

**ArXiv:** “Exponential improvement for quantum cooling through finite memory effects (2004.00323)”  
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**Extended Abstract:** Memory effects play a crucial role in complex phenomena occurring at the nanoscale, including physical and chemical processes underpinning cutting-edge technologies. Depending on the level of experimental control over the system and its interactions with the environment, such effects can lead to either an advantageous or detrimental impact on performance goals. In this presentation, I will analyze the role of memory in the paradigmatic thermodynamic task of cooling a quantum system and derive the optimal cooling protocol, which achieves an exponential advantage over the memoryless setting.

In particular, I will propose a general framework for dealing with memory effects in multi-cycle thermodynamic schemes. This is the relevant paradigm for cyclic quantum machines [1–3] and autonomous [1, 4–7] as well as algorithmic cooling techniques [8–12]; all such concrete tasks fall under the umbrella of the resource theory of thermodynamics [13], which analyzes the possible transformations of a system in contact with an arbitrary thermal bath. However, when the operation of cycles can be correlated in time, fairly comparing the performance of the former approaches is difficult due to variations on the level of assumed experimental control over the interactions; on the other hand, the overarching resource theory proves too general to isolate the source of any advantage.

The biggest challenge that our work overcomes thus concerns the inclusion of memory effects that do not trivialize the problem or introduce artificial advantages from increased control. We propose a microscopic mechanism for memory transfer through a physically-motivated generalized collision model [14, 15]; while not completely general, this approach permits a tractable amount of memory into the dynamics and allows for meaningful comparison between memory structures. Importantly, this setting does not offer increased control over system-environment interactions, coherence, or any other resource, with respect to the memoryless case, except for the ability to access a system that has been previously interacted with.

Our main result demonstrates an exponential improvement in cooling in the number of memory carriers, which stems from a Markovian (memoryless) embedding to which our non-Markovian protocol is amenable [16]. The improvement reflects a similar enhancement in heat-bath algorithmic cooling, where an experimenter controls some auxiliary systems [8–12]; not only is our result equivalent to this setting for qubits, it generalizes this scenario to arbitrary target and auxiliary systems, baths and Hamiltonians. Our work thus both generalizes and unifies many different approaches to quantum cooling with memory.

To conclude, I will discuss some practical open avenues that our framework is suited to: for instance, modeling imperfect isolation of the controlled systems. The far-reaching implications of these possible avenues of exploration highlight the substantial interest our novel approach provides for researchers interested in quantum thermodynamics, open quantum systems and quantum control (amongst others).

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