No-Go Theorem for the Characterization of Work Fluctuations in Coherent Quantum Systems

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An open question in quantum thermodynamics is how to describe the fluctuations of work for quantum coherent processes. In the standard approach, based on a projective energy measurement both at the beginning and at the end of the process [1], the first measurement destroys any initial coherence in the energy basis. Here we seek extensions of this approach which can possibly account for initially coherent states. We consider all measurement schemes to estimate work and require that (i) the difference of average energy corresponds to average work for closed quantum systems and that (ii) the work statistics agree with the standard two-measurement scheme for states with no coherence in the energy basis. We first show that such a scheme cannot exist. Next, we consider the possibility of performing collective measurements on several copies of the state and prove that it is still impossible to simultaneously satisfy requirements (i) and (ii). This represents our main result [2], as it means that there is no notion of (measurable) fluctuacting quantum work that, while agreeing with standard stochastic thermodynamics, can be successfully extended to describe all quantum coherent processes. In other words, there is always a price to measure work.
Despite this no-go result, the idea of performing collective measurements opens new possibilities, and in fact we develop a measurement scheme that acts simultaneously on two copies of the state and allows us to describe a whole class of coherent transformations. We will discuss the possibilities and limitations of this scheme, and how it extends the standard two-projective-measurement scheme to estimate work. This second part is also based on [2] but contains some new unpublished results.

[1] P. Talkner et al, Phys. Rev. E **75**, 050102(R) (2007).

[2] M. Perarnau-Llobet et al, Phys. Rev. Lett. **118**, 070601 (2017).