NEWS RELEASE 11-NOV-2024 (Press embargo at 19:00 JST)

New Controversies about the Unusual Superconductivity of Sr_2RuO_4

Researchers from Kyoto University have made important progress in understanding unusual superconductivity, a key area in modern physics that could lead to advancements in technology like quantum computing. A new perspective article published in *Nature Physics* explores the puzzling properties of strontium ruthenate (Sr_2RuO_4), a material that has challenged scientists since it was discovered to be a superconductor in 1994.

Superconductors are materials that can carry electricity without losing energy when they are very cold. However, strontium ruthenate behaves in ways that are hard to explain with current scientific theories. Initially, researchers thought it had a special type of superconductivity called a "spin-triplet" state, which has unique features such as spin supercurrent. But even after many studies, the full understanding of its behavior remained a mystery.

Recently, new experiments suggested that strontium ruthenate might act more like a "spin-singlet" state. Changes in its properties when pressure is applied also point to a different kind of behavior. Despite these new findings, scientists still do not have a full explanation for what is happening, and several research steps are still necessary to open the *Gate of Truth of superconductivity* for this material.

In this perspective article, the researchers highlight several ongoing controversies in the field, particularly the discrepancies between experiments using uniaxial pressure and ultrasound, a point that is likely to surprise the scientific community. This highlights the urgent need for further investigation and rethinking of traditional ideas about superconductivity. New forms of exotic electron pairing could be hiding in the superconducting state of strontium ruthenate, like the novel inter-orbital spin-triplet state that behaves like a spin-singlet state.

Understanding these mysteries could help us learn more about superconductivity in general. Such knowledge is important for finding new materials that can be used in advanced technologies, such as quantum computers.

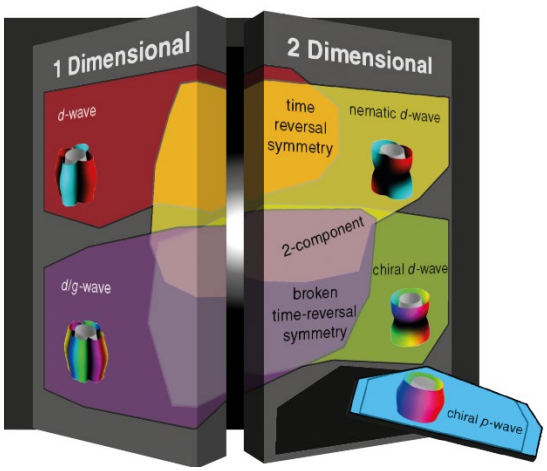

IMAGE 1: OPENING THE GATE OF TRUTH OF PUZZLING SUPERCONDUCTIVITY IN STRONTIUM RUTHENATE. (CREDIT: G. Mattoni)

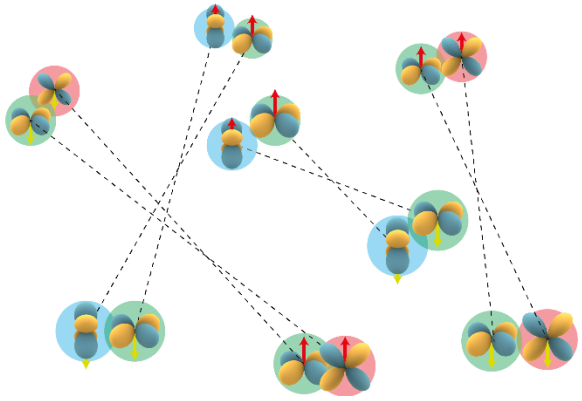

IMAGE 2: EXOTIC PAIRING BETWEEN ELECTRONS IN DIFFERENT ORBITAL STATES. SUCH INTER-ORBITAL, SPIN-TRIPLET SUPERCONDUCTIVITY IS ALSO PROPOSED FOR THE RUTHENIUM OXIDE. (CREDIT: G. Mattoni)

JOURNAL: Nature Physics **20**, 1712 – 1718 (2024)

DOI: 10.1038/s41567-024-02656-0

ARTICLE TITLE AND AUTHORS:

Thirty years of puzzling superconductivity in Sr_2RuO_4,

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ARTICLE PUBLICATION DATE: 11-NOV-2024

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