QuILT Day
Wednesday, August 12, 2020

MEETING ROOM

All presentations from 9:15am–4:15pm CDT will be held online on Zoom.

PROGRAM

9:15–9:30	Samuel Bentley (Vice President of LSU ORED) and Ryan Glasser — Introduction and in memoriam of Jonathan P. Dowling and Ward Plummer
9:30–10:00	Sai Vinjanampathy — Generalized measure of quantum synchronization
10:00–10:30	Gerard McCaul — Low-rank approximations for open system evolution
10:30–10:45	Break
10:45–11:15	Peter Bierhorst — Tsirelson polytope approximations of the quantum set and device-independent quantum information
11:15–11:45	Vishal Katariya — Geometric distinguishability measures limit quantum channel estimation and discrimination
11:45–12:15	Stav Haldar — Special and general relativistic effects in quantum-interference experiments
12:15–13:15	Lunch Break
13:15–13:45	Narayan Bhusal — Spatial mode correction of single photons using machine learning
13:45–14:15	Kurt Jacobs — Roll over Bloch-Redfield: your Lindbladian upgrade has arrived
14:15–14:30	Break
14:30–15:00	Wenlei Zhang — Robust polarimetry via convex optimization
15:00–15:30	Kahlil Dixon — Optomechanical entanglement
15:30–15:45	Break
15:45–16:15	Kunal Sharma — Reformulation of the no-free lunch theorem for entangled data sets

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ABSTRACTS
(in alphabetical order by speaker surname)

Speaker: **Narayan Bhusal** (Louisiana State University)
Title: *Spatial mode correction of single photons using machine learning*
Abstract: Spatial modes of light constitute valuable resources for a variety of quantum technologies ranging from quantum communication and quantum imaging to remote sensing. Nevertheless, their vulnerabilities to phase distortions, induced by random media upon propagation, impose significant limitations on the realistic implementation of numerous quantum-photonic technologies. Unfortunately, this problem is exacerbated at the single-photon level. Over the last two decades, this challenging problem has been tackled through conventional schemes that utilize optical nonlinearities, quantum correlations, and adaptive optics. We exploit the self-learning and self-evolving features of artificial neural networks to correct the complex spatial profile of distorted Laguerre-Gaussian modes at the single-photon level. Specifically, we demonstrate the possibility of correcting spatial modes distorted by thick atmospheric turbulence. Our results have important implications for real-time turbulence correction of structured photons and single-photon images.

Speaker: **Peter Bierhorst** (University of New Orleans)
Title: *Tsirelson polytope approximations of the quantum set and device-independent quantum information*
Abstract: I will discuss the results of arXiv:2003.12636, in which Zhang and I classified the extreme points of polytopes of probability distributions in the (2,2,2) CHSH-Bell setting that are induced by Tsirelson bounds and studied the application of these constructions to device-independent random number generation. I will then discuss future research directions exploring how these constructions and other convex properties of the quantum set can be applied more generally to device-independent quantum information tasks. I will finally talk about an open postdoctoral position at UNO.

Speaker: **Kahlil Dixon** (Louisiana State University)
Title: *Optomechanical entanglement*
Abstract: Previously, we explored experimentally accessible parameter spaces to understand the efficacy of optomechanical entangling of two coherent states. Here, we present a theoretical prediction based on the same two-photon and quantum Langevin frameworks of the output of such devices when squeezed light is input into the cavity. In this study we focus on one and two-mode squeezed light. We find an increase in the overall squeezing in the one single-mode input relative to no squeezing. Perhaps consequently, we find an enhanced entanglement effect for two single-mode squeezed inputs. However, the two-mode squeezed input yields zero output entanglement.

Speaker: **Stav Haldar** (Louisiana State University)
Title: *Special and general relativistic effects in quantum-interference experiments*
Abstract: We investigate the Hong-Ou-Mandel (HOM) effect — a two-photon quantum-interference effect — in the space-time of a rotating spherical mass. In particular, we analyze a common-path HOM setup restricted to the surface of the earth and show that, in principle, general-relativistic frame-dragging induces observable shifts in the HOM dip. For completeness and correspondence with current literature, we also analyze the emergence of gravitational time-dilation effects in HOM interference, for a dual-arm configuration. The formalism thus presented establishes a basis for encoding general-relativistic effects into local, multi-photon, quantum-interference experiments. Demonstration of these instances would signify genuine

observations of quantum and general relativistic effects, in tandem, and would also extend the domain of validity of general relativity, to the arena of quantized electromagnetic fields.

