Topological Phases and Emergent Phenomena

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Main research interests in my group

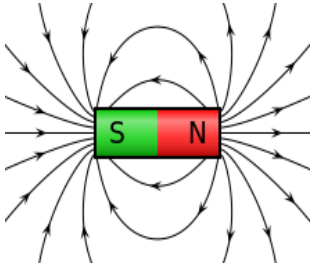
Broadly defined theoretical condensed matter physics

- topological phases of matter
- strongly correlated systems
- transport in mesoscopic systems
- non-equilibrium statistical mechanics

Two big questions in condensed matter physics

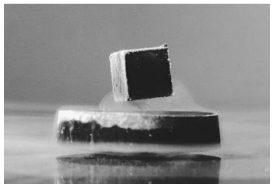
Phases of matter

crystals



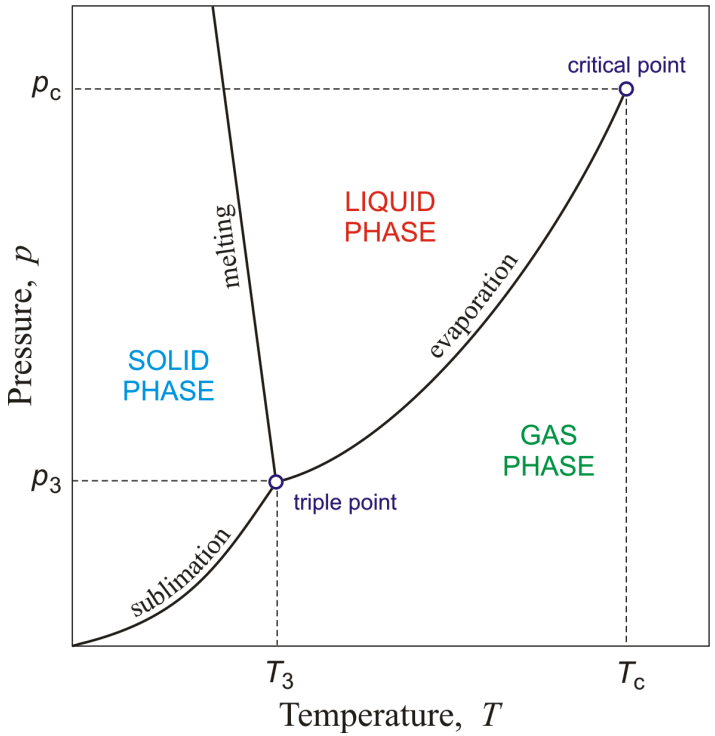
magnets

liquid



superconductors

transitions between phases



What do we study?

✦ Quantum phases and phase transitions of matter:

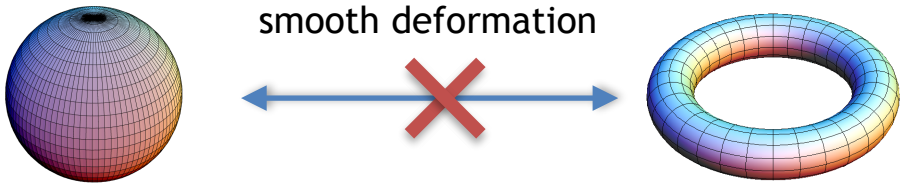
- in many-particle systems (collective behaviors)
- close to absolute zero temperature
- in systems with strong quantum mechanical effects
- with strong inter-particle correlations

What methods do we use?

- quantum field theory
- algebraic theory (category theory, cohomology theory)
- quantum transport theory (Keldysh etc)
- numerical method (density matrix renormalization group, etc)

