QI 14: Quantum Foundations

Time: Friday 9:30–12:30 Location: H9

Invited Talk QI 14.1 Fri 9:30 H9

Testing quantum theory with generalized noncontextuality — •Markus P. Müller[1,2,3] and Andrew J. P. Garner[1] — [1]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria — [2]Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — [3]Perimeter Institute for Theoretical Physics, 31 Caroline Street North, Waterloo, ON N2L 2Y5, Canada

It is a fundamental prediction of quantum theory that states of physical systems are described by complex vectors or density operators on a Hilbert space. However, many experiments admit effective descriptions in terms of other state spaces, such as classical probability distributions or quantum systems with superselection rules. Here, we ask which probabilistic theories could reasonably be found as effective descriptions of physical systems if nature is fundamentally quantum. To this end, we employ a generalized version of noncontextuality: processes that are statistically indistinguishable in an effective theory should not require explanation by multiple distinguishable processes in a more fundamental theory. We formulate this principle in terms of embeddings and simulations of one probabilistic theory by another, show how this concept subsumes standard notions of contextuality, and prove a multitude of fundamental results on approximate embeddings. We show how results on Bell inequalities can be used for the robust certification of generalized contextuality, and use this to propose a novel type of experimental test of quantum theory.

QI 14.2 Fri 10:00 H9

Proposal for demonstrating hidden nonlocality without assumptions — •Jonathan Steinberg, H. Chau Nguyen, and Matthias Kleinmann — University of Siegen, Siegen, Germany

A quantum state with hidden nonlocality does not violate any Bell inequality unless its hidden nonlocality is activated using local filters. This phenomenon has been demonstrated in experiments, however only when special Bell inequalities are considered [Kwiat et al., Nature 409, 1014 (2001)], or under the assumption that the quantum state is constrained to a special form which has a known local hidden variable [Opt. Express 28, 13638 (2020)]. Developing a general method for constructing local models for bipartite systems of a qubit and a qudit, we propose a protocol which allows one to conclusively demonstrate hidden nonlocality which is free from assumptions on both, the form of Bell inequalities and the special form of the state. By an optimization over the states and measurement directions we obtain that the required precision is within reach of near future experiments.

QI 14.3 Fri 10:15 H9

Non-locality with overlapping marginals — •Moisés Bermejo Morán — Jagiellonian University, Krakow, Poland

We investigate how non-locality can be shared in multi-partite physical systems. Going beyond the standard scenario with disjoint subsystems, we focus on the case where the subsystems participating in the Bell inequality can have overlap. The analytical methods are limited in generality and the standard numerical tools do not effectively provide good bounds when measurements with overlapping support are involved. We overcome these limitations by considering the Navascués-Pironio-Acín hierarchy for finite-dimensional systems, for a fixed dimension. Finding the optimal value via convex combinations of random states and PVMs. These allow us to find non-trivial monogamy bounds in simple scenarios.

QI 14.4 Fri 10:30 H9

Optimal convergence rate in the quantum Zeno effect for open quantum systems in infinite dimensions — •Tim Möbus and Cambyse Rouzé — Technical University Munich, Germany

In open quantum systems, the quantum Zeno effect consists in frequent applications of a given quantum operation, e.g. a measurement, used to restrict the time evolution (due e.g. to decoherence) to states that are invariant under the quantum operation. In an abstract setting, the Zeno sequence is an alternating concatenation of a contraction operator (quantum operation) and a strongly continuous contraction semigroup (time evolution) on a Banach space. In this paper, we prove the optimal convergence rate of order $1/n$ of the Zeno sequence by proving explicit error bounds. For that, we derive a new Chernoff-type lemma, which we believe to be of independent interest. Moreover, we generalize the Zeno effect in two directions: We weaken the assumptions on the generator, which induce a Zeno dynamics generated by an unbounded generator and we improve the convergence to the uniform topology. Finally, we provide a large class of examples arising from our assumptions.

QI 14.5 Fri 10:45 H9

Gravitational redshift induces quantum interference — •David Edward Bruschi[1] and Andreas Wolfgang Schell[2,3] — [1]Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, Jülich, Germany — [2]Institut für Festkörperphysik, Leibniz Universität Hannover, Hannover, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We use quantum field theory in curved spacetime to show that gravitational redshift induces a unitary transformation on the quantum state of propagating photons. This occurs for realistic photons characterized by a finite bandwidth, while ideal photons with sharp frequencies do not transform unitarily. We find that the transformation is a mode-mixing operation, and we devise a protocol that exploits gravity to induce a Hong-Ou-Mandel-like interference effect on the state of two photons. Testing the results of this work can provide a demonstration of quantum field theory in curved spacetime.

