

**Coherent vs dissipative spin torque dynamics
in single molecules:
exploring spintronic effects in the quantum limit**

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Spin torques are central to spintronics, enabling current-induced magnetization switching, domain wall motion, and auto-oscillations in nanoscale devices [1]. While the action of spin torques on the magnetization is often described in semi-classical terms, measurements of spin torques in single molecules offer a unique perspective on how electric currents influence quantum spin states [2]. By probing pentacene radicals using spin-polarized scanning tunnelling microscopy, we show that spin injection can induce either coherent or incoherent dynamics, whereby spin rotations and decoherence are controlled by tuning the applied voltage to the cotunneling and sequential tunnelling regimes, respectively [3]. We further distinguish DC and AC effects, showing how single spins can be initialized and driven to Hanle precession or electron spin resonance depending on excitation conditions and applied magnetic field.

References:

- [1] A. Manchon et al., Current-induced spin-orbit torques in ferromagnetic and antiferromagnetic systems, *Rev. Mod. Phys.* 91, 035004 (2019).
- [2] D. Ruckert et al., Coherent and Dissipative Spin Torques in Quantum Dots: A Unified Framework for Quantum Spin Dynamics, submitted.
- [3] S. Kovarik et al., Spin torque-driven electron paramagnetic resonance of a single spin in a pentacene molecule, *Science* 384, 1368 (2024).