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Topological superfluids confined in a nanoscale slab geometry[1]

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Nanofluidic samples of superfluid ^{3}He provide a route to explore odd-parity topological superfluids and their surface, edge and defect-bound excitations under well controlled conditions. We have cooled superfluid ^{3}He confined in a precisely defined nano-fabricated cavity to well below 1 mK for the first time. We fingerprint the order parameter by nuclear magnetic resonance, exploiting a SQUID NMR spectrometer of exquisite sensitivity. We demonstrate that dimensional confinement, at length scales comparable to the superfluid Cooper-pair diameter, has a profound influence on the superfluid order of ^{3}He. The chiral A-phase is stabilized at low pressures, in a cavity of height 650 nm. At higher pressures we observe ^{3}He-B with a surface induced planar distortion. ^{3}He-B is a time-reversal invariant topological superfluid, supporting gapless Majorana surface states. In the presence of the small symmetry breaking NMR static magnetic field we observe two possible B-phase states of the order parameter manifold, which can coexist as domains. Non-linear NMR on these states enables a measurement of the surface induced planar distortion, which determines the spectral weight of the surface excitations. The expected structure of the domain walls is such that, at the cavity surface, the line separating the two domains is predicted to host fermion zero modes, protected by symmetry and topology. Increasing confinement should stabilize new p-wave superfluid states of matter, such as the quasi-2D gapped A phase, which breaks time reversal symmetry, has a protected chiral edge mode, and may host half-quantum vortices with a Majorana zero-mode at the core. We discuss experimental progress toward this phase, through measurements on a 100 nm cavity. On the other hand, a cavity height of 1000 nm may stabilize a novel "striped" superfluid with spatially modulated order parameter.

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