CINS Student Symposium: Abstract Book

Sebastian Himbert (McMaster University, PI: Rheinstadter)

“The Bending Rigidity of Red Blood Cell Membranes Determined from Solid-Supported Multi-lamellar Membranes”

X-ray and neutron diffraction have been used for many decades to study the structure and dynamic of solid supported synthetic lipid bilayers. For the first time, we were able to prepare highly ordered stacks of RBC membranes on silicon wafers and determine structural parameters of this endogenous membrane. We present direct experimental evidence that these RBC membranes consist of nanometer-sized domains of integral coiled-coil peptides, as well as liquid ordered (lo) and liquid disordered (ld) lipids. This patchy nature of the red blood cell membrane has a significant effect on the bending rigidity of this molecular assembly. Inelastic neutron measurements are ideal for probing these dynamical properties. We investigated the bending modulus and membrane interaction modulus of this endogenous bilayer on a molecular scale by combining Neutron Spin-Echo measurements with diffuse X-ray diffraction measurements and molecular dynamic simulations.

Dalini Maharaj (McMaster University, PI: Gaulin):

“Octupolar vs Neel Order in Cubic $5d^2$ double perovskites”

Time-of-flight neutron spectroscopic and diffraction studies of the $5d^2$ cubic double pervoskite magnets, Ba_2MOsO_6 (M = Zn, Mg, Ca) will be presented. These cubic materials are all described by antiferromagnetically-coupled $5d^2$ Os^{6+} ions decorating a face-centred cubic (FCC) lattice. They all exhibit thermodynamic anomalies consistent with phase transitions at a temperature T_N, and exhibit a gapped magnetic excitation spectrum with spectral weight concentrated at wavevectors typical of type I antiferromagnetic orders. While muon spin resonance experiments show clear evidence for time reversal symmetry breaking, no corresponding magnetic Bragg scattering is observed at low temperatures. These results, consistent with low temperature octupolar or quadrupolar order, are discussed in the context of other $5d^2$ DP magnets, and theories for d^2 ions on a FCC lattice which predict exotic orders driven by multipolar interactions.

Michael Nguyen (University of Windsor, PI: Marquardt)

“SANS to Probe Lipid Flip-Flop in Asymmetric Liposomes”

The outer covering of organisms often come in the form of a cellular plasma membrane, providing protection from harsh external factors. At its basis, the membrane is a lipid bilayer with two apposing monolayers. These monolayers are composed of different lipid constituents (dubbed "membrane asymmetry"), conferring the monolayers unique physical and chemical properties from one another that affect protein shape and function. Despite the ubiquity of membrane asymmetry, most model membrane systems used are symmetric due to the difficulties in constructing asymmetric liposomes. Herein, asymmetric (and symmetric) liposomes were subjected to small angle neutron scattering to track the time-dependent loss of membrane asymmetry via lipid flip-flop. This system was also subjected to pore-forming peptides to shed light on their mechanisms of action. All in all, a novel method to measure lipid flip-flop in a probe-free manner is presented.

Bo Yuan (University of Toronto, PI: Kim)

"In-plane Magnetic Anisotropy Generated by Quantum Zero-point Fluctuations in a Tetragonal Quantum Antiferromagnet Bi_2CuO_4"

We carried out inelastic neutron scattering measurements to study low energy spin dynamics of a tetragonal quantum magnet Bi_2CuO_4. Unlike other previously studied cuprates, its unique magnetic lattice gives rise to an accidental in-plane spin rotational symmetry, not present in the microscopic Hamiltonian. We demonstrate that this accidental symmetry is removed by an in-plane magnetic anisotropy produced by quantum zero-point fluctuations using spin-wave theory calculations. In addition, we find that the size of the in-plane anisotropy agrees quantitatively with the spin-flop transition field of ~0.4T, revealed by our neutron scattering measurements. The spin Hamiltonian used for the calculation is determined independently from the dispersion of the out-of-plane mode. Our results show that a rare display of quantum fluctuations in a three-dimensional quantum magnet is found in Bi_2CuO_4.

