MASTER IN PHOTONICS – PHOTONICS BCN
EUROPHOTONICS-POESII MASTER COURSE

PROPOSAL FOR A MASTER THESIS

Dates: April - September 2017

Laboratory : ICFO – The Institute of Photonic Sciences
City, Country : Castelldefels, Barcelona, Spain

Title of the master thesis: Conditions for anomalous diffusion of a Brownian particle coupled to a microstructured environment

Name of the master thesis supervisor: Prof. Maciej Lewenstein
Email address : maciej.lewenstein@icfo.es
Phone number : +34 935534072
Mail address : ICFO-Institut de Ciències Fotòniques, C.F. Gauss 3, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain

Summary of the subject (maximum 1 page) :

The goal of the project is to use methods of quantum many body physics and quantum information to address open problems in the theory of classical many body open systems. There is recent interest on the study of novel, exactly soluble stochastic models related to completely integrable quantum models. These classical many body open systems can often be simulated using quantum mechanical methods based on so called tensor network states (TNS). We will follow this direction, with particular emphasis on the search for quantum generalizations of classical stochastic models. In some cases it will be interesting to go beyond the detailed balance paradigm.

Particularly, we will address the study of diffusion processes and self-organization in complex environments, modelled as classical many body open systems and approached with quantum mechanical methods. One practical motivation for this project lies in the context of biological systems: recently, it has been demonstrated that the dynamics of biomolecules diffusing in complex environments is often characterized by anomalous diffusion, aging, breakdown of ergodicity, and unusual relaxation. It is widely believed that these phenomena play a key role in the emergence and regulation of biological function. These phenomena are originated by the interaction of the molecules with their environment, which, is often highly disordered, heterogeneous, and far from equilibrium. Nevertheless, there are few microscopic theoretical models of the environment and its interactions with the dynamical particles which permit to explain and test experimentally this behavior.

We have already shown that a particle coupled to an Ising environment shows rich dynamics, but is not appropriate for designing scenarios in which the particle presents anomalous diffusion [1]. We aim to explore the dynamics of particles interacting with other traditional statistichal models, like the Potts model. We have proven that, if the distribution of transition rates is algebraic but has a maximum value, anomalous diffusion can occur at intermediate times [2]. We propose to explore sub-diffusion in a Hamiltonian description of this system, which is a candidate to show anomalous diffusion in intermediate times. An additional goal of the project is to find models which explain self-organization and, particularly, clustering of particles. To this end we will explore both the interaction with complex environments or the inhomogeneous interactions among interacting simple consitutents.

[1] G. Munoz-Gil, C. Charalambous, A. Celi, M.A. Garcia-March, S-J. Ran, C. Peng, M. Lewenstein, In preparation.

[2] G. Munoz-Gil, C. Charalambous, A. Celi, C. Manzo M.A. Garcia-March, M.F. Garcia-Parajo, M. Lewenstein, In preparation.

Additional information :
* Required skills : quantum physics; statistical physics;
* Miscellaneous :