Self-organization in Non-Newtonian Turbulence

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As first idealized by Richardson, turbulent flows are composed of a cascade of vortices of different sizes through which energy is passed down from larger to smaller scales until, at a sufficiently tiny length scale, the kinetic energy of the fluid is dissipated into heat by viscous friction. Later, Kolmogorov formalized this mechanism in his famous K41 theory. Although significant progress has been made in understanding Newtonian turbulent flows in the fully developed regime, no work has yet focused on the statistics of structural and physical properties of non-Newtonian turbulent systems. We investigate through Direct Numerical Simulations (DNS) that the statistical properties of non-Newtonian turbulent flows at the inertial subrange, calculated in terms of vortex size distributions, follow in general the behavior of Newtonian turbulence, regardless of the rheological properties of the fluid. This structural invariance is achieved through a self-organized mechanism at the microscopic scale of the turbulent motion that adjusts the ratio between the viscous dissipations inside and outside the vortices. Moreover, the deviations from the K41 theory of the structure functions exponents reveal that the anomalous scaling, observed for Newtonian turbulence, exhibits a systematic nonuniversal behavior with respect to the rheological properties of non-Newtonian fluids.