FOCUS WEEK 2: FOUNDATIONS

TITLES AND ABSTRACTS

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MINICOURSE (3 hours)

Speaker: Matthias Christandl

Title: Multiparticle entanglement

Abstract: The quantum state of a system of k particles can be viewed as a tensor of order k. Local stochastic operations on a quantum state correspond to the application of linear maps to the indices of the corresponding tensor and are studied in entanglement theory and implemented in current quantum information science experiments.
Interestingly, the notion of tensor transformation is at the heart of the study of the computational complexity of algebraic problems such as the multiplication of matrices. Strassen's breakthrough algorithm for the multiplication of d-by-d matrices that runs faster than your standard d^3 high-school algorithm spurred a whole development of tensor theory.
In these lectures, I will explain these connections in the case k = 3 and show how they elucidate our understanding of both entanglement and matrix multiplication. I will do so within the framework of resource theories and will argue that multiparticle entanglement (despite its complications), is one of the best understood resource theories within quantum information theory. Finally, I will discuss the case of higher order tensors (k>>3) and in particular tensor networks.

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TALKS

Speaker: Nicholas Gisin

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.

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Speaker: Barbara Kraus

Title: Symmetries and entanglement of multipartite states

Abstract: Symmetries play an important role in physics. Moreover, they are essential in the study of state transformations and SLOCC classes.
In this talk I will focus on the characterization of symmetries and entanglement properties of subsets of states which, on the one hand, are tractable and, on the other, are physically relevant as they naturally appear in certain physical contexts. In particular, I will concentrate on Matrix Product States (MPS) that describe translationally invariant systems (with periodic boundary conditions) [1] and on stabilizer states [2], which play a prominent role in Quantum Information Theory.

[1] D. Sauerwein, A. Molnar, J. I. Cirac, B. Kraus, Matrix Product States: Entanglement, symmetries, and state transformations, arXiv:1901.07448 (2019)

[2] M. Englbrecht, R. Brieger, D. Sauerwein, B. Kraus, in preparation (2019)

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Speaker: Debbie Leung

Title: Embezzlement and applications

Abstract: Embezzlement of entanglement is the (impossible) task of
producing an entangled state from a product state via a local change
of basis, when a suitable *catalytic* entangled state is available.
The possibility to approximate this task was first observed by van Dam
and Hayden in 2002. In this talk, we show how embezzlement can be
used to obtain an explicit nonlocal game that cannot be played
optimally with finite amount of entanglement with tight trade-off
between winning probability and dimension of the entangled state
shared by the players. We also derive properties of entanglement
measures using embezzlement.

Referenes: 0201041, 0804.4118, 1802.04926, 1904.02350 (arXiv:quant-ph)
Players: van Dam, Hayden, Toner, Watrous, Ji, Vidick, Coladangelo

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Speaker: Jonathan Oppenheim

Title: A post-quantum theory of classical gravity

Abstract: We present a consistent theory of classical gravity coupled to quantum field theory. The dynamics is linear in the density matrix, completely positive and trace-preserving, and reduces to Einstein's equations in the classical limit. The assumption that gravity is classical necessarily modifies the dynamical laws of quantum mechanics -- the theory must be fundamentally stochastic involving finite sized and probabilistic jumps in the space-time metric and in the quantum field. Nonetheless the quantum state of the system can remain pure conditioned on the classical degrees of freedom. The measurement postulate of quantum mechanics is not needed since the interaction of the quantum degrees of freedom with classical space-time necessarily causes collapse of the wave-function. More generally, we derive a form of classical-quantum dynamics using a non-commuting divergence which has as its limit deterministic classical Hamiltonian evolution, and which doesn't suffer from the pathologies of the semi-classical theory.

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Speaker: Renato Renner

Title: What quantum computers can tell us about quantum theory

Abstract: While quantum theory has been confirmed by countless experiments, it is still an open question whether its validity extends to complex systems, such as (full-fledged) quantum computers. In my talk, I will study this question from the viewpoint of a "multi-agent" thought experiment. The underlying idea is to ask whether it is possible to program a quantum computer (which takes the role of one agent) with the

laws of quantum theory in such a way that it can consistently describe and make predictions about other quantum computers (corresponding to other agents). It turns out that this is not the case in general. This shows that a straightforward extrapolation of standard quantum theory to complex systems is problematic.

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Speaker: Andreas Winter

Title: Resource theories of quantum channels and the universal role of resource erasure

Abstract: We initiate the systematic study of resource theories of quantum channels, i.e. of the dynamics that quantum systems undergo by completely positive maps, in abstracto: Resources are in principle all maps from one quantum system to another, but some maps are deemed free. The free maps are supposed to satisfy certain axioms, among them closure under tensor products, under composition and freeness of the identity map (the latter two say that the free maps form a monoid). The free maps act on the resources simply by tensor product and composition. This generalizes the much-studied resource theories of quantum states, and abolishes the distinction between resources (states) and the free maps, which act on the former, leaving only maps, divided into resource-full and resource-free ones. We discuss the axiomatic framework of quantifying channel resources, and show two general methods of constructing resource monotones of channels. Furthermore, we show that under mild regularity conditions, each resource theory of quantum channels has a distinguished monotone, the robustness (and its smoothed version), generalizing the analogous concept in resource theories of states. We give an operational interpretation of the log-robustness as the amount of heat dissipation (randomness) required for resource erasure by random reversible free maps, valid in broad classes of resource theories of quantum channels. Technically, this is based on an abstract version of the recent convex-split lemma, extended from its original domain of quantum states to ordered vector spaces with sufficiently well-behaved base norms (which includes the case of quantum channels with diamond norm or variants thereof). Finally, we remark on several key issues concerning the asymptotic theory. [Jointly with Zi-Wen Liu, 1904.04201]

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Speaker: Michael Wolf

Title: Zeno and the bomb

Abstract: The talk will revisit the Quantum Zeno effect and its application for interaction-free channel discrimination. The first part of the talk discusses a generalization of the Quantum Zeno effect to time-dependent open-system dynamics interrupted by general quantum operations. The second part addresses the question

when the Quantum Zeno effect of a general quantum channel enables interaction-free channel discrimination in the spirit of the Elitzur-Vaidman 'bomb tester'.

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