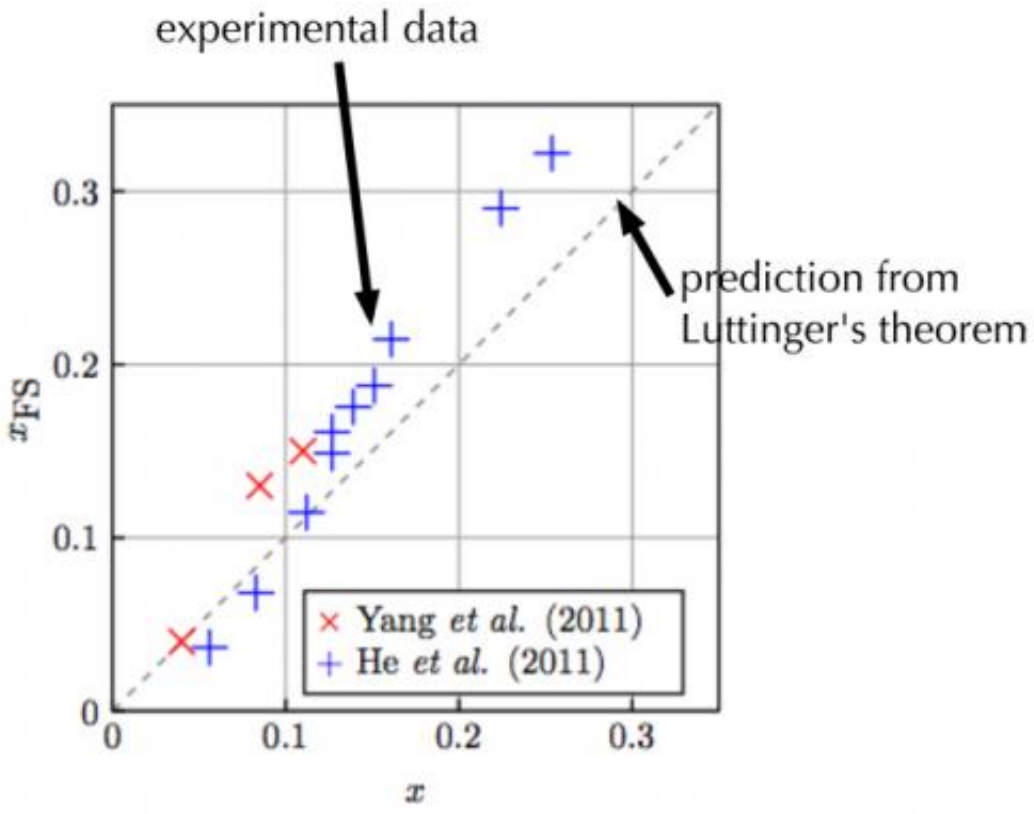
Electrons are not enough: Cuprate superconductors defy convention

March 19 2013, by Liz Ahlberg



Graph showing the breakdown of Luttinger's theorem in the normal state of cuprate superconductors. The horizontal axis is the expected number of mobile electrons while is the vertical axis is the measured number. The two should be equal if the theorem were true. Credit: Philip Phillips

(Phys.org) —To engineers, it's a tale as old as time: Electrical current is carried through materials by flowing electrons. But physicists at the

University of Illinois and the University of Pennsylvania found that for copper-containing superconductors, known as cuprates, electrons are not enough to carry the current.

"The story of electrical conduction in metals is told entirely in terms of electrons. The cuprates show that there is something completely new to be understood beyond what electrons are doing," said Philip Phillips, a professor of physics and of chemistry at the U. of I.

In physics, Luttinger's theorem states that the number of electrons in a material is the same as the number of electrons in all of its atoms added together. Electrons are the sub-atomic particles that carry the current in a conductive material. Much-studied conducting materials, such as metals and semiconductors, hold true to the theorem.

Phillips' group works on the theory behind high-temperature superconductors. In superconductors, current flows freely without resistance. Cuprate superconductors have puzzled physicists with their superconducting ability since their discovery in 1987.

The researchers developed a model outlining the breakdown of Luttinger's theorem that is applicable to cuprate superconductors, since the hypotheses that the theorem is built on are violated at certain energies in these materials. The group tested it and indeed found discrepancies between the measured charge and the number of mobile electrons in cuprate superconductors, defying Luttinger.

"This result is telling us that the physics cannot be described by electrons alone," Phillips said. "This means that the cuprates are even weirder than previously thought: Something other than electrons carries the current."

"Theorists have suspected that something like this was true but no one has been able to prove it," Phillips said. "Electrons are charged.

Therefore, if an electron does not contribute to the charge count, then there is a lot of explaining to do."

Now the researchers are exploring possible candidates for current-carriers, particularly a novel kind of excitation called unparticles.

Phillips, U. of I. undergraduate student Kiaran Dave (now a graduate student at MIT) and University of Pennsylvania professor Charles Kane published their findings in the journal *Physical Review Letters*. The paper, "Absence of Luttinger's Theorem due to Zeros in the Single-Particle Green Function," is available online.

Provided by University of Illinois at Urbana-Champaign