Nanoscale thermal imaging:
glimpse into dissipation in quantum systems down to atomic scale

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Energy dissipation is a fundamental process governing the dynamics of classical and quantum systems. Despite its vital importance, direct imaging and microscopy of dissipation in quantum systems is currently impossible because the existing thermal imaging methods lack the necessary sensitivity and are unsuitable for low temperature operation. We developed a scanning nanoSQUID with sub 50 nm diameter that resides at the apex of a sharp pipette [1] acting simultaneously as nanomagnetometer with single spin sensitivity and as nanothermometer providing cryogenic thermal imaging with four orders of magnitude improved thermal sensitivity of below 1 μK [2]. The non-contact non-invasive thermometry allows thermal imaging of minute energy dissipation down to the level equivalent to the fundamental Landauer limit for continuous readout of a single qubit. These advances enable observation of changes in dissipation due to single electron charging of a quantum dot and visualization and control of heat generated by electrons scattering off a single atomic defect in graphene [3], opening the door to direct imaging and spectroscopy of dissipation processes in quantum systems.

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