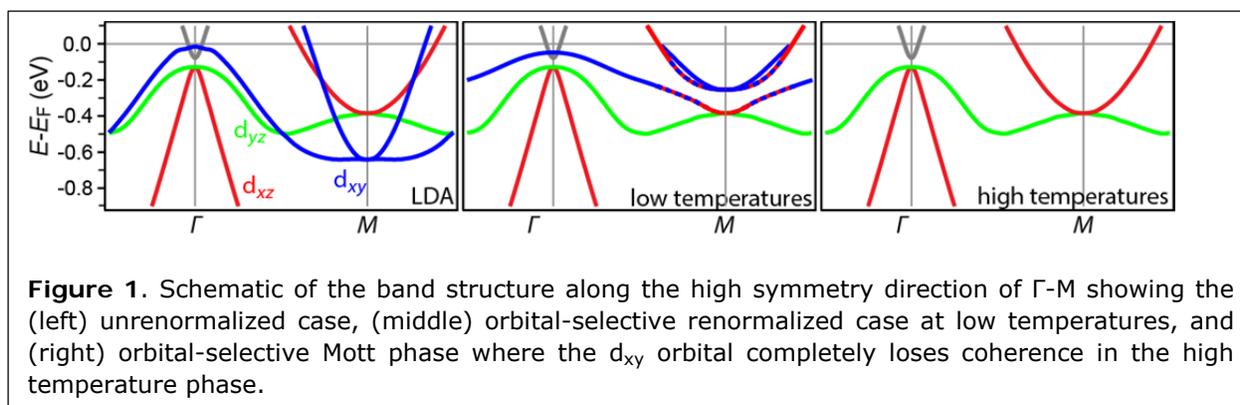


Strong Orbital-selective Correlation Effects Unite Iron Chalcogenide Superconductors

Seven years ago when superconductivity was first discovered in the iron-based compounds (FeSCs), one of the very first questions in the field was to find out whether the physics governing superconductivity in these materials were the same or different from the only other known high temperature superconductors (HTSC) – the cuprates. Or in other words, whether the FeSCs could be understood from a strongly correlated view like the cuprates. Initial studies, however, revealed that they seemed to be in fact different from the cuprates, that they were more itinerant. Subsequently, a successful theory under this itinerant view emerged, which was based on the nesting between the hole and electron Fermi surfaces that were ubiquitous among the FeSCs discovered in early days. However, the later discovery of superconductivity in the heavily electron-doped iron chalcogenides in the absence of the nesting conditions cast doubt on this itinerant picture. These heavily electron-doped chalcogenide superconductors included alkali-metal doped iron selenides (AFS), and the monolayer FeSe film grown on SrTiO₃ (FS/STO), which only have electron Fermi pockets at the Brillouin zone (BZ) corners but no hole Fermi pockets at the BZ center, and are yet still capable of superconducting at comparable temperatures as the other FeSCs.



In a recent study published in *Nature Communications*, researchers Ming Yi and Donghui Lu along with their co-workers in Prof. Zhi-Xun Shen's group and in collaboration with Prof. Ian Fisher's group at SIMES performed angle-resolved photoemission spectroscopy (ARPES) experiments at Beam Line 5-4 of SSRL and Beam Line 10.0.1 of ALS to systematically study different iron chalcogenide superconductor families, including the Fe(Te,Se) system (FTS) in addition to AFS and FS/STO. Using ARPES, they confirmed that these three systems have qualitatively different Fermi surfaces, ranging from compensated hole and electron pockets at the BZ center and corner in FTS to electron pockets only at the BZ corner in FS/STO to electron pockets at both the BZ center and corner in AFS. However, despite this apparent difference in the Fermi surface topology, all three superconductors are found to be in a regime where the orbitals are selectively renormalized (see schematic in Fig. 1). In particular, the d_{xy} orbital is much more strongly renormalized than the other orbitals in the superconducting phase. Moreover, by raising temperature, all these systems crossover into a phase where the d_{xy} orbital completely loses spectral weight while other orbitals remain metallic (Fig. 2).

