Kevin van Hoogdalem **Journal Club** 25/10/2011

T. Karzig, G. Refael, L. I. Glazman, and F. von Oppen
Energy Partitioning of Tunneling Currents into Luttinger Liquids
*Phys. Rev. Lett. **107**, 176403 (2011)*
Tunneling of electrons of definite chirality into a quantum wire creates counterpropagating excitations, carrying both charge and energy. We find that the partitioning of energy is qualitatively different from that of charge. The partition ratio of energy depends on the excess energy of the tunneling electrons (controlled by the applied bias) and on the interaction strength within the wire (characterized by the Luttinger-liquid parameter κ), while the partitioning of charge is fully determined by κ. Moreover, unlike for charge currents, the partitioning of energy current should manifest itself in dc experiments on wires contacted by conventional (Fermi-liquid) leads.

Y. Zhang, C. A. Ryan, R. Laflamme, and J. Baugh
Coherent Control of Two Nuclear Spins Using the Anisotropic Hyperfine Interaction
*Phys. Rev. Lett. **107**, 170503 (2011)*
We demonstrate coherent control of two nuclear spins mediated by the magnetic resonance of a hyperfine-coupled electron spin. This control is used to create a double-nuclear coherence in one of the two electron spin manifolds, starting from an initial thermal state, in direct analogy to the creation of an entangled (Bell) state from an initially pure unentangled state. We identify challenges and potential solutions to obtaining experimental gate fidelities useful for quantum information processing in this type of system.

I. Gerhardt, Q. Liu, A. Lamas-Linares, J. Skaar, V. Scarani, V. Makarov, and C. Kurtsiefer
Experimentally Faking the Violation of Bell's Inequalities
*Phys. Rev. Lett. **107**, 170404 (2011)*
Entanglement witnesses such as Bell inequalities are frequently used to prove the nonclassicality of a light source and its suitability for further tasks. By demonstrating Bell inequality violations using classical light in common experimental arrangements, we highlight why strict locality and efficiency conditions are not optional, particularly in security-related scenarios.

W. Dür and M. Van den Nest
Quantum Simulation of Classical Thermal States
*Phys. Rev. Lett. **107**, 170402 (2011)*
We establish a connection between ground states of local quantum Hamiltonians and thermal states of classical spin systems. For any discrete classical statistical mechanical model in any spatial dimension, we find an associated quantum state such that the reduced density operator behaves as the thermal state of the classical system. We show that all these quantum states are unique ground states of a universal 5-body local quantum Hamiltonian acting on a (polynomially enlarged) qubit system on a 2D lattice. The only free parameters of the quantum Hamiltonian are coupling strengths of two-body interactions, which allow one to choose the type and dimension of the classical model as well as the interaction strength and temperature. This opens the possibility to study and simulate classical spin models in arbitrary dimension using a 2D quantum system.

P. Yan, X. S. Wang, and X. R. Wang
All-Magnonic Spin-Transfer Torque and Domain Wall Propagation
*Phys. Rev. Lett. **107**, 177207 (2011)*
The spin-wave transportation through a transverse magnetic domain wall (DW) in a magnetic nanowire is studied. It is found that the spin wave passes through a DW without reflection. A magnon, the quantum of the spin wave, carries opposite spins on the two sides of the DW. As a result, there is a spin angular momentum transfer from the propagating magnons to the DW. This magnonic spin-transfer torque can efficiently drive a DW to propagate in the opposite direction to that of the spin wave.

D. Kochan, M. Gmitra, and J. Fabian
Theory of the ac Spin-Valve Effect
*Phys. Rev. Lett. **107**, 176604 (2011)*
The spin-valve complex magnetoimpedance of symmetric ferromagnet–normal-metal–ferromagnet junctions is investigated within the drift-diffusion (standard) model of spin injection. The ac magnetoresistance—the real part difference of the impedances of the parallel and antiparallel magnetization configurations—exhibits an overall damped oscillatory behavior, as an interplay of the diffusion and spin relaxation times. In wide junctions the ac magnetoresistance oscillates between positive and *negative* values, reflecting resonant amplification and depletion of the spin accumulation, while the line shape for thin tunnel junctions is predicted to be purely

Lorentzian. The ac spin-valve effect could be a technique to extract spin transport and spin relaxation parameters in the absence of a magnetic field and for a fixed sample size.

