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Team introduces breakthrough in understanding of high-temperature superconductivity

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Researchers from the University of Miami (UM) are unveiling a novel theory for high-temperature superconductivity. The team hopes the new finding gives insight into the process, and brings the scientific community closer to achieving superconductivity at higher temperatures than currently possible. This is a breakthrough that could transform our world.

Superconductors are composed of specific metals or mixtures of metals that at very low temperatures allow a current to flow without resistance. They are used in everything from electric devices, to medical imaging machines, to wireless communications. Although they have a wide range of applications, the possibilities are limited by temperature constraints.

"Understanding how superconductivity works at higher temperatures will make it easier to know how to look for such superconductors, how to engineer them, and then how to integrate them into new technologies," says Josef Ashkenazi, associate professor of physics at the UM College of Arts and Sciences and first author of the study. "It's always been like this when it comes to science: once you understand it, the technological applications follow."

At room temperature, superconducting materials behave like typical metals, but when the temperature is lowered toward absolute zero (at around -273oC, or -460oF), resistance to electric current suddenly drops to zero, making it ultra-efficient in terms of energy use. Although absolute zero is unachievable, substances such as liquid helium and liquid nitrogen can be used to cool materials to temperatures approaching it.

Researchers are also working on creating materials that yield superconductivity in a less frigid environment. The point at which a matter becomes a superconductor is called critical or transition temperature. So far, the highest critical temperature of a superconducting material is about -130oC (-200oF).

"But just 'cooking' new materials that produce superconductivity at higher temperatures can be very tedious and expensive, when one doesn't know exactly how the process works," says Neil Johnson, professor of physics in the UM College of Arts and Sciences and co-author of the study.

To understand the problem, the UM team studied what happens in a metal at the exact moment when it stops being a superconductor. "At that point, there are great fluctuations in the sea of electrons, and the material jumps back and forth between being a superconductor and not being one," Johnson says.

The key to understanding what happens at that critical point lies in the unique world of quantum particles. In this diminutive universe, matter behaves in ways that are impossible to replicate in the macroscopic world. It is governed not by the laws of classical physics, but by the laws of quantum mechanics.

One of the most perplexing features of quantum mechanics is that a system can be described by the combination or 'superposition' of many possible states, with each possible state being present in the system at the same time. Raising the critical temperature of superconductors is prevented in common cases, because it creates a fragmentation of the system into separate states; this act suppresses high-temperature superconductivity.

What Ashkenazi and Johnson found is that just above the critical temperature specific quantum effects can come to the floor and generate superpositions of individual states. This superposition of states provides an effective "glue," which helps repair the system, allowing superconducting behavior to emerge once again. This model provides a mechanism for high temperature superconductivity.

"Finding a path to high-temperature superconductivity is currently one of the most challenging problems in physics," says Ashkenazi. "We present for the first time, a unified approach to this problem by combining what has prevented scientists from achieving high-temperature superconductivity in the past, with what we now know is permitted under the quantum laws of nature."

"The new model combines elements at two levels: physically pulling together the fragments of the system at the quantum level, and theoretically threading together components of many other existing theories about superconductivity," Johnson says.

Understanding how superconductivity is pushed beyond the present critical temperatures will help researchers recreate the phenomenon at a wider temperature range, in different materials, and could spur the development of smaller, more powerful and energy efficient technologies that would benefit society.

More information: The study, titled "Pairing Glue Activation in Curates within the Quantum Critical Regime," is published online ahead of print by the journal *Europhysics Letters*.

Provided by University of Miami

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