Quantum algorithms for fusion and plasma physics

A PhD position is available in the groups of Animesh Datta and Tom Goffrey at the University of Warwick, in collaboration with the National Quantum Computing Centre (https://www.nqcc.ac.uk). This theoretical project will develop quantum algorithms for solving nonlinear partial differential equations that arise in the simulation of plasma and fusion physics problems. The emphasis will be placed on establishing the computational complexity of the quantum algorithms and comparing them with corresponding classical algorithms.

The student must have a strong background in linear algebra and the theory of differential equations and be interested in an interplay of quantum computation and quantum information science with simulations in plasma physics.

The student will be registered and hosted at the University of Warwick and have an expert co-supervisor at the NQCC. The student will be offered a minimum of three months to work at the NQCC with relevant research teams. This position is part of a wider cohort of 6 collaborative studentships, in which the projects have been co-developed by the NQCC and different academic institutes across the UK. The scheme will include cohort-based training and activities, enabling students to gain wider skills and develop valuable personal and professional networks.

Background: The field of quantum computation seeks to develop efficient quantum algorithms for problems that are classically inefficient to solve and are therefore computationally expensive. Plasma physics and fusion science involve some of the most computationally demanding simulations in the physical sciences, such as solving the Vlasov-Maxwell equations.

Project: The Vlasov-Maxwell (VM) system of equations -- a family of inhomogeneous, coupled, nonlinear partial differential equations, provides a first-principle kinetic description of the dynamics of plasmas in terms of its distribution function in phase space. It is particularly relevant for high temperature tokamaks such as the Spherical Tokamak for Energy Production (STEP, https://ccfe.ukaea.uk/programmes/step/). These require accurate modelling of non-local heat flows for predictive modelling of fusion experiments relying on solving the VM system.

Recently, a quantum algorithm has been proposed for classical plasma physics simulations such as those of the linearised Vlasov equation with a Maxwellian background distribution - a simulation that is, in fact, classically efficient [1]. Other studies have also been undertaken [2].

This project will develop quantum algorithms for solving the VM system of equations going beyond the Maxwellian assumption, a regime practically relevant in high temperature tokamaks. It will use linearisation methods due to Carleman and Koopman-von Neumann [3] that are employed in quantum algorithms for solving nonlinear partial differential equations [4].

This project will also quantify the reliability of the outputs of implementing the quantum algorithms developed on real quantum hardware which are improving in size and performance but remain noisy and error prone.

To apply: Follow instructions here. **Deadline: January 19, 2025**.
Informal enquires: Email Animesh Datta or Tom Goffrey with a CV.

[1] A. Engel, G. Smith, S. E. Parker, Physical Review A, 100, 062315, (2019)
[2] A. Ameri *et al* Physical Review A, 107, 062412, (2023)
[3] I. Joseph, Phys. Rev. Res. **2**, 043102 (2020)
[4] H, Krovi, Quantum, **7**, 913 (2023)