SFT-2023
Lectures on Statistical Field Theories
Galileo Galilei Institute
Florence, 6-17 February 2023

Program of lectures

Denis Bernard (LP, CNRS and ENS, Paris)
Balades around quantum stochastic processes (for and by amateurs). (6h)

I will use the opportunity — or the excuse — of discussing coherent fluctuations in mesoscopic many-body systems to address some simple but useful concepts and tools of modern (quantum) statistical physics. This will include stochastic processes, small noise theory, large deviation functions or macroscopic fluctuations theory, in the classical framework, as well as open quantum systems, quantum channels, quantum trajectories or quantum stochastic dynamics, in the quantum domain.

No prerequisite, except basic knowledge of statistical mechanics and quantum mechanics.

Anna Minguzzi (ULPMMC, CNRS and Université Grenoble Alpes, Grenoble)
Strongly interacting one-dimensional systems under confinement: exact solutions. (6h)

In this series of lectures I will present a family of exact solutions for strongly interacting one-dimensional gases, both bosons a fermions, in the presence of an external confining potential. These solutions allow us to advance on the understanding the effect of correlations in interacting many-body systems and are a very useful benchmark of other approximate or numerical approaches. I will present the derivation of the exact solution for the many-body wavefunction and the calculation of several observables, both static and dynamic, including correlation functions and arbitrary time evolution following a quantum quench. I will also briefly describe the experimental realization of strongly interacting one-dimensonal systems with ultracold atomic gases confined in atomic waveguides. The main concepts presented in the lectures and several references can be found in the recent review [A. Minguzzi and P. Vignolo AVS Quantum Sci. 4, 027102 (2022); https://doi.org/10.1116/5.0077423 **].**

Lorenzo Piroli (IPM, ENS, Paris)
Quantum-circuit models for many-body physics out of equilibrium. (10h)

In this course, we will introduce quantum circuits and quantum cellular automata as simple models allowing us to deepen our understanding of many-body quantum physics out of equilibrium. Despite being extreme idealizations of real systems, their minimal structure gives us a rare analytic handle on topical but hard questions in nonequilibrium physics, including aspects of quantum chaos, thermalization, and quantum information scrambling. After describing general properties of (local) quantum circuits and their relationship with continuous-time Hamiltonian dynamics, I will present different models, including random and dual-unitary quantum circuits and certain types of integrable quantum cellular automata. I will show how dynamical observables in these models (involving for example correlation functions or entanglement entropy) can be analyzed based on mappings to statistical-mechanics problems or using analytic tensor-network techniques. We will also briefly discuss how these dynamics can be enriched by external monitoring, leading to novel types of measurement-induced phase transitions. Finally, we will show how quantum cellular automata admit a natural topological classification and work it out explicitly for one dimensional systems.

Balt van Rees (CPHT, CNRS and Ecole Polytechnique, Saclay)
S-matrices and the bootstrap. (10h)

TBA

Francesco Zamponi (LP, CNRS and ENS, Paris)
Introduction to the dynamics of disordered systems: equilibrium and gradient descent. (6h)

The course will be a short introductory overview of the dynamics of disordered systems, focused in particular on the equilibrium dynamics and on the simplest case of off-equilibrium dynamics, namely the gradient descent dynamics. A few selected topics (and references) are chosen, based on the authors' own taste and competences, and on pedagogical reasons, without aiming at a complete review of the subject. I will begin with a general overview to the problem, mostly following the lecture notes available on arXiv:2202.02413, and explaining the connection with the glass transition in material science and several interdisciplinary applications beyond physics. Then, I will discuss in a bit more detail the derivation of the dynamical mean field theory equations that are the main tool to investigate the dynamics of mean field disordered systems.

Most of the content of the lectures, and references to introductory bibliography, can be found in these notes: https://arxiv.org/abs/2202.02413

Seminar

Leonardo Fallani (LENS, University of Florence)
Strongly interacting lattice fermions: flavour-dependent Mott localization and universal Hall response

I will present the results of recent experiments performed with multicomponent 173Yb fermions in optical lattices, in the presence of strong atom-atom interactions and coherent driving between different internal states.
I will discuss the realization of interacting SU(N) Fermi-Hubbard systems, where the addition of a coherent Raman coupling between different spin states is used to induce a controlled breaking of the SU(N) global interaction symmetry. This explicit symmetry-breaking action is shown to favour

Mott localization and determines the onset of a flavour-selective behavior [1]. I will discuss the experimental results and the connection with the physics of strongly correlated materials, where a similar orbital-selective behavior arises from the coupling of different electronic orbitals.
I will also discuss recent experiments where we have measured the Hall conductivity in interacting synthetic ladders obtained from a momentum-dependent Raman coupling, which implements the action of an external magnetic field on effectively charged particles. I will show a strong dependence of the Hall response upon changing atom-atom interactions and show the emergence of a universal regime in the strongly interacting limit [2].

[1] D. Tusi et al., Nature Physics 18, 1201 (2022).
[2] T. Zhou et al., preprint arXiv:2205.13567 (2022).