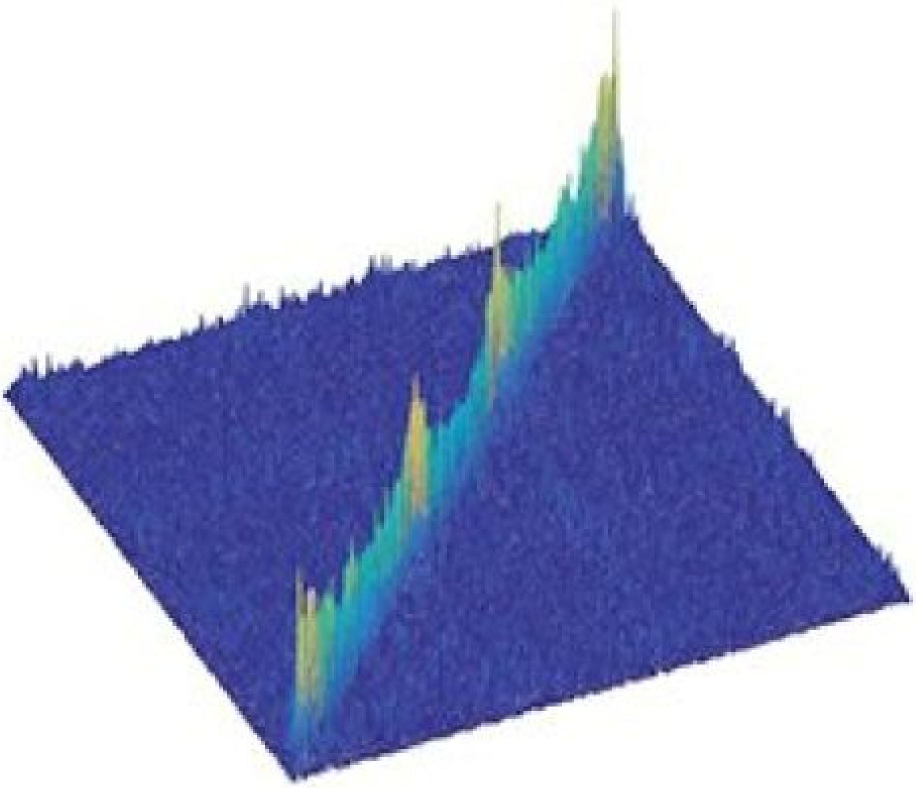

PhD Thesis Defense ANGELO PIGA 'Entanglement and Bell Correlations in Strongly Correlated Many-Body Quantum Systems'

ANGELO PIGA

March 30, 2020

11:00

Online

Monday, March 30, 2020, 11:00. Online

ANGELO PIGA

Quantum Optics Theory

ICFO-The Institute of Photonic Sciences

During the past two decades, thanks to the mutual fertilization of the research in quantum information and condensed matter, new approaches based on purely quantum features without any classical analog turned out to be very useful in the characterization of many-body quantum systems (MBQS). A peculiar role is obviously played by the study of

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purely quantum correlations, manifesting in the ï¿½spookyï¿½ properties of entangle
ent and nonlocality (or Bell correlations), which ultimately discriminate classical from qua
tum regimes. It is, in fact, such kind of correlations that give rise to the plethora of intrig
ing emergent behaviors of MBQS, which cannot be reduced to a mere sum of the behavior
of individual components, the most important example being the quantum phase transiti
ns. However, despite being indeed closely related concepts, entanglement and nonlocality
are actually two different resources.

With regard to the entanglement, we will use it to characterize several instances of MBQS, to exactly locate and characterize quantum phase transitions in spin-lattices and interacting fermionic systems, to classify different gapped quantum phases according to their topological features and to provide a purely quantum signature of chaos in dynamical systems.

Our approach will be mainly numerical and for simulating the ground states of several
one-dimensional lattice systems we draw heavily on the celebrated ï¿½density matr
x renormalization groupï¿½ (DMRG) algorithm in the ï¿½matrix product stateï¿½ (MPS) a
satz. A MPS is a one-dimensional tensor network (TN) representation for quantum st
tes and occupies a pivotal position in what we have gained in thinking MBQS from an enta
glement perspective. In fact, the success of TNs states mainly relies on their fulfill
ent, by construction, of the socalled ï¿½entanglement area lawï¿½. This is a feature s
ared by the ground states of gapped Hamiltonians with short-range interactions among th
components and consists of a sub-extensive entanglement entropy, which grows only with th
surface of the bipartition. This property translates in a reduced complexity of such syste
s, allowing affordable simulations, with an exponential reduction of computational costs.
Besides the use of already existing TN-based algorithms, an effort will be done to devel
p a new one suitable for high-dimensional lattices. While many useful results are avail
ble for the entanglement in many different contexts, less is known about the role of
onlocality. Formally, a state of a multi-party system is defined nonlocal if its correlations
iolate some ï¿½Bell inequalityï¿½ (BI). The derivation of the BIs for systems consisting of m
ny parties is a formidable task and only recently a class of them, relevant for nontrivial
tates, has been proposed. In an important chapter of the thesis, we apply these BIs to fully
haracterize the phase transition of a long-range ferromagnetic Ising model, doing a
comparison with entanglement-based results and then making one of the first efforts in t
e study of MBQS from a nonlocality perspective.

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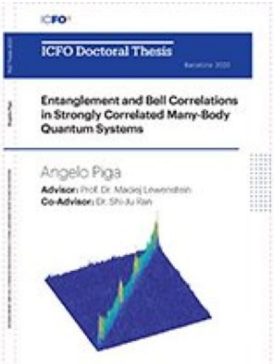
Thesis Advisor: Prof Dr Maciej Lewenstien

Thesis Co-advisor: Dr Shi-ju Ran



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