

6-3 Identification of Magnetic Fluctuations Inducing Unconventional Superconductivity — Mechanism of Superconductivity Revealed by Nuclear Magnetic Resonance —

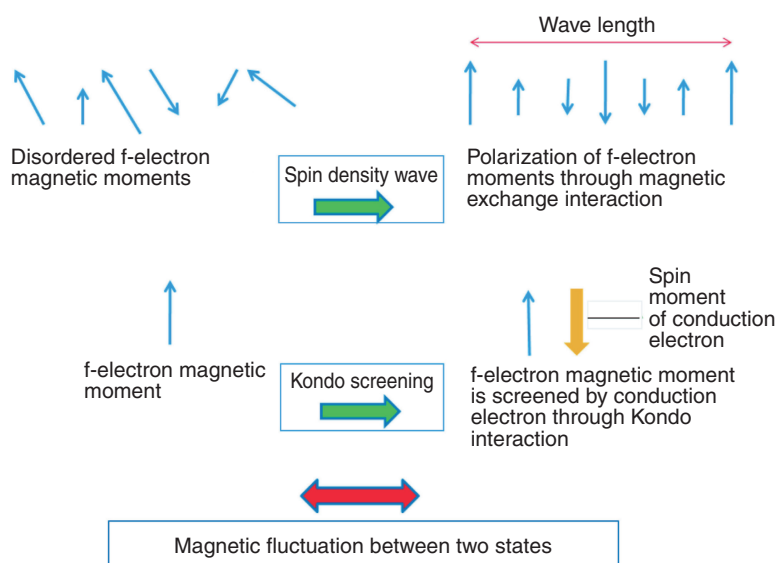


Fig.6-7 Two proposed (spin density wave and Kondo screening) models for magnetic fluctuations which may induce the unconventional superconductivity

These fluctuations can work as “glue” for inducing superconducting pairs.

In the superconducting state, two electrons form a pair (Cooper pair) due to attractive force. For conventional superconductors, lattice vibration (phonon) is the origin of attractive force. In contrast, for unconventional superconductors, magnetic fluctuations are believed to induce the Cooper pairs.

Recently, two different theoretical models (spin density wave and Kondo screening models) have been proposed to describe the magnetic fluctuation. However, no definitive experimental evidence has been obtained to determine which is the proper model so far. In this study, we have obtained clear experimental evidence which supports the spin density wave model in the uranium compound USn_3 , using the nuclear magnetic resonance (NMR) method.

In f-electron systems such as uranium compounds, local magnetic moments due to f-electrons have magnetic exchange interactions with each other, and at the same time, interact with conduction electrons through the Kondo interaction. As illustrated in Fig.6-7, if the magnetic exchange interaction is dominant, the local magnetic moments have a tendency to be polarized, making possible determination of the magnetic exchange energy (spin density

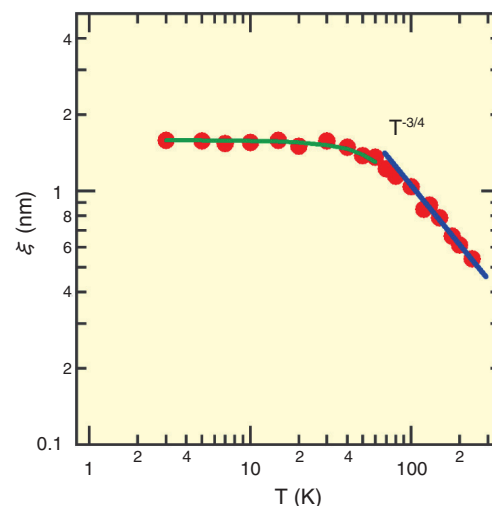


Fig.6-8 Temperature dependence of magnetic coherence length ξ in USn_3

NMR results (●) coincide well with curves calculated with the spin density wave model (blue line, green line). This indicates that the spin density wave is the origin of magnetic fluctuations.

wave state). On the other hand, the local magnetic moments would be screened by conduction electron spins if the Kondo interaction is dominant (Kondo screening state). In the present work, temperature dependence of magnetic coherence length is determined in USn_3 from NMR relaxation measurements. Obtained experimental results (●) coincide well with those calculated from the spin density wave model (green and blue lines) as clearly seen in Fig.6-8, indicating that the spin density wave is dominant in uranium compounds.

The present study suggests that the unconventional superconductivity in uranium compounds is caused by the spin density wave fluctuation. A future new superconductor with higher T_c (superconducting critical temperature) is thought to be realizable in a magnetic-fluctuation-mediated superconducting system, since T_c of phonon-mediated superconductors has reached its peak already. This study suggests that a search for materials possessing enhanced spin density wave fluctuation would be effective for finding new high T_c superconductors.

We will be investigating actinide compounds to clarify the mechanism of superconductivity in detail.

Reference

Kambe, S. et al., Crossover from the Quantum Critical to Overdamped Regime in the Heavy Fermion System USn_3 , Physical Review Letters, vol.102, issue 3, 2009, p.037208-1-037208-4.