INTERNSHIP PROPOSAL

Laboratory name: **Laboratoire de Physique et Chimie Théorique (LPCT)**
CNRS identification code: **UMR 7019**
Internship director'surname: **Cyril Elouard**
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Web page: Lab: https://lpct.cnrs.fr/ Group: https://qthermo.wordpress.com/
Internship location: **LPCT, Nancy.**

Thesis possibility after internship: **YES**
Funding: **YES** If YES, which type of funding: **ERC project**

Nonequilibrium thermodynamics of many-body quantum systems

Context: In the 90s, the scope of thermodynamics broadened to include small systems and far-from equilibrium transformations. Building on these advances, the emerging field of **Quantum Thermodynamics** recently lead to breakthroughs formulating nonequilibrium thermodynamics in the quantum regime. Motivations range from the search of quantum advantages in heat engines based on quantum systems (e.g. involving entanglement or quantum measurement [1]), to the expression of global constraints on many-body quantum dynamics stemming from the Second Law, or its generalizations called *Fluctuation Theorems* [2]. One of the recent successes of the field was to overcome foundational difficulties in defining work and heat exchanged *between* quantum systems, and express the Second law in a fully quantum context [3]. However, utilizing those frameworks require to keep track (measure/simulate) the full quantum state of the systems under study (the density operator), for instance to compute the von Neumann entropy of the system. While this is tractable for an elementary quantum system, e.g. a two-level system or a harmonic oscillator weakly coupled to their environment, it becomes quickly impossible for many-body quantum systems. Instead, it would be very precious to have statements similar to macroscopic thermodynamic laws, which provide constraints on how energy exchanges occur in many-body quantum systems, and which could be used without solving the total dynamics exactly (as it is the case in classical macroscopic thermodynamics). To reach this goal, new frameworks for quantum thermodynamics are currently being developed to make statements only based on a few macroscopic (i.e. coarse-grained) observables of the system, expected to play the role of state variables (see for example [4]).

The goal of the internship is to participate into the development of those novel methodologies by testing the approaches developed in the Nonequilibrium Quantum Thermodynamics group of the Université de Lorraine over paradigmatic examples of many-body quantum systems. Examples could include spin-chains or ensembles of quantum emitters (atoms) coupled to an electromagnetic field. The master student will work in close collaboration with a postdoc of the group involved in the development of those new framework. **Work environment:** The student will join the **Dynamics and Symmetry** Axis of the LPCT lab in Nancy (Université de Lorraine) and will be supervised by **Cyril Elouard** (Junior Professor CPJ). The project may be continued over a PhD funded by the European ERC Starting Grant project "QARNOT". The LPCT is an equal opportunity laboratory with a working environment actively promoting equality, diversity, and inclusion. **Candidate profile :** We are looking for excellent candidates with background in theoretical physics and strong interest for analytical approaches. Previous internships in quantum dynamics, quantum open systems or quantum optics will be appreciated.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES