Exploring indefinite causal order in the development of quantum batteries

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In the conventional setting of quantum physics, any pair of events are strictly related by a fixed causal order. However, the seminal work by the authors in [1] extended the notion causality by considering quantum correlations without causal order. As a result, a broader class of processes can be described in the framework they developed. This has led to the discovery of indefinite causal order (ICO), where scenarios like event A happens in the causal past of event B and event B locates in the causal past of A becomes in superposition is allowed. Indefinite causal order is of great interest due to its potential to offering practical advantages besides foundational significance [2-5].

In this talk, we will explore the role of ICO in quantum thermodynamics, specifically focusing on the advancement of protocols for charging quantum batteries [6]. Based on quantum collision models, we construct an ICO charging protocol for quantum batteries. Contrary to the intuitive expectation that stronger interactions result in higher energy charging, we unveil a novel phenomenon of inverse interaction. This discovery leads to a reversal of this relationship, enhancing thermal efficiency at the same time. These findings mark the first evidence showcasing the unique influence of ICO on quantum dynamics, and we anticipate its continued significance in shaping the landscape of future quantum technologies.

References

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[4] X. Zhao, et al., Phys. Rev. Lett. 124, 190503 (2020)
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Figures

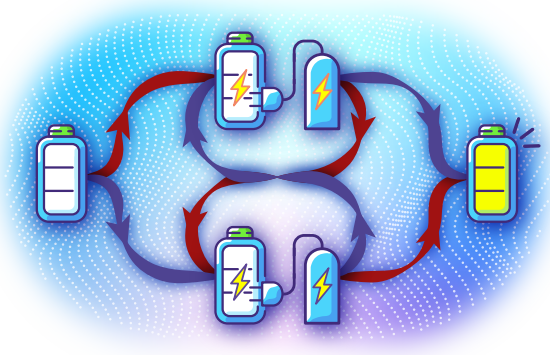

Figure 1: Quantum battery charging with indefinite causal order: a quantum battery experiences a quantum superposition of charging dynamics in the two causal orders.

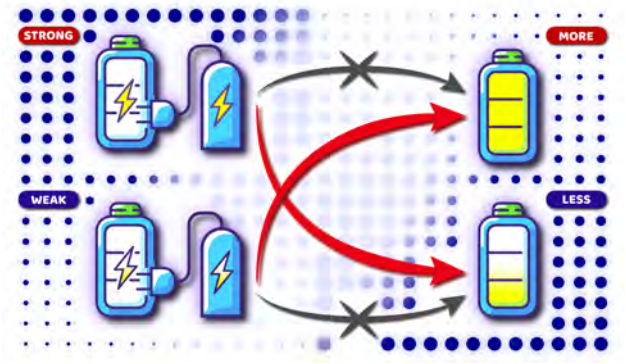

Figure 2: Common intuition suggests that a more powerful charger results in a battery with a stronger charge. However, the discovery of an inverse interaction effect stemming from ICO introduces a remarkable reversal in this relationship.