QI 20: Concepts and Methods II

Time: Wednesday 14:30–16:30 Location: B302

QI 20.1 Wed 14:30 B302

Entropy and catalysis — •HENRIK WILMING — Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

I discuss the solution of the "catalytic entropy conjecture", showing that von Neumann entropy can be characterized in the following way: Non-decreasing entropy provides a necessary and sufficient condition to convert the state of a physical system into a different state by a reversible (unitary) transformation that acts on the system of interest and a further, finite-dimenaionsal, "catalyst" whose state has to remain invariant exactly under the unitary time-evolution.

QI 20.2 Wed 14:45 B302

Foundations of fermionic particle correlations — •DAMIANO ALIVERTI-PIURI, KAUSTAV CHATTERJEE, LEXIN DING, and CHRISTIAN SCHILLING — LMU University, Faculty of Physics, Munich

Multipartite systems are an essential topic in Quantum information theory, and a comprehensive theory has been developed regarding the several kinds of correlations they can exhibit. Such correlations, especially entanglement, are both interesting on a theoretical level, and useful for quantum processing tasks. Our starting point is the well-established definitions of uncorrelated, classically correlated, and unentangled states of multipartite systems - for example, distinguishable particles. To these three sets of states correspond three correlation measures, based on geometric ideas: total correlation, quantum correlation, and relative entropy of entanglement. Inspired by recent work by other authors (Gigena and Rossignoli; Gottlieb and Mauser), we propose a systematic approach towards particle correlations in systems of *indistinguishable* particles, with an emphasis on fermions. We (i) give definitions of types of increasingly correlated fermionic states, and of the respective geometric correlation measures; (ii) motivate our definitions from the point of view of Resource theory; (iii) study some promising properties of these states and measures; (iv) obtain analytical formulas for 2-fermion systems and other simple cases.

QI 20.3 Wed 15:00 B302

Resource Theory of Fermionic Correlation — •KAUSTAV CHATTERJEE, DAMIANO ALIVERTI PIURI, LEXIN DING, and CHRISTIAN SCHILLING — Faculty of Physics, Arnold Sommerfeld Centre for Theoretical Physics, Ludwig-Maximilian-University of Munich, Germany

Resource theories are a generic approach used to manage any valuable resource, such as entanglement, purity and asymmetry. Such settings provide a novel framework to discuss information theoretic tasks like quantum state transformations and characterizing the utility of quantum states with respect to some resource measure. Analogous to resource theories of correlations and entanglement for distinguishable parties, we establish a hierarchy of resource theories for indistinguishable fermionic systems where each theory corresponds to a specific resource involving fermionic total correlation, fermionic quantum correlation or fermionic entanglement. In our theory, easily implementable operations (the free operations) are related to the set of fermionic linear optics (FLO) operations and their extensions, which naturally selects out the subset of Gaussian states as a candidate for free states in particular case where the resource is fermionic total correlations. We also introduce monotones (based on quantum relative entropy) to quantify the hierarchy of resources and explore quantum state transformation properties under such theories. We further comment on efficient classical simulation of our free operations and reveal how non-free resource states can be connected to the idea of complexity of fermionic sampling

QI 20.4 Wed 15:15 B302

Continuity of robustness measures in quantum resource theories — JONATHAN SCHLUCK, GLÁUCIA MURTA, HERMANN KAMPERMANN, DAGMAR BRUSS, and •NIKOLAI WYDERKA — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, D-40225 Düsseldorf, Germany

Robustness measures provide an intuitive and operational way to quantify resources in quantum resource theories, such as entanglement and coherence. Despite exhibiting useful mathematical properties like monotonicity, the use of robustness measures is hindered by the fact that some of their properties like continuity remain unclear, in particular when the set of resource-free states is non-convex. To that end, we investigate continuity properties of different robustness measures by showing that their continuity depends on the shape of the set of free states. In particular, we show that in many cases star-convexity is sufficient for Lipschitz-continuity, and we provide specific examples of sets leading to non-continuous robustness measures. Finally, we illustrate the applicability of our results by introducing the robustness of teleportation fidelity and by deriving bounds on the robustness of quantum discord.

