Adrian Hutter **Journal Club** 5 June 2012

Energy Landscape of 3D Spin Hamiltonians with Topological Order
Sergey Bravyi and Jeongwan Haah
Phys. Rev. Lett. **107**, 150504 (2011)

We explore the feasibility of a quantum self-correcting memory based on 3D spin Hamiltonians with topological quantum order in which thermal diffusion of topological defects is suppressed by macroscopic energy barriers. To this end we characterize the energy landscape of stabilizer code Hamiltonians with local bounded-strength interactions which have a topologically ordered ground state but do not have stringlike logical operators. We prove that any sequence of local errors mapping a ground state of such a Hamiltonian to an orthogonal ground state must cross an energy barrier growing at least as a logarithm of the lattice size. Our bound on the energy barrier is tight up to a constant factor for one particular 3D spin Hamiltonian.

Designer Spin Pseudomolecule Implemented with Trapped Ions in a Magnetic Gradient
A. Khromova, Ch. Piltz, B. Scharfenberger, T. F. Gloger, M. Johanning, A. F. Varn, and Ch. Wunderlich
Phys. Rev. Lett. **108**, 220502 (2012)

We report on the experimental investigation of an individual pseudomolecule using trapped ions with adjustable magnetically induced J-type coupling between spin states. Resonances of individual spins are well separated and are addressed with high fidelity. Quantum gates are carried out using microwave radiation in the presence of thermal excitation of the pseudomolecules vibrations. Demonstrating controlled-NOT gates between non-nearest neighbors serves as a proof-of-principle of a quantum bus employing a spin chain. Combining advantageous features of nuclear magnetic resonance experiments and trapped ions, respectively, opens up a new avenue toward scalable quantum information processing.

Role of Hidden Slow Degrees of Freedom in the Fluctuation Theorem
J. Mehl1, B. Lander, C. Bechinger, V. Blickle1, and U. Seifert
Phys. Rev. Lett. **108**, 220601 (2012)

The validity of the fluctuation theorem for entropy production as deduced from the observation of trajectories implicitly requires that all slow degrees of freedom are accessible. We experimentally investigate the role of hidden slow degrees of freedom in a system of two magnetically coupled driven colloidal particles. The apparent entropy production based on the observation of just one particle obeys a fluctuation theoremlike symmetry with a slope of 1 in the short time limit. For longer times, we find a constant slope, but different from 1. We present theoretical arguments for a generic linear behavior both for small and large apparent entropy production but not necessarily throughout. By fine-tuning experimental parameters, such an intermediate nonlinear behavior can indeed be recovered in our system as well.

Spin polarization of the quantum spin Hall edge states
Christoph Brüne, Andreas Roth, Hartmut Buhmann, Ewelina M. Hankiewicz, Laurens W. Molenkamp, Joseph Maciejko, Xiao-Liang Qi, and Shou-Cheng Zhang
Nature Physics **8**, 486491 (2012)

The prediction and experimental verification of the quantum spin Hall state marked the discovery of a new state of matter now known as topological insulators. Two-dimensional topological insulators exhibit the quantum spin-Hall effect, characterized by gapless spin-polarized counter-propagating edge channels. Whereas the helical character of these edge channels is now well established, experimental confirmation that the transport in the edge channels is spin polarized is still outstanding. We report experiments on nanostructures fabricated from HgTe quantum wells with an inverted band structure, in which a split gate technique allows us to combine both quantum spin Hall and metallic spin Hall transport in a single device. In these devices, the quantum spin Hall effect can be used as a spin current injector and detector for the metallic spin Hall effect, and vice versa, allowing for an all-electrical detection of spin polarization.

Energy-momentum dispersion relation of plasmarons in graphene
P. M. Krstajić and F. M. Peeters
Phys. Rev. B **85**, 205454 (2012)

The many-body correction to the band structure of a quasi-free-standing graphene layer is obtained within the Overhauser approach, where the electron-plasmon interaction is described as a field theoretical problem. We find that the Dirac-like spectrum is shifted by $\Delta E(\mathbf{k}=0)$, which is on the order of $50-150$ meV, depending on the electron concentration n_e, and is in semiquantitative agreement with experimental data. The value of the Fermi velocity is renormalized by several percents and decreases with increasing electron concentration as found experimentally.

Nonlocal Transport Near Charge Neutrality Point in a Two-Dimensional Electron-Hole System G. M. Gusev, E. B. Olshanetsky, Z. D. Kvon, A. D. Levin, N. N. Mikhailov, and S. A. Dvoretsky
Phys. Rev. Lett. **108**, 226804 (2012)

Nonlocal resistance is studied in a two-dimensional system with a simultaneous presence of electrons and holes in a 20 nm HgTe quantum well. A large nonlocal electric response is found near the charge neutrality point in the presence of a perpendicular magnetic field. We attribute the observed nonlocality to the edge state transport via counterpropagating chiral modes similar to the quantum spin Hall effect at a zero magnetic field and graphene near a Landau filling factor =0.

Space Dependent Fermi Velocity in Strained Graphene
Fernando de Juan, Mauricio Sturla, and Mara A. H. Vozmediano
Phys. Rev. Lett. **108**, 227205 (2012)

We investigate some apparent discrepancies between two different models for curved graphene: the one based on tight-binding and elasticity theory, and the covariant approach based on quantum field theory in curved space. We demonstrate that strained or corrugated samples will have a space-dependent Fermi velocity in either approach that can affect the interpretation of local probe experiments in graphene. We also generalize the tight-binding approach to general inhomogeneous strain and find a gauge field proportional to the derivative of the strain tensor that has the same form as the one obtained in the covariant approach.

Junction between surfaces of two topological insulators
Diptiman Sen and Oindrila Deb
Phys. Rev. B **85**, 245402 (2012)

We study the properties of a line junction which separates the surfaces of two three-dimensional topological insulators. The velocities of the Dirac electrons on the two surfaces may be unequal and may even have opposite signs. For a time-reversal invariant system, we show that the line junction is characterized by an arbitrary parameter which determines the scattering from the junction. If the surface velocities have the same sign, we show that there can be edge states which propagate along the line junction with a velocity and spin orientation which depend on α and the ratio of the velocities. Next, we study what happens if the two surfaces are at an angle φ with respect to each other. We study the scattering and differential conductance through the line junction as functions of φ and α. We also find that there are edge states which propagate along the line junction with a velocity and spin orientation which depend on φ. Finally, if the surface velocities have opposite signs, we find that the electrons must transmit into the two-dimensional interface separating the two topological insulators.

Free randomness can be amplified
Roger Colbeck and Renato Renner
Nature Physics **8**, 450454 (2012)

Are there fundamentally random processes in nature? Theoretical predictions, confirmed experimentally, such as the violation of Bell inequalities, point to an affirmative answer. However, these results are based on the assumption that measurement settings can be chosen freely at random, so assume the existence of perfectly free random processes from the outset. Here we consider a scenario in which this assumption is weakened and show that partially free random bits can be amplified to make arbitrarily free ones. More precisely, given a source of random bits whose correlation with other variables is below a certain threshold, we propose a procedure for generating fresh random bits that are virtually uncorrelated with all other variables. We also conjecture that such procedures exist for any non-trivial threshold. Our result is based solely on the no-signalling principle, which is necessary for the existence of free randomness.