Quantum Information Theory
Théorie quantique de l'information
(Org: **Nathaniel Johnston** (Mount Allison) and/et **Sarah Plosker** (Brandon))

XIAONING BIAN, Dalhousie University
Generators and relations for 3-qubit Clifford+CS operators

This is a work in progress. We found a finite presentation of the group G of 3-qubit Clifford+CS operators in terms of generators and relations. The proof is easy — applying a known method to a known result. The calculation is non-trivial, which involves simplifying hundreds of long equations. Our main contribution is the simplification method. Its idea is factoring a group into a product of cosets, in other words, finding a "nice" tower of group extensions starting from the trivial group to the group in focus. The ongoing part is to check our result in proof assistant Agda.

JASON CRANN, Carleton University
Gaussian quantum information over general kinematical systems

Mathematically, quantum kinematical systems with finitely many degrees of freedom are described by a locally compact abelian group G and a cocycle. The cocycle induces a symplectic (i.e., phase space) structure on $G \times \widehat{G}$, which encodes the canonical commutation relations of the associated (projective) Weyl representation. Such abstract quantum kinematical systems have been studied from a variety of perspectives, including finite-dimensional approximations, uncertainty relations and generalized metaplectic/Clifford operators. In this work, we continue this program by developing a formalism to study Gaussian states and channels for general quantum kinematical systems.

I will quickly review the phase space formulation for bosonic/qudit systems and discuss its generalization to abstract (2-regular) Weyl systems. I will then introduce Gaussian states and channels for abstract Weyl systems and discuss some of our main results, including a complete characterization of Gaussian states for arbitrary Weyl systems, and single letter formulae for the quantum capacities and minimum output entropies for arbitrary Gaussian channels over finite Weyl systems.

ERIC CULF, University of Ottawa
Rigidity for Monogamy-of-Entanglement Games

In a monogamy-of-entanglement (MoE) game, two players who do not communicate try to simultaneously guess a referee's measurement outcome on a shared quantum state they prepared. We study the prototypical example of a game where the referee measures in either the computational or Hadamard basis and informs the players of her choice.

We show that this game satisfies a rigidity property similar to what is known for some nonlocal games. That is, in order to win optimally, the players' strategy must be of a specific form, namely a convex combination of four unentangled optimal strategies generated by the Breidbart state. To show this, we appeal to a positivity argument via a sum-of-squares decomposition satisfied by the game polynomial. We extend this result to show that strategies that win near-optimally must also be near an optimal state of this form. We also show rigidity for multiple copies of the game played in parallel.

As an application, we show that this can be used to achieve bit commitment in a model where it is impossible classically.

FRANK FU, Dalhousie University
Programming quantum circuits with Proto-Quipper

Proto-Quipper is a family of quantum programming languages that formalizes various aspects of Quipper. In this talk, I will demonstrate a prototype of Proto-Quipper that supports linear types, dependent types, circuit boxing and dynamic lifting. I will show how these features are used in programming quantum circuits.

MICHAEL KOZDRON, University of Regina
A Quantum Martingale Convergence Theorem

It is well-known in quantum information theory that a positive operator valued measure (POVM) is the most general kind of quantum measurement. A quantum probability is a normalised POVM, namely a function on certain subsets of a (locally compact and Hausdorff) sample space that satisfies the formal requirements for a probability and whose values are positive operators acting on a complex Hilbert space. A quantum random variable is an operator valued function which is measurable with respect to a quantum probability. In this talk, we will discuss a quantum analogue of the Lebesgue dominated convergence theorem and use it to prove a quantum martingale convergence theorem (MCT). In contrast with the classical MCT, the quantum MCT exhibits non-classical behaviour; even though the limit of the martingale exists and is unique, it is not explicitly identifiable. Fortunately, a partial classification of the limit is possible through a study of the space of all quantum random variables having quantum expectation zero. Based on joint work with Kyler Johnson.

LARISSA KROELL, University of Waterloo
An operator system view on regular quantum graphs

Quantizing aspects of classical graphs has led to various equivalent definitions of a quantum graph. One definition comes from quantizing the edge relation, which leads to a specific operator system. Under certain circumstances, this can be viewed as a quantization of a classical confusability graph. Another approach involves quantizing the adjacency matrix, which leads to a concept called the quantum adjacency operator. We give an overview of the different notions of quantum graphs and discuss how to translate between them. Then, using the quantum adjacency operator perspective, we introduce a quantum notion of regularity. We show that this leads to a basis condition on the corresponding operator system for quantum graphs on full matrix algebras.

