3–3 Slow Dynamics of Electrons in Uranium Compounds

—Approaching the Mystery of Superconductors Leading to Quantum Computers—

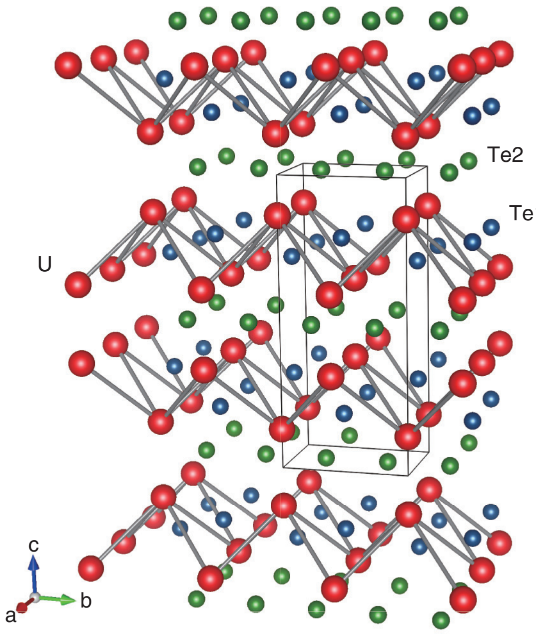

Fig.3-6 Crystal structure of UTe_2
Uranium atoms (red circles) form a characteristic zigzag structure in the crystal.

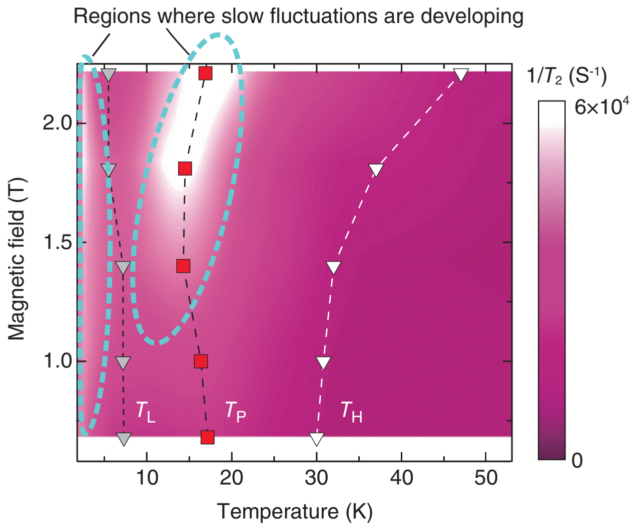

Fig.3-7 Field–temperature phase diagram of the nuclear spin–spin relaxation rate ($1/T_2$)
When the temperature decreases, the slow fluctuation of electrons starts to gradually develop below T_H (▽), and the value of $1/T_2$ increases. With further decrease in temperature, the fluctuations exhibit a peak at T_P (🟥) and decrease once; subsequently, they increase again below T_L (▽).

The discovery of new materials with new electronic properties is the foundation of technological innovations such as computers, mobile phones and the Internet that have the potential to dramatically change our social lives. Materials contain a huge number of electrons, about the same as Avogadro's number, and new electronic properties, such as new magnetism and superconductivity, often emerge when these electrons are strongly correlated with each other. Recently, strongly correlated uranium compounds have received much attention as a platform for discovering new electronic properties.

The uranium compound UTe_2 (Fig.3-6) is a novel superconductor. It discovered at the end of 2018. In ordinary spin-singlet superconductors, the spins of the pairing electrons responsible for superconductivity are aligned in opposite directions. However, in UTe_2, the spins are aligned in the same direction, resulting in a new superconducting state called the spin-triplet state.

In this study, we used nuclear magnetic resonance (NMR) techniques to investigate the electronic states of UTe_2. The NMR is an experimental technique that allows us to investigate the electronic state from a microscopic viewpoint. For this study, we grew a special UTe_2 single crystal enriched with NMR-observable ^{125}Te nuclei from 7% of their natural abundance to 99%. Using the crystal, we measured the nuclear spin–spin relaxation rate ($1/T_2$) and investigated the strength of spin and charge fluctuations inside the material. We found that slow fluctuations with frequencies below the megahertz scale, which are extremely low for electronic systems, appear at low temperatures below about 30 K (Fig.3-7). The appearance of such slow fluctuations indicates the development of strong interactions (long-range correlations) between uranium atoms, which have the characteristic structure shown in Fig.3-6. The role played by such slow fluctuations in the mechanism of spin-triplet superconductivity remains to be clarified.

Uranium-based spin-triplet superconductors, such as UTe_2, are now attracting much attention as systems that realize "topological superconductivity" in the bulk. The topological superconductivity is expected to be applied to next-generation quantum computing. If the mechanism of the spin-triplet superconductivity can be elucidated using UTe_2, it may become possible to design and develop new topological superconductors by applying the mechanism.

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Reference
Tokunaga, Y. et al., Slow Electronic Dynamics in the Paramagnetic State of UTe_2, Journal of the Physical Society of Japan, vol.91, no.2, 2022, 023707, 5p.