QI 11: Quantum Entanglement I

Time: Tuesday 11:00–13:00 Location: B305

Invited Talk QI 11.1 Tue 11:00 B305

Characterisation of multipartite entanglement beyond the single-copy paradigm — •Nicolai Friis — Institute of Atomic and Subatomic Physics - Atominstitut, TU Wien, Vienna, Austria

Scenarios with multiple parties such as one would imagine will be encountered in future large-scale quantum networks present complex challenges for the characterisation of entanglement. One of the most basic insights in the theory of multipartite entanglement is the fact that some mixed states can feature entanglement across every possible bipartition of a multipartite system, yet can be biseparable, i.e., can be produced as mixtures of partition-separable states. To distinguish biseparable states from those states that genuinely cannot be produced from mixing partition-separable states, the term genuine multipartite entanglement was coined. The premise for this distinction is that only a single copy of the state is distributed and locally acted upon. However, advances in quantum technologies prompt the question of how this picture changes when multiple copies of the same state become locally accessible. In this talk I will discuss recent work [Yamasaki et al., Quantum 6, 695 (2022), Palazuelos & de Vicente, Quantum 6, 735, (2022)] which demonstrates that multiple copies unlock genuine multipartite entanglement from partition-separable states, even from undistillable ensembles. These results show that a modern theory of entanglement in multipartite systems, which includes the potential to locally process multiple copies of distributed quantum states, exhibits a rich structure that goes beyond the convex structure of single copies.

QI 11.2 Tue 11:30 B305

Entanglement in quantum hypergraph states — •Jan Nöller[1] and Mariami Gachechiladze[2] — [1]Technische Universität Darmstadt — [2]Technische Universität Darmstadt

Hypergraph states are the natural generalization of well-known graph states, capturing multipartite entanglement between three or more parties.

We investigate how local Pauli stabilizers of symmetric hypergraph states can be used to quantify their geometric entanglement measures, and to explain exponentially increasing violation of local realism.

Specifically, we recover some known results for states with low hyperedge cardinalities and extend these further to infinitely many classes of hypergraph states.

Finally, we derive some results on robustness for the violation of separability inequalities against particle loss.

QI 11.3 Tue 11:45 B305

Bound Entanglement in Generalized Grid States — •Robin Krebs — Technical University Darmstadt, Germany

Quantum grid states are mixed quantum states introduced to study bound entanglement. They are defined by graphs on a regular grid, allowing for graph theoretical separability criteria.

Recently a generalization including hyperedges was proposed by Ghimire et al. In our work, we extend the graphical range and PPT criterion to allow treatment of hyperedges to deepen the understanding of entanglement in generalized grid states and study the behaviour of the Schmidt number under this generalization.

QI 11.4 Tue 12:00 B305

Quantifying electron entanglement faithfully — Lexin Ding[1,2], Zoltan Zimboras[3,4,5], and •Christian Schilling[1,2] — [1]Ludwig Maximilian University of Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Germany — [3]Theoretical Physics Department, Wigner Research Centre for Physics, Budapest, Hungary — [4]Algorithmiq Ltd., Helsinki, Finland — [5]Eötvös Loránd University, Budapest, Hungary

Entanglement is one of the most fascinating concepts of modern physics. In striking contrast to its abstract, mathematical foundation, its practical side is, however, remarkably underdeveloped. Even for systems of just two orbitals or sites no faithful entanglement measure is known yet. By exploiting the spin symmetries of realistic many-electron systems, we succeed in deriving a closed formula for the relative entropy of entanglement between electron orbitals. Its broad applicability in the quantum sciences is demonstrated: (i) in light of the second quantum revolution, it quantifies the true physical entanglement by incorporating the crucial fermionic superselection rule (ii) an analytic description of the long-distance entanglement in free electron chains is found, refining Kohn's locality principle (iii) the bond-order wave phase in the extended Hubbard model can be confirmed, and (iv) the quantum complexity of common molecular bonding structures could be marginalized through orbital transformations, thus rationalizing zero-seniority wave function ansatzes.

