Quantum supremacy with many-body systems: Merging thermalization with complexity theory

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Abstract

Quantum supremacy is the ability for quantum computers/devices to efficiently solve a well-defined computational task that is guaranteed to be inefficient for classical computers. The most common task to realise quantum supremacy in near-term quantum devices is sampling from the output probability distribution, demonstrated with 53 superconducting qubits by Google[1]. Despite being able to outperform classical computers, sampling from a complex quantum system has very few direct useful applications. Early proposals for realizing quantum supremacy include boson sampling, random quantum circuits and 2D Ising models. We have managed to extend this family to include to driven many-body systems in analog quantum simulators settings. The work is based on complexity theory arguments and supports earlier intuitions and heuristic claims, that is indeed computational hard to simulate complex quantum dynamics. Our result opens the path for a multitude of analog platforms to showcase and benchmark quantum supremacy, including cold atoms, ions and superconducting qubits. The connection was made via showing that sampling from the output distribution of thermalizing driven many-body systems is #P hard and the hardness is connected with the quantum phase matter is in. Recently, in collaboration with USTC China, an experiment has been performed where some of our predictions were checked in cold atom setup [3].

References

[1] Frank Arute, Kunal Arya, […], John M. Martinis, Quantum supremacy using a programmable superconducting processor Nature, 574, 505-510 (2019)

[2] J. Tangpanitanon, S. Thanasilp, M. A. Lemonde, N. Dangiam, D. G. Angelakis Quantum supremacy in driven quantum many-body systems, arxiv.org/2002.11946 (to appear in Quantum Science and Technology)

[3] Yong-Guang Zheng et al, Efficiently Extracting Multi-Point Correlations of a Floquet Thermalized System, arXiv: arXiv:2210.08556

Figures

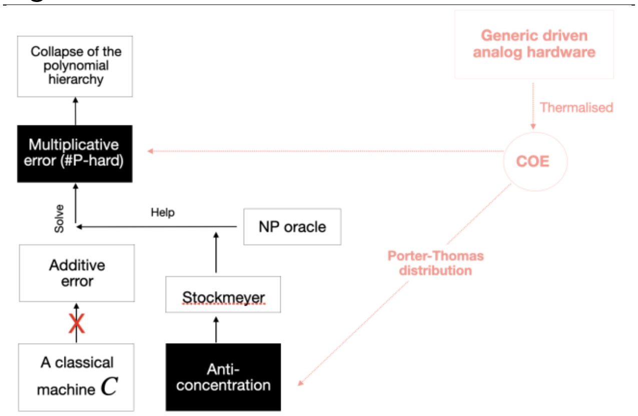

Figure 1: Sketch of the proof that is hard to sample from driven many-body systems

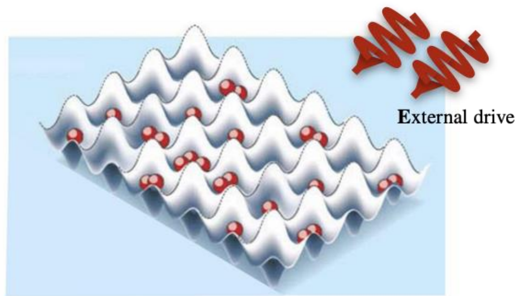

Figure 2: A driven optical lattice such as the one used in [3] to perform the experiment