

# Abstracts

**John Armstrong, Tulane University**

Title: *A Categorification of Quandle Coloring Numbers by Anafunctors*

Abstract: The number of colorings of a link by a given quandle is a classical invariant of links up to ambient isotopy. We would like to categorify and extend this invariant to the category  $\mathcal{T}$  of tangles. Here, we show how to associate, functorially, to each tangle an anafunctor between two comma categories of quandles. When we restrict this assignment to knots and links and specify a quandle  $Q$  of colors we recover the  $Q$ -coloring invariant. If we first decategorify and specify a quandle  $Q$  of colors we recover the  $Q$ -coloring matrix of a given tangle. This approach can be significantly generalized.

**Howard Barnum, Los Alamos National Laboratory**

Title: *Information-Processing Characterizations of Quantum and Classical Theory in Convex and Categorical Frameworks*

Abstract: The advent of quantum computation and quantum information science has been accompanied by a revival of the project of characterizing quantum and classical theory within a setting significantly more general than both. Part of the motivation is to obtain a clear conceptual understanding of the sources of quantum theory's greater-than-classical power in areas like cryptography and computation, as well as of the limits it appears to share with classical theory, such as the apparent inability to do NP-complete problems in polynomial time. This line of work suggests supplementing traditional approaches to the axiomatic characterization of quantum mechanics within broader classes of theories, with an approach in which some or all of the axioms concern the information-processing power of the theory.

I will present some recent results on information processing in a general framework for theories. In this framework the set of states is a convex set and the measurements are resolutions of the unit functional into elements of the unit interval in the cone dual to the cone generated by the state-set; systems are combined via tensor products respecting "no-signaling". I'll present a generalized no-broadcasting theorem (joint work with J. Barrett, M. Leifer, and A. Wilce), stating that a set of states in such a theory is broadcastable if, and only if, it is contained in a simplex whose vertices are cloneable, and therefore distinguishable by a single measurement, generalizing the quantum requirement that a broadcastable set of states commute. I'll present results showing that information that can be obtained about a system in this framework without causing disturbance to the system state, must be inherently classical. I'll also discuss preliminary results on teleportation protocols, to the effect that conclusive probabilistic teleportation is possible in this framework only in theories isomorphic to their duals, and on bit commitment, to the effect that any non-classical theory without entanglement allows exponentially secure bit commitment in this framework. I'll also sketch a category-theoretic formulation of the framework in which a theory is a monoidal tensor category whose objects are convex cones with distinguished base interpreted as a state space, and whose morphisms are positive maps. The coherence requirements on a monoidal tensor category, it is conjectured, restrict the morphisms to be maps satisfying a generalization of complete positivity.

**Paul Benioff, Argonne National Laboratory**

Title: *Space of Quantum Theory Representations of Numbers; Fields of Iterated Quantum Reference Frames.*

Abstract: Some properties of quantum theory representations of real and complex numbers will be described. The representations are presented as equivalence classes of Cauchy sequences of states of finite strings of qukits where the qukit string states represent rational numbers. Quantum theory representations differ from the usual classical representations as states of qukit strings in two ways. One is the presence of gauge freedom in choosing basis states. The other is that each quantum theory representation is part of a mathematical structure that is itself based on the real and complex numbers. This follows from the fact that states of finite qukit strings are elements of a Fock space which is such a mathematical structure. A description of some consequences of these properties will occupy much of the talk.

**Howard Brandt, Army Research Laboratory**

Title: *Charge renormalization, Apery's number, and the trefoil knot*

Abstract: In the context of the charge renormalization constant of quantum electrodynamics, I explore, by example, the connections between Feynman graphs, irrational or transcendental numbers, and knots. I first review the calculation in Feynman gauge of the divergent part of the inverse charge renormalization constant to sixth order in the bare charge of the electron. I identify those vacuum polarization graphs which yield Apery's number, and describe the gauge invariant vanishing of the overall coefficient of this irrational number appearing in the sixth-order calculation. I also elucidate the mapping of vacuum polarization graphs with crossed photon propagators onto the trefoil knot.

**Sergey Bravyi, IBM**

Title: *Measurement-based quantum computation with Kitaev's toric code states*

Abstract: Measurement-based quantum computation (MQC) is an alternative model of a quantum computer in which the basic operations are one-qubit measurements performed on a highly entangled resource state. I shall describe MQC using as a quantum resource the planar code state --- the ground state of Kitaev's toric code Hamiltonian on a lattice with open boundary conditions. It will be shown that MQC with the planar code state can be efficiently simulated on a classical computer if at each step of MQC the subset of measured qubits is simply connected. The simulation is based on a doubling transformation that relates probability of any measurement outcome to a partition function of the Ising model with complex weights defined on a planar graph. Generalizations of this result to surface code states defined on non-planar surfaces are discussed.

**Gavin Brennen, University of Innsbrook**

Title: *Quantum simulators for topological order*

Abstract: Highly correlated many-body systems can exhibit emergent symmetries not present in the microscopic equations of motion. A manifestation of this is in spin lattice models with ground states that are topologically ordered or respect a subsystem code structure. Such models are useful for protecting quantum information because the systems are gapped and the ground states are coupled only by global operations. However, this very protection can make it difficult to manipulate the information. I will discuss some new ideas for implementing analogue simulations of spin lattice models using atomic and molecular ensembles trapped in an optical lattice. Global operations are mediated by collective coupling to high-Q cavities. An application is a technique for anyonic interferometry by weaving string operators.

**Goong Chen, Texas A&M University**

Title: *Mathematical Formulations of Atom Trap Quantum Gates*

Abstract: Quantum gates made of atom traps work in somewhat similar ways as those made of ion traps, with certain advantages and disadvantages. In this talk, we will present the mathematical models for two types of atom traps based on optical lattices by providing some details of the physics of quantum devices and operations. From there, we establish the universality theorem of quantum computing gates. This talk is based on recent work with Dr. Zhigang Zhang.

