Entanglement in Quantum Systems Talk Schedule

Events for:
Monday, October 3rd - Friday, October 7th

Monday, October 3rd

9:00am **Luis Álvarez-Gaumé**

9:10am **Bruno Nachtergaele**

Title: Entanglement in quantum spin systems: mathematical perspectives

10:10am **Pieter Naaijkens**

Title: Operator-algebraic approach to topological phases

Abstract: The thermodynamic limit of topologically ordered systems can be studied using an operator-algebraic description. Not only does this yield a clean mathematical framework amenable to a rigorous analysis, it also opens up the possibility of using deep results in operator algebra not available for finite systems. In this talk I will give an example of this by looking at the total quantum dimension, an invariant of topological phases related to the anyonic excitations a topologically ordered state supports. In particular, I show howb one can use Jones' index of subfactors to find the total quantum dimension. This leads to an interpretation of the logarithm of the total quantum dimension as an entropic quantity, related to a quantum information task. In the end this gives an alternative to the topological entanglement entropy. Based on joint work with Leander Fiedler and Tobias Osborne.

11:10am **Coffee**

11:30am **Sergey Bravyi**

Title: Ground states of quantum impurity models

12:30pm **Lunch**

1:30pm **Israel Klich**

2:30pm **Andreas Ludwig**

Title: Entanglement Spectra of Symmetry Protected Topological (SPT) Phases and Boundary Conformal Field Theory

3:30pm **Tea**

4:00pm **Shinsei Ryu**

Title:

Tuesday, October 4th

9:00am **Mohammad Amin**

Title: Quantum Boltzmann Machine

10:00am **Ramis Movassagh**

Title: Quantum spin chains: Generic Properties and Exactly Solvable Models

Abstract: We will discuss the ground states, frustration free condition and the gap of generic local Hamiltonians [1,2]. There is a promising angle of attack to quantify the entanglement of such Hamiltonians that uses a genericity argument from algebraic geometry. This approach naturally motivates the search for specific and highly entangled spin chain models. In recent years, there has been a surge of activities in proposing exactly solvable quantum spin chains with the surprisingly high amount of entanglement entropies (super-logarithmic violations of the area law). We will discuss these models starting from the spin-1 Motzkin spin chain [3], to the super-critical colored-Motzkin Hamiltonian, which gives a \sqrt(n) factor violation of the area law [4], to the very recent proposal of Fredkin Spin Chain [5]. We will then prove that the gap of [5] scales as n^{-c}, where 2\le c \le 13/2 and therefore this model, like [3,4], does not have a relativistic conformal field theory description [6]. Time permitting we might discuss the gap of a deformation of [4] which violates the area law maximally [7]. [1] Movassagh, Farhi, Goldstone, Nagaj, Osborne, Shor, PRA (2010) [2] Movassagh, arXiv:1606.09313 [quant-ph], (2016) [3] Bravyi, Caha, Movassagh, Nagaj and Shor, PRL (2012) [4] Movassagh and Shor, PNAS, in press (2016) [5] Salberger, Korepin, arXiv:1605.03842 [quant-ph] (2016) [6] Movassagh, arXiv:1609.09160 [quant-ph] (2016) [7] Zhang, Ahmadain, Klich, arXiv:1606.07795 [quant-ph] (2016)

11:00am **Coffee**

11:30am **Paola Verrucci**

Title: Hybrid scheme for entanglement generation via non-linear excitations

Abstract: Many proposals for realizing quantum devices require the capability of entangling distant qubits without moving them. Quantum channels used to this purpose are often made by interacting quantum systems distributed along one-dimensional lattices, a general setup that have demonstrated effective, at the expense of a high sensitivity to noise and decoherence, thus requiring good protection against external interactions. On the other hand, chains of interacting classical systems are known to feature dynamical evolutions that make them transmission lines robust against noise of various types but, by definition, they cannot convey quantum properties. In this work we propose a hybrid scheme, where a semi-classical spin chain, i.e. a chain of interacting particles with large spin S, is locally coupled with two distant qubits: the idea is that a large value of S guarantees the presence of robust non-linear excitations (such as dynamical solitons), and yet does not totally wipe out the quantum character of the channel, that remains defined as a system with a Hilbert space, and whose components are still described by spin operators. The dimension of the Hilbert space of one such channel is too large for allowing an exact analysis of the overall (channel+qubits) dynamics; however, using spin-coherent states, we obtain an approximation scheme that allows us to evaluate the amount of entanglement dynamically generated between the two distant qubits. We find that when the evolution of the channel is ruled by strongly localized excitations, and one has the possibility of switching on and off the coupling between each qubit and the respective nearby portion of the spin-chain, non-negligible entanglement is indeed generated. We discuss if, and to what extent, this could be a possible way of reducing the vulnerability of entanglement transfer via quantum channels with respect to noise, imperfections, and decoherence.