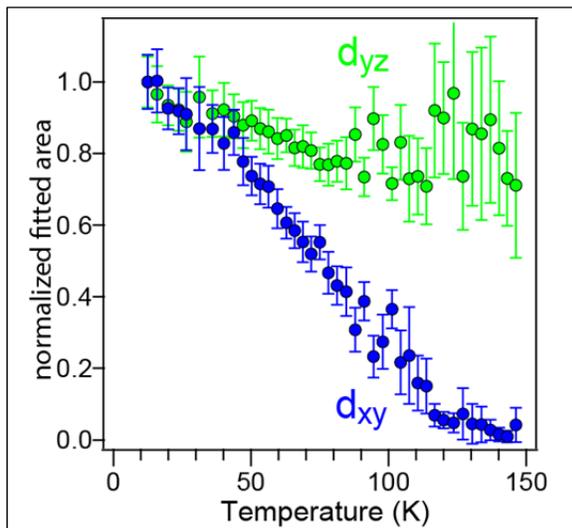


Figure 2. Measured spectral weight of the d_{xy} (blue) and d_{yz} (green) bands as a function of temperature on FS/STO. The d_{xy} spectral weight disappears above 150K while the d_{yz} spectral weight still remains finite.

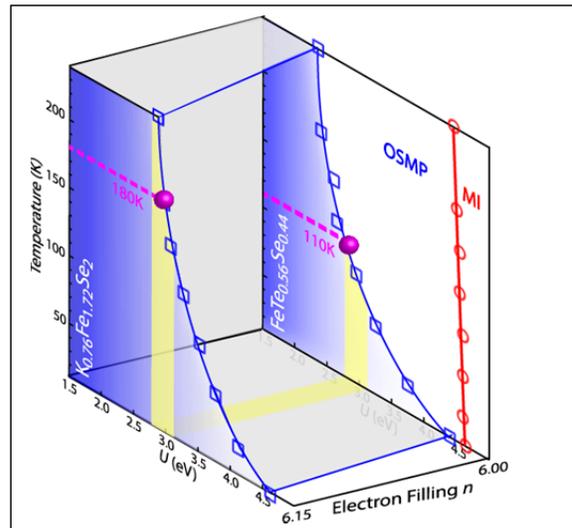


Figure 3. Calculated phase diagram of the orbital-selective Mott phase for AFS and FTS where the vertical axis is temperature and the horizontal axes are Coulomb repulsion U and the electron filling. The blue curves indicate transitions into the orbital-selective Mott phase while the red line indicates transition into the Mott insulating phase.

This is a behavior that was previously shown in the AFS system to indicate a crossover into an orbital-selective Mott phase, a phase where electrons of one of the orbitals in a multi-orbital system Mott localizes while other orbitals still have finite itinerancy [1]. Here in the current work, the SIMES researches have demonstrated that this behavior is actually a universal behavior common to all the iron chalcogenide superconductors (Fig. 3), hence finding a common thread for the iron chalcogenide superconductors which are otherwise quite different in Fermi surface topology, phase diagram, and magnetic structures. More importantly, the existence of this orbital-selective Mott phase in proximity to superconductivity suggests that the governing mechanism for superconductivity in the iron chalcogenides may be local in origin, bridging these materials to a regime closer to the cuprates.

Primary Citation

M. Yi, Z.-K. Liu, Y. Zhang, R. Yu, J.-X. Zhu, J. J. Lee, R. G. Moore, F. T. Schmitt, W. Li, S. C. Riggs, J.-H. Chu, M. Hashimoto, S.-K. Mo, Z. Hussain, Z. Q. Mao, C. W. Chu, I. R. Fisher, Q. Si, Z.-X. Shen and D. H. Lu, "Observation of Universal Strong Orbital-dependent Correlation Effects in Iron Chalcogenides", *Nat. Commun.* **6**, 7777 (2015). DOI: 10.1038/ncomms8777.

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