Speaker: Ning Bao
Title: Applications of the Holevo Information to Holography
Abstract: We use the Holevo information to estimate distinguishability of microstates of a black hole in anti-de Sitter space by measurements one can perform on a subregion of a Cauchy surface of the dual conformal field theory. We find that microstates are not distinguishable at all until the subregion reaches a certain size and that perfect distinguishability can be achieved before the subregion covers the entire Cauchy surface. We will compare our results with expectations from the entanglement wedge reconstruction, tensor network models, and the bit threads interpretation of the Ryu-Takayanagi formula.

Speaker: John Preskill
Title: Quantum algorithms for simulating quantum field theories.
Abstract: Simulation of dynamics in strongly interacting quantum field theories will be an important application for future quantum computers. I explain why such simulations can provide useful information, review recent progress (with Jordan, Lee, and Krovi) on developing quantum algorithms for this purpose, and highlight some of the challenges and opportunities that lie ahead.

Speaker: Daniel Harlow
Title: Black Holes, Entropy, and Holographic Encoding
Abstract: In this talk I review the new connection between quantum error correction and holographic duality. Using the simplest holographic code, the three qutrit code, I illustrate holographic phenomena such as radial locality and the Ryu-Takayanagi formula, and I also sketch how these results can be used to give a rather general proof of the old conjecture that there are no global symmetries in quantum gravity.

Speaker: Scott Aaronson
Title: Computability Theory of Closed Timelike Curves
Abstract: In a seminal 1991 paper, David Deutsch proposed a formal model of closed timelike curves (CTCs), or time travel into the past, which used linear algebra to "resolve the grandfather paradox." In 2008, John Watrous and I showed that, under Deutsch's model, both a classical computer and a quantum computer with access to a polynomial-size CTC could solve exactly the problems in PSPACE. In this talk, I'll review this result and then give a new extension to the setting of computability theory. Namely, I'll show that a classical or quantum computer with access to a Deutschian CTC (with no bound on its size) could solve exactly the problems that are Turing-reducible to the halting problem. Just like in the complexity setting, the most technically interesting part is the upper bound on the power of quantum computers with access to a Deutschian CTC.

This is joint work with Mohammad Bavarian and Giulio Gueltrini.

Speaker: Michael R. Douglas
Title: Computational complexity of cosmology in string theory
Abstract: We describe a new approach for quantum cosmology based on computational complexity. By defining a cosmology as a space-time containing a vacuum with specified properties (for example small cosmological constant) together with rules for how time evolution will produce the vacuum, we can associate global time in a multiverse with clock time on a supercomputer which simulates it. We argue for a principle of ``limited computational complexity'' governing early universe dynamics as simulated by this supercomputer, which translates to a global measure for regulating the infinities of eternal inflation. We also give various definitions of the computational complexity of a cosmology, and argue that there are only a few natural complexity classes.

Based on joint work with Frederik Denef, Brian Greene and Claire Zukowski, and the preprint arXiv:1706.06430 .

Speaker: Andrew Childs
Title: Simulating quantum mechanics with quantum computers
Abstract: The original motivation for quantum computing came from the problem of simulating the behavior of quantum systems, a task that is apparently intractable for classical computers. While we have known for two decades that quantum computers can efficiently simulate quantum mechanics, recent work has significantly improved the performance of the best known algorithms. In this talk, I will review recent advances in algorithms for simulating Hamiltonian dynamics. I will also describe recent work on resource requirements for quantum simulation with early quantum computers.

Speaker: Brian Swingle
Title: Complexity, Quantum Field Theory, and Black Holes
Abstract: Recent progress in understanding the physics of quantum information has led to novel methods to simulate quantum physics on existing classical computers and on future quantum computers. Crucial to these developments are operational procedures to prepare interesting quantum states, especially procedures that make efficient use of scarce quantum resources. I review recent progress in constructing tensor networks which capture the physics of a wide variety of low temperature quantum states of matter. Then I discuss work in progress showing how these classical simulations may be enhanced and rendered practical using near- to medium-term noisy quantum devices.

Speaker: Benni Reznik
Title: Simulating Abelian and non-Abelian lattice gauge theories with cold atoms
Abstract: Can high energy physics be simulated by low-energy, non-relativistic, many-body systems, such as ultracold atoms? Such ultracold atomic systems lack the type of symmetries and dynamical properties of high energy physics models: in particular, they manifest neither local gauge invariance nor Lorentz invariance, which are crucial properties of the quantum field theories which are the building blocks of the standard model of elementary particles.

