TMD Superconductors: the Monolayer Challenge
(Internship Proposal for M1 student, AY 2024-2025)

In conventional Bardeen-Cooper-Schrieffer (BCS) superconductors, Cooper pairs of electrons of opposite spin (i.e. singlet structure) form the ground state. Unconventional equal spin triplet pairs (ESTPs) have been predicted, and we have recently seen preliminary evidence for these in tunnel devices based on the transition metal dichalcogenide (TMD) superconductor 2*H*-$NbSe_2$ at high magnetic fields, in the magnetic field dependence of the superconducting energy gap. ESTPs are of great interest for superconducting spintronics and topological superconductivity, and in 2*H*-TMDs are thought to arise from the non-colinearity between the out-of-plane Ising spin-orbit field (due to the lack of inversion symmetry in the monolayer) and an applied in-plane magnetic field.

In addition to ESTPs, recent experiments on TMDs have been interpreted as evidence for other unconventional superconducting phases, e.g. the finite-momentum 'orbital FFLO' state, which requires > bilayer thickness. Other predicted unconventional phases include a striped FFLO phase and pair density waves. Recently, a transition from phonon- to Coulomb-interaction-mediated superconductivity has been predicted, likely occurring as the material goes from bilayer to monolayer thickness. Although most theoretical work has been done for monolayer $NbSe_2$ and related superconducting TMDs, so far there have been no reports on tunnelling into monolayer $NbSe_2$, and thus very little spectral evidence for above predictions.

The intern will fabricate and measure superconducting TMD tunnelling devices. The intern will be trained on a procedure we have recently developed, which gives thin flakes reliably. S/he will also gain hands-on experience in nanofabrication (e-beam lithography, metal deposition) and low-noise low-temperature (milikelvin) electronic measurements, and is welcome to contribute to the group's other TMD projects.

This project is part of a long-standing collaboration between with Hadar Steinberg and co-workers at the Hebrew University (Jerusalem).

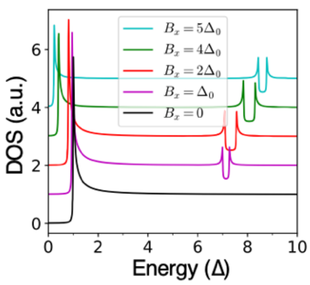

Figure (left) Optical image of a typical tunnel junction TMD device made by Banan El-Kerdi and Charis Quay. The crosses are about 8μm across. **(right)** Expected spectral signatures of triplet superconductivity. (From reference below.)

References

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