# Quantized Spin Pumping in Ferromagnetic–Superconducting Nanowires

A. Kawala[1,2] and W. Brzezicki[2,3]

[1] *Szkoła Doktorska Nauk Ścisłych i Przyrodniczych, ul. prof. S. Łojasiewicza 11, 30-348 Kraków, Poland*
[2] *International Research Centre MagTop, Aleja Lotników 32/46 PL-02668 Warszawa, Poland*
[3] *Zakład Kwantowej Teorii Wielu Ciał, ul. prof. S. Łojasiewicza 11 30-348 Kraków, Poland*

We study adiabatic spin pumping induced by the precession of magnetization in ferromagnetic–superconducting nanowires and demonstrate that magnetic dynamics provide a direct probe of topological superconducting phases. The system is described by a multiband Bogoliubov–de Gennes model, where the magnetization orientation evolves slowly in time and its phase acts as a pumping parameter.

Using a scattering-matrix approach combined with the Brouwer–Buttiker–Pretre–Thomas formalism, we compute the spin transferred per precession cycle and find robust quantization to integer values. Mapping the pumped spin as a function of the Fermi energy $E_F$ and superconducting gap $\Delta$ yields characteristic semi-elliptical regions of nontrivial topology in the phase diagram. Different topological regions are distinguished by the sign of the pumped spin, reflecting spin-resolved spectral flow across the superconducting gap.

In the trivial phase no quantization of the spin occurs. Therefore, our results establish quantized spin pumping as a powerful and experimentally relevant signature of multiband topological superconductivity in magnetic hybrid nanostructures.

**References:**

[1] V. F. Becerra, M. Trif, and T. Hyart, Phys. Rev. Lett. (2023) 130, 237002