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To the editors of PRX Quantum

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Dear Editors,

we would like to submit our manuscript "Adaptive Quantum State Tomography with Active Learning" to PRX Quantum.

In this work we present and implement an efficient adaptive scheme to reconstruct quantum states from very few measurements. It is based on a combination of active learning and neural network methods. In contrast to existing quantum state tomography (QST) schemes, our scheme can request specific, highly informative measurements during the reconstruction process and is able to actively incorporate them into the reconstruction. We show that the quality of the reconstruction is improved significantly by this scheme. To this end, we examine the quality of the reconstruction of different multi-qubit states with up to 19 qubits and varying degree of entanglement as well as ground states of a kinetically constrained spin chain.

The reconstruction of quantum states has become increasingly important in the recent years, since ever larger quantum systems are being investigated experimentally and quantum devices with more than 100 qubits are being built. To access the quality of these devices and experiments, tools for reconstructing quantum states from measurements are of high importance. However, most existing schemes have the downside that the number of samples needed for a good reconstruction scales exponentially and therefore they are limited to small systems. By learning the structure of the quantum states by means of neural networks it is possible to reduce the number of samples and access larger systems.

However, the measurement configurations in which the state is being measured have a large impact on the reconstruction quality. If one manages to select the measurement configurations containing the most relevant information about the states' amplitude and phase, the neural network tomography can reconstruct the state to a high accuracy from only very few measurements. In contrast, if the configurations are selected randomly, a significantly higher number of measurements is necessary to reconstruct the relevant features of the quantum state.

Our active learning QST scheme tackles this problem by adaptively selecting the configurations that maximize the information gain without any prior knowledge about the state. It paves the way for characterizing large quantum devices and probing quantum many-body systems, for example in quantum simulators. We have received very positive feedback on our work at recent workshops as well as seminars, e.g. at Princeton University and TU Wien, and believe that the results should appeal to a broad physics audience.

We thank you for your time and consideration. Please do not hesitate to contact us if any questions occur.

Sincerely yours,

Hannah Lange, Matjaz Kebric, Maximilian Buser, Ulrich Schollwöck, Fabian Grusdt and Annabelle Bohrdt