Mechanisms of energy transport in photosynthesis

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 first, to understand the mechanisms of excitonic energy transport at the quantum level in noisy systems such as photosynthesis, and second, to exploit the above understanding on the role of quantumness in noisy systems to advance quantum information science.

The student should be interested in a close interplay of concepts from theory of open quantum systems, ultrafast spectroscopy and quantum information theory.

Background: Experimental observation of excitonic energy transport in a wide variety of light-harvesting systems at the nanoscale has been made possible by the development of novel spectroscopy methods over the last decade. Some of these studies suggested a possible role of quantum coherence in energy transport in systems ranging from natural photosynthetic light-harvesting complexes to engineered molecular aggregates [1]. Clarification of this issue requires a thorough theoretical understanding of light-harvesting systems, which are typically modelled as a network of coupled sites placed in a bosonic environment. The comparable magnitudes of the coupling energies amongst the sites and the interaction strength to the bosonic bath, however makes theoretical studies challenging [2]. For instance, it is unclear how to identify the system-environment boundary, the starting point of all conventional studies in open quantum systems. It is also unclear as to whether the environment is Markovian or non-Markovian. New strategies are thus required to address this problem.

Project: The project will begin by identifying the dimension of the effective system under study. This will use the concept dimension witnesses from quantum information theory to obtain bound on the effective size of the system. We will also use non-classicality of quantum processes (instead of states) to place bounds on the quantumness in these systems based on experimental data. We will also develop proposals for experimental implementation of the techniques developed using ultrafast spectroscopy.

With some understanding of the system at hand, the next part of the project shall develop methods to understand the precise role of the environment, such as whether it is Markovian or not. While numerous methods of identifying non-Markovianity exist in the literature, they all start with some dynamical equation describing the open quantum system. This project shall seek to identify non-Markovianity directly from ultrafast spectroscopy data.

Finally, the project shall use the understanding of non-classicality in noisy quantum systems to improve quantum information processing protocols in the presence of noise.

The project promises an exciting mixture of mathematical techniques and physical intuition, aimed at fundamental breakthroughs in the theory of open quantum systems and quantum information science.

[1] Scholes, G. D., Fleming, G. R., Olaya-Castro, A. & van Grondelle, R. Lessons from nature about solar light harvesting. *Nat. Chem.* **3,** 763–774 (2011).
[2] Chenu, A. & Scholes, G. D. Coherence in Energy Transfer and Photosynthesis. *Annu. Rev. Phys. Chem.* **66,** 69–96 (2015).