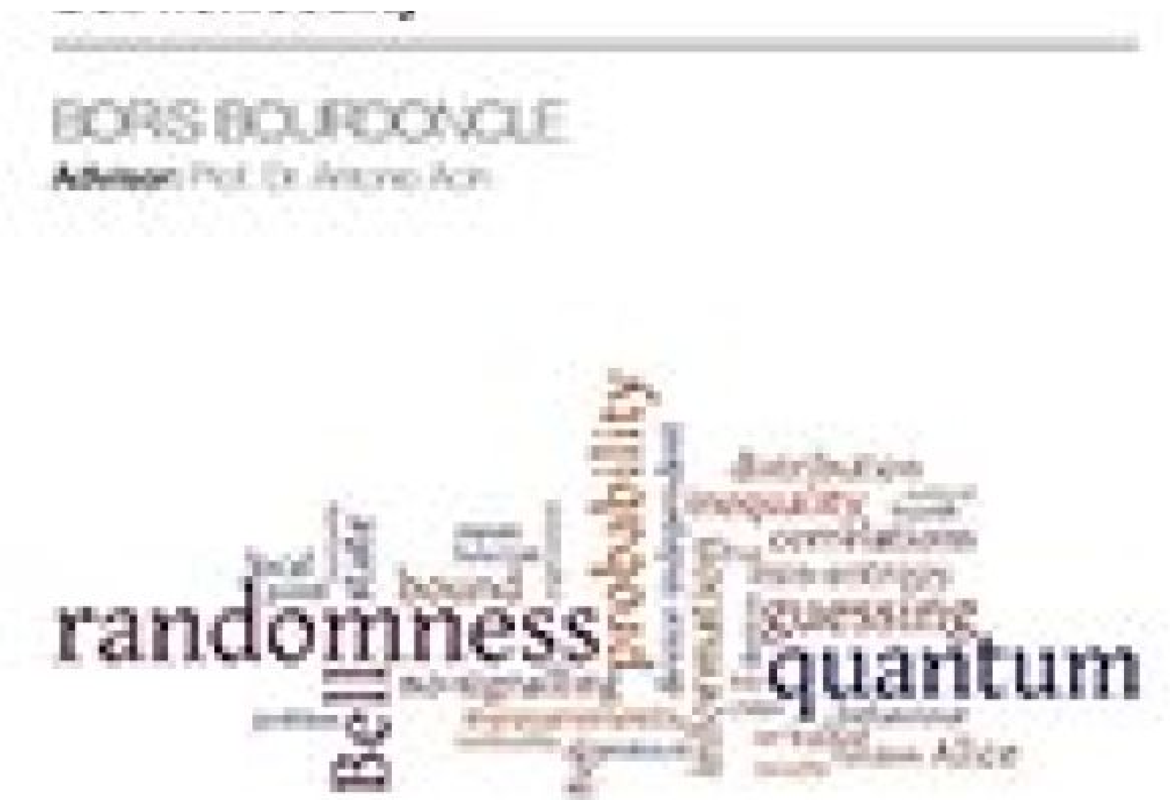

PhD Thesis Defense BORIS BOURDONCLE 'Quantifying Randomness from Bell Nonlocality'

BORIS BOURDONCLE

February 13, 2019

Wednesday, February 13, 11:00. ICFO Auditorium

BORIS BOURDONCLE

Quantum Information Theory

ICFO-The Institute of Photonic Sciences

The twentieth century was marked by two scientific revolutions. On the one hand, quantum mechanics questioned our understanding of nature and physics. On the other hand, came the realisation that information could be treated as a mathematical quantity. They together brought forward the age of information.

A conceptual leap took place in the 1980?s, that consisted in treating information in a quantum way as well. The idea that the intuitive notion of information could be governed by the counter-intuitive laws of quantum mechanics proved extremely fruitful, both from fundamental and applied points of view.

The notion of randomness plays a central role in that respect. Indeed, the laws of quantum physics are probabilistic: that contrasts with thousands of years of physical theories that aimed to derive deterministic laws of nature. This, in turn, provides us with sources of random numbers, a crucial resource for information protocols.

The fact that quantum theory only describes probabilistic behaviours was for some time regarded as a form of incompleteness. But nonlocality, in the sense of Bell, showed that this was not the case: the laws of quantum physics are inherently random, i.e., the randomness they imply cannot be traced back to a lack of knowledge.

This observation has practical consequences: the outputs of a nonlocal physical process are necessarily unpredictable. Moreover, the random character of these outputs does not depend on the physical system, but only of its nonlocal character. For that reason, nonlocality-based randomness is certified in a device-independent manner.

In this thesis, we quantify nonlocality-based randomness in various frameworks. In the first scenario, we quantify randomness without relying on the quantum formalism. We consider a nonlocal process and assume that it has a specific causal structure that is only due to how it evolves with time. We provide trade-offs between nonlocality and randomness for the various causal structures that we consider.

Nonlocality-based randomness is usually defined in a theoretical framework. In the second scenario, we take a practical approach and ask how much randomness can be certified in a practical situation, where only partial information can be gained from an experiment. We describe a method to optimise how much randomness can be certified in such a situation.

Trade-offs between nonlocality and randomness are usually studied in the bipartite case, as two agents is the minimal requirement to define nonlocality. In the third scenario, we quantify how much randomness can be certified for a tripartite process.

Though nonlocality-based randomness is device-independent, the process from which randomness is certified is actually realised with a physical state. In the fourth scenario, we ask what physical requirements should be imposed on the physical state for maximal randomness to be certified, and more specifically, how entangled the underlying state should be. We show that maximal randomness can be certified from any level of entanglement.

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