However, it turns out, surprisingly, that there are ways to configure atomic system to manifest both local gauge invariance and Lorentz invariance. In particular, local gauge invariance can arise either as an effective, low energy, symmetry, or as an "exact" symmetry, following from the conservation laws in atomic interactions. Such quantum simulators may lead to new type of (table-top) experiments, that shall be used to study various QCD phenomena, as the confinement of dynamical quarks, phase transitions, and other effects, which are inaccessible using the currently known (classical) computational methods.

I will review recent progress towards construction of quantum simulation of Abelian and non-Abelian lattice gauge theories in 1+1 and 2+1 dimensions using ultracold atoms in optical lattices.

arXiv:1503.02312v2
E. Zohar, J.I. Cirac, B. Reznik, Rep. Prog. Phys. 79 014401 2016

Speaker: Jutho Haegemann
Title: Free Fermion Entanglement Renormalization and Wavelets
Abstract: After introducing the concept of tensor network states (TNS) for quantum many body systems, I will first review some of the recent applications of TNS for quantum field theories, either as an alternative to Monte Carlo sampling of lattice field theory, or by working directly in the continuum using properly constructed continuum limits of TNS. I will then study one particular construction in detail, namely that of a multiscale entanglement renormalization ansatz (MERA) for free fermion Hamiltonians such as the one-dimensional Dirac Hamiltonian (using the Kogut-Susskind lattice formulation). The notion of entanglement renormalization provides a construction to approximate the ground state of quantum many body systems in terms of a unitary circuit (with a renormalization group interpretation), which could therefore potentially be implemented on a quantum computer. For free fermion models, the framework of wavelets can be used to construct such MERA approximations that can systematically be improved without variational optimization, and which produce provable and controllable error bounds for correlation functions. The key ingredient of our construction is a pair of wavelets that satisfy a so-called half shift condition, and for which a family of solutions was constructed by Selesnick et al. Next, we extend our construction to two-dimensional models, where we for the first time construct a so-called branching MERA to approximate the ground state of a model with a Fermi surface. We expect that further generalizations of our work can be used to construct MERA approximations for more general models (e.g. mass terms, pairing terms, Dirac cones,

topological insulators) and might serve as a useful starting point for interacting systems, e.g. when they have asymptotic freedom.

Speaker: Martin Savage
Title: Quantum Chromodynamics in the Exascale Era with the Emergence of Quantum Computing
Abstract: Quantum Chromodynamics is the quantum field theory describing the strong interactions of quarks and gluons, and when combined with the electroweak interactions, is responsible for nuclear physics - from the structure and reactions of light nuclei to the behavior of matter in explosive astrophysical environments. Addressing the Grand Challenges facing both experimental and theoretical nuclear physics requires exascale classical computing resources, and in some cases beyond exascale resources.
At the heart of these large resource needs for theory is the complexity associated with the finite-density quantum many-body problem. I will provide an overview of the (expected) future integrated nuclear physics-classical computing research program in the US, discuss the challenges that require such significant computing resources and highlight challenges for which quantum computing could be pursued as a potential future resource.

Speaker: Jacob Taylor
Title: Entanglement-based Tests of Quantum Systems
Abstract: Entanglement is often seen as a resource for quantum computation. Here I consider ways of testing quantum 'black box' devices by considering the entanglement they can transfer or generate between external actors. With this general concept, we can show that absolute quantum testing of some properties are possible for both quantum simulators and for other physical theories. Application of this concept to the quantum communication capacity of gravitational interactions suggests laboratory testing may be possible.

Speaker: Brad Lackey
Title: Optimization Algorithms and the Cosmological Constant
Abstract: We discuss the complexity associated to landscape models of the cosmological constant. One toy model of such leads to the cosmological constant being the solution to a number partitioning problem, an NP-complete family of problems. At first glance solving such a problem appears to require more work than is available to the causally connected component of the universe. We delve deeper into number partitioning problems and show however that when the number of field contributing to the landscape is very large (which is the case in such models) then number partition problems are easy, and even for sizes relevant to landscape models for the cosmological constant can be solved with current hardware.

Speaker: Stephen Jordan
Title: BQP-completeness of Scattering in Quantum Field Theory

Abstract: Recent work has shown that quantum computers can compute scattering probabilities in massive quantum field theories, with a run time that is polynomial in the number of particles, their energy, and the desired precision. Here we consider a closely related quantum field-theoretical problem: estimating the vacuum-to-vacuum transition amplitude, in the presence of spacetime-dependent classical sources, for a massive scalar field theory in (1+1) dimensions. We show that this problem is BQP-hard; in other words, its solution enables one to solve any problem that is solvable in polynomial time by a quantum computer. Hence, the vacuum-to-vacuum amplitude cannot be accurately estimated by any efficient classical algorithm, even if the field theory is very weakly coupled, unless BQP=BPP. This is joint work with Hari Krovi, Keith Lee, and John Preskill.