Quantum annealing with more than one hundred qubits
Sergio Boixo, Troels F. Rønnow, Sergei V. Isakov, Zhihui Wang, David Wecker, Daniel A. Lidar, John M. Martinis, Matthias Troyer
arXiv:1304.4595

At a time when quantum effects start to pose limits to further miniaturisation of devices and the exponential performance increase due to Moore's law, quantum technology is maturing to the point where quantum devices, such as quantum communication systems, quantum random number generators and quantum simulators, may be built with powers exceeding the performance of classical computers. A quantum annealer, in particular, finds solutions to hard optimisation problems by evolving a known initial configuration towards the ground state of a Hamiltonian that encodes an optimisation problem. Here, we present results from experiments on a 108 qubit D-Wave One device based on superconducting flux qubits. The correlations between the device and a simulated quantum annealer demonstrate that the device performs quantum annealing: unlike classical thermal annealing it exhibits a bimodal separation of hard and easy problems, with small-gap avoided level crossings characterizing the hard problems. To assess the computational power of the quantum annealer we compare it to optimised classical algorithms. We discuss how quantum speedup could be detected on devices scaled to a larger number of qubits where the limits of classical algorithms are reached.

Classical signature of quantum annealing
John A. Smolin, Graeme Smith
arXiv:1305.4904

Comment on: "Classical signature of quantum annealing"
Lei Wang, Troels F. Rønnow, Sergio Boixo, Sergei V. Isakov, Zhihui Wang, David Wecker, Daniel A. Lidar, John M. Martinis, Matthias Troyer
arXiv:1305.5837

Protecting Conditional Quantum Gates by Robust Dynamical Decoupling
Ch. Piltz, B. Scharfenberger, A. Khromova, A. F. Varón, and Ch. Wunderlich
Phys. Rev. Lett. **110**, 200501 (2013)

Dephasing—phase randomization of a quantum superposition state—is a major obstacle for the realization of high fidelity quantum logic operations. Here, we implement a two-qubit controlled-NOT gate using dynamical decoupling (DD), despite the gate time being more than 1 order of magnitude longer than the intrinsic coherence time of the system. For realizing this universal conditional quantum gate, we have devised a concatenated DD sequence that ensures robustness against imperfections of DD pulses that otherwise may destroy quantum information or interfere with gate dynamics. We compare its performance with three other types of DD sequences. These experiments are carried out using a well-controlled prototype quantum system—trapped atomic ions coupled by an effective spin-spin interaction. The scheme for protecting conditional quantum gates demonstrated here is applicable to other physical systems, such as nitrogen vacancy centers, solid state nuclear magnetic resonance, and circuit quantum electrodynamics.

Multiterminal Coulomb-Majorana Junction
Francesco Buscemi
Phys. Rev. Lett. **110**, 196401 (2013)

We study multiple helical nanowires in proximity to a common mesoscopic superconducting island, where Majorana fermion bound states are formed. We show that a weak finite charging energy of the center island may dramatically affect the low-energy behavior of the system. While for strong charging interactions, the junction decouples the connecting wires, interactions lower than a nonuniversal threshold may trigger the flow towards an exotic Kondo fixed point. In either case, the ideally Andreev reflecting fixed point characteristic for infinite capacitance (grounded) devices gets destabilized by interactions.

Non-adiabatic processes in Majorana qubit systems
Mathias S. Scheurer, Alexander Shnirman
arXiv:1305.4923

We investigate the non-adiabatic processes occurring during the manipulations of Majorana qubits in 1-D semiconducting wires with proximity induced superconductivity. Majorana qubits are usually protected by the excitation gap. Yet, manipulations performed at a finite pace can introduce both decoherence and renormalization effects. Though exponentially small for slow manipulations, these effects are important as they may constitute the ultimate decoherence mechanism. Moreover, as adiabatic topological manipulations fail to produce a universal set of quantum gates, non-adiabatic manipulations might be necessary to perform quantum computation.

