Master / PhD Thesis Project

Magnetic field effects in layered transition-metal dichalcogenide superconductors

Transition metal dichalcogenides (TMD) are layered materials with a hexagonal lattice structure similar to graphene, but with two inequivalent sites in the unit cell. Like graphene, these materials exhibit a valley degree of freedom. Unlike graphene, however the layers possess a very large intrinsic spin-orbit coupling (SOC), often called Ising SOC, which acts as an effective Zeeman field perpendicular to the plane of the material and with opposite directions in the two valleys (see figure). As a consequence, a large valley-dependent spin-splitting occurs, opening the door for novel applications of TMD monolayers in spintronics and so-called valleytronics.

A number of TMDs are superconductors down to monolayer thickness. The coupling between the spin and valley degrees of freedom has remarkable repercussions also for their superconducting properties. As shown in recent experiments [1], the in-plane upper critical field in TMD monolayers greatly surpasses the so-called Pauli limit due to the Ising SOC.

The internship aims at studying the effect of an in-plane magnetic field on quasi-2D layered structures. While in monolayers it is sufficient to consider the Zeeman effect of the magnetic field, in layered structures the orbital effect also plays an important role. In particular, the orbital effect drives a crossover from quasi-twodimensional to twodimensional superconductivity and may lead to re-entrant superconductivity [2]. During the internship, we will explore the interplay of this effect with the strong layer-dependent Ising SOC in TMDs [3], which by itself may lead to unconventional superconducting states.

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.

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References:

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