Master / PhD Thesis Project

Triplet superconductors: from weak to strong spin-orbit coupling

Many unconventional superconductors have been discovered since the 1980s. In some of them, an unconventional spin-triplet pairing, where the Cooper pairs have a spin S=1, has been demonstrated. Such materials have attracted a lot of interest because they may host topological properties.

The order parameter of a spin-triplet superconductor is not described by a scalar as in the singlet case, but by a vector containing the 3 different triplet components, $S_z = -1,0,1$. The possible spin-triplet phases, i.e., the allowed such vectors, depend on the crystal symmetry and the strength of the spin-orbit (SO) coupling of the material. Theoretically, they are typically studied either in the absence of SO coupling or when SO coupling is dominant. However, real materials may possess intermediate strengths of SO coupling. To understand the properties of the triplet superconductivity in that situation is important if one aims at investigating the spin dynamics.

Surprisingly little is known about the spin dynamics of superconductors. In contrast, collective spin modes have played a central role in the study of superfluid ^{3}He, where they have been shown to be a powerful probe of the pairing state. Though measuring the spin dynamics in superconductors is challenging, new materials and improved measurement techniques bring it into reach.

The aim of the internship is to develop a minimal multiband model of a spin-triplet superconductor that allows one to study the crossover from weak to strong SO coupling. The model will be inspired by $CdRh_2As_3$, a material in which a field-induced triplet phase was recently discovered [1,2]. The study will pave the way for computing the dynamic spin susceptibility and identifying possible spin resonances. In the longer term, the insights gained form the study will allow us to construct simpler phenomenological models in order to compute observables.

The project will be performed mainly by using the analytical tools of condensed matter field theory. Interested candidates should have a good basis in quantum mechanics, statistical physics, and solid-state physics. A PhD may follow.

[1] S. Khim et al, Science **373**, 1012 (2021), https://arxiv.org/abs/2101.09522.
[2] D.C. Cavanagh, Phys. Rev. B **105**, L020505 (2022), https://arxiv.org/abs/2106.02698.

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