15 min. break

QI 14.6 Fri 11:15 H9

Dynamical Theories in Phase-Space: The Almost Hydrogen Atom — •Martin Plávala and Matthias Kleinmann — Universität Siegen, Siegen, Deutschland

We construct a large class of operational theories of hydrogen atom that includes both classical and quantum theory as special cases. We show that one can formulate a well-defined theory of stationary bound states even without uniquely defined time-evolution and we prove that the ground state energy is finite only if the theory exhibits preparation uncertainty relation between position and momentum observables. We perturb the Hamiltonian by including external magnetic field, which leads to breaking of the degeneracy of the energy spectrum; in this setting we show that the magnetic quantum number is bounded by the principal quantum number, similarly as in quantum theory. We also perturb the Hamiltonian by nonstationary electric field and we show that this leads to excitations of the atom. Finally we investigate scattering theory where we show that Rutherford formula for scattering holds in all investigated operational theories.

QI 14.7 Fri 11:30 H9

Uncertainty relations with the variance and the quantum Fisher information — •Géza Tóth[1,2,3,4] and Florian Fröwis[5] — [1]Theoretical Physics and EHU Quantum Center, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]Donostia International Physics Center (DIPC), E-20080 San Sebastián, Spain — [3]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [4]Wigner Research Centre for Physics, H-1525 Budapest, Hungary — [5]Group of Applied Physics, University of Geneva, CH-1211 Geneva, Switzerland

We present several inequalities related to the Robertson-Schrödinger uncertainty relation. In all these inequalities, we consider a decomposition of the density matrix into a mixture of states, and use the fact that the Robertson-Schrödinger uncertainty relation is valid for all these components. By considering a convex roof of the bound, we obtain an alternative derivation of the relation in Fröwis et al. [Phys. Rev. A 92, 012102 (2015)], and we can also list a number of conditions that are needed to saturate the relation. We present a formulation of the Cramér-Rao bound involving the convex roof of the variance. By considering a concave roof of the bound in the Robertson-Schrödinger uncertainty relation over decompositions to mixed states, we obtain an improvement of the Robertson-Schrödinger uncertainty relation. We consider similar techniques for uncertainty relations with three variances. Finally, we present further uncertainty relations that provide lower bounds on the metrological usefulness of bipartite quantum states in two-mode and two-spin systems.

QI 14.8 Fri 11:45 H9

Geometry of expectation values of non-commuting observables — •Konrad Szymanski — Universität Siegen, Siegen, Deutschland

Non-commutativity lies at the heart of quantum theory and provides a rich set of mathematical and physical questions. Here, I address this topic through the concept of the Joint Numerical Range (JNR) – the set of simultaneously attainable expectation values for multiple quantum observables, which in general need not commute. I discuss mathematical and physical implications of the geometry of JNR: classification of the possible shapes of the set, as well as development of novel uncertainty relations, entanglement and Schmidt rank witnesses, and detection of vanishing energy gap.

QI 14.9 Fri 12:00 H9

Measurement-based models of friction and dissipative collapse — •Michael Gaida and Stefan Nimmrichter — Universität Siegen

Collapse models are objective modifications of quantum theory that aim to solve the measurement problem. One of the most studied models is the Continuous Spontaneous Localisation (CSL) model and its dissipative extension. We present a protocol based on randomly occurring Gaussian position measurements and unitary feedback operations that reproduces the single particle dynamics of dissipative CSL. Inspired by this protocol, we introduce a class of measurement-based models, implementing classical friction forces. We find that the specific model for linear Stokes friction reproduces the single-particle dissipative CSL master equation, as well.

QI 14.10 Fri 12:15 H9

Transcendental properties of entropy-constrained sets — •Vjosa Blakaj[1,2] and Michael Wolf[1,2] — [1]Technical University of Munich — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

For information-theoretic quantities with an asymptotic operational characterization, the question arises whether an alternative single-shot characterization exists, possibly including an optimization over an ancilla system. If the expressions are algebraic and the ancilla is finite, this leads to semialgebraic level sets. In this work, we provide a criterion for disproving that a set is semialgebraic based on an analytic continuation of the Gauss map. Applied to the von Neumann entropy, this shows that its level sets are nowhere semialgebraic in dimension $d > 2$, ruling out algebraic single-shot characterizations with finite ancilla (e.g., via catalytic transformations). We show similar results for related quantities, including the relative entropy, and discuss under which conditions entropy values are transcendental, algebraic, or rational.