QUANTUM FIELD THEORY IN CONDENSED MATTER PHYSICS
(L. Dell'Anna and L. Salasnich)

The course gives an introduction to quantum field theory and quantum entanglement for macroscopic quantum phenomena: superfluidity in ultracold atomic gases and liquid helium 4 and superconductivity in metals. The theoretical framework will be the finite-temperature functional integration of bosonic and fermionic fields with broken symmetry.

Program of the course

First part (Salasnich, 12 hours)

1.2 Interacting bosons with broken symmetry. Macroscopic order parameter.
1.3 Saddle-point approximation: Gross-Pitaevskii equation of the Bose-Einstein condensate. Solitons and quantized vortices.
1.4 Gaussian fluctuations: Bogoliubov spectrum and dimensional regularization. Critical velocity and Landau criterion for ultracold atoms and liquid helium.
1.5 Von Neuman entropy and entanglement for bipartite systems. Interacting bosons in a double-well potential: coherence visibility, Fisher information and entanglement entropy.

Second part (Dell'Anna, 12 hours)

2.2 BCS theory of metals by functional integration. Hubbard-Stratonovich transformation and the bosonic field of pairing.
2.3 Saddle point approximation: gap equation and critical temperature. Ginzburg-Landau theory from the BCS effective action.
2.4 Gaussian fluctuations: Goldstone mode, Meissner effect and Higgs mechanism.
2.5 The BCS-BEC crossover for ultracold atoms and superconductors.

Suggested books:

Period: February/April 2016, 4 hours per week.