QI 34: Concepts and Methods III

Time: Friday 11:00–13:00 Location: B302

QI 34.1 Fri 11:00 B302

Quantum Bell Inequalities from Information Causality — •Prabhav Jain[1], Mariami Gachechiladze[1], and Nikolai Miklin[2] — [1]TU Darmstadt, Germany — [2]Heinrich-Heine-Universität Düsseldorf, Germany

Characterizing the set of quantum correlations in the space of all possible non-signalling theories is a hard but important problem. For a given Bell scenario, quantum bell inequalities which bound the set of possible observed correlation are relevant not only as a theoretical interest but for several applications such as QKD etc. A fundamental goal is to 'derive' this quantum set from physical/empirical principles without assuming any of the formalism.

In this work, we propose to use information causality as one such physical principle. We derive new quantum Bell inequalities for arbitrary measurement settings and outcomes in a bipartite scenario while improving on some previous known results by obtaining the tightest bounds so far for such scenarios. We also investigate how our new polynomial inequalities in the observed probability distributions relate to other well known principles such as macroscopic locality and almost quantum correlations.

QI 34.2 Fri 11:15 B302

Solution of the convex single-body quantum marginal problem and its physical relevance — •Julia Liebert[1], Federico Castillo[2], Jean-Philippe Labbé[3], Arnau Padrol[4], Eva Philippe[4], Rolando Reiner[1], and Christian Schilling[1] — [1]University of Munich (LMU), Munich, Germany — [2]Pontificia Universidad Catolica de Chile, Macul, Chile — [3]École de Technologie Supérieure, Montréal, Canada — [4]Sorbonne Université, Paris, France

The single-body quantum marginal problem asks whether given single-body reduced density matrices are compatible to some multipartite quantum state. In a recent breakthrough, A. Klyachko has solved this general problem on an abstract mathematical level. Urged by the limited scope of that solution to artificially small quantum systems, we explain why the convex-relaxed variant of that compatibility problem is the more relevant one for practical purposes. By using tools from convex analysis, we then provide a comprehensive solution to the latter problem for any multipartite quantum state with a fixed spectrum, leading to a complete hierarchy of necessary and sufficient spectral constraints which are valid for systems of arbitrary size. In the context of fermions and bosons, these novel conditions lead to a physical relevant generalization of Pauli's famous exclusion principle.

QI 34.3 Fri 11:30 B302

Compensating for non-linear distortions in controlled quantum systems — •Juhi Singh[1,2], Robert Zeier[1], Tommaso Calarco[1,2], and Felix Motzoi[1] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8), 52425 Jülich, Germany — [2]Institute for Theoretical Physics, University of Cologne, 50937 Köln, Germany

Predictive design and optimization methods for controlled quantum systems depend on the accuracy of the system model. Any distortion of the input fields in an experimental platform alters the model accuracy and eventually disturbs the predicted dynamics. These distortions can be non-linear with a strong frequency dependence so that the field interacting with the microscopic quantum system has limited resemblance to the input signal. We present an effective method for estimating these distortions which is suitable for non-linear transfer functions of arbitrary lengths and magnitudes provided the available training data has enough spectral components. Using a quadratic estimation, we have successfully tested our approach for a numerical example of a single Rydberg atom system. The transfer function estimated from the presented method is incorporated into an open-loop control optimization algorithm allowing for high-fidelity operations in quantum experiments.

QI 34.4 Fri 11:45 B302

Entanglement Batteries — •Ye-Chao Liu, Otfried Gühne, and Stefan Nimmrichter — Universität Siegen, Siegen, Germany

Quantum entanglement is an essential resource for many kinds of applications like quantum communication over a quantum network, eventually realizing the quantum internet. The unavoidable noise and losses between the links call for additional hardware that can gradually build up and store entanglement for later use – an entanglement battery.

In this contribution, we introduce the concept of entanglement batteries charged by repeated interactions with a provided stream of Bell pairs. We show that, although perfect SWAP and iSWAP gates can both fully charge entanglement batteries using Bell states, their behaviors differ significantly if the charging interaction strength is restricted to a partial swap or even fluctuates. We compare two exemplary charging protocols: one that repeatedly uses a single Bell state for charging, and another one that uses a fresh Bell state for each charging step. We further assess the performance of entanglement charging under losses.

