Giovanni Scala

Research Statement

*"Look up at the stars and not down at your feet.
Be curious." (S. Hawking)*

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Research Statement

My scientific interest is Quantum Foundations, Mathematical Physics, Quantum Information, and Quantum Optics. Currently, I am involved in a project for a generalization of CHSH inequality and information causality at the International Centre for Theory of Quantum Technologies (ICTQT) in Gdańsk; A developed formalism for deriving new Bell's inequalities and causal inequality is crucial to better discern the assumption of the locality and the realism in the physical theories. The problem is notoriously difficult (actually, it belongs to the class of so-called NP-hard problems) and the potential solution might pave the way to further applications in other fields, as well as, in Computer Science and Convex Optimization. Furthermore, I am carrying out research seeking to prove a no-go theorem based on the identity indiscernibles principle, which might be violated by physical theories like quantum mechanics in collaboration with the Chapman University in Los Angeles.
During my Ph. D. studies I won an internship that opened a line of research on entanglement detection. In particular, I constructed a new family of entanglement witnesses which might determine if a quantum state is separable or entangled. I also generalized this family of witnesses for a multipartite scenario and enhanced the power of the entanglement detection of this family via optimality, LOCC filtering, and neural networks. In addition to that, at the first stage of my researches, I have studied the correlations between intensity fluctuations measured on two detectors. Therefore, I wrote an algorithm to compute recursively the 8-points correlation functions based on Wick-Isserlis. Thanks to my algorithm the experimentalists can easily calculate the advantages of different experimental configurations and compare them without going through mistakable and lengthy predictions. These setups shed light on understanding the counter-intuitive higher-order interference effects in the absence of field coherence. I also spent a period abroad at the University of N. Copernicus in Toruń, where I have studied the cavity system within the formalism of Quantum electrodynamics. I participated in a project entitled "Light interactions to asymmetric quantum systems" and I proved that the coupling with the environment and the presence of the asymmetric effects generally enhances the survival

probability of a prepared quantum state. As one can notice, I am open to broadening my scientific interests, and I like to summarize that my main target is to answer fundamental questions concerning the formalism of the physical theories.

Hence, during these years I developed abilities to elaborate theorems in an abstract sense or to use, where it is possible, the auxiliary of the simulations (also based on Machine Learning and Parallelization Computing) to acquire hints for the analytical proof. As an example, in this way, I found a unifying separability criterion that covers several known criteria. I also showed that my criterion is equivalent to the strongest effectively computable simplification of the Correlation Matrix Criterion [1,2]. I also provided a physical interpretation of the decay rate of an extended quantum system depending on its internal asymmetric structure and the surrounding dispersive environment with the massive support of a *"numerical suggestion"* [3]. In [4,5] I determine advantages among interferometric setups calculating the Signal-to-Ratio and the a method for the remote sensing. My active engagement in the aforementioned research activities demonstrates how motivated and diligent I am as a researcher and I hope that these qualities, together with my creative thinking, bring me ever closer to the fundamental basis of the laws of Nature.

References

1. G. Sarbicki, G. Scala, D. Chruściński, "A family of multipartite separability criteria based on correlation tensor", *Phys. Rev. A* (January 27, 2020) 101, 012341
2. G. Sarbicki, G. Scala, D. Chruściński, "Enhanced realignment criterion vs. linear entanglement witnesses", *J. Phys. A: Math. Theor* (October 21, 2020) 53, 455302
3. G. Scala, F. V. Pepe, P. Facchi, S. Pascazio, K. Słowik, "Light interaction with extended quantum systems in dispersive media", *New Journal Physics* (December 30, 2020) 22, 123047
4. G. Scala, M. D'Angelo, A. Garuccio, S. Pascazio, F. V. Pepe, "Signal-to-noise properties of correlation plenoptic imaging with chaotic light", *Phys. Rev. A* (May 7, 2019) 99, 053808
5. F. V. Pepe, G. Chilleri, G. Scala, D. Triggiani, Y. Kims, V. Tamma, "Distance sensing with remote double slits", arxiv.org/abs/2011.05224