Physicists offer new theory for iron compounds

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An international team of physicists from the United States and China this week offered a new theory to both explain and predict the complex quantum behavior of a new class of high-temperature superconductors.

The findings, which are available online this week from the Proceedings of the National Academy of Sciences, are about materials known as iron pnictides (pronounced NIK-tides). The discovery of high-temperature superconductivity in pnictides a year ago is a boon for physicists who have struggled for more than two decades to explain the phenomena based on observations from a class of copper-based superconductors called cuprates (pronounced COO-prayts).

"Our research addresses the quantum magnetic fluctuations that have been observed in iron pnictides and offers a theory to explain how electron-electron interactions govern this behavior," said study co-author Qimiao Si, a physicist from Rice University. "The origins of superconductivity are believed to be rooted in these effects, so understanding them is extremely important."

In the PNAS paper, Si and collaborators from Rutgers University, Zhejiang University and the Los Alamos National Laboratory explain some of the similarities and differences between cuprates and pnictides. Under certain circumstances, the atomic arrangements in both materials cause electrons to behave collectively, marching in lock step with one another. Experimental physicists study how changes in temperature, magnetic fields and the like cause the coordinated effects to change.

They also look for changes arising from differences in the way the compounds are prepared, such as when other substances are added via a technique called "doping."

"In cuprates, the parent compounds are not metallic, and they only become superconducting when they are doped," said Rutgers University physicist and co-author Elihu Abrahams. "In contrast, the parent compounds of pnictides are metallic, but like the undoped cuprates they exhibit a quantum magnetic property called antiferromagnetism."

Based on what's known about electron-electron interactions and about antiferromagnetism in other metals, the authors created a theoretical framework to explain the behavior of the pnictides, offering some specific predictions about how they will behave as they change phases.

Matter is commonly transformed when it changes phases; the melting of ice, for example, marks water's change from a solid phase to a liquid phase. In materials like cuprates and pnictides, the tendency of electrons to act in concert can lead to "quantum" phase changes, shifts from one phase to another that arise entirely from the movements of subatomic particles. The study of quantum "critical points," the tipping points that mark these phase changes, is known as "quantum criticality."

"Our work opens up the iron pnictides as a new setting to study the rich complexities of quantum criticality," said Si. "This is much needed since quantum critical points, which are believed to be important for a wide range of quantum materials, have so far been observed in only a small number of materials."

Source: Rice University (news : web)