Topological phases

✦ Topology



topological space 1 topological space 2

✦ Topological phases

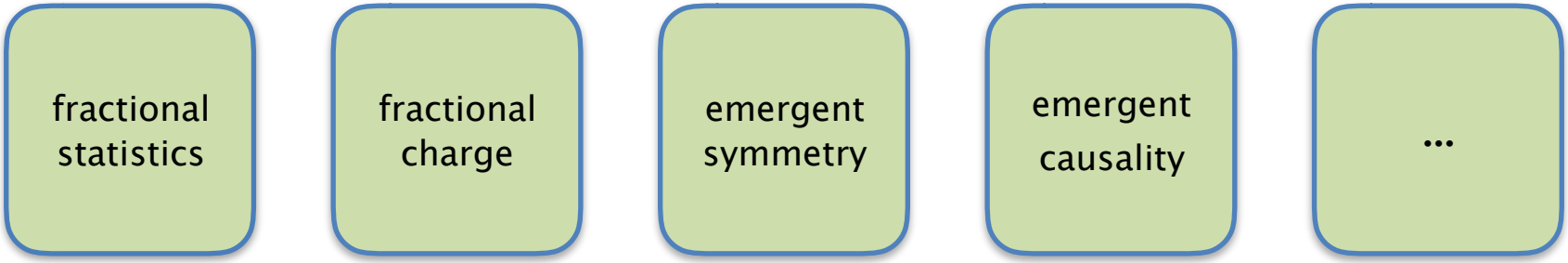
“smooth deformation”

$|\text{state of matter 1}\rangle$ $|\text{state of matter 2}\rangle$

✦ Examples

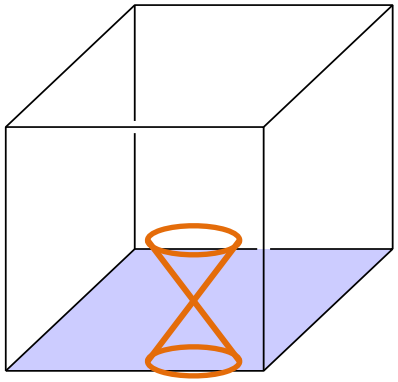
- quantum Hall effects
- quantum spin liquids
- topological insulators
- topological superconductors

Emergent phenomena

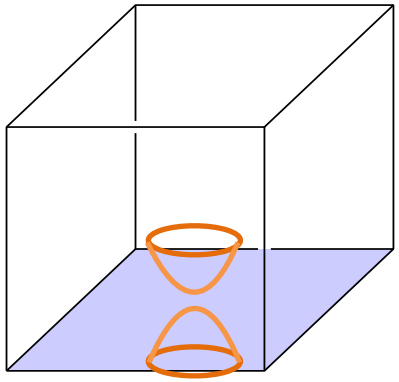


- ✦ fractional charges
  - e+: proton
  - e-: electron, muon
  - e/3 ? Yes, emergent particles in fractional quantum Hall states
- ✦ fractional statistics
  - bosons: photon, Higgs boson
  - fermions: electron, proton
  - in between? yes, in many topological phases

