FM 11: Entanglement: Many-Body States I

Time: Monday 14:00–16:00 Location: 2004

Invited Talk FM 11.1 Mon 14:00 2004

Correlations in many-body states: The simplest constraints for their distribution — •Jens Siewert — University of the Basque Country UPV/EHU, 48080 Bilbao, Spain — IKERBASQUE, Basque Foundation for Science, 48013 Bilbao, Spain

It has long been known that correlations in many-body systems cannot be freely distributed. Correspondingly, not all choices of reduced states (the marginals) are compatible with a joint global state of the system. This difficulty is known as the quantum marginal problem. In solid-state physics and quantum chemistry problems of this kind were discussed in the context of 'N-representability', whereas in quantum information the term 'monogamy of entanglement' (and other correlations) was coined.

Surprisingly, this problem is not completely solved even in the simplest of its variants, the existence of so-called absolutely maximally entangled states of N distinguishible quantum systems, each of which has d levels. However, substantial progress in this field was achieved recently by analyzing the Bloch representation of quantum states: This representation corresponds to an expansion of an N-party density matrix into all its k-particle correlations ($k \leqq N$). The simplest correlation quantifiers based on this are the k-sector lengths. By using these tools, constraints for the distribution of correlations viz. sector lengths can be derived systematically and transparently. They may also be viewed as monogamy relations for entanglement as well as, e.g., inequalities for the linear entropy or conditions for the existence of quantum error correcting codes.

FM 11.2 Mon 14:30 2004

Characterizing Quantum States using Sector Lengths — •Nikolai Wyderka[1], Jens Siewert[2,3], and Otfried Gühne[1] — [1]Naturwissenschaftlich Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany — [2]University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [3]IKERBASQUE Basque Foundation for Science, E-48013 Bilbao, Spain

A powerful tool to study entanglement properties of multi-partite quantum states are LU invariants, and sector lengths, quantifying the amount of k-body correlations in a state, are a particularly useful subset of these invariants. These quantify, for different k, the amount of k-partite correlations in a quantum state in a basis-independent manner.

I will show how sector lengths can be used to detect different types of entanglement. Furthermore, I will highlight connections to monogamy of entanglement, limiting the entanglement between certain subgroups of the particles.

FM 11.3 Mon 14:45 2004

Reference-frame independent quantification of bipartite entanglement — •Michael Krebsbach, Heinz-Peter Breuer, and Andreas Ketterer — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

The experimental detection of entanglement usually involves a number of appropriately chosen local quantum measurements aligned with respect to a previously shared common reference-frame. Establishing the latter, however, requires the exchange of classical information which represents an additional technical overhead, in particular if the involved parties are in motion. In this work we investigate the reference-frame independent quantification of bipartite entanglement using moments of randomly measured correlation functions [1]. In particular, we find that the concurrence of Bell-diagonal states is determined by the first three non-vanishing moments, a result that leads to lower bounds on the concurrence of general two-qubit states. Lastly, extensions of the presented methods to systems of larger local dimensions are considered as well.

[1] A. Ketterer, N. Wyderka, O. Gühne, Phys. Rev. Lett. **122**, 120505 (2019).

FM 11.4 Mon 15:00 2004

Detection of Genuine Multipartite Entanglement Without Any Reference Frames — •Jan Dziewior[1,2], Lukas Knips[1,2], Waldemar Klobus[3], Wieslaw Laskowski[3], Tomasz Paterek[4,5], Harald Weinfurter[1,2], and Jasmin Meinecke[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Department für Physik, Ludwig-Maximilians-Universitaät, 80797 München, Germany — [3]Institute of Theoretical Physics and Astrophysics, University of Gdansk, 80-308 Gdansk, Poland — [4]School of Physical and Mathematical Sciences, Nanyang Technological University, 637371 Singapore — [5]MajuLab, CNRS-UCA-SU-NUS-NTU International Joint Research Unit, UMI 3654 Singapore

Quantum entanglement is usually revealed by a carefully chosen set of measurements. Under a number of experimental conditions, especially for communication in multiparty quantum networks, the relative measurement directions fluctuate and are hard to calibrate. Yet, even with absolutely random measurements one can still gain information about the state and its entanglement. Here we extend previous attempts and perform numerical as well as experimental analysis of the performance of the method. From detailed distributions of measurement outcomes and their correlations different types of multipartite entanglement are identified making our method useful for entanglement verification in the presence of noise. It overcomes any type and strength of localized unitary noise as long as the rate of entanglement generation is sufficiently high.

