Journal Club, 6th May 2014, James Wootton

Violation of the Arrhenius law below the transition temperature
Beni Yoshida,
arXiv:1404.0457

When interacting spin systems possess non-zero magnetization or topological entanglement entropy below the transition temperature, they often serve as classical or quantum self-correcting memory. In particular, their memory time grows exponentially in the system size due to polynomially growing energy barrier, as in the 2D Ising model and 4D Toric code. Here, we argue that this is not always the case. We demonstrate that memory time of classical clock model (a generalization of ferromagnet to q-state spins) may be polynomially long even when the system possesses finite magnetization. This weak violation of the Arrhenius law occurs above the percolation temperature, but below the transition temperature, a regime where excitation droplets percolate the entire lattice, yet the system retains a finite magnetization. We present numerical evidences for polynomial scaling as well as analytical argument showing that energy barrier is effectively suppressed and is only logarithmically divergent. We also suggest an intriguing possibility of experimentally observing the precession of magnetization vectors at experimentally relevant time scale.

Quantum random number generation on a mobile phone
Bruno Sanguinetti, Anthony Martin, Hugo Zbinden, Nicolas Gisin,
arXiv:1405.0435

Conventional quantum error correcting codes require multiple rounds of measurements to detect errors with enough confidence in fault-tolerant scenarios. Here I show that for suitable topological stabilizer codes, such as gauge color codes, a single round is indeed enough. This feature is generic and is related to self-correction in the corresponding quantum Hamiltonian model.

Suppressing qubit dephasing using real-time Hamiltonian estimation
Michael D. Shulman, Shannon P. Harvey, John M. Nichol, Stephen D. Bartlett, Andrew C. Doherty, Vladimir Umansky, Amir Yacoby,
arXiv:1405.0485

Unwanted interaction between a quantum system and its fluctuating environment leads to decoherence and is the primary obstacle to establishing a scalable quantum information processing architecture. Strategies such as environmental and materials engineering, quantum error correction and dynamical decoupling can mitigate decoherence, but generally increase experimental complexity. Here we improve coherence in a qubit using real-time Hamiltonian parameter estimation. Using a rapidly converging Bayesian approach, we precisely measure the splitting in a singlet-triplet spin qubit faster than the surrounding nuclear bath fluctuates. We continuously adjust qubit control parameters based on this information, thereby improving the inhomogenously broadened coherence time (T2) from tens of nanoseconds to above 2 s and demonstrating the effectiveness of Hamiltonian estimation in reducing the effects of correlated noise in quantum systems. Because the technique demonstrated here is compatible with arbitrary qubit operations, it is a natural complement to quantum error correction and can be used to improve the performance of a wide variety of qubits in both metrological and quantum-information-processing applications.

Entanglement area law in thermodynamically gapped spin systems
Jaeyoon Cho,
arXiv:1404.7616

We consider general locally-interacting arbitrary-dimensional lattice spin systems that are gapped for any system size. We show under a reasonable condition that nondegerate ground states of such systems obey the entanglement area law. In so doing, we offer an intuitive picture on how a spectral gap restricts the correlations that a ground state can accommodate and leads to such a special feature.

Quantum Non-Markovianity: Characterization, Quantification and Detection
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arXiv:1405.0303

We present a comprehensive and up to date review on the concept of quantum non-Markovianity, a central theme in the theory of open quantum systems. We introduce the concept of quantum Markovian process as a generalization of the classical definition of Markovianity via the so-called divisibility property and relate this notion to the intuitive idea that links non-Markovianity with the persistence of memory effects. A detailed comparison with other definitions presented in the literature is provided. We then discuss several existing proposals to quantify the degree of non-Markovianity of quantum dynamics and to witness non-Markovian behavior, the latter providing sufficient conditions to detect deviations from strict Markovianity. Finally, we conclude by enumerating some timely open problems in the field and provide an outlook on possible research directions.

