Theories of high-temperature superconductivity violate Pauli principle

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Scientists seeking to explain high-temperature superconductivity have been violating the Pauli exclusion principle, a team of researchers from the University of Illinois at Urbana-Champaign and Rutgers University report. Any theory that does not embrace the Pauli principle has a lot of explaining to do, they say.
The basic organizing precept behind the periodic table is the Pauli principle, which says that electrons with the same spin cannot occupy the same energy state. The Pauli principle leads to the shell structure of atoms, and is inviolate for electronic systems. Many researchers, however, have been breaking this important rule when proposing theories to explain the mechanism behind high-temperature superconductivity.

"Within a class of materials known as doped Mott insulators, such as the high-temperature copper-oxide superconductors, the Pauli principle emerges as a sum-rule connecting high- and low-energy scales," said Philip Phillips, a professor of physics at the University of Illinois at Urbana-Champaign, who will present the team's findings at the spring meeting of the American Physical Society, to be held in Los Angeles, March 21-25. This work also appeared in the Dec. 31, 2004, issue of the journal Physical Review Letters.

"It is standard practice in physics to separate high- and low-energy scales through a procedure known as renormalization," Phillips said. "We have shown that this procedure changes the statics of the excitations within doped Mott insulators, resulting in a violation of the Pauli principle.

Since such a violation is not possible, we conclude that high- and low-energy scales are inextricably linked in doped Mott insulators."

Unlike low-temperature superconductors, which are metals, high-temperature superconductors are insulators in their normal state. Even more puzzling, half of the electron states are empty.

"Since there are plenty of available positions for electrons, you would think these materials should be metallic," Phillips said. "Even though there are many unoccupied states, strong electron interactions cause them to be insulators."

Strong electron interaction is the key to understanding Mott insulators, Phillips said. "The interactions cause a mixing of the high- and low-energy scales. Because the electrons at all energy levels are interconnected, performing renormalization will be done at a price -- in this case at the expense of the Pauli exclusion principle."

Phillips and his colleagues -- Illinois graduate student Dimitrios Galanakis and former graduate student Tudor D. Stanescu (now a postdoctoral research associate at Rutgers University) -- also suggest that the mixing of high- and low-energy scales might explain the absence of well-resolved electron-like features in the normal state of the copper-oxide superconductors.

Experiments have demonstrated that removing an electron from a metal results in a very narrow peak in the photoemission spectrum. Removing an electron from the normal state of a high-temperature superconductor results in a very broad feature.

"If you remove the high-energy scale through the process of renormalization, the spectral features are very sharp," Phillips said. "But if you retain it, the features are very broad. If the physics changes when you remove the high-energy scale, then renormalization is out the window. The Pauli principle can not be violated."

Source: University of Illinois at Urbana-Champaign