QI 34.5 Fri 12:00 B302

Device-independent randomness extraction from almost separable multipartite states — •Giacomo Carrara, Federico Grasselli, Hermann Kampermann, Dagmar Bruss, and Gláucia Murta — Heinrich-Heine-Universität Düsseldorf

Bell inequalities represent a fundamental tool for many quantum information tasks that exploit nonlocality. In particular they can be used for device-independent (DI) protocols, where the parties do not need to trust or characterize the underlying systems and measurement devices. Specifically, the violation of a Bell inequality allows to certify the randomness of the parties' outcomes with respect to a potential eavesdropper. Even though entanglement is necessary for the violation of a Bell inequality, the relation between nonlocality and entanglement is more intricate than one might expect. In [*Phys. Rev. Lett.*, **108**, 100402 (2012)] the authors show that maximal DI randomness can be obtained, in the bipartite scenario, from almost separable states. In this work, we extend this result to the multipartite scenario. In particular, we analyze the amount of randomness that can be extracted from a state arbitrarily close to a fully separable state using a suitably chosen multipartite Bell inequality. In order to achieve this result, we employ both standard numerical convex optimization and analytical methods.

QI 34.6 Fri 12:15 B302

Symmetry restoration of mean-field approaches: Rationalization through quantum information theory — •Javier Faba[1,2], Vicente Martín[1], Luis Robledo[2], Lexin Ding[3], and Christian Schilling[3] — [1]Center for Computational Simulation, Universidad Politécnica de Madrid, Campus Montegancedo, 28660 Boadilla del Monte, Madrid, Spain — [2]Departamento de Física Teórica and CIAFF, Universidad Autónoma de Madrid, 28049 Madrid, Spain — [3]Faculty of Physics, Arnold Sommerfeld Centre for Theoretical Physics (ASC), Ludwig-Maximilians-Universität München, Theresienstr. 37, 80333 München, Germany

The quantum many-body problem is of central importance in various subfields of the quantum sciences, particularly in quantum chemistry, solid state and nuclear physics. A promising solution strategy — developed and primarily used so far only in nuclear physics — is based on the following wisdom: Starting from a mean-field solution one systematically improves the variational energy by introducing different levels of quantum correlation through a restoration of the symmetries broken by the former.

In this talk, we will rationalize this general wisdom by providing a concise definition of quantum correlation in this context. To be more specific, we will explain how quantum information concepts can help us in order to describe the correlation structure of mean field and symmetry restored ground states of relevant models that exhibit spontaneous symmetry breaking of both abelian and non abelian symmetries.

QI 34.7 Fri 12:30 B302

Rescaling decoder for 2D topological quantum color codes on 4.8.8 lattices — Pedro Parrado Rodriguez[1], •Manuel Rispler[2,3], and Markus Müller[2,3] — [1]Department of Physics, College of Science, Swansea University, — [2]Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany — [3]Peter Grünberg Institute, Theoretical Nanoelectronics, Forschungszentrum Jülich, D-52425 Jülich, Germany

Fault-tolerant quantum computation relies on scaling up quantum error correcting codes in order to suppress the error rate on the encoded quantum states. Topological codes, such as the surface code or color codes, are leading candidates for practical scalable quantum error correction and require efficient and scalable decoders. In this work, we propose and study the efficiency of a decoder for two-dimensional topological color codes on the 4.8.8 lattice (also known as the square-octagon code), by building on the work of Sarvepalli and Raussendorf [Phys. Rev. A 85, 022317 (2012)], for color codes on hexagonal lattices. The decoder is based on a rescaling approach, in which syndrome information on a part of the qubit lattice is processed locally, and then the lattice is rescaled iteratively to smaller sizes. We find a threshold of 6.0% for code capacity noise.

QI 34.8 Fri 12:45 B302

Exploiting Graph Symmetries for Quantum Dynamics Algorithmically — •Armin Johannes Römer[1,2], Robert Zeier[3], and Thomas Schulte-Herbrüggen[1,4,5] — [1]Technische Universität München (TUM) — [2]Forschungszentrum Jülich GmbH, IEK-9 — [3]Forschungszentrum Jülich GmbH, PGI-8 (Quantum Control) — [4]Munich Center for Quantum Science and Technology (MCQST) — [5]Munich Quantum Valley e.V. (MQV)

Coupled n-level systems (spins) can classically be represented as coloured graphs, where vertices relate to local spins and differently coloured edges stand for pairwise couplings of different type.

We present an efficient algorithm to exploit graph symmetries for arriving at symmetry-adapted bases. Its core scales classically with the number of spins as vertices of the graph: *its input is merely the graph's adjacency matrix*, it avoids calculating the underlying graph automorphism group, *and its output is a transformation matrix into a symmetry adapted basis.* It connects the Weisfeiler-Leman algorithm, known from graph isomorphism problems, with cutting-edge versions of calculating central idempotents in MAGMA.

We demonstrate how classical graph symmetry carries over to quantum Hilbert space. Worked examples illustrate principles and practice in a manner applicable to, e.g., quantum simulation, quantum dynamics, and quantum information.