Journal Club on 22 July (Kouki Nakata)

July 21, 2014

- **Bose-Einstein condensation in an ultra-hot gas of pumped magnons**
  Alexander A. Serga et al., and Burkard Hillebrands
  [Nature Communications **5** (2014) 3452]
  Bose-Einstein condensation of quasi-particles such as excitons, polaritons, magnons and photons is a fascinating quantum mechanical phenomenon. Unlike the Bose-Einstein condensation of real particles (like atoms), these processes do not require low temperatures, since the high densities of low-energy quasi-particles needed for the condensate to form can be produced via external pumping. Here we demonstrate that such a pumping can create remarkably high effective temperatures in a narrow spectral region of the lowest energy states in a magnon gas, resulting in strikingly unexpected transitional dynamics of Bose-Einstein magnon condensate: the density of the condensate increases immediately after the external magnon flow is switched off and initially decreases if it is switched on again. This behaviour finds explanation in a nonlinear 'evaporative supercooling' mechanism that couples the low-energy magnons overheated by pumping with all the other thermal magnons, removing the excess heat, and allowing Bose-Einstein condensate formation.

- **Bose-Einstein condensation in quantum magnets**
  Vivien Zapf, Marcelo Jaime, and C. D. Batista
  [Rev. Mod. Phys. **86**, 563 (2014)]
  This article reviews experimental and theoretical work on Bose-Einstein condensation in quantum magnets. These magnets are natural realizations of gases of interacting bosons whose relevant parameters such as dimensionality, lattice geometry, amount of disorder, nature of the interactions, and particle concentration can vary widely between different compounds. The particle concentration can be easily tuned by applying an external magnetic field which plays the role of a chemical potential. This rich spectrum of realizations offers a unique possibility for studying the different physical behaviors that emerge in interacting Bose gases from the interplay between their relevant parameters. The plethora of other bosonic phases that can emerge in quantum magnets, of which the Bose-Einstein condensate is the most basic ground state, is reviewed. The compounds discussed in this review have been intensively studied in the last two decades and have led to important contributions in the area of quantum magnetism. In spite of their apparent simplicity, these systems often exhibit surprising behaviors. The possibility of using controlled theoretical approaches has triggered the discovery of unusual effects induced by frustration, dimensionality, or disorder.

- **Superfluid Spin Transport Through Easy-Plane Ferromagnetic Insulators**
  So Takei and Yaroslav Tserkovnyak
  [Phys. Rev. Lett. **112**, 227201 (2014)]
  Superfluid spin transport dissipationless transport of spin is theoretically studied in a ferromagnetic insulator with easy-plane anisotropy. We consider an open geometry where the spin current is injected into the ferromagnet from one side by a metallic reservoir with a nonequilibrium spin accumulation and ejected into another metallic reservoir located downstream. Spin transport is studied using a combination of magnetoelectric circuit theory, Landau-Lifshitz-Gilbert phenomenology, and microscopic linear-response theory. We discuss how spin superfluidity can be probed in a magnetically mediated negative electron-drag experiment.

- **Spin superfluidity in coplanar multiferroics**
  Wei Chen and Manfred Sigrist
  [Phys. Rev. B **89**, 024511 (2014)]
  Multiferroics with coplanar magnetic order are discussed in terms of a superfluid condensate, with special emphasis on spin supercurrents created by phase gradients of the condensate and the effect of external electric fields. By drawing the analogy to a superconducting condensate, phenomena such as persistent currents in rings, the Little-Parks effect, fluxoid quantization, the Josephson-like effect through spin domain walls, and interference behavior in a superconducting quantum interference device (SQUID)-like geometry are analyzed for coplanar multiferroics.

- **Thermal Hall effect of magnons in magnets with dipolar interaction**
  Ryo Matsumoto, Ryuichi Shindou, and Shuichi Murakami
  [Phys. Rev. B **89**, 054420 (2014)]

Thermal Hall conductivity of magnons described by a noninteracting boson Hamiltonian is derived by the linear response theory. The thermal Hall conductivity is expressed by the Berry curvature in momentum space, which also has the prevailing form for bosonic systems. This theory covers various spin waves, such as spin waves in antiferromagnets and magnetostatic spin waves. As an example, we calculate the thermal Hall conductivity by the magnetostatic spin wave in yttrium iron garnet and reveal its dependence on a magnetic field and temperature.

