Calorimetry of a phase slip in a Josephson junction

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Josephson junctions are a central element in superconducting quantum technology; in these devices, irreversibility arises from abrupt slips of the quantum phase difference across the junction. This phase slip is often visualized as the tunneling of a flux quantum in the transverse direction to the superconducting weak link, which produces dissipation.

Recently, the instantaneous heat release caused by a phase slip in a Josephson junction has been experimentally detected by using time-resolved electron thermometry on a nanocalorimeter [1]. In this presentation, we shall focus on the theoretical description of such an effect. First, by employing the quasiclassical Keldysh Green's formalism we shall examine the proximity effect in a diffusive SNS Josephson junction focusing on the supercurrent and spectral properties of the normal-metal region. Having obtained the critical current and the density of states, we can calculate the screening current responsible for the occurrence of phase slips [1].

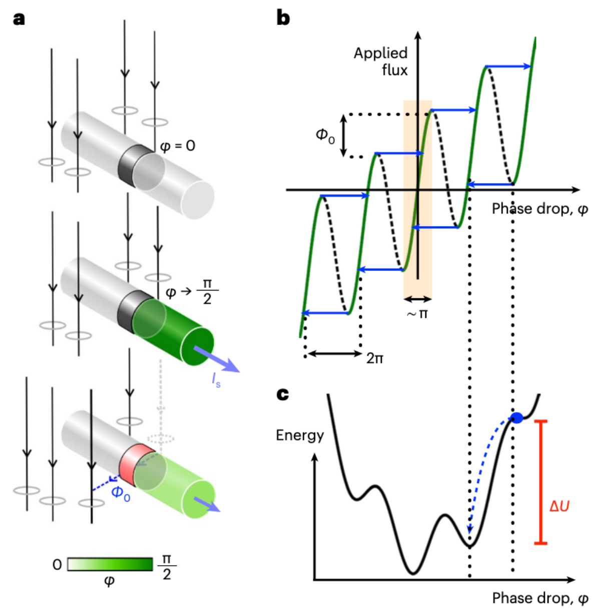

Fig. 1: Phase slip in a hysteretic Josephson junction. a The phase-slip mechanism: at the instability point of the $\Phi_X(\varphi)$ relation, the phase drop φ and the screening current I_S abruptly relax to smaller values, as a quantum of flux tunnels perpendicular to the Josephson junction (dark grey), releasing heat. **b**, Phase drop φ across the SNS junction versus applied flux to the SQUIPT. **c** Potential energy of the SQUIPT as a function of φ. A local energy minimum can become unstable as the externally applied flux is changed. By macroscopic quantum tunnelling of the phase, a lower energy valley is reached, releasing an energy ΔU.

The second part of the presentation will be devoted to the dynamics of the heat released upon an individual phase slip. We shall briefly introduce an ultrasensitive proximity thermometer utilized for detecting the temperature dynamics based on the junction's zero-bias anomaly [2]. Finally, we shall provide a full description of the thermodynamics of the effect by examining the dynamics of the heat transfer, which is mainly due to the electron-phonon cooling channel [3].

References:

[1] E. Gümüş, D. Majidi, D. Nikolić *et al, Nat. Phys.* https://doi.org/10.1038/s41567-022-01844-0 (2023).
[2] B. Karimi, D. Nikolić *et al*, *Phys. Rev. Appl.* **13**, 054001 (2020).
[3] D. Nikolić, D. M. Basko, and W. Belzig, *Phys. Rev. B* **102**, 214514 (2020).