Topological superconductivity in a quantum wire proximate to a helical magnet and conventional superconductor

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In one-dimensional systems, superconductors with triplet pairing are known to always reside in a topological class that can host non-trivial topological phases. To engineer topological superconductivity in one dimension, the dominant approach has been to combine proximity-induced s-wave superconductivity with strong spin-orbit coupling semi-conductors and time-reversal symmetry breaking magnetic fields. This approach is in practice associated with a number of challenges, the most prominent being that the time-reversal breaking field must be finely tuned such that it is large enough to realize an effective spin-polarized regime, but small enough not to suppresses the effective superconducting gap. To avoid this problem it would be desirable to find a protocol for topological superconductivity where the spin-polarized regime and the superconducting gap both are increasing functions of some control parameter.
In a recent publication [1], we show that a topological magnon-mediated superconducting phase can emerge as the result of interactions between electrons in a quantum wire and magnons in a helical magnet (cf. Figure 1). The superconducting gap depends exponentially on the spin-electron coupling, allowing it to be enhanced through material engineering techniques. To further stabilize the triplet superconductivity we combine this setup with a conventional superconductor, forming a superconductor-quantum wire-helical magnet heterostructure. The non-collinear magnetic order induces an effective SOC and Zeeman field among the electrons, thereby realizing an effective single-band regime. Within the effective single-band regime, the system enters a topological phase, with unpaired Majorana bound states at each end of the wire.

Figures

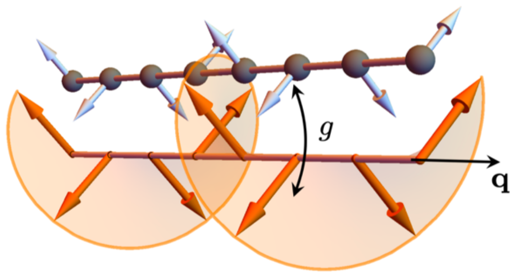

Figure 1: Magnon fluctuations around the equilibrium of the spin spiral (orange arrows) induces an effective superconductive pairing of the electrons (grey spheres). The static spin spiral induces an effective spin-orbit interaction and a Zeeman splitting of the electronic bands via the spin-electron coupling *g*.

References

[1] F. Viñas Boström and E. Viñas Boström, Phys. Rev. Res. 6, L022042 (2024)