Subtle leakage of a Majorana mode into a quantum dot
E. Vernek, P. H. Penteado, A. C. Seridonio, and J. C. Egues
Phys. Rev. B 89, 165314
We investigate quantum transport through a quantum dot connected to source and drain leads and side coupled to a topological superconducting nanowire (Kitaev chain) sustaining Majorana end modes. Using a recursive Green's-function approach, we determine the local density of states of the system and find that the end Majorana mode of the wire leaks into the dot, thus, emerging as a unique dot level pinned to the Fermi energy F of the leads. Surprisingly, this resonance pinning, resembling, in this sense, a Kondo resonance, occurs even when the gate-controlled dot level dot(Vg) is far above or far below F. The calculated conductance G of the dot exhibits an unambiguous signature for the Majorana end mode of the wire: In essence, an off-resonance dot [dot(Vg)F], which should have G=0, shows, instead, a conductance e2/2h over a wide range of Vg due to this pinned dot mode. Interestingly, this pinning effect only occurs when the dot level is coupled to a Majorana mode; ordinary fermionic modes (e.g., disorder) in the wire simply split and broaden (if a continuum) the dot level. We discuss experimental scenarios to probe Majorana modes in wires via these leaked/pinned dot modes.

Long-Range Spin Transfer in Triple Quantum Dots
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Phys. Rev. Lett. 112, 176803
Tunneling in a quantum coherent structure is not restricted to only nearest neighbors. Hopping between distant sites is possible via the virtual occupation of otherwise avoided intermediate states. Here we report the observation of long-range transitions in the transport through three quantum dots coupled in series. A single electron is delocalized between the left and right quantum dots, while the center one remains always empty. Superpositions are formed, and both charge and spin are exchanged between the outermost dots. The delocalized electron acts as a quantum bus transferring the spin state from one end to the other. Spin selection is enabled by spin correlations. The process is detected via the observation of narrow resonances which are insensitive to Pauli spin blockade.

Topological protection, disorder, and interactions: Survival at the surface of three-dimensional topological superconductors
Matthew S. Foster, Hong-Yi Xie, and Yang-Zhi Chou
Phys. Rev. B 89, 155140
We consider the interplay of disorder and interactions upon the gapless surface states of 3D topological superconductors. The combination of topology and superconducting order inverts the action of time-reversal symmetry, so that extrinsic time-reversal invariant surface perturbations appear only as pseudomagnetic fields (Abelian and non-Abelian vector potentials, which couple to spin and valley currents). The main effect of disorder is to induce multifractal scaling in surface state wave functions. These critically delocalized, yet strongly inhomogeneous states renormalize interaction matrix elements relative to the clean system. We compute the enhancement or suppression of interaction scaling dimensions due to the disorder exactly, using conformal field theory. We determine the conditions under which interactions remain irrelevant in the presence of disorder for symmetry classes AIII and DIII. In the limit of large topological winding numbers (many surface valleys), we show that the effective field theory takes the form of a Finkel'stein nonlinear sigma model, augmented by the Wess-Zumino-Novikov-Witten term. The sigma model incorporates interaction effects to all orders and provides a framework for a controlled perturbative expansion; the inverse spin or thermal conductance is the small parameter. For class DIII, we show that interactions are always irrelevant, while in class AIII, there is a finite window of stability, controlled by the disorder. Outside of this window, we identify new interaction-stabilized fixed points.

Non-Abelian Majorana Doublets in Time-Reversal-Invariant Topological Superconductors
Xiong-Jun Liu, Chris L.M. Wong, and K.T. Law
Phys. Rev. X 4, 021018
The study of non-Abelian Majorana zero modes advances our understanding of the fundamental physics in quantum matter and pushes the potential applications of such exotic states to topological quantum computation. It has been shown that in two-dimensional (2D) and 1D chiral superconductors, the isolated Majorana fermions obey non-Abelian statistics. However, Majorana modes in a Z2 time-reversal-invariant (TRI) topological superconductor come in pairs due to Kramerss theorem. Therefore, braiding operations in TRI superconductors always exchange two pairs of Majoranas. In this work, we show interestingly that, due to the protection of time-reversal symmetry, non-Abelian statistics can be obtained in 1D TRI topological superconductors and may have advantages in applications to topological quantum computation. Furthermore, we unveil an intriguing phenomenon in the Josephson effect, that the periodicity of Josephson currents depends on the fermion parity of the superconducting state. This effect provides direct measurements of the topological qubit states in such 1D TRI superconductors.