FM 11.5 Mon 15:15 2004

Optimal measurement strategies for fast entanglement detection — •Nadia Milazzo[1,2], Daniel Braun[1], and Olivier Giraud[2] — [1]Institut für theoretische Physik, Universität Tübingen, 72076 Tübingen, Germany — [2]LPTMS, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France

The recent emergence of small quantum processors in quantum information technology has seen the increasing need of characterizing their behavior as "truly" quantum mechanical or not. Already for an unknown quantum state, verifying whether the statistics arising from it can be explained by a classical state is challenging, as long as non-classicality measures or witnesses are based on full tomography. Which is then the most efficient measurement strategy to prove that a state is entangled (or more generally: non-classical)? We tackle this problem by introducing the statistics of lengths of measurement sequences that allow one to certify entanglement across a given bi-partition of a multi-qubit system over the possible sequence of measurements of random unknown states. Perfectly suited for this approach is the formalism of "truncated moment sequences", that allows one to deal naturally with incomplete information about a quantum state. We use it to identify the best measurement strategy in the sense of the (on average) shortest measurement sequence of (multi-qubit) Pauli-measurements. We find that the set of measurements corresponding to diagonal entries of the moment matrix associated to the state are particularly efficient. For symmetric states their number grows like the third power of the number of qubits and their efficiency increases rapidly with that number.

FM 11.6 Mon 15:30 2004

Many-body entanglement criteria and the truncated moment problem — •Bharath H. M.[1] and Grigoriy Blekherman[2] — [1]Fakultät für Physik, LMU München — [2]School of Mathematics, Georgia Tech

A central problem in quantum technologies is to prepare, measure and control many-body entangled states. The latter has applications in quantum information, communication and metrology. A mathematical challenge in this problem is to develop criteria to decide whether a many-body state prepared in the lab is entangled based on a small number of measured observables. While instances of this problem have been addressed by several measures of entanglement, the general problem itself scales unfavorably in the number of atoms. We show that this problem is related to the so-called truncated moment problem, well known in convex algebraic geometry, and that a powerful set of tools is available to tackle it. The space of separable mixed states is convex and so is the space of the corresponding observable values. Therefore, the problem of determining whether a set of observable values come from an entangled state is tantamount to checking for membership in a convex set, also known as a moment cone, of a point with coordinates given by the set of observable values. The latter is an instance of the truncated moment problem. Here, we develop asymptotically tight criteria for entanglement in a many-body system of bosonic atoms by importing techniques from convex algebraic geometry [1].

[1] Grigoriy Blekherman and Bharath Hebbe Madhusudhana, arXiv: 1904.00072.

FM 11.7 Mon 15:45 2004

Entanglement witnesses 2.0 : entanglement witnesses can be compressed — •Joonwoo Bae[1], Dariusz Chruscinski[2], and Beatrix Hiesmayr[3] — [1]School of Electrical Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea — [2]Institute of Physics, Faculty of Physics, Astronomy, and Informatics, Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland — [3]University of Vienna, Faculty of Physics, Boltzmanngasse 5, 1090 Vienna, Austria

An entanglement witness is an observable detecting entanglement for a subset of states. We present a framework that makes an entanglement witness twice as powerful due to the general existence of a second (lower) bound, in addition to the (upper) bound of the very definition. This second bound, if non-trivial, is violated by another subset of entangled states. Differently stated, we prove via the structural physical approximation that two witnesses can be compressed into a single one. Consequently, our framework shows that any entanglement witness can be upgraded to a witness 2.0. The generality and its power are demonstrate by applications to bipartite and multipartite qubit/qudit systems.