DEBBIE LEUNG, University of Waterloo
The platypus of the quantum channel zoo and their generic nonadditivity

Understanding quantum channels and the strange behavior of their capacities is a key objective of quantum information theory. One approach is to develop the menagerie of the diverse and complex phenomena displayed by quantum channels. To this end, we construct several families of quantum channels with exotic quantum information-theoretic features. The simplest example of the first family is obtained by gluing together a maximally useful and a completely useless qubit channel, and the resulting channel is unlike either of the constituent channels, and unlike any other known class of channels. In particular, it has additive quantum, private and classical capacity expressions, but the private capacity is significantly larger than the quantum capacity, and the channel has superadditive quantum capacity when used jointly with many other generically chosen channels. While part of the above results rely on a convincing conjecture, we construct a second related family of channels and prove similar results unconditionally.

Joint work with Felix Leditzky, Vikesh Siddhu, Graeme Smith, John Smolin

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JEREMY LEVICK, University of Guelph
Generalizing a result of Watrous on Mixed Unitarity

We show some avenues for generalizing a result of Watrous that there is a ball around the completely depolarizing channel consisting of all mixed-unitary unital channels. We also discuss some applications.

SHIRIN MOEIN, Mount Allison University
Absolutely k-Incoherent Quantum States and Spectral Inequalities for Factor Width of a Matrix

Coherence quantifies the amount of superposition and quantum states, k-incoherence is a refinement of this property. Based on the eigenvalues, we investigate the set of quantum states that can be shown to be k-incoherent. The absolute separability problem asks for a characterization of which quantum states can be determined to be separable based only on their eigenvalues, we introduce the corresponding "absolute" question for the resource theory of k-coherence. To this end, absolutely k-incoherent quantum states are introduced, and several necessary and sufficient conditions for them are derived.

This is joint work with Dr. Nathaniel Johnston, Dr. Rajesh Pereira, and Dr. Sarah Plosker.

CARLO MARIA SCANDOLO, University of Calgary

The operational foundations of PT-symmetric and quasi-Hermitian quantum theory

PT-symmetric quantum theory was originally proposed with the aim of extending standard quantum theory by relaxing the Hermiticity constraint on Hamiltonians. However, no such extension has been formulated that consistently describes states, transformations, measurements and composition, which is a requirement for any theory. We aim to answer the question of whether a consistent theory with PT-symmetric observables extends standard quantum theory. We work within the framework of general probabilistic theories, which is the most general framework for physical theories. We construct the set of states of a system with PT-symmetric observables, and show that the resulting theory allows only one trivial state. We then analyze one of the most popular fixes to the issues of PT-symmetric quantum theory, which is the requirement of quasi-Hermiticity on observables. After showing that quasi-Hermitian systems are equivalent to standard quantum systems, we prove that if PT-symmetry is added on top of quasi-Hermiticity, then the system is equivalent to a real quantum system. Thus our results show that neither PT-symmetry nor quasi-Hermiticity constraints are sufficient to extend standard quantum theory consistently.

THOMAS THEURER, University of Calgary

Resource theories of operations

The question where quantum mechanics differs from classical physics is not only of interest, but has technological implications too. To address it in a systematic manner, so-called quantum resource theories were developed. These are mathematical frameworks that emerge from restrictions that are put on top of the laws of quantum mechanics and single out specific aspects of quantum theory as resources. It is then investigated how these restrictions influence our abilities to do certain tasks, how these restrictions can be overcome, and how the resulting resources can be quantified. Historically, resource theories were mainly focused on the resources present in quantum states. In this talk, I will speak about how these concepts can be extended to quantum operations. This allows us to describe quantum resources that cannot be captured in resource theories of states and leads to various interesting applications.

YUMING ZHAO, University of Waterloo

An operator-algebraic formulation of self-testing

We give a new definition of self-testing for quantum correlations in terms of states on C^*-algebras. We show that this definition is equivalent to the standard definition for any class of finite-dimensional quantum models which is closed under submodels and direct sums, provided that the correlation is extreme and has a full-rank model in the class. This last condition automatically holds for the class of POVM quantum models, but does not necessarily hold for the class of projective models by a result of Mančinska and Kaniewski. For extreme binary correlations and for extreme synchronous correlations, we show that any self-test for projective models is also a self-test for all POVM models. The question of whether there is a self-test for projective models which is not a self-test for POVM models remains open.

An advantage of our new definition is that it extends naturally to commuting operator models. We show that an extreme correlation is a self-test for finite-dimensional quantum models if and only if it is a self-test for finite-dimensional commuting operator models, and also observe that many know finite-dimensional self-tests are in fact self-tests for infinite-dimensional commuting operator models.

Joint work with Connor Paddock, William Slofstra, and Yangchen Zhou