Data mining quantum simulators

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Recent experiments with quantum simulators and computers have demonstrated unparalleled capabilities of probing many-body wave functions at the single quantum level via projective measurements. However, very little is known about to interpret and analyse such huge datasets. This represents a fundamental challenge for theory to understand experimental data, that is also relevant to other fields where similarly large data sets are routinely explored - from classical simulations of gauge theories, to observatory studies of many-body ensembles in chemistry and biology.

In this talk, I will show how it is possible to provide such characterisation of quantum hardware via direct and assumption-free unsupervised machine learning and modelling inspired by data science. The core idea of this programme is the fact that snapshots of many body systems can be construed as a very high-dimensional manifold. Such a manifold can be characterised via basic concepts, in particular, by their intrinsic dimension, and by advanced theoretical tools from network theory and (non-parametric) unsupervised learning.

This new approach to the many-body problem opens ups a cornucopia of methods to connect physical properties to a stochastic sampling of the system wave function. I will focus here on two specific applications. Firstly, I will discuss theoretical results for both classical and quantum many-body spin systems that illustrate how data structures undergo structural transitions whenever the underlying physical system does, and display universal (critical) behavior in both classical and quantum mechanical cases. These results pave the way for a systematic understanding of field theory aspects in data space, a topic of current interesting in particle and statistical physics. Secondly, I will discuss how our methods allow to track algorithmic complexity in quantum simulators and quantum computers, providing novel insights onto the working of such systems, in terms of both practical and fundamental aspects - including cross-certification of quantum devices, a grand challenge in the field. Finally, I will show how these developments can lead to a stochastic classification of quantum matter.