Signatures of Majorana Surface States of Superfluid ^{3}He-B

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We report calculations of surface spectrum, spin- and mass current densities originating from the Andreev surface states for confined ^{3}He-B. The surface states are Majorana Fermions with their spins polarized transverse to their direction of propagation along the surface, $\vec{p}_\parallel$. The negative energy states give rise to a ground-state helical spin current confined on the surface. The spectral functions reveal the subtle role of the spin-polarized surface states in relation to the ground-state spin current. By contrast, these states do not contribute to the $T = 0$ mass current. Superfluid flow through a channel of width $D > D_c \approx 10\xi_0$ of confined ^{3}He-B is characterized by the flow field, $\vec{p}_s = \hbar\vec{\nabla}\vartheta$, where $\vartheta(\vec{r})$ is the global phase of the B-phase Cooper pairs. The flow field breaks $SO(2)_{L_z+S_z}$ rotational symmetry, as well time reversal symmetry ($\mathcal{T}$) and particle-hole symmetry ($\mathcal{C}$). However, the Bogoliubov-Nambu Hamiltonian remains invariant under the combined (chiral) symmetry, $\Gamma = \mathcal{C}\mathcal{T}$. As a result the B-phase in the presence of a superflow remains a topological phase with a gapless spectrum of Majorana modes on the surface. Thermal excitation of the Doppler shifted Majorana branches leads to a power law suppression of the superfluid mass current for $0 < T \lesssim 0.5T_c$, providing a direct signature of the Majorana branches of surface excitations in the fully gapped 3D topological superfluid, ^{3}He-B. Quantitative results will be presented for the superfluid fraction (mass current), helical spin current and heat capacity of confined ^{3}He, including the temperature dependences, as well as dependences on confinement, surface scattering and pressure.

Supported by NSF Grant: DMR-1106315.

Section: QF - Quantum Fluids

Keywords: Topological Superfluid, Andreev states, Majorana Fermions, Spin Current, Superflow