Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Quantum Information Theory group,
Institut de Ciències Fotòniques (ICFO)
Barcelona

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https://www.icfo.eu/lang/research/groups/groups-details?group_id=19

Thesis possibility after internship: YES (under institution conditions) Funding: YES

The Nonlocality of Quantum physics in Networks

In 1964, John Stewart Bell proved that quantum physics is incompatible with our intuition that our world is local. More precisely, when two experimentalists measure the properties of two photons created by a same quantum source, they can produce correlations which cannot be explained by any classical theory. This was verified by famous experimental demonstrations, such as Aspect experiment. Those correlations, called quantum nonlocal correlations, are the fingerprint of quantum phenomena and at the origin of tremendous applications of quantum physics (Quantum Key Distribution, Quantum Random Number Generation, Device Independent Certification of Quantum devices, …).

A decade ago, physicists understood that Bell's theorem is the first elementary manifestation of a broader phenomenon called Network Nonlocality. When several sources distributed in a network are measured in different nodes, certain correlations may be created that cannot be explained by classical physics. Such correlations are called Network Nonlocal correlations. In spite of its importance, manifestation of Network Nonlocality is extremely difficult to exhibit and characterize, and only a few examples in limited networks structures are known.

The project is to find and characterize new manifestation of this phenomenon. Depending on the profile of the candidate, several approaches can be considered:

- Find connections with graph theory (see https://arxiv.org/abs/2011.02769)
- Improve the noise tolerance of existing theoretical results to make possible experimental realizations (e.g. of https://arxiv.org/abs/1801.10444)
  i. either using an analytical approach
  ii. or using a numerical approach based on SemiDefinite Programming (SDP) relaxation method developed by Navascués, Pironio, and Acín (NPA) hierarchy (https://arxiv.org/abs/quant-ph/0607119)

Other internship projects can be proposed depending on the student background and interest:

-in condensed matter, to estimate the ground state energy of Hamiltonian using the NPA method, adapting and developing tools to approach specific symmetric or sparse problems.
- In self-testing, where quantum properties are certified using experimental correlations. In particular, this subject is related to C*-algebras [Phys. Rev. Lett. 121, 250507 (2019), arXiv:1807.03332 (2019)].

Condensed Matter Physics: POSSIBLY	Macroscopic Physics and complexity: NO
Quantum Physics: YES	Theoretical Physics: YES