Supersonic turbulence in shock-bound interaction zones I: symmetric settings

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Colliding hypersonic flows play a decisive role in many astrophysical objects. They contribute, for example, to molecular cloud structure, the X-ray emission of O-stars, differentiation of galactic sheets, the appearance of wind-driven structures, or, possibly, the prompt emission of γ-ray bursts. Our intention is the thorough investigation of the turbulent interaction zone of such flows, the cold dense layer (CDL). In this paper, we focus on the idealized model of a 2D plane parallel isothermal slab and on symmetric settings, where both flows have equal parameters. We performed a set of high-resolution simulations with upwind Mach numbers, $5 < M_{\mathrm{u}} < 90$.

We find that the CDL is irregularly shaped and has a patchy and filamentary interior. The size of these structures increases with ℓ_{cdl}, the extension of the CDL. On average, but not at each moment, the solution is about self-similar and depends only on M_{u}. We give the corresponding analytical expressions, with numerical constants derived from the simulation results. In particular, we find the root mean square Mach number to scale as $M_{\mathrm{rms}} \approx 0.2 M_{\mathrm{u}}$. Independent of M_{u} is the mean density, $\rho_{\mathrm{m}} \approx 30 \rho_{\mathrm{u}}$. The fraction f_{eff} of the upwind kinetic energy that survives shock passage scales as $f_{\mathrm{eff}}= 1 - M_{\mathrm{rms}}^{-0.6}$. This dependence persists if the upwind flow parameters differ from one side to the other of the CDL, indicating that the turbulence within the CDL and its driving are mutually coupled. In the same direction points the finding that the auto-correlation length of the confining shocks and the characteristic length scale of the turbulence within the CDL are proportional.

In summary, larger upstream Mach numbers lead to a faster expanding CDL with more strongly inclined confining interfaces relative to the upstream flows, more efficient driving, and finer interior structure relative to the extension of the CDL.

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