INTERNSHIP PROPOSAL

Laboratory name: Institut de Physique Theorique (IPhT)
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Thesis possibility after internship: YES
Funding: NO

Limits of Quantum Correlations

As a theory for physical phenomenons, quantum theory has the curious feature that it does not actually predict the results that are to be observed in an experiment, but only their statistical distribution. This fundamentally probabilistic nature has deep consequences both on our understanding of the theory and on the potential applications that can be built with it. Indeed, quantum correlations are at the root of Bell experiments, which are some of the most fundamental tests of nature to date as recognized by the 2022 Nobel prize. At the same time, quantum correlations allow for new kinds of practical tasks with unparalleled security guarantees, known as device-independent protocols [1]. More generally, quantum statistics play a key role throughout quantum information theory, all the way from quantum computing to many-body physics.

Yet, quantum correlations remain poorly understood. While some methods have been proposed to approach these statistics, they are generally either partial or implicit.

The aim of this internship is to identify some explicit regions of the quantum boundary analytically. This work will build on two recent results which identified a series of extremal quantum statistics [2], and constructed the first extreme tests for quantum statistics [3]. It will involve analytic and possibly numerical tools from non-commutative optimization, convex duality, and the quantum formalism.

By providing new ways of testing whether some statistics admit a quantum explanation or not, this work will help to characterize both the power and the limitations of quantum predictions. It may also lead to applications in self-testing and the certification of quantum technology devices, as well as in the study of quantum networks.

[1] Nadlinger et al., *Experimental quantum key distribution certified by Bell's theorem*, arXiv:2109.14600
[2] Barizien et al., *Quantum statistics in the minimal scenario*, arXiv:2406.09350
[3] Barizien et al., *Extremal Tsirelson inequalities*, arXiv:2401.12791

Condensed Matter Physics: NO Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES