Inverse cascades sustained by the transfer rate of angular momentum in a 3D turbulent flow

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The existence of energy cascades as signatures of conserved magnitudes is one of the universal characteristics of turbulent flows. In homogeneous 3D turbulence the energy conservation produces a direct cascade from large to small scales, although in 2D it produces an inverse cascade pointing towards small wavenumbers. In this work we present the first evidence of an inverse cascade in a fully developed 3D experimental turbulent flow where the conserved magnitude is the angular momentum.

We analyze the behavior of a fluid in a closed cavity where two inhomogeneous and strongly turbulent flows collide in a thin region. Depending on the spatial position different cascades have been found. Far from the collision layer a classical Kolmogorov scenario is found, but in the shear region inverse cascades appear.

The experimental volume is a closed cylinder with diameter $D = 20cm$ and $H = 20cm$. Two impellers of diameter $D_{prop} = 17.5$cm with 10 curved blades rotate in opposite directions, powered by two independent motors (maximum power of 1.5kW) regulated through a computer. The rotation frequency of the propellers can be adjusted independently between $f = 0.5 - 12.5$Hz generating a maximum torque of 15Nm. A key characteristic of this setup is the high inertia of the propeller and motor set and the high stability of the propellers, i.e. the instantaneous fluctuations of each one of the propeller's velocities are well below one part in one thousand 0.1%.

We have performed PIV (high spatial resolution) and LDA (high temporal resolution) measurements of the velocity fields. From these data, we can determine that the Reynolds number is $Re = 7 \times 10^5$, the typical turbulent intensity is 50%, the $Re_\lambda = 900$, the Taylor microscale $\lambda_T = 1.8$mm and the integral scale $L_I = 15$mm. The analysis of the data series, both in space and time, reveal that below the injection scales there are inverse cascades (-1/3 in time, -7/3 in space) that can be explained as the transfer of angular momentum between the diferent fluid layers.

With these results as an starting point, a new experiment in Helium superfluid has been run in the Superfluid Helium Facility (SHREK) in Grenoble, where a Reynolds number of 10^8 has been reached.

More information can be found in[1,2].

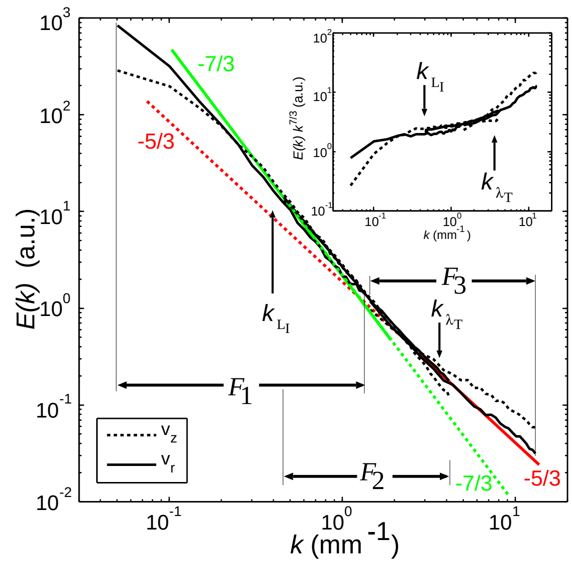

FIG. 1. Spatial spectra computed from PIV measurements. The wave number ranges covered by the different fields of view F1, F2, and F3 are presented (the full range covers from 0.05 to 13 mm^{-1}). Inset: Spectra compensated by $k^{7/3}$ where the slope change is clearly visible. k_{L_I} and k_{λ_T} correspond to the integral scale and the Taylor microscale. Each one of these spectra is the average of 1500 realizations along a diameter.

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[1] A. de la Torre, J. Burguete, Phys Rev Lett 99 (2007) 054101.

[2] M. Lopez-Caballero, J. Burguete, Phys Rev Lett 110 (2013) 124501.