QI 11.5 Tue 12:15 B305

Constructing entanglement witnesses based on the Schmidt decomposition of operators — •Sophia Denker[1], Chengjie Zhang[2], Ali Asadian[3], and Otfried Gühne[1] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany — [2]School of Physical Science and Technology, Ningbo University, Ningbo, 315211, China — [3]Department of Physics, Institute for Advanced Studies in Basic Sciences (IASBS), Gava Zang, Zanjan 45137-66731, Iran

Characterizing entanglement is an important issue in quantum information, as entanglement is considered to be a resource for quantum key distribution or quantum metrology. One useful tool to detect and quantify entanglement are witness operators. A standard way to design entanglement witnesses for two or more particles is based on the fidelity of a pure quantum state; in mathematical terms this construction relies on the Schmidt decomposition of vectors. In this contribution, we present a method to build entanglement witnesses based on the Schmidt decomposition of operators. Our scheme works for the bipartite and the multipartite case and is found to be strictly stronger than the concept of fidelity-based witnesses. We discuss in detail how to improve known witnesses for genuine multipartite entanglement for various multipartite quantum states. Finally, we demonstrate that our approach can also be used to quantify quantum correlations as well as characterize the dimensionality of entanglement.

QI 11.6 Tue 12:30 B305

Maximally entangled symmetric states of two qubits — •Eduardo Serrano-Ensástiga[1,2] and John Martin[2] — [1]Centro de Nanociencias y Nanotecnología, Universidad Nacional Autónoma de México, Ensenada, Baja California, México — [2]Institut de Physique Nucléaire, Atomique et de Spectroscopie, CESAM, University of Liège, Liège, Belgium

The problem studied by Verstraete, Audenaert and De Moor [1] -about which global unitary operations maximize the entanglement of a bipartite qubit system- is revisited and solved when permutation symmetry between the qubits is taken into account. This condition appears naturally in bosonic systems or spin-1 systems [2]. Our results [3] allow us to characterize the set of symmetric absolutely separable states (SAS) for two qubits. In particular, we calculate the maximal radius of a ball of SAS states around the maximally mixed state in the symmetric sector, and the minimum radius of a ball that includes the set of SAS states. For symmetric 3-qubit systems, we deduce a necessary condition for absolute separability and bounds for the radii of similar balls studied in the two-qubit system. [1] F. Verstraete, K. Audenaert, and B. De Moor, Phys. Rev. A, 64, 012316, (2001). [2] O. Giraud, P. Braun, and D. Braun, Phys. Rev. A, 78, 042112, (2008). [3] E. Serrano-Ensástiga, and J. Martin, ArXiv:2112.05102 (2021).

QI 11.7 Tue 12:45 B305

Geometry of the state space of two qubits — •Simon Morelli[1], Christopher Eltschka[2], Marcus Huber[3], and Jens Siewert[4,5] — [1]Basque Center for Applied Mathematics (BCAM), 48009 Bilbao, Spain — [2]Istitut für Theoretische Physik, Universität Regensburg, 93053 Regensburg, Germany — [3]Atominstitut, Technische Universität Wien, 1020 Vienna, Austria — [4]University of the Basque Country UPV/EHU, 48080 Bilbao, Spain — [5]IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain

The quantum marginal problem and related questions have received considerable attention recently. We investigate an even simpler question for which there is no answer so far: Given the purities of the two local states of a bipartite system, what is the maximum purity the global state can achieve? We derive an exact solution for two qubits. Together with previous findings [1], this result gives rise for a new representation of the state space – the Bloch ball – of two qubits. We show that this visualization has various interesting properties regarding geometry, majorization, and entanglement.

[1] S. Morelli, C. Kloeckl, C. Eltschka, J. Siewert, and M. Huber, Lin. Alg. App. **584**, 294 (2020).