Collective modes at pressure-induced quantum phase transitions

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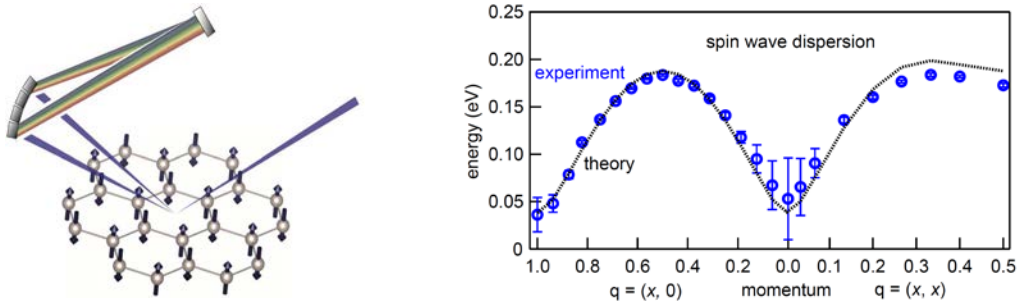
High-resolution resonant inelastic x-ray scattering (RIXS) allows energy- and momentum-resolved spectroscopy of electronic collective modes, which are hallmarks of the electronic interactions that drive unconventional superconductivity and other quantum phenomena. In this project, Bernhard Keimer and his group will take advantage of uniaxial pressure methods developed by Andrew Mackenzie to drive quantum materials across quantum phase transitions and use RIXS to monitor the behavior of electronic collective modes as these transitions are traversed. Complementary transport and scanning tunneling spectroscopy measurements will be carried out in the groups of Andrew Mackenzie and J.C. Séamus Davis.



(left) Schematic of a RIXS experiment on the honeycomb antiferromagnet $SrRu_2O_6$. (right) Spin wave dispersions measured on a single crystal of 50 micrometer diameter.

The project will focus on two classes of quantum materials:

a) Keimer's group has recently built a RIXS spectrometer for quantum materials with 4d valence electrons and carried out initial measurements on the high-temperature antiferromagnet $SrRu_2O_6$ (Suzuki *et al.*, Nature Materials **18**, 563 (2019)) and the unconventional superconductor Sr_2RuO_4 (Suzuki *et al.*, unpublished). Following up on transport experiments in Mackenzie's group, which uncovered a uniaxial-pressure-induced quantum phase transition with a change in Fermi surface topology in Sr_2RuO_4 (Barber *et al.*, Phys. Rev. Lett. **120**, 076602 (2018)), we will use this spectrometer to track electronic collective modes across this transition. The RIXS data, as well as complementary transport and STM experiments under uniaxial pressure, will allow microscopic insight into the origin of the superconducting state and provide a benchmark for many-body calculations on this model quantum material.

b) In collaboration with the Mackenzie group, Keimer's group has carried out non-resonant x-ray scattering experiments on the high-temperature superconductor $YBa_2Cu_3O_7$ under uniaxial pressure, which led to the discovery of a pressure-induced three-dimensional charge density wave competing with superconductivity (Kim *et al.*, Science **362**, 1040 (2018)). We will perform RIXS experiments on collective spin and charge excitations associated with this state and correlate the results with complementary transport and STM experiments.