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Analysis of turbulent structures in supersonic wall-bounded flows

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— The statistical properties of compressible wall-bounded flows are analyzed by means of direct numerical simulations of a spatially evolving boundary layer on an adiabatic flat plate at $M_\infty = 2.25$, with the objective to characterize the turbulent structures in terms of flow visualizations as well as by quantitative analysis of the joint PDF of the velocity gradient tensor invariants. Several vortex identification criteria have been considered, including the Δ criterion, the Q-criterion, and the λ_2 criterion. Preliminary results indicate that hairpin-like structures, universally observed in low-speed wall bounded flows, also dominate in the (low) supersonic regime, and shocklets are virtually absent under the selected test conditions. Such scenario is consistent with the commonly accepted notion that compressibility effects in wall bounded flows are negligible up to very large main flow Mach numbers. The analysis of the joint PDF of the velocity gradient tensor invariants at several stations in the wall-normal direction (viscous sublayer, buffer layer, log region, outer region) seems to confirm the findings of Chong et al. (JFM 98) and Pirozzoli & Grasso (PF 04): the joint PDF in the Q-R plane exhibits (in large part of the boundary layer) a universal, tear-drop shape, and the vorticity is preferentially aligned with the intermediate eigenvector of the (traceless part of the) strain- rate tensor, which accounts for the vortex stretching mechanism.

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