System reduction strategy for Galerkin models of fluid flows

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Building on the companion talk of Gilead Tadmor, we propose a system reduction strategy for spectral and Galerkin models of incompressible fluid flows. This approach leads to dynamic models of lower order, based on a partition in slow, dominant and fast modes. In the reduced models, slow dynamics are incorporated as nonlinear manifold consistent with mean-field theory. Fast dynamics are stochastically treated and can be lumped in eddy viscosity approaches.

The employed interaction models between slow, dominant and fast dynamics respect momentum and energy balance equations in a mathematically rigorous manner unlike unsteady Reynolds-averaged Navier-Stokes models or Smagorinsky-type reductions of the Navier-Stokes equation. The proposed system reduction strategy is employed to unsteady shear flows.

Key enabler of this strategy is a finite-time thermodynamics (FTT) formalism as statistical closure of Galerkin models [Noack et al. 2008 J.~Non-Equilib. Thermodyn. 33]. The FTT formalism elucidates how linear and nonlinear processes balance between the extremes of linear instability and thermal equilibrium of the truncated system --- including the Landau model for onset of oscillations as particular intermediate step.

The talk comprises joint work
with Boye Ahlborn, Gerd Mutschke, the Collaborative Research Center SFB 557 'Control of complex turbulent shear flows' at TU Berlin, the DFG-CNRS Research Group FOR 508 'Noise generation in turbulent flows', and the Laboratoire d'Etudes Aerodynamiques (Poitiers, France).