Condensed Matter Physics Seminar Series

Universal electronic structure of layered nickelates via oxygen-centered planar orbitals

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In a series of groundbreaking discoveries, superconductivity has recently been demonstrated in $La_3Ni_2O_7$ up to 91 K under moderate pressure in bulk crystals, and up to 48 K at ambient pressure in thin films grown under compressive strain. Key questions remain open regarding the crystal structure and low-energy electronic states that support superconductivity in these compounds. Here we take advantage of the natural polymorphism between bilayer (2222) or alternating monolayer-trilayer (1313) stacking sequences that arises in bulk $La_3Ni_2O_7$ crystals to identify universal features in this family of materials. Employing angle-resolved photoemission spectroscopy (ARPES) we observe the fingerprint of a spin-density wave (SDW) instability, strong and coherent enough to modify the electronic structure[1]. We demonstrate that this feature is a 'translated' β Fermi surface associated with a scattering vector $Q_{t\beta}$ which matches the Q_{SDW} detected by neutron and x-ray scattering experiments. This observation provides an important link between surface and bulk probes, and demonstrates a universal connection between magnetism and fermiology in $La_3Ni_2O_7$ as well as $La_4Ni_3O_{10}$. Using an effective tight-binding model, we simulate the spectral weight distribution observed in our ARPES dichroism experiments and establish that the low-energy electronic phenomenology is dominated by oxygen-centered planar orbitals, which – upon moving along the Fermi surface away from the Ni-O-Ni bond directions – evolve from the $d3x^2{-}r^2$ and $d3y^2{-}r^2$ symmetry characteristic of 3-spin polarons to the familiar $dx^2{-}y^2$ Zhang-Rice singlets that support high-temperature superconductivity in cuprates. Despite the multiorbital nature of the nickelates, our work establishes an empirical correspondence between the low-energy electronic structure of cuprates and nickelates, thus suggesting a common origin for their unconventional superconductivity[1].

Dr. Andrea Damascelli, Canada Research Chair in Electronic Structure of Quantum Materials, utilizes spectroscopic techniques including time-, spin-, and angle-resolved photoemission spectroscopy (ARPES), as well as resonant elastic x-ray scattering (REXS), to study the low-energy electronic structure of solids. He specializes in quantum materials – systems that show new electronic properties that defy our ability to understand or predict them. These properties include high-temperature superconductivity, unconventional magnetism, and exotic phases of matter.

Thursday, September 4th at 3PM
4-330 PAB