Interplay between superconductivity, magnetism, and nematic/orbital order in the iron pnictides

Rafael M. Fernandes

Columbia University & Los Alamos National Laboratory, USA

The recent discovery of iron-based compounds displaying superconductivity at nearly 60K opened a new direction in the research of high-temperature superconductors. Much of the interest lies in understanding not only their superconducting pairing mechanism, but also their normal state properties. Indeed, these materials are characterized by a very rich phase diagram, displaying magnetic, superconducting, structural, and orbital order. In these lectures, I will present a microscopic electronic model that consistently describes the interplay between these different degrees of freedom, shedding light on the primary role played by magnetism.

I will show that magnetic fluctuations enhance the repulsive electronic interaction between different pockets of the Fermi surface, giving rise to a superconducting state whose gap function has opposite signs on distinct Fermi surface sheets. This is the so called s^{+-} state, which may or may not have accidental gap nodes. While magnetic fluctuations support an unconventional superconducting state, long-range magnetic order competes with superconductivity, since the same electronic states are responsible for both the superfluid condensate and the staggered magnetic moment. From this competition, a new thermodynamic state can emerge, where both long-range magnetic and superconducting order coexist microscopically. I will also show that the degeneracy of the magnetic ground state, allied to the presence of magnetic fluctuations, gives rise to an emergent Ising-nematic phase that spontaneously breaks the tetragonal symmetry of the system, triggering both structural and orbital order. Due to its magnetic origin, nematic order competes indirectly with superconductivity, but nematic fluctuations may enhance the superconducting transition temperature. I will show that these nematic degrees of freedom are present in the phase diagrams of the iron pnictides over wide temperature and doping ranges, affecting the character of the magneto-elastic transitions, renormalizing the elastic moduli, and giving rise to a resistivity anisotropy with different signs in electron-doped and hole-doped compounds.