4th Year Projects 2017: Shortcuts to Adiabaticity in Quantum Optics

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The preparation and control of quantum states in a quick and robust way is very important for future quantum technologies. So far, the most robust state preparation techniques were provided by adiabatic processes: the external parameters of the Hamiltonian are varied slowly and the populations of the system in the instantaneous basis remain constant. Nevertheless, in many cases this takes too long and become impractical since their slowness makes them extremely sensitive to decoherence and noise.

This fact has prompted recently a lot of theoretical and experimental activity to find new schemes to speed up adiabatic processes while keeping their robustness, leading to the research field of "Shortcuts to Adiabaticity". All the following projects will be contained in this research field. The goal of the projects will be to develop new "shortcuts" or to examine and optimize the stability and robustness of existing shortcut schemes. Note that the first step in all projects will be (of course) to study the existing literature and to get into the field of "Shortcuts to Adiabaticity".

If you have further questions, please come to my office (**Room 216A**) or send me an email (**aruschhaupt@ucc.ie**).

Project 1 (short or long project)

Preliminary title: **Stability of Shortcuts to Spatial Adiabatic Passage**

The stability of the derived shortcuts to spatial adiabatic passage [1] against different perturbations (like fluctuations of the couplings) should be studied because preserving this stability would be essential for experimental implementations.

The project will require an understanding of [1], analytical calculations as well as numerical simulations of a three-level system with Mathematica.

Ref: [1]   A. Benseny et. al., EPJ Quantum Technology (2017) 4:3

Project 2 (short or long project, demanding):

Preliminary title: **Effect of Poisson Noise on Adiabatic Processes**

In [1], a detailed derivation of the master equation describing a general time-dependent quantum system with classical Poisson white noise has been derived and its various properties have been outlined. Using this, various settings have been simulated to illustrate different effects of Poisson noise.

In this project, further examples should be derived and studied numerically with Mathematica based on the formalism derived in [1]. Therefore, this project will require analytical calculations as well as numerical calculations with Mathematica.

Ref.: [1]   A. Kiely et. al., Phys. Rev. A 95, 012115 (2017)

<u>Project 3 (short or long project):</u>

Preliminary title: **Visualisation of Quantum Algorithms**

The main goal of quantum information processing is to use quantum mechanics to overcome the limitations of classical computers. There are in existence today quantum algorithms which are able to perform given tasks, in principle faster than any known classical algorithm.

The first task of this project is to understand a main quantum algorithm as Shor's algorithm (factorisation) or Grover's algorithm (database search). The main task is then a visualisation on a classical computer based on Mathematica or C/C++.