Q 2: Quanteninformation: Konzepte und Methoden 1

Time: Monday 10:30–12:45 Location: V7.03

Q 2.1 Mon 10:30 V7.03

Towards classification of multipartite entanglement — •Cornelia Spee, Julio de Vicente, and Barbara Kraus — Institut für Theoretische Physik, Universität Innsbruck, Austria

The investigation of the entanglement properties of multipartite systems is generally very hard due to the exponential growth of the dimension of the Hilbert space as a function of the number of constituent systems. In order to scope with these difficulties we consider on the one hand certain subsets of multipartite states and on the other hand small system sizes. In both approaches the aim is to classify multipartite entanglement and to find new applications of multipartite entangled states.

Regarding the considered subsets, we investigate the entanglement properties and applications of so-called locally maximally entanglable states (LMESs), which is a physically motivated class of multipartite states. We showed for instance that any M-state, which is relevant in the context of simulatability of quantum algorithms, can be prepared by a single one-qubit measurement on a LMES. Regarding the entanglement properties of few-qubit systems, we derived for instance a state which can be used as a universal resource for the generation of arbitrary 3-qubit states and investigated its entanglement properties.

Q 2.2 Mon 10:45 V7.03

Quantifying entanglement via static structure factors — •Hermann Kampermann[1], Marcus Cramer[2], Fabian Wolf[1], Oliver Marty[2], Alexander Streltsov[1], Martin Plenio[2], and Dagmar Bruss[1] — [1]Institut für theoretische Physik III, Universität Düsseldorf, Germany — [2]Institut für theoretische Physik, Universität Ulm, Germany

The static structure factor is a global and accessible observable in experimental setups like e.g. in neutron scattering. Recently it was shown how to use such structure factors as entanglement witnesses and entanglement monotones [1,2]. We generalize these concepts to structure factors with arbitrary spin, and compare different types of witnesses as well as entanglement monotones.

[1] P. Krammer et al., Phys. Rev. Lett. 103, 100502 (2009)
[2] M. Cramer et al., Phys. Rev. Lett. 106, 020401 (2011)

Q 2.3 Mon 11:00 V7.03

Characteristic Properties of Fibonacci-Based Mutually Unbiased Bases — •Ulrich Seyfarth[1], Kedar Ranade[2], and Gernot Alber[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Institut für Quantenphysik, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Complete sets of mutually unbiased bases (MUBs) offer interesting applications in quantum information processing ranging from quantum cryptography to quantum state tomography.

Different construction schemes provide different perspectives on these bases which are typically also deeply connected to various mathematical research areas. In this talk we discuss characteristic properties resulting from a recently established connection between construction methods for cyclic MUBs and Fibonacci polynomials [1,2]. As a remarkable fact this connection leads to construction methods which do not involve any relations to mathematical properties of finite fields. This work was supported by CASED.

Q 2.4 Mon 11:15 V7.03

Scaling of genuine multipartite entanglement in one dimensional spin chains — •Martin Hofmann and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Walter-Flex-Straße 3, Universität Siegen

The study of entanglement in quantum phase transitions can help towards a general understanding of spin models. Especially one dimensional spin chains proved to be suitable to obtain analytic results. In Ref. [1] the scaling of two-qubit entanglement close to a quantum phase transition is investigated.

We extend their work from the investigation of bipartite entanglement to the phenomenon of genuine multipartite entanglement in three-particle reduced states. In order to quantify the entanglement we used the computable entanglement monotone for multi-particle entanglement arising from the approach of PPT mixtures [2]. Interestingly the genuine multipartite entanglement showed a similar scaling behaviour as the bipartite entanglement in Ref. [1].

[1] A. Osterloh *et al.*, Nature **416**, 608-610 (2002).
[2] B. Jungnitsch *et al.*, Phys. Rev. Lett. **106**, 190502 (2011)

Q 2.5 Mon 11:30 V7.03

Purification to locally maximally entanglable states — •Tatjana Carle, Julio de Vicente, and Barbara Kraus — Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck

We present a multipartite purification protocol for a certain class of multipartite entangled quantum states, the so-called locally maximally entanglable (LME) states. The LME states form a large class of multipartite entangled quantum states which can for example be used to encode optimally the maximal number of classical bits and which contains prominent subclasses such as stabilizer states and graph states. There exist already multipartite purification protocols for graph and stabilizer states. However, since the stabilizer of the LME states are in general non-local we had to develop new methods which go beyond the commonly used CNOT-procedure. One of the main challenges was to find protocols to access and process the non-local information contained in the states using only local operations and classical communication.

