Department of Physics and Astronomy
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Resonance and Superconductivity

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The latest discovery from Professor Pengcheng Dai's group has an unusual twist: sometimes to prove why something exists, you have to make it disappear. Such is the case with the group's latest publication, "Quantum spin correlations through the superconductivity-to-normal phase transition in electron-doped superconducting $Pr_{0.88}LaCe_{0.12}CuO_{4-\delta}$," which details how they suppressed superconductivity to get a better idea of what causes it in the first place. The article appears in the *Proceedings of the National Academy of Sciences* (September 20, 2007).

Superconductivity arrived on the scientific stage in the early 1900s and since then has slowly revealed more of its character. In simple terms, it's a phenomenon where electrons pair up to carry along a current with no resistance. In conventional superconductors (those first discovered), the negatively-charged electrons—which normally repel one another—get together two-by-two via a net attractive force through their interaction with lattice vibrations, or phonons. Yet it has not been so easy to pin down how electrons pair up in the case of high-temperature superconductors—copper oxide materials discovered 20 years ago with a transition temperature exceeding the liquid nitrogen boiling temperature (77 K). Solving that mystery would go a long way in helping scientists take full advantage of superconductivity's promise: electric power with little or no energy loss at temperatures not possible for conventional superconductors, superconducting magnets as the basis for electric motors, or biomagnetic technologies for non-invasive medical procedures.

The Dai group has been working to answer the question of electron pairing by exploring physical properties of superconducting materials, specifically copper oxide crystals that they grow in their on-campus laboratory. They have focused on the spin—an intrinsic property—of these crystals, and especially the magnetic resonance that accompanies it. In the *PNAS* publication, they report on how the resonance mode is intimately connected to superconductivity and therefore could be important to its microscopic origin.

Paired electrons in a superconductor are typically considered a condensate, like water droplets that bead up on a glass as the water inside it warms up. What Professor Dai and his colleagues discovered is that the condensation energy of a superconductor is closely linked to a magnetic excitation, termed resonance. To make the necessary measurements, however, they had to suppress superconductivity in their experimental materials. What they found is that the magnetic field that suppresses the condensation energy also suppresses the resonance in a remarkably similar way. A connection between magnetic resonance and the formation of electron pairs would be another step forward in understanding how superconductors work. The results were obtained via neutron scattering: firing neutrons at a sample target and then observing how they scatter in order to learn something about the atomic structure of the material.

The work builds on earlier studies the group published in the July 6, 2006, issue of *Nature* and has also been chosen as a NIST Center for Neutron Research (NCNR) research highlight for 2007. The lead author on the *PNAS* publication is Stephen D. Wilson, who completed the Ph.D. with Dr. Dai's group in May 2007 and is now with Lawrence Berkeley National Laboratory and the University of California-Berkeley. Co-authors are Shiliang Li and Jun Zhao of UT, Gang Mu and Hai-Hu Wen of the Chinese Academy of Sciences, Jeffrey W. Lynn of the National Institute of Standards and Technology, Paul G. Freeman of the Institut Laue-Langevin, Louis-Pierre Regnault of the Commissariat á l'Énergie Atomique, Klaus Habicht of the Hahn-Meitner-Institut and Pengcheng Dai, professor of physics at UT with a joint appointment at Oak Ridge National Laboratory.