Quantum turbulence in superfluid He-4: creation, evolution and decay in novel geometries

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Turbulence is ubiquitous in the real world and affects almost every aspect of our daily lives, including transport, energy production, climate, and biological processes. Despite its universal importance, turbulence is hard to understand at a fundamental level because of the complexity of turbulent motion of the fluid over an extremely wide range of length scales. Quantum mechanics often makes complex problems conceptually simpler, and quantum turbulence (QT) in superfluids is a prime example, consisting of a tangle of vortices that are quantised, and identical. As in classical turbulence, QT is a non-equilibrium phenomenon: remove the driving force, and it decays – though perhaps not completely in superfluid 4He, due to residual quantised vortices pinned metastably to the walls. When the superfluid flows fast enough, the production of QT usually can be "seeded" by such remanent vortices.

We describe an experiment [1] to explore fundamental properties of remanent vortices in the low temperature limit of pure superfluid 4He. We investigate QT for superfluid inside a pill-box-shaped cell fixed symmetrically to a torsional oscillator (TO). In this geometry there is no flow over convex surfaces to create turbulent instabilities. However, we expect the cell movements to generate Kelvin waves on any remanent vortices present if they are pinned to the parallel faces, resulting in reconnections above a critical velocity leading to dissipation through the creation of QT, and correspondingly a change in damping of the TO.

As well as seeking evidence of critical velocities, we are also investigating the pinning of remanent vortices. At finite temperature, we might expect that thermal fluctuations will enable a line to de-pin/re-pin sequentially, sliding its end across the surface whereas, at T=0, the lines would become frozen on pinning sites. There are indications, however, that this may not be what happens in reality. We report preliminary experimental results and discuss future plans for the experiments.

[1] A. M. Guénault, P. V. E. McClintock, M. Poole, R. Schanen, V. Tsepelin, D. Zmeev, D. Schmoranzer and W. F. Vinen, arXiv:2201.08503v1 [cond-mat.other] 21 Jan 2022.