12:30pm **Lunch**

1:30pm **Alexei Tsvelik**

Title: Composite order in strongly correlated systems.

Abstract: I will discuss microscopic models giving rise to special types of order in which conduction electrons are bound together in many body bound states with localized spins to create composite order parameters. It is shown that composite order is related to the formation of a spin liquid with gapped excitations carrying quantum numbers which are a fraction of those of electron. The ground state of this spin liquid is topologically nontrivial and the excitations are highly entangled.

2:30pm **Frank Verstratete**

Title: Quantum entanglement in 1+1 dimensional quantum field theories: a tensor network point of view

3:45pm **Tea for Math Physics Colloquium**

4:15pm **Physics/SCGP Colloquium: Ashoke Sen**

Speaker: Ashoke Sen

Title: Managing divergences in string theory

Abstract: Quantum field theories suffer from two kinds of divergences -- infrared and ultraviolet. String theory is known to be free from ultraviolet divergences but suffers from the usual infrared divergences of quantum field theories. After briefly reviewing the absence of ultraviolet divergences in string theory, I shall describe recent progress towards understanding infrared divergences in string theory.

Wednesday, October 5th

9:00am **Zoltan Zimboras**

Title: Mutual information and negativity asymptotics in ground states of spin and fermion chains

10:00am **Balazs Hetenyi**

Title: Baeriswyl based variational approach to the Bose-Hubbard model: is it supersolid or not?

Abstract: One of the intriguing results of low temperature physics in the twentieth century was the discovery of superfluidity, a highly coherent quantum phase of matter exhibiting frictionless flow through cavities. Even more counterintuitive was the suggestion that this can occur in a phase of matter in which long-range crystalline order is maintained. In 2004 Kim and Chan [1], by measuring the rotational inertia of a solid sample in torsional oscillator experiment raised the possibility of a supersolid phase in helium II. The results of this experiment have been questioned since, the issue of supersolidity in helium II is still open. Anderson [2] argued that the ground state of the bosonic Hubbard model also exhibits a supersolid phase at integer fillings. Anderson`s argument is based on the leading terms of a perturbative expression of the Hamiltonian and analyzing the response to a boundary twist [3]. In this talk it is shown how a variational Monte Carlo method [4] can be constructed based on the Baeriswyl wavefunction [5]. The scheme is equivalent to the perturbation expansion used by Anderson, however, in this case the full expansion is performed. The phase diagram obtained is in excellent agreement with quantum Monte Carlo results. We also investigate the sensitivity of the system to a boundary twist, and find that it is sizeable even for integer fillings. To understand the nature of the phase we use a single-particle [6] and a many-particle localization quantity [7] and find that at integer fillings the system exhibits many-particle localization, at the same time, single particles as a result of bosonic exchange, can delocalize over the entire lattice. Away from integer fillings, where the system is known to be superfluid, delocalization is found at both the single-particle and many-particle level. We interpret these results as a signature of supersolidity in the Bose-Hubbard model at integer filling. References: [1] E. Kim and M. H. W. Chan, Science, 305 1941 (2004). [2] P. W. Anderson, J. Low Temp. Phys., 169 124 (2012). [3] W. Kohn, Phys. Rev., A133 171 (1964). [4] B. Hetényi and B. Tanatar, work in progress. [5] D. Baeriswyl in Nonlinearity in Condensed Matter, Ed. A. R. Bishop, D. K. Campbell, D. Kumar, and S. E. Trullinger, Springer-Verlag (1986). [6] A. Selloni, P. Carnevali, R. Car, and M. Parrinello, Phys. Rev. Lett. 59 823 (1987); E. S. Fois, A. Selloni, M. Parrinello, and R. Car, J. Phys. Chem. 92 3268 (1988). [7] R. Resta, Phys. Rev. Lett., 80 1800 (1998); R. Resta and S. Sorella, Phys. Rev. Lett. 82 370 (1999).