QI 20.5 Wed 15:30 B302

Graph state preparation with noisy interactions — •KONRAD SZYMANSKI — Universität Siegen, Siegen, Germany

Graph states are regarded as a testing ground of various quantum information schemes – they are useful in analysis of e.g. cryptography, measurement-based quantum computation, error correction, and metrology. Their preparation relies on the interaction pattern provided by a graph – an Ising-like Hamiltonian $\hat{H}$ is built from it and the *graph state* is the result of evolution of the multiqubit $|+\rangle^{\otimes N}$ state under $\hat{H}$. Due to the simplicity, implementation is possible for a wide array of physical systems, including ion traps, nitrogen vacancies, and superconducting qubits.

However, such realizations invariably suffer from noise, which presents itself in a multitude of ways: the engineered interactions may have imperfect strengths, additional transitions may arise, and the systems rarely can be protected from coupling with the outside world.

All of these contribute to the reduced utility of the produced quantum states. Here, I investigate the effects of *preparation noise* in this context. In particular, imperfect interaction strengths effectively lead to an *ensemble* of graph states being prepared, which still possess some of the desirable qualities of the *perfectly prepared* state. Theoretical considerations are compared with real-world implementations of graph states.

QI 20.6 Wed 15:45 B302

Computational Complexity in Functional Theory — •LUKAS KIENESBERGER, JULIA LIEBERT, and CHRISTIAN SCHILLING — University of Munich (LMU), Munich, Germany

Using tools from quantum information theory, we investigate the computational complexity of calculating the universal energy functional in functional theories. Firstly, we prove for the two-fermion Hubbard model that the space of density matrices constituting the functional's domain decomposes into exponentially many regions, separated by submanifolds where the functional fails to be analytic. As our second main result, we show that determining the functional itself on those cells is weakly np-complete. We demonstrate how these findings contradict the generally accepted assumption of a single analytic functional. Third, we analyze and quantify the relations between the number of subdomains and the spectrum of a generic interaction.

QI 20.7 Wed 16:00 B302

On a Matrix Ensemble for Arbitrary Complex Quantum Systems — WILLIAM SALAZAR and •JAVIER MADROÑERO — Centre for Bioinformatics and Photonics (CIBioFi), Universidad del Valle, Cali, Colombia

We propose a specific system dependent matrix ensemble as an alternative to the unitary Haar one as a model for the study of the late time dynamics of correlation functions in arbitrary complex quantum systems. We show that for arbitrary systems this ensemble yields an unitary 1-design and for strongly chaotic systems it becomes an approximated 2-design. We are able to provide universal expressions for two- and four-point ensemble-averaged correlation functions. Additionally, we show that for small energy windows our ensemble reduces to the eigenstate thermalization hypothesis.

QI 20.8 Wed 16:15 B302

Exact Unification of Spacetime, Gravity and Quanta — •HANS-OTTO CARMESIN — Gymn. Athenaeum, Harsefelder Str. 40, 21680 Stade — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

Quantum physics, QP, and its relation to general relativity, GR, provide an exciting problem of physics [1]. That problem is solved as follows [2]: Firstly, a quadruple of four basic principles, the spacetime quadruple, SQ, is identified: Gaussian gravity, special relativity, the equivalence principle and the physical reality of cosmological vacuum. In particular, we introduce a measurement of a gravitational parallax distance r by using a pair of hand leads. So, that distance is an element of physical reality. Secondly, the dynamics of cosmological vacuum, VD, is derived from the SQ. Thirdly, the postulates [3] of quantum physics and GR are derived from VD. Fourthly, solutions for the essential paradoxes of QP are provided. In particular, consequences for quantum information are discussed.

[1] Einstein, A. and Podolski, B. and Rosen, N. (1935): Can the quantum-mechanical description of physical reality be considered complete? Phys. Rev., 47, pp. 777-780.

[2] Carmesin, H.-O. (December 2022): Unification of Spacetime, Gravity and Quanta. Berlin: Verlag Dr. Köster.

[3] Ballentine, L. (1998): Quantum Mechanics. London - Singapore: World Scientific Publishing.