- **Propulsion of a domain wall in an antiferromagnet by magnons**
  Se Kwon Kim, Yaroslav Tserkovnyak, Oleg Tchernyshyov [arXiv:1406.6051]

We analyze the dynamics of a domain wall in an easy-axis antiferromagnet driven by circularly polarized magnons. Magnons pass through a stationary domain wall without reflection and thus exert no force on it. ($\cdots$). We point out a second mechanism of propulsion, which we term redshift: magnons passing through a precessing domain wall lower their frequency by twice the angular velocity of the domain wall; the concomitant reduction of magnons' linear momentum indicates momentum transfer to the domain wall. We solve the equations of motion for spin waves in the background of a uniformly precessing domain wall with the aid of supersymmetric quantum mechanics and compute the net force and torque applied by magnons to the domain wall. Redshift is the dominant mechanism of propulsion at low spin-wave intensities; reflection dominates at higher intensities. We derive a set of coupled algebraic equations to determine the linear velocity and angular frequency of the domain wall in a steady state. The theory agrees well with numerical micromagnetic simulations.

- **Interface enhancement of Gilbert damping from first-principles**
  Yi Liu, Zhe Yuan, R. J. H. Wesselink, Anton A. Starikov, Paul J. Kelly [arXiv:1406.6225]

The enhancement of Gilbert damping observed for $Ni_{80}Fe_{20}$ (Py) films in contact with the non-magnetic metals Cu, Pd, Ta and Pt, is quantitatively reproduced using first-principles scattering theory. The "spin-pumping" theory that qualitatively explains its dependence on the Py thickness is generalized to include a number of factors known to be important for spin transport through interfaces. Determining the parameters in this theory from first-principles shows that interface spin-flipping makes an essential contribution to the damping enhancement. Without it, a much shorter spin-flip diffusion length for Pt would be needed than the value we calculate independently.

- **Observation of propagating edge spin waves modes**
- **Spin waves along the edge states**
  A. Lara et al., [arXiv:1406.7186], [arXiv:1406.7200]

- **Entanglement Hamiltonian of the quantum Neel state**
  Didier Poilblanc, [arXiv:1407.3830]
- **AC Josephson effect without superconductivity**
  Benoit Gaury, Joseph Weston, Xavier Waintal [arXiv:1407.3911]
- **Criticality in Translation-Invariant Parafermion Chains**
  Wei Li, Shuo Yang, Hong-Hao Tu, Meng Cheng [arXiv:1407.3790]

- **Accessing topological order in fractionalized liquids with gapped edges**
  Thomas Iadecola, Titus Neupert, Claudio Chamon, Christopher Mudry [arXiv:1407.4129]
- **Classification of spin liquids on the square lattice with strong spin-orbit coupling**
  Johannes Reuther, Shu-Ping Lee, Jason Alicea [arXiv:1407.4124]
- **Quantum revivals and many-body localization**
  R. Vasseur, S. A. Parameswaran, J. E. Moore [arXiv:1407.4476]
- **Theory of Intertwined Orders in High Temperature Superconductors**
  Eduardo Fradkin, Steven A. Kivelson, John M. Tranquada [arXiv:1407.4480]

- **Microwave-induced spin currents in ferromagnetic-insulator—normal-metal bilayer system**
  Milan Agrawal, Alexander A. Serga, Viktor Lauer, Evangelos Th. Papaioannou,
  Burkard Hillebrands, Vitaliy I. Vasyuchka [arXiv:1407.4957]
- **Universal High-Frequency Behavior of Periodically Driven Systems: from Dynamical Stabilization to Floquet Engineering**
  Marin Bukov, Luca D'Alessio, Anatoli Polkovnikov [arXiv:1407.4803]