Thermodynamics of Resonance Fluorescence

C. Elouard[a], D. Herrera-Martí[b], M. Esposito[c], A. N. Jordan[a], and A. Auffèves[b]

[a]Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627, USA.
[b]CNRS and Université Grenoble Alpes, Institut Néel, F-38042 Grenoble, France
[c]Physics and Materials Science Research unit, University of Luxembourg, L-1511 Luxembourg, Luxembourg

Atomic resonance fluorescence is a canonical phenomenon of quantum optics, that gave rise to pioneering attempts to extend the laws of thermodynamics to quantum systems. Despite it involves genuinely quantum, coherent energy exchanges between light and matter, the identification of clear quantum components in heat, work and entropy production has remained elusive. We propose a thermodynamic analysis of resonance fluorescence that evidences the existence of such signatures. The driven dissipative atom is analyzed as an out-of-equilibrium system with no classical equivalent, where irreversibility stems from laser induced build up of coherences that are continuously removed by the thermal bath. Our analysis is consistently performed on average and at the level of single trajectories where detailed fluctuation theorems for measurable quantities are derived in the deep quantum regime. It provides a convenient paradigm to analyze the energetic and entropic footprints of quantum protocols and to understand the link between heat dissipation, decoherence and irreversibility in the quantum realm.