# Once thought a rival phase, antiferromagnetism coexists with superconductivity

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High-temperature superconductivity can be looked at as a fight for survival at the atomic scale. In an effort to reach that point where electrons pair up and resistance is reduced to zero, superconductivity must compete with numerous, seemingly rival phases of matter.

Understanding those phases and whether or not they are rivals or complementary phenomena has consumed the attention of theoreticians and experimentalists in the quest to find superconducting materials capable of functioning at close-to-room temperature, a potential that has gone unrealized for nearly three decades.

One of those phases, antiferromagnetism (AFM), shows evidence of co-existing with superconductivity under examination by two high-tech procedures for measuring the activity of neutrons and electrons, an international team of physicists report in the current edition of the journal Nature Physics.

The findings add further evidence to the team's earlier discovery that spin excitations – the dynamic harmonic oscillations of the magnetic moments associated with subatomic particles like electrons – play a crucial role in superconductivity, said lead author and Boston College Associate Professor of Physics Vidya Madhavan.

The team – including researchers from Boston College, Chinese

Academy of Sciences, National Institute of Standards and Technology, Oak Ridge National Laboratory and the University of Tennessee, – used neutron scattering and scanning tunneling microscopy to determine the interplay between AFM and superconductivity.

In certain solids, antiferromagnetism exists when adjacent ions – each bearing a small magnet called a 'spin' – line up in opposite directions throughout the material, neutralizing its magnetic force. Essentially, the magnetic atoms or ions pointed in one direction cancel out the magnetic atoms or ions pointing in the opposite direction.

Madhavan said all high temperature superconductors are close to the AFM phase. But it has been thought that AFM disappears, giving way to the emergence of superconductivity.

But tests on a copper oxide doped with additional electrons displayed activity that runs counter to the theory that the phases exclude each other, said Madhavan. Instead, AFM remains as superconductivity is reached in the high-temperature superconductor.

"The two phases actually compete and co-exist," said Madhavan. The neutron scattering and scanning tunneling microscopy revealed spin excitations in both modes – AFM and superconductivity. While neutron scattering can directly probe spin excitations, STM can identify the behavior of the electrons. Together, the evidence shows spin excitations in the electronic spectrum, which signals that electron coupling is taking place.

The experimental evidence is crucial to better understanding superconductivity, Madhavan said.

"These strongly correlated materials are very hard to handle from a theoretical standpoint because there are so many possibilities," said

Madhavan. "In this field we need to really understand these materials experimentally because theory is very difficult to do."

This experimental work gives additional evidence that spin excitations are critical to superconductivity, Madhavan said, "and it gives us a deeper understanding of the interplay between various phases."

Provided by Boston College