Master in Photonics – "PHOTONICS BCN"
Master ERASMUS+ "EuroPhotonics"

MASTER THESIS PROPOSAL

Dates: April 2020 - September 2021

Laboratory: Quantum Information Theory group
Institution: ICFO
City, Country: Castelldefels (Barcelona)

Title of the master thesis: Network nonlocality with continuous variables

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Keywords: Quantum nonlocality, causal networks, Gaussian states, entanglement.

Summary of the subject:
In the early days of Quantum Mechanics, Einstein together with Podolsky and Rosen, noticed in their seminal EPR paper [1] that quantum mechanics entails a "spooky action at a distance" that is incompatible with a description of reality that is at the same time *local* and *realistic*.
That feature is nowadays known as "entanglement". In 1964 Bell [2] formalized the same idea showing that the predictions of quantum mechanics are incompatible with local hidden variable (LHV) models trying to explain the emerging uncertainty in quantum measurements results.
In more recent years the theory of Quantum Nonlocality has seen its new renaissance, due to theoretical foundational advances, new numerical methods and experimental progress [3].
Moreover it has found practical importance in connection to practical tasks for quantum cryptography, device-independent detection of entanglement, random number generation etc. [3].
It has been now realised that the problem of compatibility of the measurement results of a given experiment with a LHV model, is no other than a particular instance of a problem of causal model compatibility [4-5-6], that is, when looking at the statistical output of an experiment:

- We assume a given network of parties (outputting variables publicly) with shared, possibly hidden resources, and given causal relations (normally described by a directed acyclic graph, or DAG) that describe which variables can influence others.
- We then ask the question: are the results of the experiment compatible with such a network?
- There is usually a gap between the probabilistic outputs that can be obtained for a given DAG with quantum sources and classical sources, which allows to detect the hidden "quantumness" in the network without knowing any specifics of the systems (*device-independently*).

In this project, we want to study the problem of nonlocality in simple causality networks, such as the bilocality scenario [7-8], with a particular focus on the continuous variable setting and states and measurements that are closer to photonic implementations, such as combinations of gaussian states, photodetections and phase measurements [9-10].

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[10] Adesso, G., Ragy, S. and Lee, A.R., 2014. Continuous variable quantum information: Gaussian states and beyond. *Open Systems & Information Dynamics*, *21*(01n02), p.1440001.

Additional information (if needed):
* Required skills : knowledge of quantum mechanics and the very basics of quantum information.
* Useful (but not mandatory!) skills : knowledge of quantum optics, programming.