

Research pokes holes in Hubbard model: Could help solve enigma of high-temperature superconductors

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New UBC research has literally and figuratively poked holes in singleband Hubbard physics--a model that has been used to predict and calculate the behavior of high-temperature superconductors for 20 years.

The findings are the first compelling evidence challenging the model under certain conditions, and could necessitate entirely new theoretical approaches to explaining superconductivity in cuprate materials, one of the outstanding mysteries in condensed-matter physics.

"Single-band Hubbard physics has been used for 20 years to predict how superconducting cuprate materials accommodate the 'holes' left by electron removal," says Darren Peets, lead author of the study who conducted the research while a UBC doctoral student. "But now it looks like the approaches that underpin a large fraction of the theoretical work in the field just don't work across all the ranges of superconductivity we can study. The part of the cuprates' superconducting phase diagram we looked at could exhibit less-bizarre behaviour, or we could be seeing completely new physics, but in either case the usual theoretical approaches do not work here."

The findings were published today in the journal <u>Physical Review</u> <u>Letters</u>.

Cuprates normally act as insulators but become superconductors when



electrons are removed--a process known as 'doping' holes into the material. Physicists consider a material optimally doped when it achieves <u>superconductivity</u> at the highest, most accessible temperature.

UBC researchers where able to break the single-band Hubbard model by 'overdoping' a crystal cuprate superconductor past its optimal range--a level of doping that is difficult to achieve and very rarely studied. While the model explains the material's electron behaviour during doping, Peets and his team found the model falls apart as even more electrons are removed.

"By probing the <u>electronic states</u> using tunable-energy X-rays, we were able to show that this region accommodates electron holes in a fundamentally different manner, and that the interactions among the holes already in the material change completely."

Special crystal samples grown at UBC enabled the team to overdope the superconductor to a degree rarely possible with most materials. "Few materials exist in this doping range, and they tend to be very difficult to grow crystals of," says Peets. "In the case of these crystals, thallium oxide--which is toxic--boils off near growth temperatures if you allow it. So a fair bit of work and care is required."

Discovered in 1986, <u>high-temperature superconductors</u> are cuprates--copper oxides. The materials, which exhibit superconducting properties at usually cold temperatures--often in excess of 90 kelvin--remain an enigma despite intense scrutiny. And because their superconducting state persists at more manageable temperatures, more commercial applications are feasible.

Source: University of British Columbia (news : web)



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