ALS SCIENCE HIGHLIGHT

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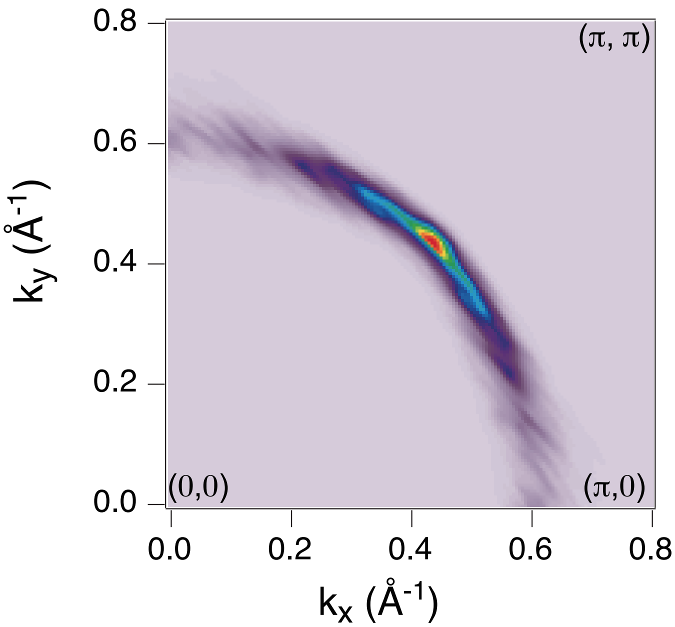
# An Iridate with Fermi Arcs

Researchers have discovered that "Fermi arcs," which are much-debated features found in the electronic structure of high-temperature superconducting (HTSC) cuprates, can also be found in an iridate (iridium oxide) compound. At the ALS, the researchers observed the electronic structure of strontium iridate as it evolved through different doping levels and temperatures by using angle-resolved photoemission spectroscopy (ARPES) with in situ electron doping of the sample surface. The existence of a "strange" metallic phase with Fermi arcs and a pseudogap suggests the possible emergence of high-temperature superconductivity in this non-cuprate compound.




**A Fermi arc in strontium iridate ($Sr_2IrO_4$). In momentum space, Fermi arcs are isolated segments of a broken Fermi surface.**

In conventional superconductors, the superconducting gap—an indicator of superconductivity—vanishes above the superconducting transition temperature ($T_c$). In HTSC cuprates, however, the gap can be seen above $T_c$ and has been dubbed the "pseudogap," as its origin is, so far, unknown; the explanation of this mystery is expected to contain crucial information about the HTSC mechanism. "Fermi arcs" are another remarkable cuprate feature: these are fragments of the Fermi surface that retract and become isolated from each other as temperature and doping decrease. Because Fermi arcs cannot be regarded as a normal (continuous) Fermi surface, the Fermi-arc phase is regarded as a "strange" metallic phase that cannot be explained by a general understanding of electron behavior in a normal metal.

Although explanations of the pseudogap and Fermi arcs remain open to debate, scientists in the HTSC field commonly believe that certain unique cuprate features are essential to superconductivity: spin-1/2 moment on a quasi-two-dimensional square lattice, Heisenberg antiferromagnetic coupling, and no orbital degeneracy. A minimal model based on these assumptions can reproduce much of the phenomenology of HTSC cuprates. Although it would be informative to study these key features in a non-cuprate sample, so far no ideal material has been found.

The 5d transition-metal oxide, strontium iridate ($Sr_2IrO_4$), is the most promising candidate, exhibiting all three of the above features. As a result, its effective low-energy physics can be described by the same minimal model as for cuprates, suggesting that it will also be a possible unconventional HTSC upon charge-carrier doping. However, very little is known about what occurs in the elec-

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## A New Member of the Family?