M. Mochizuki, N. Furukawa, and N. Nagaosa
Theory of spin-phonon coupling in multiferroic manganese perovskites *R*MnO3
*Phys. Rev. B **84**, 144409 (2011)*
Magnetoelectric phase diagrams of the rare-earth (*R*) Mn perovskites *R*MnO3 are theoretically studied by focusing on crucial roles of the symmetric magnetostriction or the Peierls-type spin-phonon coupling through extending our previous work [M. Mochizuki *et al.* **Phys. Rev. Lett.** **105** 037205 (2010)]. We first construct a microscopic classical Heisenberg model for *R*MnO3 including the frustrated spin exchanges, single-ion anisotropy, and Dzyaloshinskii-Moriya interaction. We also incorporate the lattice degree of freedom coupled to the Mn spins via the Peierls-type magnetostriction. By analyzing this model using the replica-exchange Monte Carlo technique, we reproduce the entire phase diagram of *R*MnO3 in the plane of temperature and magnitude of the orthorhombic lattice distortion. Surprisingly it is found that in the *ab*-plane spiral spin phase, the ($S{\cdot}S$)-type magnetostriction plays an important role for the ferroelectric order with polarization $P \| a$ whose contribution is comparable to or larger than the contribution from the ($S{\times}S$)-type magnetostriction, whereas in the *bc*-plane spiral phase, the ferroelectric order with $P \| c$ is purely of ($S{\times}S$) origin. This explains much larger *P* in the *ab*-plane spiral phase than the *bc*-plane spiral phase as observed experimentally and gives a clue how to enhance the magnetoelectric coupling in the spin-spiral-based multiferroics. We also predict a noncollinear deformation of the *E*-type spin structure resulting in the finite ($S{\times}S$) contribution to the ferroelectric order with $P \| a$, and a wide coexisting regime of the commensurate *E* and incommensurate spiral states, which resolve several experimental puzzles.

Y. Hu, F. Kuemmeth, . M. Lieber, C. M. Marcus
Spin Relaxation in Ge/Si Core-Shell Nanowire Qubits
arXiv:1110.4742v1 [cond-mat.mes-hall]
Controlling decoherence is the most challenging task in realizing quantum information hardware. Single electron spins in gallium arsenide are a leading candidate among solid- state implementations, however strong coupling to nuclear spins in the substrate hinders this approach. To realize spin qubits in a nuclear-spin-free system, intensive studies based on group-IV semiconductor are being pursued. In this case, the challenge is primarily control of materials and interfaces, and device nanofabrication. We report important steps toward implementing spin qubits in a predominantly nuclear-spin-free system by demonstrating state preparation, pulsed gate control, and charge-sensing spin readout of confined hole spins in a one-dimensional Ge/Si nanowire. With fast gating, we measure T1 spin relaxation times in coupled quantum dots approaching 1 ms, increasing with lower magnetic field, consistent with a spin-orbit mechanism that is usually masked by hyperfine contributions.

J. D. Sanchez-Yamagishi, T. Taychatanapat, K. Watanabe, T. Taniguchi, A. Yacoby, P. Jarillo-Herrero
Quantum Hall Effect, Screening and Layer-Polarized Insulating States in Twisted Bilayer Graphene
arXiv:1110.4628v1 [cond-mat.mes-hall]
We investigate electronic transport in dual-gated twisted bilayer graphene. Despite the sub-nanometer proximity between the layers, we identify independent contributions to the magnetoresistance from the graphene Landau level spectrum of each layer. We demonstrate that the filling factor of each layer can be independently controlled via the dual gates, which we use to induce Landau level crossings between the layers. By analyzing the gate dependence of the Landau level crossings, we characterize the finite inter-layer screening and extract the capacitance between the atomically-spaced layers. At zero filling factor, we observe magnetic and displacement field dependent insulating states, which indicate the presence of counter-propagating edge states with inter-layer coupling.

N. Y. Yao, C. R. Laumann, A. V. Gorshkov, H. Weimer, L. Jiang, J. Ignacio Cirac, P. Zoller, M. D. Lukin
Topologically Protected Quantum State Transfer in a Chiral Spin Liquid
arXiv:1110.3788v1 [quant-ph]
Topology plays a central role in ensuring the robustness of a wide variety of physical phenomena. Notable examples range from the robust current carrying edge states associated with the quantum Hall and the quantum spin Hall effects to proposals involving topologically protected quantum memory and quantum logic operations. Here, we propose and analyze a topologically protected channel for the transfer of quantum states between remote quantum nodes. In our approach, state transfer is mediated by the edge mode of a chiral spin liquid. We demonstrate that the proposed method is intrinsically robust to realistic imperfections associated with disorder and decoherence. Possible experimental implementations and applications to the detection and characterization of spin liquid phases are discussed.