Intermittency of velocity circulation in quantum turbulence

Nicolás P. Müller, Juan Ignacio Polanco & Giorgio Krstulovic

Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Boulevard de l'Observatoire CS 34229 - F 06304 NICE Cedex 4, France
nicolas.muller@oca.eu

The velocity circulation, a measure of the rotation of a fluid within a closed path, is a fundamental observable in classical and quantum flows. In quantum flows, circulation is quantized, taking discrete values that are directly related to the number and the orientation of thin vortex filaments enclosed by the path. By varying the size of such closed loops, the circulation provides a measure of the dependence of the flow structure on the considered scale. Here, we consider the scale dependence of circulation statistics in quantum turbulence, using high-resolution direct numerical simulations of a generalized Gross–Pitaevskii model. Results are compared to simulations of the incompressible Navier–Stokes equations. When the integration path is smaller than the mean intervortex distance, the statistics of circulation in quantum turbulence displays extreme intermittent behavior due to the quantization of circulation, in stark contrast with the viscous scales of classical flows. In contrast, at larger scales, circulation moments display striking similarities with the statistics probed in the inertial range of classical turbulence, including scalings predicted by Kolmogorov's theory and a bifractal behavior in the intermittency deviations [1]. Our results strongly reinforce the resemblance between classical and quantum turbulence, highlighting the universality of inertial-range dynamics, including intermittency.

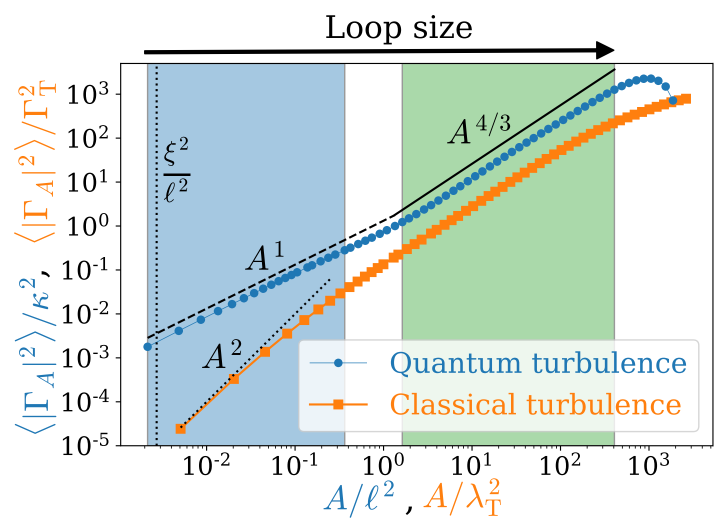

Figure 1. Variance of the circulation around square loops of area $A = r^2$. Blue line correspond to a generalized Gross–Pitaevskii simulation (resolution 2048^3), and orange line shows a Navier–Stokes simulation (resolution 1024^3). The quantum variance is rescaled by the circulation quanta κ and the area by the intervortex distance ℓ, while the classical variance is rescaled by $\Gamma_T^2 = \frac{\lambda_T^4}{3}\langle|\boldsymbol{\omega}|^2\rangle$, with λ_T the Taylor microscale and $\boldsymbol{\omega}$ the vorticity field.

References

1. K. P. Iyer, K. R. sreenivasan & P. K. Yeung, Circulation in High Reynolds Number Isotropic Turbulence Is a Bifractal, *Phys. Rev. X*, **9**, 041006 (2019).