Accreditation of quantum 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 protocols for quantum 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, quantum simulators are erroneous, being incapable of large-scale quantum error correction and fault tolerance for the foreseeable future. Secondly, the solutions of quantum simulations, unlike problems such as integer factorization cannot be checked for correctness efficiently classically. Therefore, without accreditation, quantum 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: Quantum simulators consisting around 50 quantum units (trapped ion qubits, neutral atoms) are now exploring quantum many-body physics phenomena [1]. Attempts are also underway to solve optimisation problems using a few hundred neutral atoms [2]. Validating the outputs of these noisy, error-prone quantum simulators – analogue and digital, is a central open problem [3] limiting their reliable usage is science and technology.

Project: This project will develop the accreditation of quantum simulators to tackle this open problem. Accreditation provides an upper bound on the variation distance between the output probability distribution of a noisy, error- prone digital quantum computer and its ideal – noiseless, error-free counterpart. It also provides an associated confidence level. The two main objectives will be to develop (i) an accreditation protocol for analogue quantum simulators, and (ii) validation protocol(s) for the theoretical assumptions made during (i) in experimental setups. The protocols are expected to be platform agnostic.

The project will build upon prior work from our group on accrediting outputs of noisy quantum computing devices [4]. Our accreditation protocol does not require knowing the ideal output of a quantum computation or simulation which makes other measures such as quantum volume or cross entropy unscalable. This makes it practical in the near term and scalable in the long term while making minimal experimentally motivated assumptions.

We will seek ways of accrediting quantum simulations of spin models [1]. 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 protocols developed in the project should be applicable across quantum simulator hardware platforms. To that end, we will be interacting with experimental groups. 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.

For informal enquires email Animesh Datta with a CV, explaining your excellence and suitability for the project.

1. H. Bernien et al. Nature, **551** 579, (2017); J. Zhang et al. Nature, **551** 11, (2017)
2. L. Zhou et al. Physical Review X, **10** 021067, (2020)
3. Page 23 of NSF report at https://arxiv.org/abs/1912.06938
4. S. Ferracin, T. Kapourniotis, A Datta, New J. Phys. **21** 113038 (2019)