QI 9: Quantum Correlations

Time: Thursday 9:30–12:15 Location: H8

QI 9.1 Thu 9:30 H8

Dimension-free entanglement detection in multipartite Werner states — •Felix Huber[1], Igor Klep[2], Victor Magron[3], and Jurij Volčič[4] — [1]Institute of Theoretical Physics, Jagiellonian University, 30-348 Kraków, Poland — [2]Faculty of Mathematics and Physics, University of Ljubljana, Slovenia — [3]LAAS-CNRS & Institute of Mathematics from Toulouse, France — [4]Department of Mathematical Sciences, University of Copenhagen, Denmark

Werner states are multipartite quantum states that are invariant under the diagonal conjugate action of the unitary group. We give a complete characterization of their entanglement that is independent of the underlying local Hilbert space: for every entangled Werner state there exists a dimension-free entanglement witness. The construction of such a witness is formulated as an optimization problem. To solve it, two semidefinite programming hierarchies are introduced. The first one is derived using real algebraic geometry applied to positive polynomials in the entries of a Gram matrix, and is complete in the sense that for every entangled Werner state it converges to an entanglement witness. The second one is based on a sum-of-squares certificate for the positivity of trace polynomials in noncommuting variables, and is a relaxation that involves smaller semidefinite constraints.

QI 9.2 Thu 9:45 H8

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 various examples and demonstrate that our approach can also be used to quantify quantum correlations as well as characterize the dimensionality of entanglement.

QI 9.3 Thu 10:00 H8

Nonlinear Entanglement Detection from Immanant Inequalities — •Albert Rico and Felix Huber — Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University, 30-348 Kraków, Poland

We develop a method for nonlinear entanglement detection which is based on inequalities for immanants. This allows to use multipartite witnesses to detect bipartite states in a non-conventional way. We give examples and compare their effectiveness to the standard usage of witnesses. We show that this type of nonlinear entanglement detection can outperform its linear version, and how the detection can be performed in the laboratory through randomized measurements.

QI 9.4 Thu 10:15 H8

The shape of higher-dimensional state space: Bloch ball analog for a qutrit — Christopher Eltschka[1], Marcus Huber[2,3], Simon Morelli[2,3], and •Jens Siewert[4,5] — [1]Institut für Theoretische Physik, Universität Regensburg, Regensburg, Germany — [2]IQOQI Vienna, Vienna, Austria — [3]Atominstitut TU Wien, Vienna, Austria — [4]University of the Basque Country UPV/EHU and EHU Quantum Center, Bilbao, Spain — [5]Ikerbasque, Basque Foundation for Science, Bilbao, Spain

The Bloch ball as a geometric representation of the state space for qubits is an ubiquitous tool to gain deeper insight and intuitive understanding of quantum-mechanical phenomena. Unfortunately, even for the next more complex system, the qutrit, such a geometric representation (rather than cross sections or projections) is not known. In order to serve as a model for higher-dimensional state space, it should display a number of desirable properties, such as different surface parts corresponding to pure or mixed states, convexity, inner and outer sphere with the corresponding radii, pure states should form a connected set, etc. [1]. We show that, based on the Bloch representation of qutrit states, such a model can be constructed that captures many of the geometric features discussed in Ref. [1].

[1] I. Bengtsson, S. Weis, K. Zyczkowski, Geometry of the Set of Mixed Quantum States: An Apophatic Approach. In: P. Kielanowski et al (eds) Geometric Methods in Physics. Trends in Mathematics (Birkhäuser, Basel, 2013).

QI 9.5 Thu 10:30 H8

Nearly optimal separability certification of quantum states — •Ties-Albrecht Ohst[1], Chau Nguyen[1], Otfried Gühne[1], and Xiao-Dong Yu[2] — [1]Naturwissenschaftlich-Technische Fakultät, Universität Siegen — [2]Department of Physics, Shandong University, Jinan

Entanglement describes the possibility of local parties sharing a joint global system state that cannot be expressed as a probabilistic mixture of locally prepared states. The question on whether some given state is entangled or separable, on the contrary, is generically difficult to answer. We present an algorithm for the quantum separability problem for intermediate dimensions with evidences of being nearly optimal. The basic idea of our considerations can in general be described by a systematic search for separable decompositions of a given state by polytope approximations to a local system. As a benchmark we can compute the separability thresholds for known bound entangled states of two coupled qutrits with an accuracy that has not been achieved before. Also, for bi-partite systems of higher dimension we can certify the separability of states reliably which follows from the comparison with data by known entanglement criteria. For three coupled qubit systems, our ideas allow for an efficient distinction between different separability classes that lie at the heart of the theory of multi-partite entanglement. We developed an algorithm for the search among all fully bi-separable states to find the one whose entanglement robustness is as large as possible. Quite interestingly, the obtained states show a deep connection to the post measurement states in the teleportation protocol.

