-paradigm quantum phase transitions driven by global topologies

2) QCPs in Topological superfluids and superconductors

3) Bulk signatures of QCPs and what happens to surface states

4) Strong coupling topological QCPs

5) Surface states as QCPs

6) Emergent SUSY in topological matter and topological surfaces

General References:

1) *Quantum Phase Transitions,* Subir Sachdev (Cambridge University Press, 2nd ed., 2011).
2) An introduction to Quantum field theory, Michael Peskin and Daniel Schroeder (CRC press, Taylor and Francis, 1995)

Important:

1) This course is intended for discussions on quantum criticality and its applications in various condensed matter or man-body systems available in labs. The pre-requisite are Phys500, Phys503. In addition, Phys516 (statistical mechanics) and Phys 526 (QFT I) are also highly recommended; materials covered there form the foundation/starting points of many discussions we are going to have this term.

2) Apart from the two general references listed above, other more specialized references (review articles and research papers) will be provided as the course progresses.

3) There will be about 4-6 HW sets (60%) and one final presentation on quantum criticality (40%).

4) We will meet every Tuesday/Thursday 1230pm-2pm.

(This page may be further updated/revised)