Fields of dreams: Magnetic stresses on cuprate superconductor show unique conductivity

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Resistance studies reveal ‘strange metal’s’ electrical peculiarity

LOS ALAMOS, N.M., Aug 3, 2018—Using incredibly high magnetic fields, researchers from Los Alamos National Laboratory and partners are exploring the electrical resistance of a copper-oxide based superconducting material, seeking to clarify its behavior in the highest superconducting transition temperatures. Superconducting materials are essential to such products as more efficient power transmission lines, medical equipment and power storage devices.

“We have discovered that these materials, called ‘strange metals,’ have a behavior under high magnetic fields that is actually a whole new way to conduct electricity,” said Arkady Shekhter, one of the study’s co-authors. “We need to find a new language to think about these materials.”

Resistance measurements of the cuprate superconductor La2-xSrxCu04 are helping the research team understand the role of scale (or more importantly, the lack of scale) in grasping the behavior of unconventional metals. By using some of the National High Magnetic Field Laboratory Pulsed Field Facility’s highest available magnetic fields, they are able to explore the anomalous metallic state associated with the highest superconducting transition temperatures.

For normal metals the Fermi energy scale—the energy of the most energetic electrons in the system—is important because they are the only states to “slosh around” carrying current. To date this Fermi-liquid description of metals enables the charge transport in all but the most strongly interacting materials to be described in terms of the dynamics of long-lived electron-like quasi-particles at the Fermi energy

But the description doesn’t work for everything. This new work addresses how this Fermi liquid concept breaks down for the most strongly interacting materials, such as the anomalous “strange-metal” phase of high-temperature superconductors.

The team put the significant capabilities of the Los Alamos Pulsed Field Facility to work to explore how a magnetic field affects the resistance. “Like waves on the surface of a pond, in a metal the way electrons are pushed around the ‘Fermi-surface’ normally determines the magnetoresistance,” said Ross McDonald, NHMFL deputy director.

The material's behavior is a breakdown of conventional Fermi liquid theory calling into question the very existence of electron-like quasi-particles in these materials. Furthermore, the ubiquity of this behavior in multiple families of both the copper and iron based high-temperature superconductors, indicates a commonality in the underlying physics of these (quantum-critical) strange-metals that birth the highest temperature superconductivity.

Although there is as yet no microscopic description of this scale invariance, its observation is a key step in the necessary understanding if we ever stand a chance of engineering that uses strongly interacting quantum materials.

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Authors: P. Giraldo-Gallo (National MagLab and the Universidad de los Andes); J.A. Galvis (National MagLab and Universidad Central); Zachary Stegen (National MagLab and FSU); K.A. Modic (Max-Planck-Institute for Chemical Physics of Solids); F.F. Balakirev and J.B. Betts, (Los Alamos National Lab); X. Lian, and C. Moir (National MagLab and FSU); S.C. Riggs (National MagLab); J. Wu and A.T. Bollinger (Brookhaven National Lab); X. He (Brookhaven and Yale University); B.J. Ramshaw (LANL and Cornell University); R. D. McDonald (LANL); and G.S. Boebinger (National MagLab and FSU).

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