

Superconductivity emerging in some heavy-fermion systems at the verge of their magnetic instability continues to be one of the most intriguing yet still unsolved central problems of modern condensed matter physics. This is due to the special character of the superconducting state, which cannot be described in terms of the conventional theory of superconductivity, as well as due to a variety of unusual physical behavior observed in the normal state. The microscopic nature of all these anomalous phenomena originates from strong electronic correlations in metallic systems bearing localized magnetic moments. In recent years, significant progress has been made in understanding the fundamental mechanisms responsible for the simultaneous occurrence of magnetism and superconductivity. In consequence, the scenarios of competition, coexistence or sometimes even interplay of the two cooperative phenomena have been recognized. Nevertheless, a consistent universal theory of the heavy-fermion superconductivity that might account for all its intriguing aspects is still lacking. Furthermore, new experimental discoveries in the field often result in identification of novel scientific challenges.

Few weeks ago, a new idea has been formulated in the literature regarding the coexistence of superconductivity and long-range antiferromagnetic ordering in crystalline systems bearing multiple inequivalent lattices of localized magnetic moments. As a result of their Kondo-type interactions with spins of conduction electrons, different ground states may emerge in distinct electronic sublattices, e.g., antiferromagnetism in one of them and weakly-polarized heavy-fermion state in the other(s). The latter may give rise to the formation of superconducting condensate. Most importantly, despite formal separation in the reciprocal space, the two cooperative phenomena can exhibit strong interdependence, which might lead to unique physical properties of the crystalline system.

The essential objective of the present project is detailed examination of the interplay between superconductivity and long-range magnetic ordering emerging in distinct Kondo sublattices. We intend to perform comprehensive studies on the magnetic, transport and thermal properties of several representatives of the archetypal series of Ce-based heavy-fermion superconductors with the general chemical formula $Ce_nT_mIn_{3n+2m}$, where T is a d-electron transition metal. The particular compounds to be investigated are either so-far poorly characterized or totally unknown, and the results will be evaluated and interpreted in relation to the rich literature database available for a few other members of the series. The measurements will be carried out on high-quality single-crystalline specimens in wide ranges of temperature, magnetic field and hydrostatic pressure, employing a wide variety of modern bulk and local-probe research techniques, available in our own laboratories, or provided by our domestic and foreign partners. The experimental activities will be accompanied by ab-initio electronic structures calculations and some theoretical modeling, performed in cooperation with a few experts in the relevant field.

One expects that successful accomplishment of the project will not only substantially enhance the knowledge on the heavy-fermion compounds $Ce_nT_mIn_{3n+2m}$, but also significantly contribute to the current general understanding of the mechanisms responsible for the coexistence of magnetism and superconductivity in strongly correlated electron systems. Positive verification of the key research hypothesis in the project should provide a basis for developing some new universal scenarios of the interplay between the two cooperative phenomena, and in consequence facilitate building a theory of superconductivity, which would account for unconventional features commonly observed at the verge of magnetic instability in heavy-fermion systems, cuprates, iron pnictides and chalcogenides, and some organic superconductors.