Workshop on
Mathematical Physics meets Quantum Information Theory

Hôtel Classic Leysin (Vaud)

June 23-28, 2019

Colloquium Talks – invited Speakers

Nicolas Brunner (U Geneva)

Title :

Constraints on physical correlations in networks

Abstract :

The no-signaling principle imposes constraints on physical correlations. Here we consider this issue in the context of networks, where independent sources distribute physical resources to distant nodes. Surprisingly, we find that no-signaling imposes strong constraints on correlations in networks, even when considering network scenarios without inputs. We give an intuitive understanding of this effect, and derive strong constraints for the well- known "triangle network" without inputs.

Vadim Cheianov (Leiden)

Title :

Adiabatic protocols in driven many-body systems and the orthogonality catastrophe

Abstract :

Quantum adiabatic protocols are routines in which the Hamiltonian of a quantum system undergoes gradual deformation from a given initial to a given final value. Adiabaticity means that the routine is performed slowly enough to ensure complete control, in some well-defined sense, over the system's quantum state. Adiabatic protocols offer a natural framework for coherent quantum state manipulation, therefore the last several years have been marked by increasing interest in their practical implementation. The existence of an adiabatically slow regime for every quantum protocol is guaranteed by the adiabatic theorem established by Born and Fock as early as 1928. However, the practically important question as to what specific conditions are needed to ensure adiabaticity of a given protocol remains a hard and largely unresolved problem. Here I discuss how this gap can be bridged for a broad natural class of physical systems, namely, many-body systems where a small move in the parameter space induces an orthogonality catastrophe. In this class, the conditions for adiabaticity are derived from the scaling properties of the parameter-dependent ground state without a reference to the excitation spectrum. This finding constitutes a major simplification of a complex problem, which otherwise requires solving nonautonomous time evolution in a large Hilbert space.

Matthias Christandl (U Copenhagen)

Title :

Tensor network representations from the geometry of entangled states

Abstract :

Tensor network states provide successful descriptions of strongly correlated quantum systems with applications ranging from condensed matter physics to cosmology. Any family of tensor network states possesses an underlying entanglement structure given by a graph of maximally entangled states along the edges that identify the indices of the tensors to be contracted. Recently, more general tensor networks have been considered, where the maximally entangled states on edges are replaced by multipartite entangled states on plaquettes. Both the structure of the underlying graph and the dimensionality of the entangled states influence the computational cost of contracting these networks. Using the geometrical properties of entangled states, we provide a method to construct tensor network representations with smaller effective bond dimension. We illustrate our method with the resonating valence bond state on the kagome lattice.

Elizabeth Crosson (U New Mexico)

Title :

TBA

Abstract :

TBA

Nilanjana Datta (U Cambridge)

Title :

Convergence rates for quantum evolution & entropic continuity bounds in infinite dimensions

Abstract :

How fast do infinite-dimensional quantum systems evolve? How fast can entropies of infinite-dimensional quantum systems change?

These are the questions that will addressed in this talk. By extending the concept of energy-constrained diamond norms, we obtain continuity bounds on the dynamics of both closed and open quantum systems in infinite-dimensions, which are stronger than previously known bounds. Our results have interesting applications including quantum speed limits, attenuator and amplifier channels, the quantum Boltzmann equation, and quantum Brownian motion. Next, we obtain explicit log-Lipschitz continuity bounds for entropies of infinite-dimensional quantum systems, and classical capacities of infinite-dimensional quantum channels under energy-constraints. These bounds are determined by the high energy spectrum of the underlying Hamiltonian and can be evaluated using Weyl's law.

This is joint work with Simon Becker.

Jens Eisert (FU Berlin)

Title :

Towards closing the loopholes of showing a quantum advantage

Abstract :

Quantum devices promise the efficient solution of problems out of reach for classical computers. However, before reaching the ultimate goal of realizing Shor-class fault tolerant quantum computers, one has to unambiguously show the possibility of a quantum advantage in the first place. In this talk, we will discuss prospects of achieving a complexity-theoretic quantum advantage that both lives up to mathematically rigorous standards and is practically feasible. On the mathematical technical level, we will see how proof techniques of anti-concentration bounds, of black-box verification and of average-case complexity come into play. On a more physical level, we will elaborate on how such schemes may be realized with realistic near-term quantum devices.

Omar Fawzi (ENS Lyon)

Title :

Lyapunov exponents and entropy accumulation

Abstract :

Lyapunov exponents describe the asymptotic behavior of the singular values of large products of random matrices. A direct computation of these exponents is however often infeasible. Inspired by a connection to the tool of entropy accumulation studied in quantum information theory, we derive an analytical upper and lower bound for the maximal and minimal Lyapunov exponent, respectively. Based on joint work with Renato Renner and David Sutter available at https://arxiv.org/abs/1905.03270

Jürg Fröhlich (ETH Zürich)

Title :

Demystifying Quantum Mechanics - the ETH Approach

Abstract :

New Foundations of Quantum Mechanics are proposed: the "E T H - Approach to Quantum Mechanics" where "E" stands for Events, "T" for Trees, and "H" for Histories. This approach enables us to introduce a precise notion of "events" into Quantum Mechanics, explain what it means to observe an event by recording the value of an appropriate physical quantity, and to exhibit the stochastic dynamics of states of isolated open systems featuring events. The "ETH - Approach to QM" results in a "Quantum Theory without observers". It does away with "extensions of Quantum Mechanics", all of which have remained unacceptably vague.

