Frequency Dependence of the Transition to Quantum Turbulence in Superfluid ^{4}He

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Mechanical resonators such as vibrating wires and tuning forks are widely used for the study of quantum fluids. Here we use an array of custom-made quartz tuning forks. Each fork in the array is nominally identical to the other forks, except for the prong lengths which vary to give a range of fundamental resonance frequencies from 6 kHz to 160 kHz. This allows us to study the frequency dependence of fluid properties for nominally identical geometries.
We have measured the response of the tuning forks in superfluid ^{4}He over a wide range of velocities spanning the transition to turbulence. We compare measurements over the full temperature range, showing how the behavior evolves from classical fluid flow in normal helium above 2.2 K, through the two-fluid regime at intermediate temperatures, to pure quantum turbulence at the lowest (mK) temperatures. We show that for temperatures below 0.8 K where the normal fluid is a gas of ballistic phonons, the normal fluid drag is unaffected by quantum turbulence and the turbulent drag is independent of temperature. At higher temperatures the turbulent drag steadily increases towards the classical drag measured in normal helium.
We present measurements of the critical velocity for the nucleation of quantum turbulence and find that $v_c \approx \sqrt{\kappa\omega}$. We also show measurements of the turbulent drag at low temperatures for a wide range of frequencies.

Section: VT - Vortices and turbulence

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