Non-equilibrium thermodynamics of quantum processes

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Thermodynamics is one of the pillars of physical, chemical and biological sciences. It is able to predict the occurrence and efficiency of complex chemical reactions and biological processes. In physics, the conduction of heat across a medium or the concept of the arrow of time are formulated thermodynamically. In information theory, the definitions of information and entropy are given in thermodynamical terms. Even more, the tightness of the link between information and thermodynamics can be deduced from the thermodynamic interpretation of the landmark embodied by Landauer's erasure principle, Jaynes principle of maximum entropy, or the exorcism of Maxwell's demon operated using information theoretical tools. Another example is the analysis of the spectrum of blackbody radiation made by Planck, which triggered the quantum mechanical revolution. However, science and technology have evolved immensely from the early days of the quantum era, allowing us to witness quantum effects that could only be dreamed of decades ago. Our capabilities to control and guide processes at the microscopic scale has reached outstanding levels of dexterity.

Yet, a series of tantalising questions arise: what happens to the principles of thermodynamics when we deal with the quick dynamics of small quantum systems brought dramatically out of equilibrium? Can we formulate in a thermodynamical way the working principles of quantum devices designed to perform transformations analogous to "canonical" thermo-machines?

In this talk I will present a framework that is able to show the emergence of thermodynamics out of genuinely quantum processes enforced on quantum systems. I will focus on the thermodynamics of paradigmatic quantum optics systems, such as optomechanics and ultracold atoms in cavity. I will discuss how work can be extracted from mesoscopic quantum systems and suggest tantalising connections between the irreversible quantum entropy produced across a process and the establishment of quantum correlations among the constituents of a quantum device.

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