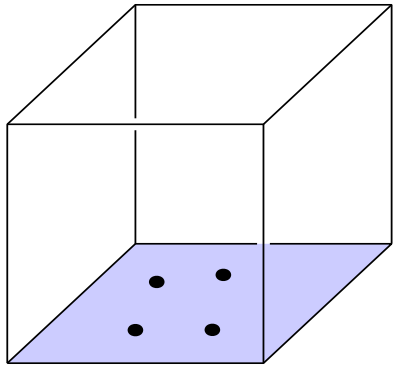
(1) Bulk-boundary correspondence



1. Gapless (CFTs)



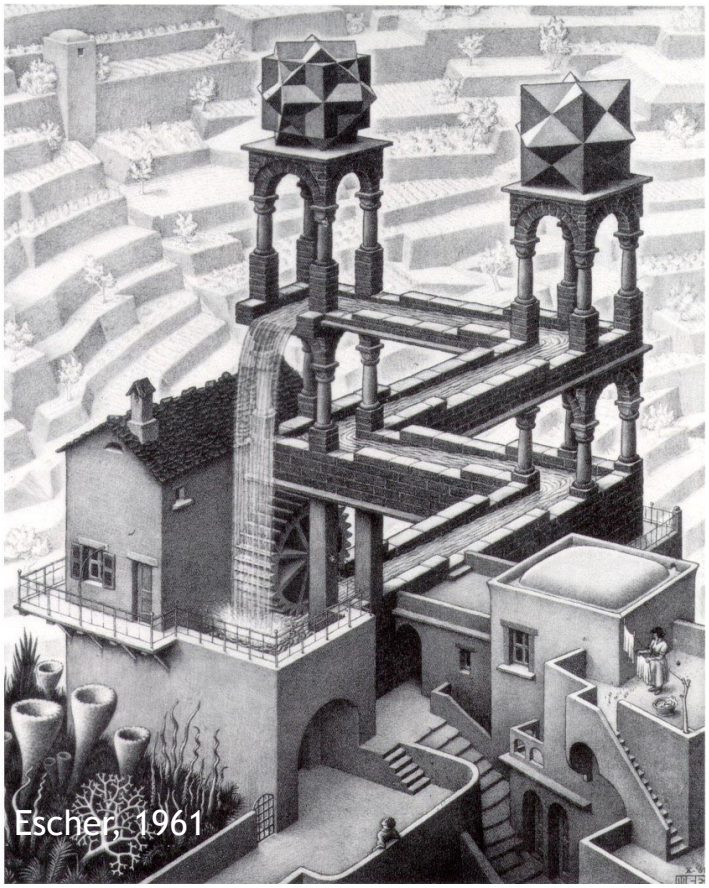
2. Spontaneous breaking

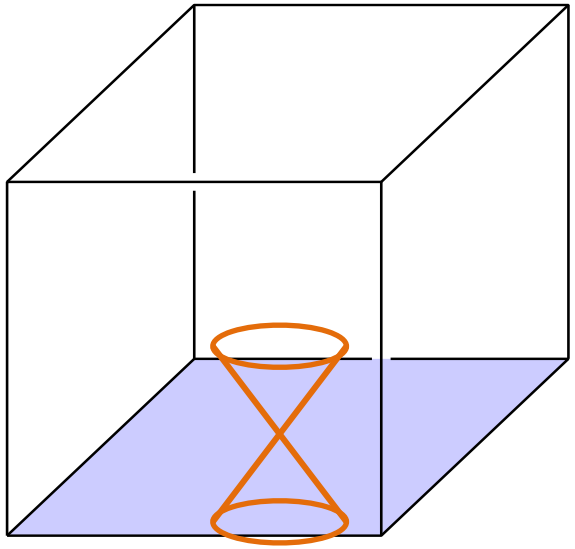


3. Topologically orders = TQFTs

surface observables —> bulk observables

quantum anomaly

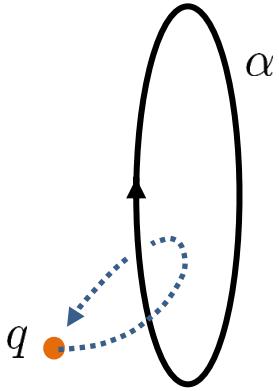




Examples:
- axial anomaly
- parity anomaly
- time-reversal anomaly

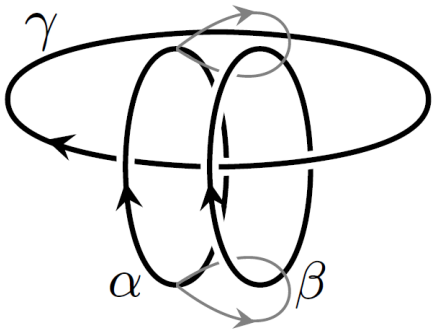
(2) Fractional loop statistics

particle-particle



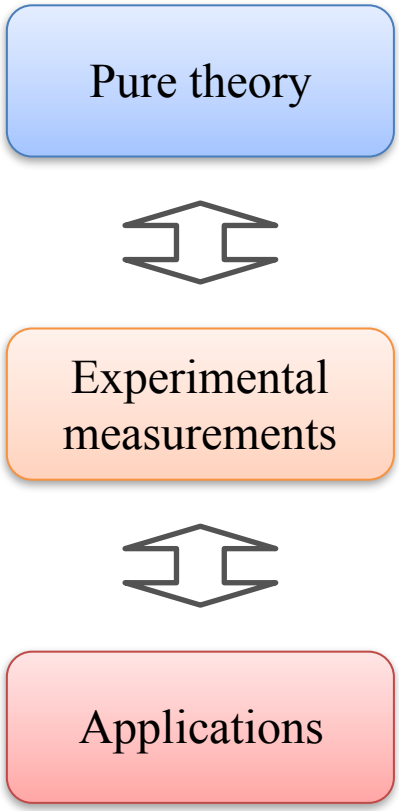
particle-loop

$q\phi_\alpha$



Three-loop braiding

$\theta_{\alpha\beta,\gamma}$



Anyon theory, exactly soluble models, field theory

Quantum transport, current and noise spectroscopy, interferometry

topological quantum computation

Research in my group

Thank you!

Welcome to contact me if you want to know more:
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