Turbulence in superfluid helium and atomic condensates: classical and quantum aspects

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Abstract

Quantum turbulence consists of a tangle of discrete, reconnecting quantised vortex lines. This form of turbulence is being studied in superfluid ^{4}He, superfluid ^{3}He-B, and, more recently, in atomic Bose–Einstein condensates. These systems are described by a complex order parameter of the form $\psi = |\psi| e^{i\theta}$. Their fluid properties are defined by the property that the velocity field is proportional to the gradient of the phase of ψ:

$$\mathbf{v} = \frac{h}{m} \nabla \theta,$$

where m is the mass of the relevant boson and h is Planck's constant.

Recent work has revealed that there are remarkable similarities between quantum turbulence and turbulence in ordinary (classical) fluids, e.g. the same Kolmogorov energy spectrum in continuously excited turbulence and the same temporal decay of the vorticity in decaying turbulence.

These results have attracted attention to the problem of the relation between a classical fluid (which obeys the Euler or Navier–Stokes equations) and a quantum fluid, stimulating apparently simple questions such as whether classical behaviour is merely the consequence of many quanta.

In this lecture I shall review the classical aspects of quantum turbulence, in particular energy spectra, and discuss a remarkable difference between classical and quantum turbulence which has been recently discovered: the non-Gaussian statistics of the velocity components.