From quantum supremacy to quantum simulations

We are looking for a post-graduate student to join the quantum information science group of Animesh Datta at the University of Warwick. The goals of this theoretical project are to develop theoretical capabilities of a quantum simulation device to (i) implement a physics problem that is hard to solve on a classical computer, and (ii) provide confidence in the correctness of the solution. It will involve interactions with the UK National Quantum Technology hub (http://nqit.ox.ac.uk) and the Google Quantum AI Laboratory.

The student should be interested in a close interplay of quantum information theory, quantum verification, and many-body physics of correlated fermions.

Background: Quantum simulation involves problems outside the complexity class NP, the correctness of whose solutions cannot be checked efficiently (such as factoring) classically. Hence, the end goal of quantum-enhanced simulation is not only to perform a hard classical simulation efficiently, but also to establish its correctness. The latter is called verification. Almost all verification methods are however derived in the MBQC picture. Translating these to a circuit-based picture in which most experiments are conducted remains an open challenge. These two pictures are polynomially equivalent, but can impose prohibitive practical overheads. Marrying simulation issues (such as Trotter expansions) with verification in the circuit-based picture is crucial to establishing any new hardware (NQIT or Google) for quantum enabled applications and discovery.

Project: This PhD project will leverage recent results from Warwick [1] for verifying the supremacy of noisy quantum Ising samplers. The student will use this to propose protocols that can demonstrate quantum-enhanced simulations on planned quantum architectures, which will be noisy and not fault-tolerant. It will cement the value of these devices machines solving simulation and sampling problems reliably and verifiably in the circuit picture.

Another aim of the project is to merge recent formal results from Warwick [2] with more experimentally popular methods such as quantum gate and state tomography. This would require the development of novel verification techniques, possibly in the MBQC picture and translating them to the circuit picture.

A close interaction between theory and experiments in academia and industry will place the student in a uniquely beneficial position for a future in the quantum technologies market. The interaction with the Google Quantum AI group will provide the student a privileged perspective on quantum simulations in a complementary industrial research setting, unavailable to any other in the UK or elsewhere.

1. Theodoros Kapourniotis, Animesh Datta, *Nonadaptive fault-tolerant verification of quantum supremacy with noise*, arXiv:1703.09568
2. Samuele Ferracin, Theodoros Kapourniotis, Animesh Datta, *A trap based technique for verification of quantum computations*, arXiv:1709.10050