Nicolas Gisin (U Geneva)

Title :

Quantum Non-Locality in Networks

Abstract :

Quantum non-locality, i.e. the violation of some Bell inequality, has proven to be an extremely useful concept in analyzing entanglement, quantum randomness and cryptography, among others. In particular, it led to the fascinating field of device-independent quantum information processing. Historically, the idea was that the particles emitted by various quantum sources carry additional variables, known as local hidden variables. The more modern view, strongly influenced by computer science, refers to these additional variables merely as shared randomness. This, however, leads to ambiguity when there is more than one source, as in quantum networks. Should the randomness produced by each source be considered as fully correlated, as in most common analyses, or should one analyze the situation assuming that each source produces independent randomness, closer to the historical spirit? The latter is known, for the case of n independent sources, as n-locality. For example, in entanglement swapping there are two sources, hence "quantumness" should be analyzed using 2-locality (or, equivalently, bi-locality). The situation when the network has loops is especially interesting. Recent results for triangular networks will be presented.

Gian Michele Graf (ETH Zurich)

Title :

Indirect Measurements of a Harmonic Oscillator

Abstract :

The measurement of a quantum system becomes itself a quantum-mechanical process once the apparatus is internalized. That shift of perspective may result in different physical predictions about measurement outcomes for a variety of reasons. In fact, whereas the ideal measurement, as described by Born's rule, is instantaneous, the apparatus produces an outcome over time. In contrast to the often purported view that perfect measurement emerges in the long-time limit, because decoherence supposedly improves with time, it is found that the operation may be of transient character. Following an initial time interval, during which the system under observation and the apparatus remain uncorrelated, there is a ``window of opportunity'' during which suitable observables of the two systems are witnesses to each other. After that time window however, the apparatus is dominated by noise, making it useless.

These conclusions are drawn from a model describing both system and apparatus and consisting of a harmonic oscillator coupled to a field.

The equation of motion is a quantum stochastic differential equation. By solving it we establish different time scales relevant to the measurement process, including a classical and noisy large-time limit.

(Joint work with Martin Fraas and Lisa Hänggli.)

David Gross (U Cologne)

Title :

The representation theory of the Clifford group, with applications to quantum information and to Howe duality

Abstract :

TBA

Alexander Holevo (Steklov Mathematical Institute, Moscow).

Title :

TBA

Abstract :

TBA

Michal Horodecki (U Gdansk)

Title :

Topics in quantum non-locality

Abstract :

In this talk I will cover recent developments in different topics within the larger field of quantum non-locality, such as Bell inequalities, limits for embezzling, and port-based teleportation.

Arthur Jaffe (Harvard)

Title :

The Quon Language for Quantum Information.

Abstract :

The Quon Picture Language was introduced in joint work with Zhengwei Liu and Alex Wozniakowski. It has proved very useful in quantum information and in other areas of mathematical physics.

Robert Koenig (TU Munich)

Title :

Quantum advantage with noisy shallow circuits in 3D

Abstract :

Prior work has shown that there exists a relation problem which can be solved with certainty by a constant-depth quantum circuit composed of geometrically local gates in two dimensions, but cannot be solved with high probability by any classical constant depth circuit composed of bounded fan-in gates. Here we provide two extensions of this result. Firstly, we show that a separation in computational power persists even when the constant-depth quantum circuit is restricted to geometrically local gates in one dimension. The corresponding quantum algorithm is the simplest we know of which achieves a quantum advantage of this type. It may also be more practical for future implementations. Our second, main result, is that a separation persists even if the shallow quantum circuit is corrupted by noise. We construct a relation problem which can be solved with near certainty using a noisy constant-depth quantum circuit composed of geometrically local gates in three dimensions, provided the noise rate is below a certain constant threshold value. On the other hand, the problem cannot be solved with high probability by a noise-free classical circuit of constant depth. A key component of the proof is a quantum error-correcting code which admits constant-depth logical Clifford gates and single-shot logical state preparation. We show that the surface code meets these criteria. To this end, we provide a protocol for single-shot logical state preparation in the surface code which may be of independent interest.
This is joint work with Sergey Bravyi, David Gosset and Marco Tomamichel.

Zhengwei Liu (Harvard)

Title :

Quantum Graphs and Error Corrections

Abstract :

Graph theory is important in information theory. We will give a quantum analogue of graphs using quon language and apply that to quantum information. We will discuss some examples for quantum error corrections.

Mark Wilde (Louisiana State University)

Title :

Resource theory of asymmetric distinguishability

Abstract :

We systematically develop the resource theory of asymmetric distinguishability, as initiated roughly a decade ago [K. Matsumoto, arXiv:1006.0302 (2010)]. The key constituents of this resource theory are quantum boxes, consisting of a pair of quantum states, which can be manipulated for free by means of an arbitrary quantum channel. We introduce bits of asymmetric distinguishability as the basic currency in this resource theory, and we prove that it is a reversible resource theory in the asymptotic limit, with the quantum relative entropy being the fundamental rate of resource interconversion. The distillable distinguishability is the optimal rate at which a quantum box consisting of independent and identically distributed (i.i.d.) states can be converted to bits of asymmetric distinguishability, and the distinguishability cost is the optimal rate for the reverse transformation. Both of these quantities are equal to the quantum relative entropy. The exact one-shot distillable distinguishability is equal to the Petz--Renyi relative entropy of order zero, and the exact one-shot distinguishability cost is equal to the max-relative entropy. Generalizing these results, the approximate one-shot distillable distinguishability is equal to the hypothesis testing relative entropy, and the approximate one-shot distinguishability cost is equal to the smooth max-relative entropy. As a notable application of the former results, we prove that the optimal rate of asymptotic conversion from a pair of i.i.d. quantum states to another pair of i.i.d. quantum states is fully characterized by the ratio of their quantum relative entropies. In forthcoming work, we extend these results to quantum channels, forming the dynamical resource theory of asymmetric distinguishability. This is joint work with Xin Wang of QuICS at University of Maryland.