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Casimir Cascades in Two-Dimensional Turbulence

The nonlinear terms of the 2D incompressible Navier-Stokes equation are well-known to conserve energy and enstrophy. In addition, they also conserve the global integral of any continuously differentiable function of the scalar vorticity field. However, the phenomenological role of these additional inviscid invariants remains unclear: Polyakov's minimal conformal field theory model indicates that high-order Casimir invariants cascade to large scales, while Eyink suggests that they might instead cascade to small scales.

Numerical investigations of this problem are hampered by the fact that pseudospectral simulations, which necessarily truncate the wavenumber domain, do not exactly conserve global integrals of arbitrary powers of the vorticity. Given that the "rugged" quadratic energy and enstrophy invariants (which do survive spectral truncation) play a key role in the Kolmogorov theory of the turbulent cascade, it is natural to ask whether higher-order invariants might also play a role. In this work, well-resolved numerical simulations based on a specially optimized dealiased ternary convolution are used to demonstrate that the fourth power of the vorticity cascades to small scales. Inertial-range pumping of this quantity by the large-scale forcing, as discussed by Falkovich and Lebedev, is also examined.