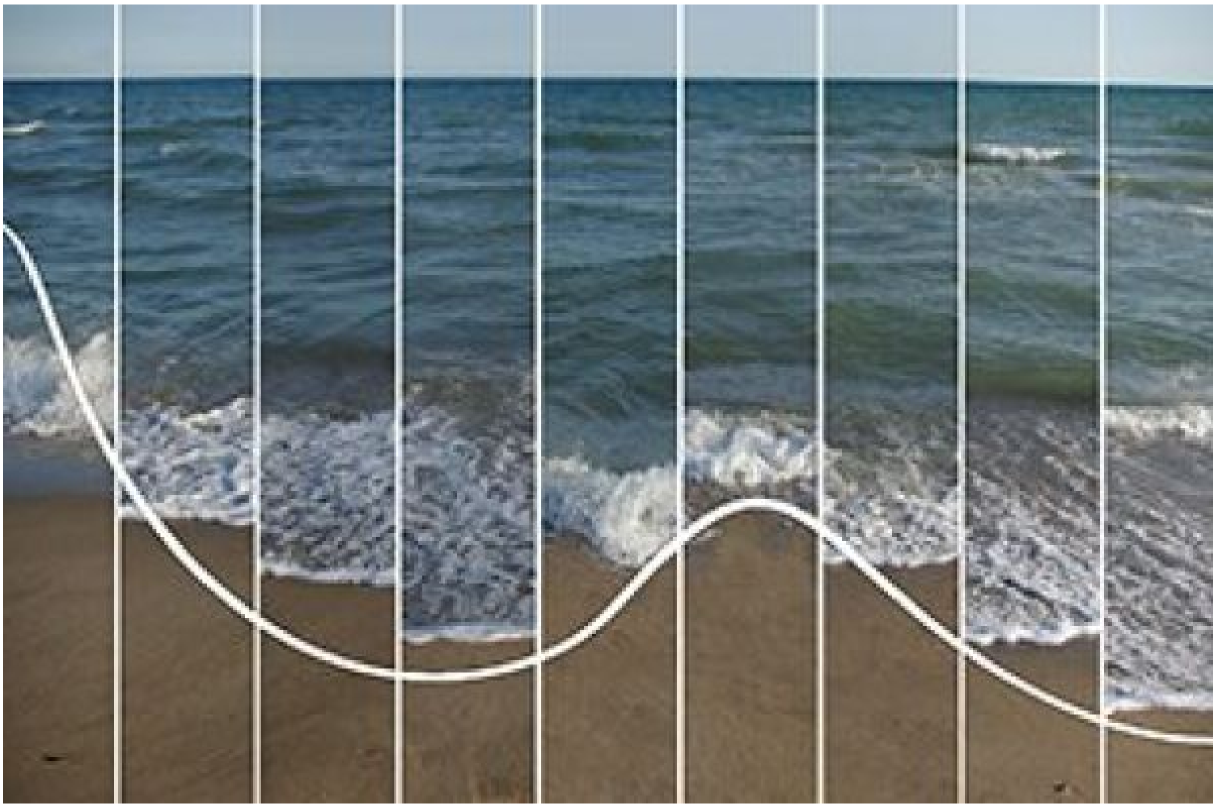

PhD Thesis Defense DARIO DE SANTIS 'Witnessing Non-Markovian Evolutions'

DARIO DE SANTIS

June 22, 2021

09:30

ICFO Auditorium and Online (Teams)

Tuesday, June 22, 2021, 09:30. Auditorium and Online (Teams)

DARIO DE SANTIS

Quantum Information Theory

ICFO-The Institute of Photonic Sciences

The formulation of quantum physics stands among the most revolutionary theories of the twentieth century. During the first decades of this century, many phenomena concerning the microscopic world were unexplained or had ad-hoc descriptions. The theory of quantum physics introduced a framework that allowed predicting these phenomena with unprecedented precision. While quantum mechanics offered counter-intuitive explanations for these experimental results, it predicted unexpected quantum phenomena which were considered symptoms of an ill-defined theory.

Decades passed and more and more empirical evidences sustained the existence of purely quantum effects and therefore the validity of this theory. Hence, it became a solid branch of science and physicists started to engineer scenarios where quantum effects could provide improvements if compared with classical scenarios. This approach gave birth to quantum information science, where quantum particles are manipulated to perform information tasks. Several innovative protocols, e.g. concerning state teleportation, dense coding, cryptography and integer factorization algorithms, proved that quantum physics allowed performances unattainable in classical settings.

The formulation of quantum protocols able to provide substantial speed-ups raised wide interest of the academic world and private companies. Nonetheless, the implementation of more and more complex quantum protocols became an increasingly harder task. Indeed, manipulating a large number of quantum particles with a level of noise that is small enough to obtain quantum advantages is, even nowadays, a demanding goal. The purely-quantum features essential for these speed-ups are fragile when noise influences experimental apparatus. Hence, in order to access the full potential of quantum theory, the ability to handle noisy environments is a fundamental goal.

This thesis is devoted to the study of open quantum systems (OQS), namely those where the interaction between the target quantum system and its surrounding environment is taken under consideration during the evolution. Indeed, isolated systems cannot provide realistic descriptions of dynamics. Understanding how to exploit and manipulate environments in order to obtain dynamics that are less aggressive with the information stored in our OQS is therefore an essential goal to achieve quantum advantages. There are two possible dynamical regimes for the information encoded in an OQS. We call an evolution Markovian when there is a one-way flow of information from the OQS to the environment. Instead, the non-Markovian regime is distinguished by one or more time intervals when this flow is reversed. In this case, we say that we witness information backflows. A characterization based on the different types of information quantifiers that can be considered in this context is fundamental to exploit these phenomena in information processing scenarios.

The main goal of this thesis is to examine the potential of correlation measures to show backflows when the OQS dynamics is non-Markovian. The first three works that we expose are devoted to this topic. First, we study how entanglement and quantum mutual information behave under non-Markovian evolutions. We follow with the formulation of a correlation measure that is able to witness almost-all non-Markovian evolutions. The last work along this topic provides the first one-to-one relation between correlation backflows and non-Markovian evolutions. The last work in this thesis adopts a different point of view under which we can characterize OQS evolutions. We quantify non-Markovianity through the minimal amount of Markovian noise that has to be added in order to make an evolution Markovian.

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Thesis Advisor: Prof Dr Antonio Acin

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