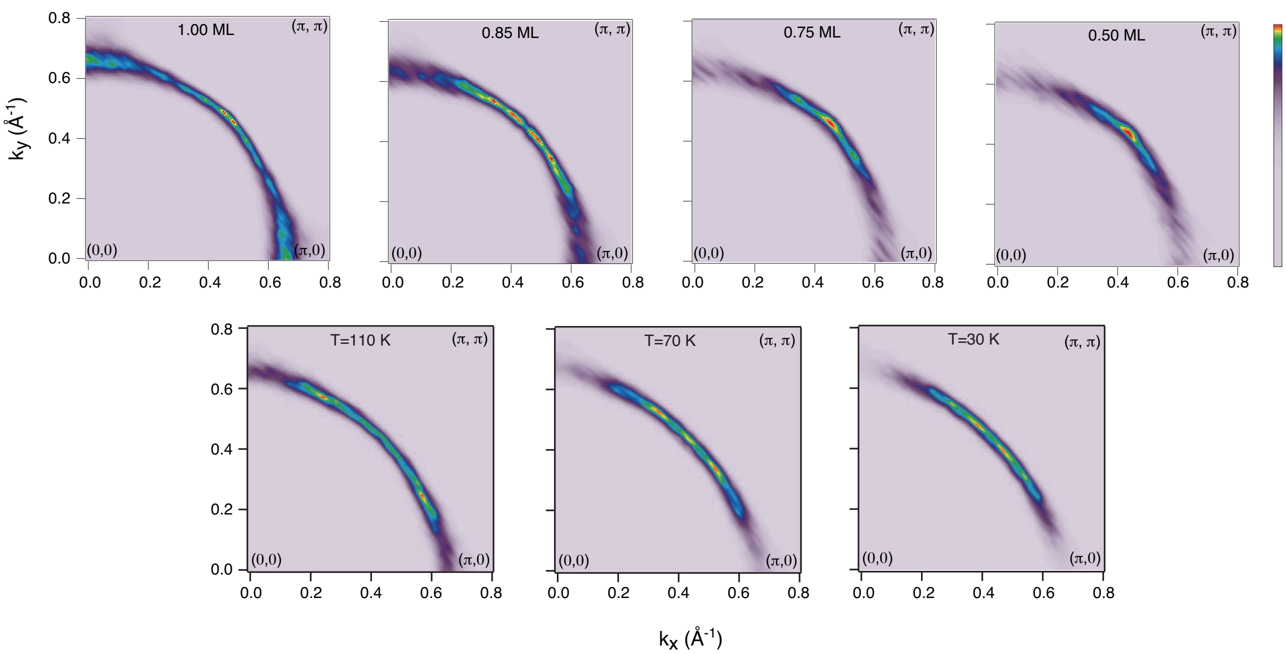
The high-temperature branch of the superconductivity family tree has so far been dominated by one group of materials: the cuprates, all of which contain in their molecular structures a copper oxide layer that is thought to be key to the superconducting state. Recently, however, an interesting new possibility has appeared, in the form of strontium iridate. There's definitely a family resemblance between the cuprate and iridate molecular structures, with the copper oxide layers of the cuprate replaced by iridium oxide layers in the iridate. But iridium is a heavier element than copper, with stronger coupling between its electrons' spins and orbits. This difference could have interesting consequences for superconductivity as well as for other electronic properties.

As reported here by Kim et al., the appearance of "Fermi arcs" in the data describing the behavior of the electrons in strontium iridate is another, more subtle (and more intriguing) resemblance between these materials. Even in the extensively studied cuprates, the significance of the Fermi arcs is a topic of lively discussion and controversy. High-temperature superconductivity is, in general, still poorly understood. Now, with the discovery of a whole new branch of materials with a broader "gene pool" than just the cuprates, scientists can perhaps make further progress in cracking the high-temperature superconductivity code.

tronic phases of strontium iridate when additional carriers are provided.

To address this issue, the researchers performed at ALS Beamline 4.0.3 a complete ARPES experiment, directly mapping out the electronic structure using ultraviolet light. They employed an in situ doping technique that deposited potassium atoms on the sample surface, adding electrons to the system. By controlling the surface coverage (i.e., the doping level), the researchers succeeded in revealing the evolution of the electronic structure from a Mott insulator to a normal metallic phase. At intermediate coverage, they observed a Fermi arc and related pseudogap that resembled that of an HTSC cuprate. Further temperature- and coverage-dependent studies showed that the parallel between strontium iridate and cuprates persists in the metallic phase and that the breakup of a Fermi surface into segments is a general phenomenon of a system containing certain generic cuprate characteristics.

The nature of the phase that manifests Fermi arcs in electron-doped strontium iridate is unclear at this point. A growing body of evidence in cuprates suggests that Fermi arcs and pseudogaps are associated with distinct phases in HTSCs, such as density waves, stripes, and checkerboard orders. If so, it would prompt investigation of such phases in carrier-doped strontium iridate. If, on the other hand, Fermi arcs and pseudogaps are precursory signatures of high-temperature superconductivity, strontium iridate may become superconducting. In any case, the results suggest that strontium iridate is a useful model system for reproducing the physics expected in HTSC cuprates. The researchers expect that further study of this material will shed new light on the long-sought connection between the pseudogap and high-temperature superconductivity.




**Evolution of the Fermi arc in strontium iridate as surface doping decreases from 1 to 0.5 monolayer (ML) and as temperature decreases from 110 to 30 K.**

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