**Alioscia Hamma, University of Southern California**

Title: *Topological order and entanglement*

Abstract: Topological order is a novel subject in theoretical condensed matter. It describes those states of the matter, like the fractional quantum Hall liquids, that defy the description in terms of breaking of symmetry and local order parameters. Topological order is based instead on topological symmetries. Topological order is important also in quantum information science because topologically ordered states are resilient to external perturbations and decoherence. Entanglement, on the other hand, is the fundamental resource of quantum information. How much entanglement can be stored in a bipartite system with topological order? How does it behave for a critical system? How fast can we produce topological order? Does entanglement reveal topological order? How does entanglement resist to temperature? What is the entanglement of a fractal boundary? The talk will provide answers to these questions.

**Masud Haque, Max Plank Institute**

Title: *Quantum information concepts used to probe condensed-matter systems, particularly topologically ordered states*

Abstract: I will first give an overview of recent uses of entanglement concepts from quantum information to probe quantum many-particle physics. In particular, I will focus on the entropy of entanglement between regions of a topologically ordered state.

I will then present calculations of the entanglement entropy in fractional quantum Hall (FQH) states. Calculating the entanglement entropy between spatially separated regions allows us to probe the topological order in Laughlin and Moore-Read states. In addition, the entanglement entropy between particle subsets in the FQH states probes the "exclusion statistics" of FQH quasiparticles.

**Louis Kauffman, University of Illinois, Chicago**

Title: *Anyonic Topological Computing, Knots and Spin Networks*

Abstract: We show how a rich class of unitary representations of the Artin Braid group arise from  $q$ -deformed spin networks (constructed using the bracket model of the Jones polynomial and the recoupling theory using the Temperley Lieb algebra). These representations generate enough unitary transformations to accomplish quantum computing. This gives an elementary representation of quantum computing within topological quantum field theory and shows the fundamental nature of the Jones polynomial in relation to this subject. Applications to the quantum computation of colored Jones polynomials and the Witten-Reshetikhin-Turaev invariant will be discussed.

**Eun-Ah Kim, Stanford University**

Title: TBA

Abstract: TBA

**Vladimir Korepin, Stony Brook University**

Title: *Entanglement in Spin Chains*

Abstract: Entanglement is a resource for quantum computation. How much quantum effects we can use to control one quantum system by another. For pure states entanglement can be measured by entropy of a subsystem. I consider ground states of different dynamical models with unique ground state: spin chains, strongly correlated electrons, Bose gas. I study how the entropy scales with the size of the subsystem.

**Samuel Lomonaco, University of Maryland**

Title: *Quantum algorithms for the Jones polynomial*

Abstract: We begin with a description of recent quantum algorithms for computing approximate values of the Jones polynomial, and then focus on analyzing the

significant components of the quantum control structures found within these algorithms.

**John M. Myers, Harvard University**

Title: *Expressing the distinction between theory and experiment within the mathematics of quantum mechanics.*

Abstract: In quantum mechanics one calculates probabilities from state vectors and linear operators. Under the assumption that it is only the probabilities and neither the state vectors nor the operators that admit direct comparison with experiment, I review some recent proofs of an independence of quantum equations from experiment, showing a role for choice on the part of a scientist. A start is made toward showing how such choices enter topologies of spaces relevant to quantum physics.

**Eric Rowell, Texas A&M University**

Title: *Properties of Modular Categories and their Quantum Computational Consequences*

Abstract: Modular categories carry the algebraic essence of 3D topological quantum field theory, and hence that of topological quantum computers and their physical realizations. I will discuss modular categories and some properties that speak to their potential utility in quantum computation.

**Travis Schedler, University of Chicago**

Title: *Noncommutative Batalin-Vilkovisky structures (based on joint work with Victor Ginzburg)*

Abstract: We introduce a noncommutative analogue of Batalin-Vilkovisky structures and (affine) Calabi-Yau varieties. This extends the "double Poisson/Gerstenhaber" formalism of Van den Bergh. As in the commutative case, this is a double Gerstenhaber algebra together with a differential that generates the bracket. We generalize the notion of differential operators to apply to the "double tangent complex" of a smooth associative algebra, and prove a result that roughly says that  $BV = \text{Calabi-Yau}$ . Following Kontsevich's philosophy, we show that these notions map to the usual commutative ones upon taking the representation functor. We specialize these constructions to obtain information about quantized necklace algebras of quivers. Finally, we formulate a noncommutative version of Kontsevich's formality theorem for  $R^n$  (or, noncommutative deformation quantization).

**Peter Shor, Massachusetts Institute of Technology**

Title: *On the difficulty of approximating the Jones polynomial of the trace closure of a knot.* (Tentative)

Abstract: TBA

**Yong Zhang, University of Utah**

Title: *From Extraspecial Two-Groups To GHZ States*

Abstract: In this work we explore natural connections among extraspecial 2-groups, almost-complex structures, unitary representations of the braid group and the Greenberger-Horne-Zeilinger (GHZ) states. We first present new representations of extraspecial 2-groups in terms of almost-complex structures and use them to derive new unitary braid representations as extensions of representations of the extraspecial 2-groups by the symmetric group. A few subtleties related to the correspondence between the unitary braid representations and the GHZ states (particularly those for an odd number of qubits) are clarified. We also discuss Yang-Baxterization of the new braid group representations and unitary evolution of the GHZ states. Our study suggests that the unitary braiding quantum gates may play an important role, through extraspecial 2-groups, in quantum error correction and topological quantum computing.