Boosting Majorana zero modes
Torsten Karzig, Gil Refael, Felix von Oppen
arXiv:1305.3626

One-dimensional topological superconductors are known to host Majorana zero modes at domain walls terminating the topological phase. Their nonabelian nature allows for processing quantum information by braiding operations which are insensitive to local perturbations, making Majorana zero modes a promising platform for topological quantum computation. Motivated by the ultimate goal of executing quantum information processing on a finite timescale, we study domain walls moving at a constant velocity. We exploit an effective Lorentz invariance of the Hamiltonian to obtain an exact solution of the associated quasiparticle spectrum and wave functions for arbitrary velocities. Essential features of the solution have a natural interpretation in terms of the familiar relativistic effects of Lorentz contraction and time dilation. We find that the Majorana zero modes remain stable as long as the domain wall moves at subluminal velocities with respect to the effective speed of light of the system. However, the Majorana bound state dissolves into a continuous quasiparticle spectrum once the domain wall propagates at luminal or even superluminal velocities. This relativistic catastrophe implies that there is an upper limit for possible braiding frequencies even in a perfectly clean system with an arbitrarily large topological gap. We also exploit our exact solution to consider domain walls moving past static impurities present in the system.

Designing short robust NOT gates for quantum computation
Jonathan A. Jones
Phys. Rev. A **87**, 052317 (2013)

Composite pulses, originally developed in nuclear magnetic resonance (NMR), have found widespread use in experimental quantum information processing (QIP) to reduce the effects of systematic errors. Most pulses used so far have simply been adapted from existing NMR designs, and while techniques have been developed for designing composite pulses with arbitrary precision, the results have been quite complicated and have found little application. Here, I describe techniques for designing short but effective composite pulses to implement robust not gates, bringing together existing insights from NMR and QIP, and present some composite pulses.

Electron spin relaxation in graphene nanoribbon quantum dots
Matthias Droth and Guido Burkard
Phys. Rev. B **87**, 205432 (2013)

Graphene is promising as a host material for electron spin qubits because of its predicted potential for long coherence times. In armchair graphene nanoribbons (aGNRs) a small band gap is opened, allowing for electrically gated quantum dots, and furthermore the valley degeneracy is lifted. The spin lifetime T_1 is limited by spin relaxation, where the Zeeman energy is absorbed by lattice vibrations, mediated by spin-orbit and electron-phonon coupling. We have calculated T_1 by treating all couplings analytically and find that T_1 can be in the range of seconds for several reasons: (i) low phonon density of states away from Van Hove singularities; (ii) destructive interference between two relaxation mechanisms; (iii) Van Vleck cancellation at low magnetic fields; (iv) vanishing coupling to out-of-plane modes in lowest order due to the electronic structure of aGNRs. Owing to the vanishing nuclear spin of ^{12}C, T_1 may be a good measure for overall coherence. These results and recent advances in the controlled production of graphene nanoribbons make this system interesting for spintronics applications.

Possibility of Direct Observation of Edge Majorana Modes in Quantum Chains
A. A. Zvyagin
Phys. Rev. Lett. **110**, 217207 (2013)

Several scenarios for the realization of edge Majorana modes in quantum chain systems, spin chains, chains of Josephson junctions, and chains of coupled cavities in quantum optics, are considered. For all these systems excitations can be presented as superpositions of a spinless fermion and a hole, characteristic of a Majorana fermion. We discuss the features of our exact solution with respect to possible experiments, in which edge Majorana fermions can be directly observed when studying magnetic, superconducting, and optical characteristics of such systems.

Are the 'weak measurements' really measurements?
D. Sokolovski
arXiv:1305.4809

Weak measurements can be seen as an attempt at answering the 'Which way?' question without destroying interference between the pathways involved. Unusual mean values obtained in such measurements represent the response of a quantum system to this 'forbidden' question, in which the 'true' composition of virtual pathways is hidden from the observer. Such values indicate a failure of a measurement where the uncertainty principle says it must fail, rather than provide an additional insight into physical reality.

