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»Prospecting for unconventional superconductors«

Einführung: J. Schmalian

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Prospecting for unconventional superconductors

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One of the most exciting recent developments in condensed matter research has been the demonstration of superconductivity in superhydrides near room temperature but at very high pressure [1]. The compressed superhydrides demonstrate the potential of engineering a phonon-mediated superconducting pairing mechanism towards optimal outcomes. Further gains are possible by widening the scope towards unconventional superconductors, which harness the strong electronic interactions that are also responsible for magnetism and that are known in some cases to reach coupling strengths equivalent to several thousand Kelvin.

We need new superconductors with superior properties, be it transition temperature, critical current or magnetic field, metallurgy or cost, because they can have transformative impact in applications such as powerful magnets in MRI scanners, particle accelerators and fusion research, lightweight generators, loss-free power transmission, microwave devices, low-power, fast electronics, and quantum computing.

Unconventional superconductivity is rare, and locating it by random search within the combinatorially large material space is ineffective. Fig. 1 illustrates that it is usually confined to a narrow parameter range close to the threshold of magnetic order [2], which in turn can be used to guide the search. Using such heuristic guiding principles, the Quantum Matter group have found several new superconductors, most recently the layered iron germanide YFe_2Ge_2, its sister compound $LuFe_2Ge_2$, and the high pressure phase of $CeSb_2$.

Materials are complicated. Numerous factors – competing interactions, disorder, structural transitions, the role of orbital and charge degrees of freedom – interfere with simple guiding principles but also represent tuning parameters that may be used to advantage. The talk will present high pressure and quantum oscillation measurements in (Y/Lu)Fe_2Ge_2, $CeSb_2$, and UTe_2 [3] to illustrate opportunities and challenges in the search for new unconventional superconductors.

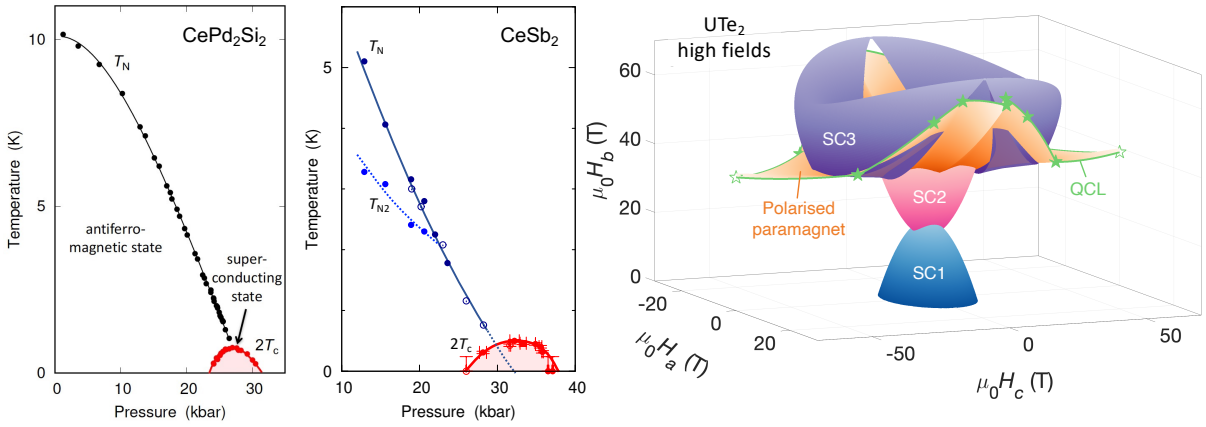

FIG. 1. (left) **Guiding principle:** typical phase diagram of unconventional superconductors, showing a superconducting dome attached to the threshold of antiferromagnetic order [2]. (right) **Superconducting states** in UTe_2 can be switched by applied magnetic field, and the field-resilient state SC3 appears to be anchored to a metamagnetic quantum critical line (QCL).

[1] A. P. Drozdov *et al.*, Nature **569**, 528 (2019), M. Somayazulu *et al.*, Phys. Rev. Lett. **122**, 027001 (2019).
[2] N. D. Mathur *et al.*, Nature **394**, 39 (1998), O. P. Squire *et al.*, Phys. Rev. Lett. **131**, 026001 (2023).
[3] A. G. Eaton *et al.*, Nature Comm. **15**, 223 (2024), T. I. Weinberger *et al.*, Phys. Rev. Lett. **132**, 266503 (2024)