Quantifying accuracy and confidence in NISQ simulators

We are looking for a post-graduate student to join the quantum information science group of Animesh Datta at the University of Warwick. This theoretical project will develop accreditation methods for noisy intermediate-scale quantum (NISQ) simulators such that their predictions about novel quantum simulations can be made with quantifiable accuracy and confidence. This is necessary for two central reasons. Firstly, NISQ simulators are erroneous, being incapable of large-scale quantum error correction and fault tolerance. Secondly, the solutions of quantum simulations, unlike problems such as integer factorization cannot be checked for correctness efficiently classically. Therefore, without establishing their credibility in a quantitative manner, NISQ simulators will remain worthless scientifically and technologically.

The student must be interested in a close interplay of quantum computation, simulation, and condensed matter physics.

Background: Existing state-of-the-art methods either benchmark NISQ simulators by comparing their outputs against classical simulation or by assuming specific forms of noise and imperfections [1]. The first is impossible for genuine applications due to the very reason of exponential scaling that motivated quantum simulators, while the second is inaccurate and incomplete without a full characterisation of the hardware, which is again exponentially expensive.

Project: The project will build upon prior work in our group on accrediting outputs of noisy intermediate-scale quantum (NISQ) computing devices from Warwick [2]. Our accreditation methods are fundamentally different from existing state-of-the-art methods in being practical in the near term and scalable in the long term while making minimal experimentally motivated assumptions.

Since partition functions and their derivatives identify the equilibrium properties of systems such as phase transitions, we will seek ways of accrediting approximations of partition functions of spin models [3]. We will extend this study to interesting theoretical condensed matter physics models such as the 2D Hubbard model, which may provide insights into open problems such as high-temperature superconductivity. The project will advance with an eye on the ongoing experimental advances, although the methods developed in the project should be applicable across quantum simulator hardware platforms. To that end, we will be interacting with experimental groups in academia and industry.

A close interaction between theoretical physics and quantum information science will place the student in a uniquely beneficial position for a future in academia as well as industry in the quantum technologies market.

1. Frank Arute *et al.*, *Quantum supremacy using a programmable superconducting processor,* Nature, 574, 505, (2019)
2. Samuele Ferracin, Theodoros Kapourniotis, Animesh Datta, Accrediting outputs of noisy intermediate-scale quantum computing devices, arXiv:1811.09709 (Accepted in New Journal of Physics)
3. Theodoros Kapourniotis, Animesh Datta, Nonadaptive fault-tolerant verification of quantum supremacy with noise, Quantum 3, 164 (2019)