Quantum thermodynamics from the nonequilibrium dynamics of open systems

Bei-Lok Hu and Jen-Tsung Hsiang

University of Maryland, College Park, USA

Quantum Thermodynamics [1] in a stricter sense is the study of the thermodynamical properties of quantum many-body systems. In fusing the two terms quantum and thermodynamics together it exposes the intrinsic dislocations or even contradictions, namely, while quantum deals with the microscopic world and quantum features manifest usually at low or zero temperatures, thermodynamics is formulated mainly in the context of classical phenomena, restricted to the macroscopic realm, and functions better at high enough temperatures where thermal properties prevail over quantum. What makes quantum thermodynamics interesting is precisely because of these dislocations. They bring out foundational issues at the micro-macro (m-M) and the quantum-classical (q-C) interface. A basic approach which can unify these aspects and enables one to see the emergence of thermodynamics for quantum systems is by studying the nonequilibrium dynamics of open quantum systems. Using a Brownian motion model which is exactly solvable [2] we come to a better understanding of several foundational issues at the m-M/q-C interface from this broader perspective [3] such as the conditions for the applicability of the canonical ensemble, the extensivity of energy, the positivity of the heat capacity at absolute zero and the validity of the Third Law. Many open questions remain such as the definition of thermodynamic potentials and the validity of thermodynamics laws at strong coupling [4-6].

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