What a '2D' quantum superfluid feels like to the touch

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The experiments were carried out at about a 10000th of a degree above absolute zero in a special refrigerator and made use of mechanical resonator the size of a finger to probe the very cold superfluid; Dr Samuli Autti (right) at Lancaster University. Credit: Mike Thompson

Researchers from Lancaster University in the UK have discovered how superfluid helium ^{3}He would feel if you could put your hand into it. Dr. Samuli Autti is the lead author of the research published in *Nature Communications*.

The interface between the exotic world of quantum physics and classical

physics of the human experience is one of the major open problems in modern physics.

Dr. Autti said, "In practical terms, we don't know the answer to the question 'How does it feel to touch quantum physics?' These experimental conditions are extreme and the techniques complicated, but I can now tell you how it would feel if you could put your hand into this quantum system.

"Nobody has been able to answer this question during the 100-year history of quantum physics. We now show that—at least in superfluid ^{3}He—this question can be answered."

The experiments were carried out at about a 10,000th of a degree above absolute zero in a special refrigerator, and made use of mechanical resonator the size of a finger to probe the very cold superfluid.

When stirred with a rod, superfluid ^{3}He carries the generated heat away along the surfaces of the container. The bulk of the superfluid behaves like a vacuum and remains entirely passive.

Dr. Autti said, "This liquid would feel two-dimensional if you could stick your finger into it. The bulk of the superfluid feels empty, while heat flows in a two-dimensional subsystem along the edges of the bulk—in other words, along your finger."

The researchers conclude that the bulk of superfluid ^{3}He is wrapped by an independent two-dimensional superfluid that interacts with mechanical probes instead of the bulk superfluid, only providing access to the bulk superfluid if given a sudden burst of energy.

That is, superfluid ^{3}He at the lowest temperatures and applied energies is thermo-mechanically two-dimensional.

"This also redefines our understanding of superfluid ^{3}He. For the scientist, that may be even more influential than hands-in quantum physics."

Superfluid ^{3}He is one of the most versatile macroscopic quantum systems in the laboratory. It often influences seemingly distant fields such as particle physics (for example the Higgs mechanism), cosmology (Kibble mechanism), and quantum information processing (time crystals).

A redefinition of its basic structure may therefore have far-reaching consequences.

More information: S. Autti et al, Transport of bound quasiparticle states in a two-dimensional boundary superfluid, *Nature Communications* (2023). dx.doi.org/10.1038/s41467-023-42520-y

On *arXiv* (2023). DOI: 10.48550/arxiv.2303.16518

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