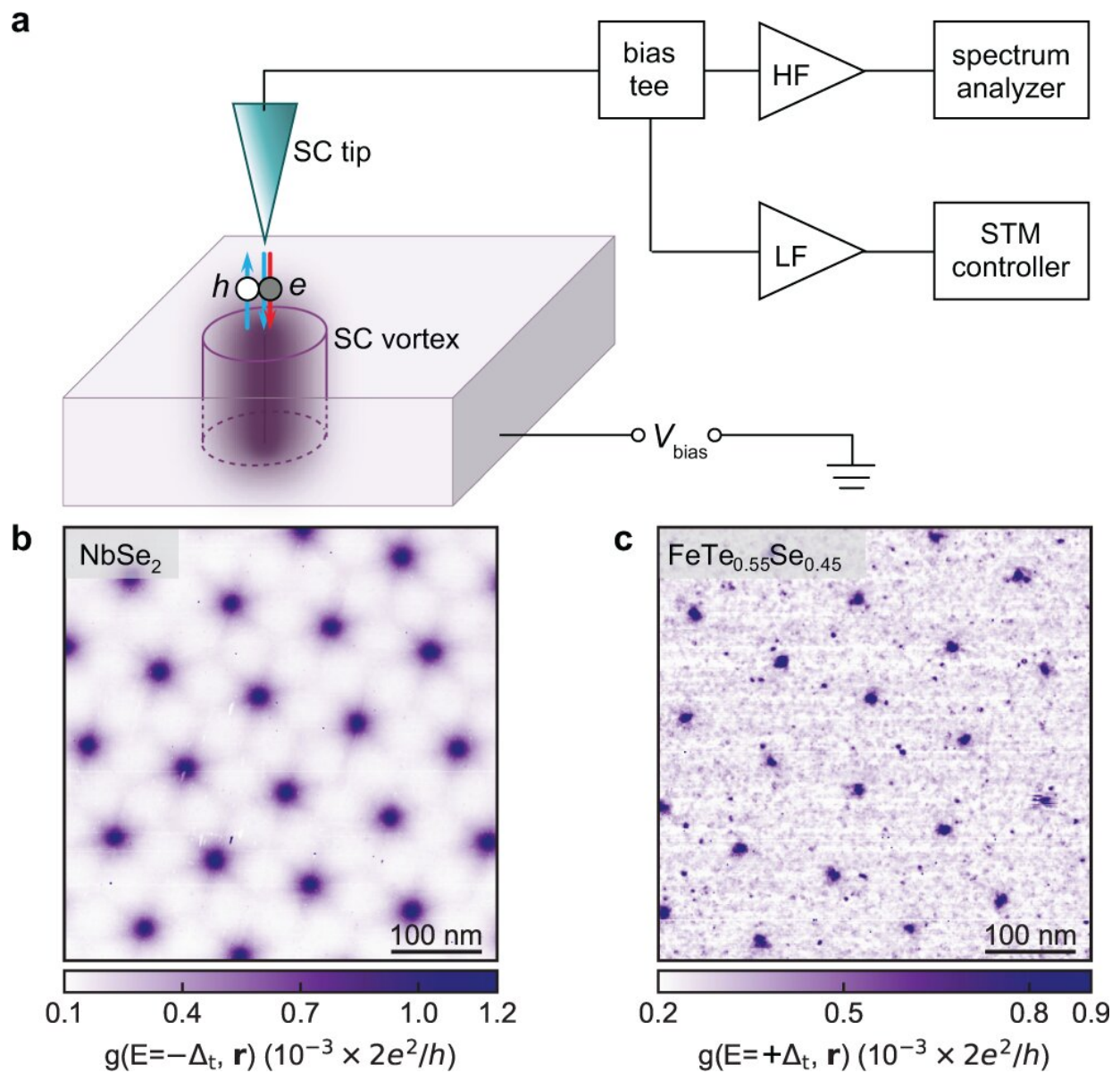


New method to find Majorana particles tested for the first time

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Local tunneling shot noise measurements of vortex bound states. **a** Schematic illustration of the scanning tunneling noise microscope setup. A bias voltage (V_{bias}) is applied between the superconducting (SC) tip and sample, while the cylinder represents a SC vortex. If the tunneling process is a single-electron (gray) into vortex bound states (red arrow), an effective charge $q^* = 1e$ is transferred from the tip to the vortex. When Andreev reflection takes place (blue arrows), a hole (white) is reflected, and the effective charge doubles $q^* = 2e$. HF and LF stand for the high- and low-frequency amplifier, respectively. STM, scanning tunneling microscope. Full flux quantum ($h/2e$) vortex lattice in NbSe_2 (**b**) and $\text{FeSe}_{0.55}\text{Te}_{0.45}$ (**c**) revealed by spatially resolved differential conductance at a magnetic field of 0.1 T. Setup conditions: b, $V_{\text{set}} = -5$ mV, $I_{\text{set}} = 200$ pA; c, $V_{\text{set}} = 10$ mV, $I_{\text{set}} = 250$ pA. Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-39109-w

Fifteen years ago, an alternative technique to look for the elusive Majorana particles was conceived theoretically. But no one carried out the experiment, until now. Physicist Jianfeng Ge and his colleagues from the Allan lab of the Leiden Institute of Physics have now successfully carried out the first measurements. The work is published in the journal *Nature Communications*.

There are a few ways in which physicists can look for Majorana quasiparticles. The main approach is based on conductivity measurements, but that hasn't provided the definitive results scientists hoped for. Therefore, Ge looked for a new approach. "Back when I was at Harvard, I talked to my colleague Eugene Demler about shot noise measurements that should be able to identify Majoranas. He had theorized this fifteen years ago, but no one ever tried it. I thought it was promising so I convinced Milan Allan from the Quantum Matter group to do it. And now we have our first results."

The hunt for exotic Majorana particles

Majoranas are [hypothetical particles](#) that are their own antiparticles. This makes them different from any of the particles we already know, and finding them could lead to new discoveries in physics. Ge is actually looking for Majorana quasiparticles in quantum matter. This is a collection of electrons that behave similarly to a Majorana particle.

One of the reasons scientists want to find Majoranas is their potential to revolutionize quantum computing. The [qubits](#) that are currently used in quantum computers are not very stable and prone to errors. Majorana qubits could be the long-sought cornerstone for fault-tolerant quantum computers.

Paving the way for ultimate proof of Majoranas

The Majorana particles are expected to live in the vortices of an iron-based superconductor that Ge studies. "These vortices are only a few nanometers in size. Only in recent years technology has advanced to the point where we can measure at this small scale," he explains. "We are the first ones in the world to do this experiment. I find that very exciting."

The results are very promising at this stage. "We nailed down the origin of the quasiparticles within two possible explanations, one of which is Majoranas. These measurements pave the way for ultimate proof of Majoranas. We learned a lot and know how to improve the setup for future measurements."

"I share the enthusiasm about the potential for quantum computing but it is not what excites me most about this research," Ge says. "What drives me is curiosity. I want to understand the fundamental principles of the physics itself. It will be a long journey to find the ultimate proof for Majorana particles, let alone develop applications like a quantum computer. But with this experiment we know what to do next. It will not

be easy and take a lot of technical instrument development, but I am proud that we are one step closer to finding Majoranas."

More information: Jian-Feng Ge et al, Single-electron charge transfer into putative Majorana and trivial modes in individual vortices, *Nature Communications* (2023). [DOI: 10.1038/s41467-023-39109-w](https://doi.org/10.1038/s41467-023-39109-w)

Provided by Leiden University

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