Scientists closer to solving a superconducting puzzle with applications in medicine, transport and power transmission

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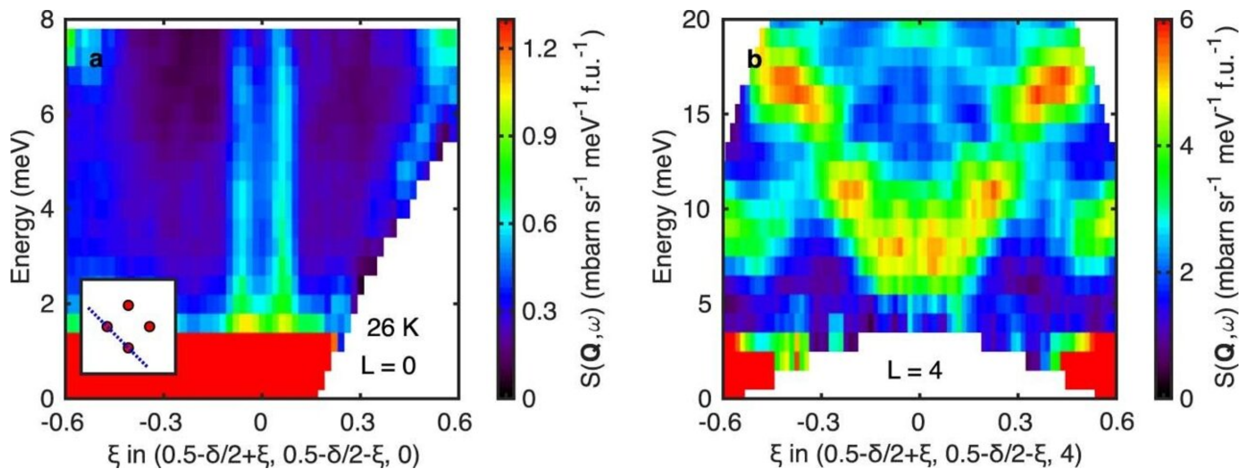

Spin fluctuations and phonons in La2-xSrxCuO4 (x = 0.22) near Qδ. S(Q, ω) as a function of energy and wavevector along a trajectory through two incommensurate wave vectors Qδ = (0.5-δ, 0.5, L) and (0.5, 0.5-δ, L) (see inset to panel a). Integration ranges are a L ∈ [− 1, 1] and b L ∈ [3.8, 4.2]. Strong phonons are observed (panel b) for L ≈ 4, but these are not visible near L = 0 (panel a) where spin fluctuations are seen. Data were collected on LET (panel a) and MERLIN (panel b). Credit: *Nature Physics* (2022). DOI: 10.1038/s41567-022-01825-3

Researchers studying the magnetic behavior of a cuprate superconductor may have explained some of the unusual properties of their conduction electrons.

Cuprate superconductors are used in levitating trains, quantum computing and power transmission. They are of a family of materials made of layers of copper oxides alternating with layers of other metal oxides, which act as charge reservoirs.

The largest use of superconductors is currently for manufacturing superconducting magnets used for medical MRI machines and for scientific applications such as particle accelerators.

For the potential applications of superconducting materials to be fully realized, developing superconductors that maintain their properties at higher temperatures is crucial for scientists. The cuprate superconductors currently exhibit relatively high transition point temperatures and therefore give scientists an opportunity to study what makes higher temperature superconductivity possible.

In this study, published in *Nature Physics*, a collaboration involving the University of Bristol and the ISIS Pulsed Neutron and Muon Source, they focused on the cuprate superconductor $La_{2-x}Sr_xCuO_4$ (LSCO). Superconductivity in this system is very sensitive to the exact ratio of Lanthanum (La) to Strontium (Sr) offering the ability to understand which properties are correlated with superconductivity. LSCO is also close to being magnetically ordered and one possibility is that the magnetic fluctuations are what enables its superconductivity.

Inelastic neutron scattering offers an excellent method to study these magnetic fluctuations. The researchers were able to measure over a wide range of reciprocal space and energy scales. This enabled them to build a full picture of the spin fluctuations and phonons, allowing very low energy spin fluctuations to be isolated.

Although cuprate superconductors are metals above the temperature where they become superconducting, the electrons that carry current behave very strangely. As the temperature is increased, their ability to carry current is dramatically reduced. The low-energy spin fluctuations could scatter the conduction electrons and explain this strange metal behavior.

Furthermore, when the superconductor was cooled and the superconductivity suppressed with a magnetic field, the spin fluctuations became stronger and slow down suggesting the material is close to magnetic order. This could help to explain the unusual electronic properties of the cuprates.

Prof Stephen Hayden of Bristol's School of Physics said, "This study has demonstrated the potential importance of spin fluctuations in understanding cuprates. A deeper understanding of their properties and their relation to superconductivity is another step towards designing materials with higher superconducting temperatures.

"In the future they should be used for quantum computing, transport including levitating trains and compact motor as well as power transmission. There are already demonstration projects for the latter.

"The work relies on the unique instrumentation and sample environment available at ISIS."

More information: M. Zhu et al, Spin fluctuations associated with the collapse of the pseudogap in a cuprate superconductor, *Nature Physics* (2022). DOI: 10.1038/s41567-022-01825-3

Provided by University of Bristol