Turbulent Taylor-Couette Flow

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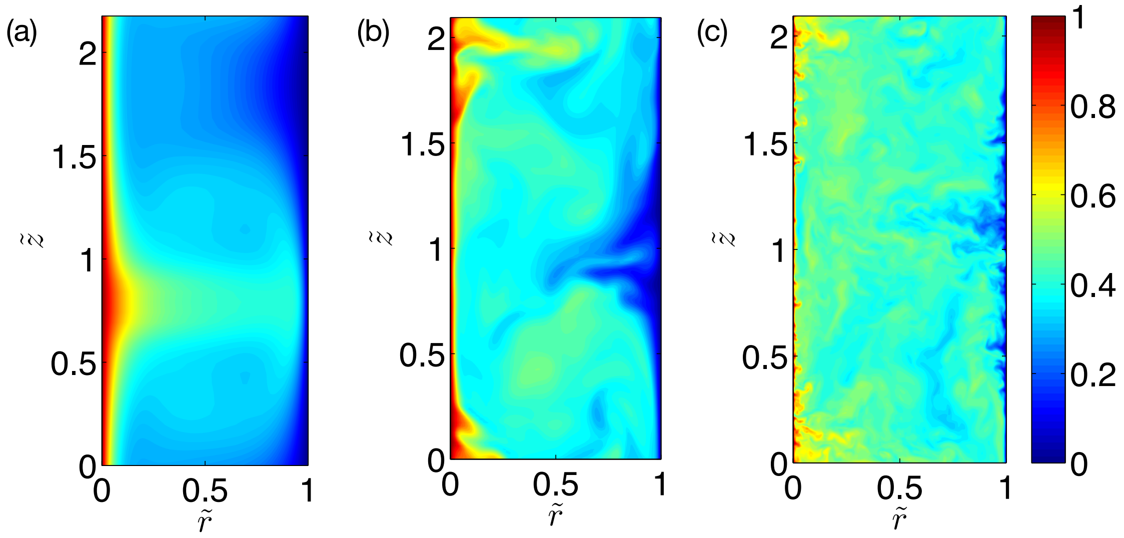
Taylor-Couette flow, the flow between two coaxial co- or counter-rotating cylinders, is one of the paradigmatic systems in the physics of fluids. The (dimensionless) control parameters are the Reynolds numbers of the inner and outer cylinders, the ratio of the cylinder radii, and the aspect ratio. One key response of the system is the torque required to retain constant angular velocities, which can be connected to the angular velocity transport through the gap. Whereas the low–Reynolds number regime was well explored in the 1980s and 1990s of the past century, in the fully turbulent regime major research activity developed only in the past decade. We review this recent progress in our understanding of fully developed Taylor-Couette turbulence from the experimental, numerical, and theoretical points of view. We focus on the parameter dependence of the global torque and on the local flow organization, including velocity profiles and boundary layers. We in particular discuss transitions between different (turbulent) flow states [1].

For real-world applications of wall-bounded turbulence, the underlying surfaces are however always rough; yet characterizing and understanding the effects of wall roughness for turbulence remains an elusive challenge. By combining extensive experiments and numerical simulations, we uncover the mechanism that causes the considerable enhancement of the overall transport properties by wall roughness. If only one of the walls is rough, we reveal that the bulk velocity is slaved to the rough side, due to the much stronger coupling to that wall by the detaching flow structures. If both walls are rough, the viscosity dependence is thoroughly eliminated and we thus achieve what we call *asymptotic ultimate turbulence*, i.e. the upper limit of transport, whose existence had been predicted by Robert Kraichnan in 1962 [2] and in which the scalings laws can be extrapolated to arbitrarily large Reynolds numbers.

REFERENCES

[1] Grossmann, S., Lohse, D. & Sun, C. (2016), High-Reynolds number Taylor-Couette Turbulence, Ann. Rev. Fluid. Mech 48, 53-80.
[2] Kraichan, R. (1962), Turbulent thermal convection at arbitrary Prandtl number, Phys. Fluids 5, 1374.



Numerical results for the azimuthal velocity component at three different and from left to right increasing degrees of Taylor Couette turbulence.