Family Ties

The Dai Group Finds that Iron-Based Superconductors Could Have Similar Magnetic Origins

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Even at their lowest energies, they might behave completely differently. They may not arrange their ions in quite the same way. And some of them really do have bad parents. But Professor Pengcheng Dai's group has reason to believe that, despite their differences, iron-based superconductors have a common ancestry. Recent experiments published in *Nature Communications* indicate that magnetism in these materials may have identical origins, a development that takes yet another step in pinning down their properties.

The family tree of superconductivity has grown considerably since it was first discovered in 1911. First came the conventional superconductors like metals such as aluminum and mercury, where scientists surmised that superconductivity is the result of electrons pairing off to let electric current move along unimpeded. This pairing is caused by vibrations in the materials' lattice structure with itinerant electrons. The problem was that superconductivity vanished at high temperatures, a significant shortcoming considering the heat generated in applications like computing and transportation, where it would be nice if electricity ran with no interruption. Then came the high-temperature (or high *Tc*) superconductors, many fashioned from compounds where copper was the star of the show. They did a slightly better job, but still functioned far below practical temperatures. Scientists tried to identify the exact cause of their electron pairing so they could coax them into working at elevated temperatures, but with limited success. It wasn't until 2008 that a new arrival in the family sparked tremendous excitement. A new kind of high-Tc materials came into the picture, these based on iron rather than copper.

Professor Dai's group has been a witness to (and in some cases the author of) superconductivity's more recent family history. They originally worked with copper-based high-Tc materials, but when iron-based superconductors exploded onto the scene, they quickly changed directions. In May 2008 they published one of the highest-cited papers on these new materials: "Magnetic Order Close to Superconductivity in the Iron-Based Layered $La(O_{1-x},F_x)FeAs$ Systems," which appeared in *Nature*.

In recent experimental work, Dai's group focused on iron pnictides, materials that come from the nitrogen group of the periodic table. The parent compounds of these superconductors are so-called bad metals, which have complicated excitations at low energies.

In a *Nature Communications* paper appearing this week, Dai's group discusses how these iron pnictides compare with the recently discovered alkaline iron selenide superconductors. The latter have generated a lot of excitement because studies indicate the source of their electron pairing (and hence their superconductivity) may deviate from that proposed for the earliest iron-based examples.

As with members of any family, these two types of superconductors have some marked differences. They differ in their lowest-energy (ground) states: some are metallic and some are insulating. They have different antiferromagnetic, or AF, structures. (In an antiferromagnetic material, the adjacent ions are aligned in opposite or "anti-parallel" arrays, such as an up arrow next to a down arrow, and so on). They also have different Néel temperatures: the mark above which an AF material becomes paramagnetic; acquiring magnetization when a magnetic field is applied, but losing it once the field is removed. Yet both materials are still iron-based and both are superconductors.

To find a link between the two, the Dai group produced samples made from iron, rubidium, and selenium in their on-campus laboratory for study at the Spallation Neutron Source at Oak Ridge National Laboratory. Using the Angular-Range Chopper Spectrometer (ARCS), they used inelastic neutron scattering to map out the samples' spin waves, a collective excitation associated with magnetic systems. This showed that the iron pnictides and the alkaline iron selenides had similar magnetic interactions in their next-nearest-neighbors—sites within the surface lattice that are diagonal from each other. The group concluded that this similarity in the magnetic properties of the parent compounds suggests a common origin for magnetism in all iron-based superconductors.

The findings are reported in "Spin waves and magnetic exchange interactions in insulating $Rb_{0.89}$ $Fe_{1.58}$ Se_2," appearing in *Nature Communications* December 6. Among the authors is Tucker Netherton, an undergraduate major and scholarship student in the UTK Physics Department. The complete list of authors includes Miaoyin Wang, Leland W. Harriger, Tucker Netherton, Yu Song, Chenglin Zhang, and Pengcheng Dai of UTK; GuoTai Tan of UTK and Beijing Normal University; Meng Wang of UTK and the Chinese Academy of Sciences; Chen Fang of Purdue University; Dao-Xin Yao of Sun Yat-sen University; Matthew B. Stone of ORNL; Wei Tian of Iowa State University; and Jiangping Hu of Purdue University and the Chinese Academy of Sciences.

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