Localization and self-organization in flow of non-Newtonian fluids

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In the first part of the talk we show through extensive numerical simulations that the flow pattern inside a “swiss-cheese” type of pore geometry can be systematically controlled through the intrinsic rheological properties of the fluid. Precisely, our analysis reveals that the velocity field in the interstitial pore space tends to display enhanced channeling under certain flow conditions. This observed flow “localization”, quantified by the spatial distribution of kinetic energy, can then be explained in terms of the strong interplay between the disordered geometry of the pore space and the nonlinear rheology of the fluid. Our results disclose the possibility that the constitutive properties of the fluid can enhance the performance of chemical reactors and chromatographic devices through control of the channeling patterns inside disordered porous media. Recent results from high-resolution microfluidic experiments supporting these observations are also shown. In the second part of the talk, we focus on the statistics of structural and physical properties of non-Newtonian turbulent systems. Precisely, we show 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 and structure functions, 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. However, 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.