Quantum turbulence : an energy-consistent closure for the HVBK equations

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Below its superfluid transition, helium is described as an intimate mixture of two interacting fluids known as the superfluid and the normal fluid. The superfluid consists in a tangle of quantized vortices with atomic-scale diameters, whereas the normal fluid is a classical viscous fluid. The interaction between both fluids is mediated by vortices.

The HVBK equations describe the superfluid at a coarse-grained scale, reducing it to a simple Euler equation. Unfortunately, this procedure eliminates information about the density of vortices at subgrain scales, which is necessary to evaluate the inter-fluid coupling.

We propose an energy-consistent phenomenological model for the dynamics of vortices at subgrain scales, which allows to close the HVBK system of equation without adjustable parameters. The result is a set of three equations accounting for the dynamics of turbulent helium in its superfluid state.

Numerical simulations are presented and compared with the state-of-the-art numerics of the HVBK equations done with alternative closures.

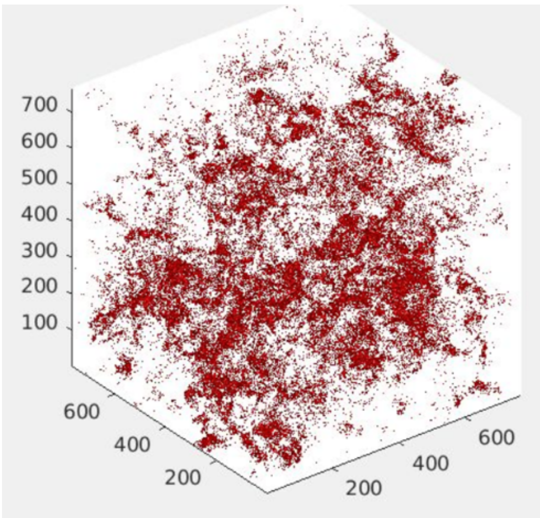

Figure Snapshot depicting the distribution of sub-grained density of quantum vortices in a turbulent periodic box. This quantity is not accounted for in the standard HVBK equation, , leading to an underestimation of the coupling between the superfluid and normal fluid

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