Project: Quantum Many-Body Problems for Near Term Quantum Computers

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Quantum computers and quantum simulators are developing at a remarkable pace. In recent years, they have reached a regime where they can perform tasks which are getting out of reach for classical computers. Nevertheless, it remains challenging to identify relevant use cases for near-term quantum computers and simulators, as many paradigmatic problems such as factoring numbers require quantum computers of a size far beyond what is foreseeable for the near future. A promising class of applications for near-term quantum devices is the simulation of quantum many-body systems, such as in the study of correlated quantum materials or of chemical reactions. These problems, in particular in the context of condensed matter systems, are most promising as their structure is naturally captured by most quantum computing and simulation architectures, and a limited degree of quantum control is sufficient to tackle problems of practical relevance.

The advertised PhD project will be focused on studying the application of near-term quantum devices to address quantum many-body problems. The precise scope of the project will be developed with the successful applicant; possible topics include: (i) The identification and study of classes of quantum states/systems which are especially suitable for applications in near-term quantum devices (such as tensor network states, frustration free systems, or systems with small quantum entanglement), as they capture relevant physical problems, and since they can be efficiently prepared and probed. (ii) The development and improvement of methods to efficiently prepare interesting quantum states on specific quantum computer and simulation architectures, e.g. through efficient quantum circuits, adiabatic preparation, or suitable algorithmic cooling. (iii) Ways to test and verify the successful preparation of those states on a given architecture, both in a practical setting and from a quantum complexity theory perspective, where the preparation and verification is regarded as a quantum game. (iv) The development of new applications for quantum computers and simulators in the study of quantum many-body problems.

The concrete thesis project will be developed jointly with the successful applicant along the lines described above, within the topical area of the project. The scope of the projects will be primarily analytical, but can – given interest – be complemented by numerical work.

Key requirement for the position are thorough knowledge of linear algebra, familiarity the basics of quantum computing, and ideally some basic knowledge in functional analysis. Moreover, an interest in physically motivated problem settings, and the willingness to interact with both mathematicians and physicists alike, as well as with both analytically and numerically oriented collaborators, is strongly desirable.