Elena Timakova (McMaster University/Sunnybrook Health Sciences, PI: Sarfehnia/Pang)

"Development of a scintillator-based MR-compatible neutron meter: A prototype detector"

External beam therapy (EBT) is the most common form of radiation therapy, and can be used to control and/or eliminate tumours. It is provided through the use of a linear accelerator (linac), and with advances in technology, now through an MR-Linac as well. However, linacs can also produce unwanted radiation--namely neutrons, which contribute to stochastic effects measured as recurrent, secondary or novel appearance of cancer instances. Hence, neutron dose is an important factor to consider in relation to EBT. Problems with existing neutron dosimeters include incompatibility with MR, bulkiness, and/or high cost. The authors propose a design for a scintillation-based, MR-compatible neutron meter. This presentation outlines the choice of components, design and assembly, and initial testing outcomes of the prototype meter.

Mitchell DiPasquale (University of Windsor, PI: Marquardt)

"The Effect of the Antioxidant Vitamin E on Cell Membrane Organization"

Over 90 years ago, vitamin E was discovered as a vital dietary supplement, yet to this day its precise biological role remains the subject of controversy. Often proclaimed to be the cell membrane's front-line antioxidant defence, research over the years has discovered pivotal roles for vitamin E in cellular signalling, apoptosis, and protein and gene regulation, all without defined molecular mechanisms. Importantly, the consequential effect of vitamin E residing in the cell membrane is largely understudied. This facet has begun to be addressed by neutron diffraction studies to define the location and orientation of vitamin E in membranes. Here we expand on its membrane behaviour by exploiting contrast-matched small angle neutron scattering to shed light on a potential lipid raft modulating mechanism of vitamin E.

Melissa Henderson (IQC/University of Waterloo, PI: Pushin)

"Above Room Temperature Skyrmions and Neutron Tomography"

Bulk crystal materials capable of hosting room temperature skyrmion lattices present a unique candidate for spintronic applications owing to their nanometric size, topological stability, and ability to be driven by ultralow current densities. However, the bulk properties of skyrmions have yet to be thoroughly investigated using neutron scattering techniques—primary techniques employ resonant elastic x-ray scattering. We have synthesized an above room temperature intermetallic triangular lattice skyrmion and performed small angle neutron scattering in combination with tomographic reconstructions to generate density maps of the skyrmion lattice. We observe the average penetration depth of the skyrmion lattices to be on the order of microns, in addition to exotic phenomena such as skyrmion splitting.

Eva Mueller (McMaster University, PI: Hoare)

"Cationic, anionic, and amphoteric dual pH/temperature-responsive degradable microgels via self-assembly of functionalized oligomeric precursor polymers"

'Smart' poly(N-isopropylacrylamide) (PNIPAM) microgels can change their properties in response to temperature. Conventional precipitation-based PNIPAM microgels are limited in degradability. As such, we have developed a novel approach to overcome this limitation by creating degradable thermosensitive microgels by the controlled precipitation of well-defined hydrazide and aldehyde-functionalized PNIPAM oligomers. By copolymerizing charged monomers into the precursor polymers used in self-assembly, pH-responsive swelling behaviors can be achieved. Optimal conditions associated with the production of these pH-responsive PNIPAM microgels were explored and evaluated in terms of size, charge, degradation, and internal morphology. The latter was analyzed using SANS and USANS experimental data and compared to the homogenous internal structure of the uncharged self-assembled PNIPAM microgels. The significance of this self-assembly approach relative to conventional microgel synthesis is based on (1) the potential for degradation via hydrolysis and (2) the ability to form particles by simple sequential mixing within minutes.

Evan Smith (McMaster University, PI: Gaulin)

"Quantum Spin Ice Dynamics in the Dipole-Octupole Pyrochlore Magnet $Ce_2Zr_2O_7$"

The pyrochlore antiferromagnet $Ce_2Zr_2O_7$ is sensitive to an instability of the Ce^{3+} oxidation state, whereby the $4f^1$ electronic configuration of Ce^{3+} can be diluted via sample oxidation and the concomitant introduction of Ce^{4+} to the lattice. For that reason, reduction of $Ce_2Zr_2O_7$ samples is required to enable a neutron scattering study of this material. The Ce^{3+} spins in $Ce_2Zr_2O_7$ possess a local Ising anisotropy and interact via an antiferromagnetic coupling, which typically results in all-in all-out antiferromagnetic order. However, the crystal electric field (CEF) wavefunctions of the Ce^{3+} ground state can have a dipole-octupole nature which is an ingredient for moment fragmentation and can allow for a disordered U(1) quantum spin liquid ground state. High energy neutron spectroscopy confirms the dipole-octupole CEF ground state, and higher energy resolution neutron scattering shows a disordered ground state for $Ce_2Zr_2O_7$ with a dynamic structure factor resembling that of a quantum spin ice.