Q 2.6 Mon 11:45 V7.03

Entanglement spectrum and boundary theories with projected entangled-pair states — Ignacio Cirac[1], Didier Poilblanc[2], •Norbert Schuch[3], and Frank Verstraete[4] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Laboratoire de Physique Theorique, C.N.R.S. and Universite de Toulouse, Toulouse, France — [3]California Institute of Technology, Pasadena, USA — [4]Universität Wien, Vienna, Austria

In many physical scenarios, close relations between the bulk properties of quantum systems and theories associated to their boundaries have been observed. In this work, we provide an exact duality mapping between the bulk of a quantum spin system and its boundary using Projected Entangled Pair States (PEPS). This duality associates to every region a Hamiltonian on its boundary, in such a way that the entanglement spectrum of the bulk corresponds to the excitation spectrum of the boundary Hamiltonian. We study various models and find that a gapped bulk phase with local order corresponds to a boundary Hamiltonian with local interactions, whereas critical behavior in the bulk is reflected on a diverging interaction length of the boundary Hamiltonian. Furthermore, topologically ordered states yield non-local Hamiltonians. As our duality also associates a boundary operator to any operator in the bulk, it in fact provides a full holographic framework for the study of quantum many-body systems via their boundary.

Q 2.7 Mon 12:00 V7.03

Accessible nonlinear entanglement witnesses. — •Oleg Gittsovich[1,2], Juan Miguel Arrazola[1,2], and Norbert Lütkenhaus[1,2] — [1]Institute for Quantum Computing, University of Waterloo, 200 University Avenue West, N2L 3G1 Waterloo, Ontario, Canada — [2]Department of Physics and Astronomy, University of Waterloo, 200 University Avenue West, N2L 3G1 Waterloo, Ontario, Canada

Deciding whether a given quantum state is entangled or not is a difficult task. In a vast majority of experiments entanglement witnesses are used in order to prove presence of entanglement. Entanglement witnesses can be constructed from available measurement results and do not require reconstruction of the whole density matrix (full tomography). We provide a method to construct *accessible nonlinear entanglement witnesses*, which incorporate two important properties. First, they improve linear entanglement witnesses and as a result detect more entangled states with high statistical significance. Second, we can go from evaluating linear entanglement witnesses to their nonlinear counterpart without additional experimental effort, which makes them attractive for implementations in current experiments.

Q 2.8 Mon 12:15 V7.03

Gaussification and entanglement distillation of continuous

variable systems: a unifying picture — •Earl Campbell and Jens Eisert — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

Distillation of entanglement using only Gaussian operations is an important primitive in quantum communication, quantum repeater architectures, and distributed quantum computing. Existing distillation protocols for continuous degrees of freedom are only known to converge to a Gaussian state when measurements yield precisely the vacuum outcome. In sharp contrast, non-Gaussian states can be deterministically converted into Gaussian states while preserving their second moments, albeit by usually reducing their degree of entanglement. In this work – based on a novel instance of a non-commutative central limit theorem – we introduce a picture general enough to encompass the known protocols leading to Gaussian states, and also demonstrate convergence for a class of new protocols. This gives the experimental option of balancing the merits of success probability against entanglement produced. The generality of results also opens up entirely new territory, by providing means of multi-partite distillation and more efficient hybrid quantum repeater schemes.

http://arxiv.org/abs/1107.1406 In press at Phys. Rev. Lett

Q 2.9 Mon 12:30 V7.03

Multipartite entanglement in Grover's algorithm — •Matteo Rossi[1], Dagmar Bruss[2], and Chiara Macchiavello[1] — [1]Dipartimento di Fisica "A. Volta" and INFN-Sezione di Pavia, Via Bassi 6, I-27100 Pavia, Italy — [2]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

We compute the entanglement of the multiqubit quantum states employed in the Grover algorithm, by following its dynamics at each step of the computation. We quantify it by the geometric measure of entanglement, focusing on both the entanglement of any kind and the genuine multipartite entanglement. We show that multipartite entanglement is always present at each step and that its dynamics is independent of the number of qubits n for a large n, thus exhibiting a scale invariance property. Moreover, we study the classical simulatability of the algorithm under different perspectives and simulation protocols.