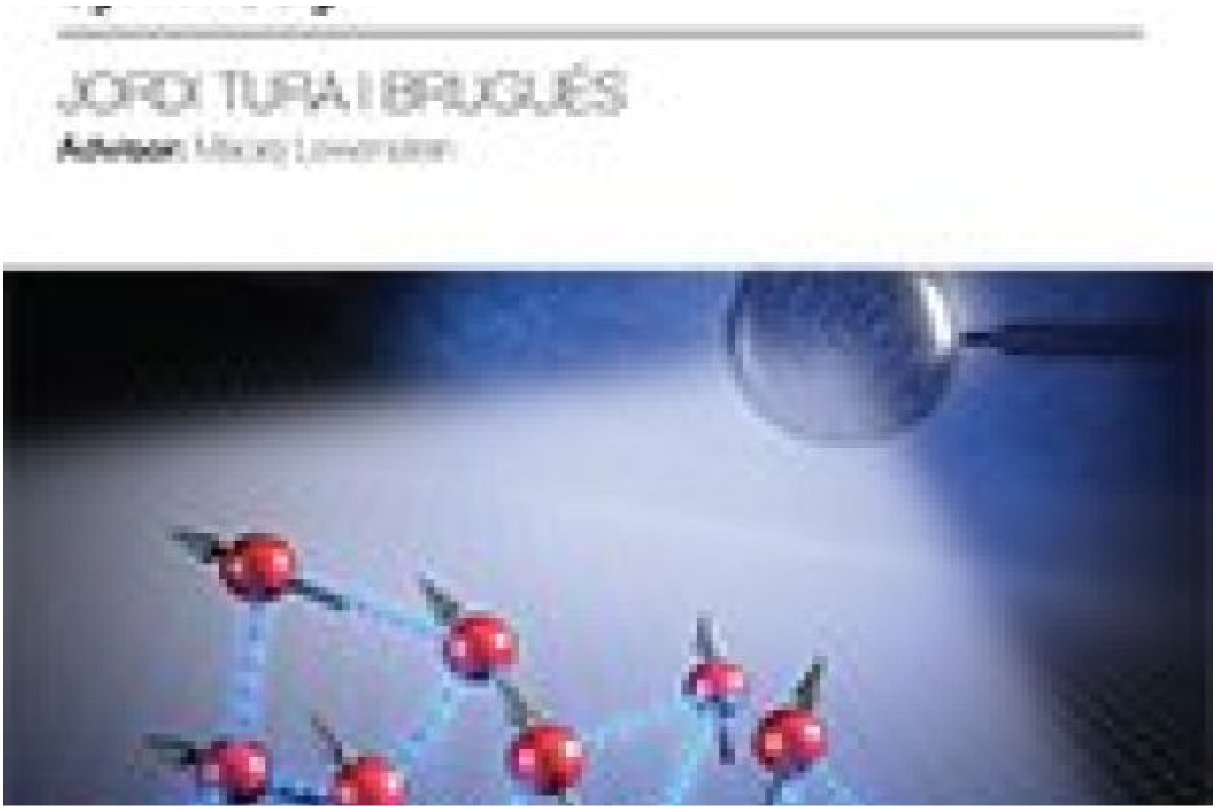


# PhD Thesis Defense JORDI TURA 'Characterizing Entanglement and Quantum Correlations Constrained by Symmetry'

JORDI TURA

July 20, 2015

Monday, July 20, 11:00. ICFO Auditorium

**JORDI TURA**

Quantum Optics Theory

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Entanglement and nonlocal correlations constitute two fundamental resources for quantum information processing, as they allow for novel tasks that are otherwise impossible in a classical scenario. However, their elusive characterization is still a central problem in Quantum Information Theory. The main reason why such a fundamental issue remains a formidable challenge lies in the exponential growth in complexity of the Hilbert space, as well as the space of nonlocal correlations. Physical systems of interest, on the other hand, display symmetries that can be exploited to reduce this complexity, opening the possibility that, for such systems, some of these questions become tractable.

This PhD Thesis is dedicated to the study and characterization of entanglement and nonlocal correlations constrained under symmetries. It contains original results in these four threads of research: PPT entanglement in the symmetric states, nonlocality detection in many-body systems, the non-equivalence between entanglement and nonlocality and elemental monogamies of correlations.

First, we study PPT entanglement in fully symmetric n-qubit states. We solve the open question on the existence of four-qubit PPT entangled states of these kind, providing constructive examples and methods. Furthermore, we develop criteria for separability, edgeness and the Schmidt number of PPT entangled symmetric states. Geometrically, we focus on the characterization of extremal states of this family and we provide an algorithm to find states with such properties.

Second, we study nonlocality in many-body systems. We consider permutationally and translationally invariant Bell inequalities consisting of two-body correlators. These constitute the first tools to detect nonlocality in many-body systems in an experimentally friendly way with our current technology. Furthermore, we show how these Bell inequalities detect nonlocality in physically relevant systems such as ground states of Hamiltonians that naturally arise e.g., in nuclear physics. We provide analytical classes of Bell inequalities and we analytically characterize which states and measurements are best suited for them. We show that the method we introduce can be fully generalized to correlators of any order in any Bell scenario. Finally, we provide some feedback from a more experimental point of view.

Third, we demonstrate that entanglement and nonlocality are inequivalent concepts in general; a question that remained open in the multipartite case. We show that the strongest form of entanglement, genuinely multipartite entanglement, does not imply

the strongest form of nonlocality, genuinely multipartite nonlocality, in any case. We give a constructive method that, starting from a multipartite genuinely multipartite state admitting a K-local model, extends it to a genuinely multipartite entangled state of any number of parties while preserving the degree of locality.

Finally, we show that nonlocal correlations are monogamous in a much stronger sense than the typical one, in which the figure of merit compares a Bell inequality violation between two sets of parties. We show that the amount of Bell violation that a set of parties observes limits the knowledge that any external observer may gain on any of the outcomes of any of the parties performing the Bell experiment. We show that this holds even if such observer is not limited by quantum physics, but it only obeys the no-signalling principle. Apart from its fundamental interest, we show how these stronger monogamy relations boost the performance of some device-independent (DI) protocols such as DI quantum key distribution or DI randomness amplification.

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