## Nonequilibrium phenomena in superfluid systems: atomic nuclei, liquid helium, ultracold gases, and neutron stars

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## A single superconducting vortex on a leash: thermodynamics and applications

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We introduce the Single Vortex Box (SVB) –a nanodevice that allows to treat a single superconducting vortex as a macroscopic, yet quantized, "particle" that can be created and annihilated on demand using electrical current pulses[1]. By applying fast, nanosecond-resolving switching thermometry [2], we measure the temperature rise and the subsequent thermal relaxation resulting from the expulsion of just a single magnetic vortex from the aluminum SVB. Our experiment provides a calorimetric estimation of the energy dissipated in a superconductor due to a single moving vortex –a fundamentally important measurement that has never been accomplished before due to the lack of appropriate tools. Our pioneering demonstration is also a pivotal step towards the development of the vortex-based electronics including memory cells, superconducting diodes, logic elements, and heat valves. We raise a fundamental question: does the vortex dissipate energy as it moves across the superconducting strip, or is dissipation triggered only when the vortex is annihilated?

[1] M. Foltyn, K. Norowski, A. Savin, M. Zgirski, Quantum thermodynamics with a single superconducting vortex, Science Advances 10, eado4032 (2024).

[2] M. Zgirski, M. Foltyn, A. Savin, A. Naumov, K. Norowski, Heat Hunting in a Freezer: Direct Measurement of Quasiparticle Diffusion in Superconducting Nanowire, Phys. Rev. Applied 14, 044024 (2020)

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