Counterflow-induced inverse energy cascade in three-dimensional superfluid turbulence

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Finite-temperature quantum turbulence is often described in terms of two immiscible components, an inviscid and a classical fluid, which can flow with a nonzero mean relative velocity. Such out-of-equilibrium state is known as counterflow superfluid turbulence. We describe here the emergence of a counterflow-induced inverse energy cascade in forced three-dimensional superfluid flows, by performing extensive numerical simulations of the Hall–Vinen–Bekarevich–Khalatnikov model [1]. As the intensity of the mean counterflow is increased, an abrupt transition, from a fully three-dimensional turbulent flow to a quasi-two-dimensional system exhibiting a split energy cascade, is observed (fig. 1). In addition, we characterise the critical counterflow velocity leading to this abrupt transition, in terms of the parameters of the forcing and of the mutual friction between both fluid components. The findings of this work could motivate new experimental settings to study quasi-two-dimensional superfluid turbulence in the bulk of three-dimensional experiments. They might also find applications beyond superfluids in other systems described by more than one fluid component.

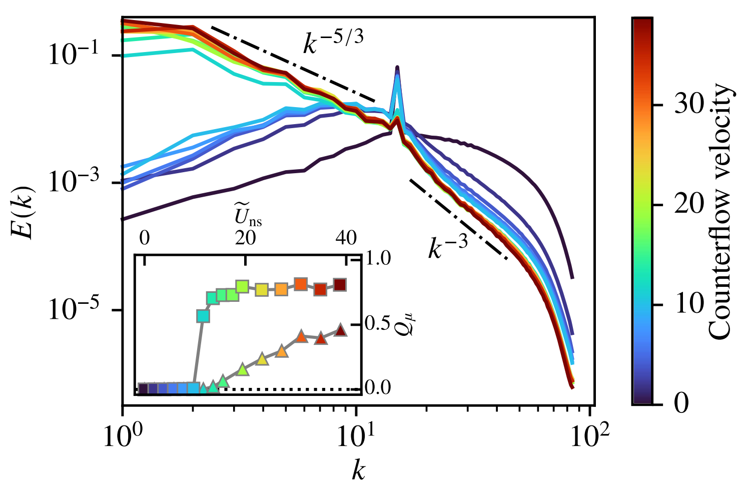

Figure 1. Kinetic energy spectrum for different counterflow velocities U_{ns}, using a two-dimensional forcing scheme. Inset: normalised large-scale energy dissipation rate Q_μ, indicating the presence of an inverse energy cascade at sufficiently large U_{ns}. Forcing schemes are 2D (squares) and 3D (triangles).

References

1. J.I. Polanco & G. Krstulovic, Counterflow-Induced Inverse Energy Cascade in Three-Dimensional Superfluid Turbulence, *Phys. Rev. Lett*, **125**, 254504 (2020).

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