Condensed Matter Theory

Condensed matter theory research at Yale spans a broad range of topics:

(i) Many-body physics:
   • Number of particles is large
   • Interactions among constituents can be strong

(ii) Phases of matter:
   • Superfluidity, superconductivity, Bose-Einstein condensate (BEC)
   • Ferromagnetic and anti-ferromagnetic phases
   • Topological phases (cannot be understood by symmetry breaking)
   • Fractonic phases (beyond the standard quantum field theory framework)

(iii) Cold atom physics:
   • Interactions between particles can be tuned
   • Simulations of quantum condensed matter systems

(iv) Quantum computation
Condensed Matter Theory at Yale

Broad research: From bulk systems to nanoscale physics
From mathematical foundations to numerical studies

Other departments: applied physics, mechanical engineering,…

Collaborations across departments: physics and applied physics
(theory and experiment)

Interdisciplinary research
Nuclear Theory

Francesco Iachello

• Neutrinoless double beta decay
• Clustering in nuclei
• Quantum phase transitions

Yoram Alhassid

• Nuclear many-body theory
• Ultra-cold atoms
• Mesoscopic physics and nanoscience (condensed matter)

Broad research across different subfields
We study correlated quantum systems in which the number of particles is large but still small enough for finite-size effects to be important:

-- nuclei, cold atoms, quantum dots, and nanoparticles

We are developing novel quantum many-body and computational methods, allowing microscopic calculations that were previously beyond reach.

(i) Nuclear many-body theory

Derive statistical properties of nuclei from the underlying effective interactions among their constituent particles

• Important for understanding astrophysical processes: stellar nucleosynthesis, supernovas,…

• Quantum phase transitions in finite systems
(ii) Ultra-cold atoms

The cold atomic Fermi gas provides a well-defined paradigm of strongly correlated systems such as nuclei, quark matter and neutron stars.

- A continuous crossover from a Bose-Einstein condensate (BEC) to “paired” fermionic atoms (BCS)
- A possible exotic pseudogap regime

• Interdisciplinary work on the interface of nuclear many-body theory, cold atoms, and mesoscopic physics/nanoscience has led to important progress in our understanding of finite-size correlated quantum systems.