Congratulations to New ICFO PhD graduate

Dr. Flavio Baccari graduated with a thesis entitled "Certification of Many-Body Systems"

May 17, 2019

Dr. Flavio Baccari received his Master in Physics at the University of Rome before joining the Quantum Information Theory group led by ICREA Prof. at ICFO Dr. Antonio Acin. During his PhD studies, he studied scalable certification tools that apply to various operational properties of many-body quantum systems. Dr. Baccari?s thesis, entitled "Certification of Many-Body Systems", was supervised by Prof. Antonio Acin.

ABSTRACT:

Quantum physics is arguably both the most successful and the most counterintuitive physical theory of all times. Its extremely accurate predictions on the behaviour of microscopic particles have led to unprecedented technological advances in various fields

and yet, many quantum phenomena defy our classical intuition.

Starting from the 1980?s, however, a paradigm shift has gradually taken hold in the scientific community, consisting in studying quantum phenomena not as inexplicable conundrums but as useful resources. This shift marked the birth of the field of quantum information science, which has since then explored the advantages that quantum theory can bring to the way we process and transfer information.

In this thesis, we introduce scalable certification tools that apply to various operational properties of many-body quantum systems. In the first three cases we consider, we base our certification protocols on the detection of nonlocal correlations. These kinds of non-classical correlations that can be displayed by quantum states allow one to assess relevant properties in a device-independent manner, that is, without assuming anything about the specific functioning of the device producing the state of interest or the implemented measurements.

In the first scenario we present an efficient method to detect multipartite entanglement in a device-independent way. We do so by introducing a numerical test for nonlocal correlations that involves computational and experimental resources that scale polynomially with the system number of particles. We show the range of applicability of the method by using it to detect entanglement in various families of multipartite systems. In multipartite systems, however, it is often more informative to provide quantitative statements. We address this problem in the second scenario by introducing scalable methods to quantify the nonlocality depth of a multipartite systems, that is, the number of particles sharing nonlocal correlations among each other. We show how to do that by making use of the knowledge of two-body correlations only and we apply the resulting techniques to experimental data from a system of a few hundreds of atoms. In the third scenario, we move to consider self-testing, which is the most informative certification method based on nonlocality. Indeed, in a self-testing task, one is interested in characterising the state of the system and the measurement performed on it, by simply looking at the resulting correlations. We introduce the first scalable self-testing method based on Bell inequalities and apply it to graph states, a well-known family of multipartite quantum states. Moreover, we show that the certification achieved with our method is robust against experimental imperfections. Lastly, we address the problem of certifying the result of quantum optimizers. They are quantum devices designed to estimate the groundstate energy of classical spin systems. We provide a way to efficiently compute a convergent series of upper and lower bounds to the minimum of interest, which at each step allows one to certify the output of any quantum optimizer.

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