Speaker: **Kurt Jacobs** (U.S. Army Research Laboratory and University of Massachusetts Boston)
Title: *Roll over Bloch-Redfield: your Lindbladian upgrade has arrived*
Abstract: Realistic models of quantum systems must include dissipative interactions with a thermal environment. For weakly-damped systems, while the Lindblad-form Markovian master equation is invaluable for this task, it applies only when the frequencies of any subset of the system's transitions are degenerate, or their differences are much greater than the transitions' linewidths. Outside of these regimes the only available efficient description has been the Bloch-Redfield (B-R) master equation, the efficacy of which has long been controversial due to its failure to guarantee the positivity of the density matrix. The ability to efficiently simulate weakly-damped systems across all regimes is becoming increasingly important, especially in quantum technologies. Here we solve this long-standing problem by deriving a Lindblad-form master equation for weakly-damped systems that is accurate for all regimes. We further show that when this master equation breaks down, so do all time-independent Markovian equations, including the B-R equation. We thus obtain a replacement for the B-R equation for thermal damping that is no less accurate, simpler in structure, completely positive, allows simulation by efficient quantum trajectory methods, and unifies the previous Lindblad master equations. We also show via exact simulations that the new master equation can describe systems in which slowly-varying transition frequencies cross each other during the evolution. System identification tools, developed in systems engineering, play an important role in our analysis. We expect these tools to prove useful in other areas of physics involving complex systems.

Speaker: **Vishal Katariya** (Louisiana State University)
Title: *Geometric distinguishability measures limit quantum channel estimation and discrimination*
Abstract: Quantum channel estimation and discrimination are fundamentally related information processing tasks of interest in quantum information science. We analyze these tasks by employing the right logarithmic derivative Fisher information and the geometric Rényi relative entropy, respectively, identifying connections between these distinguishability measures. A key result of our paper is a chain-rule property for the right logarithmic derivative Fisher information and the geometric Rényi relative entropy for the Rényi parameter $\alpha \in (0, 1)$. In channel estimation, these results imply a condition for the unattainability of Heisenberg scaling, while in channel discrimination, they lead to improved bounds on error rates in the Chernoff and Hoeffding error exponent settings. More generally, we introduce the amortized quantum Fisher information as a conceptual framework for analyzing general sequential protocols that estimate a parameter encoded in a quantum channel. We then identify a number of other conceptual and technical connections between the tasks of estimation and discrimination and the distinguishability measures involved in analyzing each.

Speaker: **Gerard McCaul** (Tulane University)
Title: *Low-rank approximations for open system evolution*
Abstract: One of the main issues in quantum dynamics (for quantum information and computing in particular) is the modelling and simulation of environmental effects. This is of critical importance, given the need for quantum technology to preserve fragile coherences against environmental noise. Unfortunately the modelling of such open systems is numerically expensive, given the requirement that one must evolve a density matrix rather than a wavefunction. This makes the investigation of environmental effects on "realistic" systems extremely challenging. Here we present a low-rank approximation for the evolution of a density matrix, which for systems of dimension N is approximately a factor of N faster than exact methods. We demonstrate this model's effectiveness in describing the dissipative evolution of a single qubit, a spin-chain, and a system of interacting electrons. In particular, we find that at weak environmental couplings this method is significantly faster and more accurate than other approximate methods, such as Monte Carlo random jumps.

Speaker: **Kunal Sharma** (Louisiana State University)
Title: *Reformulation of the no-free lunch theorem for entangled data sets*
Abstract: The No-Free-Lunch (NFL) theorem is a celebrated result in learning theory that limits one's ability to learn a function with a training data set. With the recent rise of quantum machine learning, it is natural to ask whether there is a quantum analog of the NFL theorem, which would restrict a quantum computer's ability to learn a unitary process (the quantum analog of a function) with quantum training data. However, in the quantum setting, the training data can possess entanglement, a strong correlation with no classical analog. In this work, we show that entangled data sets lead to an apparent violation of the (classical) NFL theorem. This motivates a reformulation that accounts for the degree of entanglement in the training set. As our main result, we prove a quantum NFL theorem, whereby the fundamental limit on the learnability of a unitary is reduced by entanglement. We employ Rigetti's quantum computer to test both the classical and quantum NFL theorems. Our work establishes that entanglement is a commodity in quantum machine learning.

Speaker: **Sai Vinjanampathy** (Indian Institute of Technology-Bombay)
Title: *Generalized measure of quantum synchronization*
Abstract: I will introduce the emerging field of quantum synchronization with examples. I will then discuss a generalized information-theoretic measure of synchronization that is applicable to study the dynamics of anharmonic oscillators, few-level atoms, and coupled oscillator networks. In many cases of interest, I will present closed-form expressions for the proposed measure. Based on arXiv:2006.13623 with Noufal Jaseem *et al.*

Speaker: **Wenlei Zhang** (Tulane University)
Title: *Robust polarimetry via convex optimization*
Abstract: We present mathematical methods, based on convex optimization, for correcting non-physical coherency matrices measured in polarimetry. We also develop the method for recovering the coherency matrices corresponding to the smallest and largest values of the degree of polarization given the experimental data and a specified tolerance. We use experimental non-physical results obtained with the standard polarimetry scheme and a commercial polarimeter to illustrate these methods. Our techniques are applied in post-processing, which compliments other experimental methods for robust polarimetry.