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Local or Roaming?

The Dai Group Investigates Magnetism in Iron-Arsenic Superconductors

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Is magnetism a stay-at-home phenomenon, or does it like to travel?

Professor Pengcheng Dai's group addresses this question with respect to superconductors in their most recent paper, "Spin waves and magnetic exchange interactions in $CaFe_2As_2$," which appeared in the July 13 issue of *Nature Physics*.

Superconducting materials date to 1911, when it was first discovered that certain metals lose all resistance when cooled to almost absolute zero. The phenomenon occurs when electrons, which normally repel one another, instead form pairs and usher electrical current through a material without interference. In these traditional, low-temperature superconductors, the pairing results when electrons interact with vibrations in the material's lattice—the arrangement of its atoms, ions, or molecules. These vibrations are called phonons.

Another breakthrough came in the mid-1980s with the revelation of high-temperature (high T_c) superconductors. (Here, high temperature means about 30 Kelvin or above, still well below room temperature.) Most of these samples comprise copper and oxygen and are called cuprates. But in 2008, researchers discovered a new class of high-T_c superconductors made of iron and arsenic. The Dai group has been studying these materials since they arrived on the scene last spring.

High-T_c superconductors differ from the conventional set because science has yet to conclusively determine what causes their electrons to form pairs. The traditional phonons mechanism has many difficulties in interpreting experimental results. One explanation that has emerged, however, is magnetism; or, more technically, antiferromagnetic (AFM) order since the parent compounds of all high-temperature superconductors orders antiferromagnetically. In its AFM ordered arrangement, neighboring ions in a sample line up in opposite directions. External magnetic fields have no influence over this arrangement at low temperatures and very little at higher temperatures. Adding an electron to this configuration, or a space for one, makes both the cuprates and the iron-arsenic materials superconducting. Consequently, exactly what causes AFM order in the iron-arsenic compounds has become an intriguing question; one the Dai group's paper addresses. They consider two possibilities: a "local moment" picture and an itinerant model. The former means the magnetic electrons tend to stay in one place, while in the itinerant model they have more freedom to move around.

Dai and his colleagues studied the spin waves in single crystals of a compound made from calcium, iron, and arsenic. (Spin is an intrinsic property of elementary particles, the same as charge or mass.) They mapped spin wave fluctuations using inelastic neutron scattering, where neutrons are scattered off a sample and the changes in their energy reveal information about the material's nuclear and magnetic structure. What they discovered is that magnetism in the parent compounds of iron arsenic superconductors can't be categorized as completely local or purely itinerant, but instead, as the paper states, is "a complicated mixture of the two." The experiments were carried out on the MERLIN time-of-flight chopper spectrometer at the Rutherford Appleton Laboratory in Didcot, UK.