New particle explains odd behavior in cuprate superconductors

July 17 2007

New fundamental particles aren't found only at Fermilab and at other particle accelerators. They also can be found hiding in plain pieces of ceramic, scientists at the University of Illinois report.

The newly formulated particle is a boson and has a charge of 2e, but does not consist of two electrons, the scientists say. The particle arises from the strong, repulsive interactions between electrons, and provides another piece of the high-temperature superconductivity puzzle.

Twenty-one years ago, superconductivity at high temperatures was discovered in copper-oxide ceramics (cuprates). Existing explanations of superconductivity proved inadequate because, unlike low-temperature superconductors, which are metals, the parent materials from which all high-temperature superconductors arise are insulators.

Now, a new theory suggests something has been overlooked. "Hidden in the copper-oxide materials is a new particle, a boson with a charge of 2e," said Philip Phillips, a professor of physics at Illinois.

Surprisingly, this boson is not formed from the elementary excitations – that is, electrons and ions. Instead, the particle emerges as a remnant of the strong interactions between electrons in the normal state.

"High- and low-energy scales are inextricably coupled in the cuprates," Phillips said. "Normally, when you remove a single electron from most systems, one empty state is created. In the cuprates, however, when you remove an electron, you create two empty states – both of which occur at low energy, but paradoxically, one of the states comes from the high-energy scale."

Experimental evidence of this "one to two" phenomenon was first reported in 1990 and explained phenomenologically by University of Groningen physicist George A. Sawatzky (now at the University of British Columbia) and colleagues. What was missing was a low-energy theory that explained how a high-energy state could live at low energy.

Phillips, with physics professor Robert G. Leigh and graduate student Ting-Pong Choy, have constructed such a theory, and have shown that a charged 2e boson makes this all possible.

"When this 2e boson binds with a hole, the result is a new electronic state that has a charge of e," Phillips said. "In this case, the electron is a combination of this new state and the standard, low-energy state. Electrons are not as simple as we thought."

The new boson is an example of an emergent phenomenon – something that can't be seen in any of the constituents, but is present as the constituents interact with one another.

By constructing a low-energy theory of the cuprates, the researchers have moved a step closer to unraveling the mystery of high-temperature superconductivity.

"Until we understand how these materials behave in their normal state, we cannot understand the mechanism behind their high-temperature superconductivity," Phillips said.

Source: University of Illinois at Urbana-Champaign

Citation: New particle explains odd behavior in cuprate superconductors (2007, July 17) retrieved 26 April 2024 from https://phys.org/news/2007-07-particle-odd-behavior-cuprate-superconductors.html