11:00am **Coffee**

11:30am **David Gosset**

Title: Complexity of quantum impurity problems

12:30pm **Lunch**

1:30pm **Adolfo del Campo**

Title: nonequilibrium dynamics of spin chains/Kibble-Zurek and annealing.

2:30pm **Bela Bauer**

Title: Floquet Time Crystals

3:30pm **Tea**

4:00pm **Wojciech de Roeck**

Title: TBA

Thursday, October 6th

9:00am **Luigi Amico**

Title: Entanglement response to external perturbations in many-body systems

10:00am **Sougato Bose**

Title: Quenches, Entanglement Spectrum and Irreversible Work in Quantum Impurity Models

11:00am **Coffee**

11:30am **Olof Salberger**

Title: Area law violation in the Fredkin spin chain.

Abstract: I will discuss a family of spin chains with abnormally high levels of entanglement, which builds on earlier work by Shor & Movassagh. The family is characterized by being SU(k) symmetric. For nonabelian symmetry groups (k = 2 and up), a block of length L will have an entanglement entropy proportional to sqrt(L) with respect to its environment, in violation of the area law. The model has a polynomially closing gap. It also exhibits remarkable similarities to the Heisenberg and AKLT spin chains in its dynamics and exhibits highly non-classical correlations.

12:30pm **Lunch**

1:30pm **Nikita Nekrasov**

Title: New statistical mechanical models inspired by gauge theories in various dimensions

2:30pm **Giuseppe Mussardo**

Title: Prime Suspects and Coprime Fellows. Quantum Tales in Number Theory

3:30pm **Tea**

4:00pm **Maxim Olshanii (Olchanyi)**

Title: Quantum Galilean Cannon as a Schrodinger Cat

Abstract: In this presentation we show that a quantum few-body system with a properly tuned set of masses is capable of evolving from a disentangled state to a state where the heavy particles are entangled with the light ones. Here, we focus on the so-called Galilean Cannon: a one-dimensional sequence of N hard-core particles in a ratio 1 : 1/3 : 1/6 : 1/10 : ... : 2/N(N+1) interacting with a hard wall. In this system, nontrivial conservation laws associated with a reflection group A_N—symmetry on an N-dimensional regular tetrahedron—protect the evolution from both classical stochastization and quantum diffraction. In one of the examples, the Renyi entropy increases from zero in the beginning of the evolution to almost ln(2) in the end. We consider specie-alternating mutually repulsive bosonic soliton trains as an empirical realization of the scheme. We finally suggest a concrete way to exploit the heavy-light entanglement by proposing a quantum atomic sensor containing N_atoms atoms whose sensitivity is \sqrt{N} higher than the one for a one-atom sensor with signal-to-noise reduced after N_{atoms} repetitions. Another attractive feature of this device is that it circumvents completely the usual difficulty in realizing beam-splitting of massive objects: in our scheme, the beamsplitter acts only on a single light particle, who is subsequently entangled with the heavy via robust processes only. In collaboration with Thibault Scoquart and Steven Glenn Jackson. Supported by the NSF, ONR and IFRAF. TS's was supported by the École Normale Supérieure.

Friday, October 7th

9:00am **Raul Santos**

Title: Entanglement in symmetry protected topological phases; A case study.

10:00am **Julian Sonner**

Title: Entanglement Dynamics and Black Hole Collapse

Abstract: Holography allows us to formulate questions about quantum gravity in terms of more ordinary quantum field theories without gravity. I will describe some recent progress formulating the spherical collapse of an in-falling shell of null matter in terms of a first-principles CFT calculation. I will argue that the apparent loss of information, as probed via entanglement dynamics as well as correlation functions in the CFT, can be traced back to late-time non-perturbative effects in an expansion in large central charge.

11:00am **Coffee**

11:30am **Vladimir Korepin**

12:30pm **Lunch**

3:30pm **Tea**