QI 9.6 Thu 10:45 H8

Hilbert-Schmidt geometry of two-qubit correlations — •Santiago Llorens[1] and Jens Siewert[2,3] — [1]Grup d'Informació Quàntica, Universitat Autònoma de Barcelona, Barcelona, Spain — [2]University of the Basque Country and EHU Quantum Center, Bilbao, Spain — [3]Ikerbasque, Basque Foundation for Science, Bilbao, Spain

The Bloch representation of quantum states endows the state space with a natural Euclidean geometry via the Hilbert-Schmidt scalar product. Based on this, a Bloch ball-type global view of the state space for a qutrit was found recently. This imposes the question whether an analogous method exists for the simplest quantum correlations – those in a system of two qubits. From such a visualization one may expect a better understanding of the links between the algebraic correlation constraints and their geometric background. We show that indeed the 2-sector (aka as the correlation tensor) of two-qubit states allows for a geometric representation of the algebraic constraints to the entries of the Bloch vector. In this context we provide novel insight into the relation between entanglement quantifiers and characteristic parameters of the Bloch representation of bipartite systems.

15 min. break

QI 9.7 Thu 11:15 H8

Schmidt number witnesses for high-dimensional quantum states in photonic temporal mode setups — •Nikolai Wyderka[1], Giovanni Chesi[2], Hermann Kampermann[1], and Dagmar Bruss[1] — [1]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany — [2]Istituto Nazionale di Fisica Nucleare Sezione di Pavia, Via Agostino Bassi 6, I-27100 Pavia, Italy

Photonic temporal modes offer a robust and efficient toolbox for high-dimensional quantum information applications. In order to characterize the experimentally generated quantum states, we aim to use witnesses to certify their Schmidt numbers as a robust entanglement measure. To that end, we develop an iterative algorithm that yields Schmidt number witness candidates that require only a few of those measurements inherent to the temporal mode framework using quantum pulse gates. Finally, we use the numerical candidates to derive a proper Schmidt number witness for states close to the maximally entangled state.

QI 9.8 Thu 11:30 H8

Complete hierarchy for high-dimensional steering certification — •Carlos de Gois, Martin Plávala, and Otfried Gühne — Naturwissenschaftlich Technische Fakultät, Universität Siegen

Steerability can be employed as a semi-device independent test of the Schmidt number. As such, it is a promising component in quantum informational protocols that make use of entanglement dimension certification. Recently proposed and experimentally demonstrated for the special case in which the assemblage is prepared from two choices of measurements, high-dimensional steering is so far lacking a general certification procedure. Herein, we provide necessary and, at a limit, sufficient conditions to certify the entanglement dimension of a steering assemblage. These conditions are stated in terms of a hierarchy of semidefinite programs, which can also be used to compute the steering dimension robustness.

QI 9.9 Thu 11:45 H8

Distance-based resource quantification for sets of quantum measurements — •Lucas Tendick, Martin Kliesch, Hermann Kampermann, and Dagmar Bruss — Institute for Theoretical Physics, Heinrich Heine University Düsseldorf, D-40225 Düsseldorf, Germany

The advantage that quantum systems provide for certain quantum information processing tasks over their classical counterparts can be quantified within the general framework of resource theories. Certain distance functions between quantum states have successfully been used to quantify resources like entanglement and coherence. Perhaps surprisingly, such a distance-based approach has not been adopted to study resources of quantum measurements, where other geometric quantifiers are used instead. Here, we define distance functions between sets of quantum measurements and show that they naturally induce resource monotones for convex resource theories of measurements. By focusing on a distance based on the diamond norm, we establish a hierarchy of measurement resources and derive analytical bounds on the incompatibility of any set of measurements. We show that these bounds are tight for certain projective measurements based on mutually unbiased bases and identify scenarios where different measurement resources attain the same value when quantified by our resource monotone. Our results provide a general framework to compare distance-based resources for sets of measurements and allow us to obtain limitations on Bell-type experiments.

QI 9.10 Thu 12:00 H8

On entanglement swapping and teleportation with local hidden variables — •Eugen Muchowski — Primelstrasse 10, 85591 Vaterstetten

A model with local hidden variables is presented, which describes phenomena such as entanglement swapping and teleportation and also reproduces the quantum mechanical expectation values for the measurement of entangled photons. It refutes Bell's theorem and at the same time expands our physical understanding of entangled states since it can also explain the phenomena mentioned above.