Helical Edge Resistance Introduced by Charge Puddles
Jukka I. Väyrynen, Moshe Goldstein, and Leonid I. Glazman
Phys. Rev. Lett. **110**, 216402 (2013)

We study the influence of electron puddles created by doping of a 2D topological insulator on its helical edge conductance. A single puddle is modeled by a quantum dot tunnel coupled to the helical edge. It may lead to significant inelastic backscattering within the edge because of the long electron dwelling time in the dot. We find the resulting correction to the perfect edge conductance. Generalizing to multiple puddles, we assess the dependence of the helical edge resistance on the temperature and doping level and compare it with recent experimental data.

Optical Resonator Analog of a Two-Dimensional Topological Insulator
G. Q. Liang and Y. D. Chong
Phys. Rev. Lett. **110**, 203904 (2013)

A lattice of optical ring resonators can exhibit a topological insulator phase, with the role of spin played by the direction of propagation of light within each ring. Unlike the system studied by Hafezi et al., [Nat. Phys. 7 907 (2011)] topological protection is achieved without fine-tuning the interresonator couplings, which are given the same periodicity as the underlying lattice. The topological insulator phase occurs for strong couplings, when the tight-binding method is inapplicable. Using the transfer matrix method, we derive the band structure and phase diagram, and demonstrate the existence of robust edge states. When gain and loss are introduced, the system functions as a diode for coupled resonator modes.

Adiabatic quantum computation with Rydberg-dressed atoms
Tyler Keating, Krittika Goyal, Yuan-Yu Jau, Grant W. Biedermann, Andrew J. Landahl, and Ivan H. Deutsch
Phys. Rev. Lett. **110**, 052314 (2013)

We study an architecture for implementing adiabatic quantum computation with trapped neutral atoms. Ground-state atoms are dressed by laser fields in a manner conditional on the Rydberg blockade mechanism, thereby providing the requisite entangling interactions. As a benchmark, we study the performance of quantum annealing to the ground state of an Ising spin lattice. We model a proof-of-principle experiment in a realistic architecture, including details of the atomic implementation, with qubits encoded in the clock states of ^{133}Cs*. Numerical simulation yields fidelities* >0.98 *for up to four qubits, and implementations of 10–20 qubits are within the range of current technology.*

3D Computational Imaging with Single-Pixel Detectors
B. Sun1, M. P. Edgar, R. Bowman, L. E. Vittert, S. Welsh, A. Bowman, M. J. Padgett
Science **340**, 844 (2013)

Three-dimensional (3D) images can be captured by, for example, holographic imaging or stereoimaging techniques. To avoid using expensive optical components that are limited to specialized bands of wavelengths, Sun et al. (p. 844; see the Perspective by Faccio and Leach) projected pulses of randomly textured light onto an object. They were able to reconstruct an image of the 3D object by detecting the reflected light with several photodetectors without any need for lenses. The patterned light beams can thus in principle be substituted for light sources of any wavelength. Computational imaging enables retrieval of the spatial information of an object with the use of single-pixel detectors. By projecting a series of known random patterns and measuring the backscattered intensity, it is possible to reconstruct a two-dimensional (2D) image. We used several single-pixel detectors in different locations to capture the 3D form of an object. From each detector we derived a 2D image that appeared to be illuminated from a different direction, even though only a single digital projector was used for illumination. From the shading of the images, the surface gradients could be derived and the 3D object reconstructed. We compare our result to that obtained from a stereophotogrammetric system using multiple cameras. Our simplified approach to 3D imaging can readily be extended to nonvisible wavebands.

Magnetically-Defined Qubits on 3D Topological Insulators
Gerson J. Ferreira, Daniel Loss
arXiv:1305.5003

Correlations between Majorana fermions through a superconductor
A.A. Zyuzin, Diego Rainis, Jelena Klinovaja, Daniel Loss
arXiv:1305.4187

Long-Range Interaction of Singlet-Triplet Qubits via Ferromagnets
Luka Trifunovic, Fabio L. Pedrocchi, Daniel Loss
arXiv:1305.2451

Integer and Fractional Quantum Hall Effect in a Strip of Stripes
Jelena Klinovaja, Daniel Loss
arXiv:1305.1569