Funded Internship offer

Quantum Info Theory, Quantum Distributed Computing, Polynomial Optimization, C*/Operator Algebra

Location : Ecole Polytechnique Palaiseau (Paris), France
Marc-Olivier RENOU (marc-olivier.renou@inria.fr)
Thesis possibility after internship: YES (under institution conditions)

Beyond Bell theorem: Quantum 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, recently rewarded by a Nobel price. 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 quantum 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 quantum network nonlocal correlations.

The project is to understand network nonlocal correlations which can be obtained with quantum sources, or which could in principle be obtained in an exotic theory generalizing quantum theory, and to exploit them to either understand the foundations of physics or find practical applications to quantum theory (in randomness generation, cryptography, …). Depending on the profile of the candidate, several approaches can be considered either in an analytical mathematical, a practical coding, a conceptual, a distributed computing, a cryptographic (crypto primitives) direction:

- Find generalization of the Bell theorem based on Network nonlocality concepts (see https://www.scientificamerican.com/article/quantum-physics-falls-apart-without-imaginary-numbers/, https://arxiv.org/abs/2105.09381)
- Understand the limits of quantum distributed computing (see https://arxiv.org/abs/2307.09444)
- Look for practical applications of Network nonlocality for randomness generation, cryptography, … (see https://arxiv.org/abs/2104.10700, https://arxiv.org/abs/2209.09921)
- Understand the Navascués, Pironio, and Acín (NPA) hierarchy to improve the noise tolerance of existing theoretical results to make possible experimental realizations (see https://arxiv.org/abs/2201.05032, https://arxiv.org/abs/2011.02769)
- Understand the quantum inflation technic and look for its analytical convergence (see https://arxiv.org/abs/2210.09065)
- Find numerical methods to boost the inflation technic (see https://arxiv.org/abs/1609.00672)
- Other possibilities can be discussed.

I will guide the candidate in their choice of destination for a PhD. In case of continuation with a PhD, it may include collaborations with:

- Quantum Info Theory: Nicolas Gisin (Geneva), Antonio Acin (Barcelona), David Gross (Cologne), Omar Fawzi (INRIA Lyon)
- Quantum Distributed Computing: Jukka Suomela (Aalto, Finland), Pierre Fraigniaud, Frédéric Magniez (Paris)
- Polynomial Optimization, C*/Operator Algebra: Victor Magron (Toulouse), Igor Klep (Ljubljana)