



04/05/2026 – 19/06/2026

**Title of the project:** Thermodynamics of autonomous quantum refrigerators

**Supervisor(s):**

Laboratory / Department / Team : Lab. Interdisciplinaire Carnot de Bourgogne (ICB)/ ICQ / DiTeQ

**Collaborations:** Mohammed-Bilal Puthuveedu Shebeek (PhD candidate of the DiTeQ team).

Possible interaction with Cyril Elouard, Junior Professor, Université de Lorraine (Nancy).

**Summary:**

A promising type of quantum devices [1] are the ones referred to as autonomous quantum devices: these are devices which operate without external control from an agent or from an auxiliary (classical) system. Some experimental proof-of-principles has been realized for instance with superconducting quantum circuits [2].

In this context, a recent paper introduces a thermodynamic framework [3] allowing to design autonomous quantum devices exploiting resources (in the form of non-thermal characteristics) contained in arbitrary quantum systems. As illustrative application, one can design an autonomous quantum refrigerator composed only of a qubit and a quantum harmonic oscillator (for instance a cavity mode). Their interaction, when some well-chosen non-thermal resource is initially present in the harmonic oscillator, is enough to refrigerate the qubit (to lower its entropy), without need of thermal baths and external controls. This is impossible without non-thermal resources (unless, obviously, if the harmonic oscillator is initial colder than the qubit).

The aim of the project is to use the thermodynamic framework mentioned above to analyze the energy efficiency of quantum autonomous refrigerators, like the one realized in [2]. The first step will consist in a numerical simulation of the dynamics. For that, we will use some simplifying assumptions, and we will follow two possible model for the thermal bath: (i) single harmonic oscillator or (ii) thermal bath in the weak coupling limit. Once a satisfying simulations is obtained, the thermodynamic analysis will be carried out to determine the energy efficiency. The result will be compared to other approaches [4]. Additionally, we will study the influence of parameters like coupling strength, and energy gaps on the efficiency, the minimal achievable temperature, and the time needed to reach it.

**References:**

[1] J. A. M. Guzmán, P. Erker, S. Gasparinetti, M. Huber, and N. Y. Halpern, Key issues review: useful autonomous quantum machines, *Rep. Prog. Phys.* 87, 122001 (2024).

[2] M. A. Aamir, P. Jamet Suria, J. A. Marín Guzmán, C. Castillo-Moreno, J. M. Epstein, N. Yunger Halpern, and S. Gasparinetti, Thermally driven quantum refrigerator autonomously resets a superconducting qubit, *Nat. Phys.* 21, 318 (2025).

[3] C. Elouard and C. Lombard Latune, Extending the Laws of Thermodynamics for Arbitrary Autonomous Quantum Systems, *PRX Quantum* 4, 020309 (2023).

[4] M. T. Mitchison, M. Huber, J. Prior, M. P. Woods, and M. B. Plenio, Realising a quantum absorption refrigerator with an atom-cavity system, *Quantum Sci. Technol.* 1, 015001 (2016).

**Type of project (theory/experiment):** theory

**Required skills:** Interest in and good understanding of open quantum systems with good programming skills.