FRI 7: Entanglement and Complexity: Contributed Session to Symposium III

Time: Friday 10:45–12:15 Location: ZHG008

FRI 7.1 Fri 10:45 ZHG008

Entanglement theory with limited computational resources — Lorenzo Leone, Jacopo Rizzo, Jens Eisert, and •Sofiene Jerbi — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Germany

The precise quantification of the ultimate efficiency in manipulating quantum resources lies at the core of quantum information theory. However, purely information-theoretic measures fail to capture the actual computational complexity involved in performing certain tasks. In this work, we rigorously address this issue within the realm of entanglement theory. We consider two key figures of merit: the computational distillable entanglement and the computational entanglement cost, quantifying the optimal rate of entangled bits (ebits) that can be extracted from or used to dilute many identical copies of n-qubit bipartite pure states, using computationally efficient LOCC. We demonstrate that computational entanglement measures diverge significantly from their information-theoretic counterparts. While the von Neumann entropy captures information-theoretic rates for pure-state transformations, we show that under computational constraints, the min-entropy instead governs optimal entanglement distillation. Meanwhile, efficient entanglement dilution requires maximal ($\tilde{\Omega}(n)$) ebits even for nearly unentangled states. Our results establish a stark, maximal separation of $\tilde{\Omega}(n)$ vs o(1) between computational and information-theoretic entanglement measures. Finally, we find new sample-complexity bounds for measuring and testing the von Neumann entropy, efficient state compression, and efficient LOCC tomography protocols.

FRI 7.2 Fri 11:00 ZHG008

Quantum Magic and Entanglement in Nuclear Many-Body Systems — •Federico Rocco[1], James W. T. Keeble[1], and Caroline Robin[1,2] — [1]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, D-64291 Darmstadt, Germany

Concepts of quantum information science shed light on the complexity of quantum many-body systems, providing new insights into the structure of matter and emergence of degrees of freedom. Nonstabilizerness, or magic, is related to the amount of non-Clifford resources required to perform a quantum simulation and has emerged as a central quantity in the study of quantum complexity. Beyond that, estimates of non-local magic between different partitions of the nuclear system can uncover many-body correlations not captured by entanglement. In this talk, I will discuss investigations of magic and non-local magic based on stabilizer Rényi entropies in atomic nuclei, as well as the connection between quantum complexity, emergent collective behavior and shape deformation.

FRI 7.3 Fri 11:15 ZHG008

Revealing continuous-variable entanglement through derivatives of phase-space distributions — •Elena Callus[1], Martin Gärttner[1], and Tobias Haas[2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena — [2]Institute of Theoretical Physics, Universität Ulm

The Peres–Horodecki, or positive partial transpose, criterion is a necessary condition for bipartite separability, and its violation is sufficient to certify the presence of entanglement. In this work, we explore the implication of this criterion on phase-space distributions of separable states. More specifically, we show that one can formulate separability criteria in terms correlations of phase-space distributions, together with their spatial derivatives, at arbitrary points in phase space. This approach complements work on certification of nonclassicality by means of such distributions [1]. We demonstrate the versatility of this approach by considering the relevance of low-ordered criteria in certifying entanglement in important classes of states. Finally, we also discuss possible experimental approaches in order to access these entanglement witnesses.

[1] M. Bohmann, E. Agudelo, and J. Sperling, “Probing nonclassicality with matrices of phase-space distributions”, Quantum 4, 343 (2020).

FRI 7.4 Fri 11:30 ZHG008

Demonstration of verified BosonSampling — •Naomi Spier[1], Redlef B G Braamhaar[1], Riko Schadow[2], Sara Marzban[1], Jens Eisert[2], Nathan Walk[2], and Jelmer J Renema[1] — [1]University of Twente — [2]Freie Universität Berlin

Sampling from random quantum circuits has been proposed as a first demonstration of a concrete computational advantage for special purpose, non-universal quantum processors. Whilst ideal sampling implementations have extremely strong complexity theoretic arguments for their classical intractability, real sampling devices are vulnerable to the potential existence of efficient, classical simulation algorithms and the status of many claimed advantage demonstrations remains contested. The original sampling proposal, BosonSampling, involves the propagation of single photon states through a random linear optical interferometer and has received significant attention, especially due to the rapid increase in the size, quality and configurability of integrated photonic waveguides. Whilst photon loss errors are immediately apparent from the data, errors due interferometer imperfections and photon distinguishability can also destroy quantum advantage but are more challenging to quantify. In this work, utilising recently developed photonic fidelity witnesses, we carry out a proof-of-principle, efficient verification of a BosonSampler using an integrated, reconfigurable interferometer. The verification is shown to detect errors due to interferometer noise, distinguishability and Poissonian photon sources.

FRI 7.5 Fri 11:45 ZHG008

Purification of Noisy Measurements and Faithful Distillation of Entanglement — •Jaemin Kim, Jiyoung Yun, and Joonwoo Bae — School of Electrical Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea

We consider entanglement distillation with noisy operations in which quantum measurements that constitute a general quantum operation are particularly noisy. We present a protocol for purifying noisy measurements and show that imperfect local operations can distill entanglement. The protocol works for arbitrary noisy measurements in general and is cost-effective and resource-efficient with single additional qubit per party to resolve the distillation of entanglement. The purification protocol is feasible with currently available quantum technologies and readily applied to entanglement applications.

FRI 7.6 Fri 12:00 ZHG008

Entangled subspaces through algebraic geometry — •Masoud Gharahi[1] and Stefano Mancini[2] — [1]University of Trieste, Trieste, Italy — [2]University of Camerino, Camerino, Italy

We propose an algebraic geometry-inspired approach for constructing entangled subspaces within the Hilbert space of a multipartite quantum system. Specifically, our method employs a modified Veronese embedding, restricted to the conic, to define subspaces within the symmetric part of the Hilbert space. By utilizing this technique, we construct the minimal-dimensional, non-orthogonal yet Unextendible Product Basis (nUPB), enabling the decomposition of the multipartite Hilbert space into a two-dimensional subspace, complemented by a Genuinely Entangled Subspace (GES) and a maximal-dimensional Completely Entangled Subspace (CES). In multiqudit systems, we determine the maximum achievable dimension of a symmetric GES and demonstrate its realization through this construction. Furthermore, we systematically investigate the transition from the conventional Veronese embedding to the modified one by imposing various constraints on the affine coordinates, which, in turn, increases the CES dimension while reducing that of the GES.