Flow collision zones: ubiquitous and - anisotropically, inhomogeneously - turbulent

Doris FOLINI[1], Rolf WALDER[1] & Jean M. FAVRE[2]
[1.] École normale supérieure, Lyon, CRAL, UMR CNRS 5574, Université de Lyon, France
[2.] Swiss National Supercomputing Center, CSCS Lugano, Switzerland

Colliding supersonic flows are ubiquitous in astrophysics and play an important role in a wide range of objects, from O-star winds to molecular clouds, galactic sheets, or γ -ray bursts. We investigate characteristics of supersonically turbulent flow collision zones by numerically solving the Euler equations for the case of 3D isothermal plane parallel head on colliding flows, assuming symmetric settings (both flows have equal parameters) and upwind Mach-numbers $3 < M_u < 43$.
The turbulence within the collision zone is driven by the incoming upstream flows, whose kinetic energy is partly thermalized and spatially modulated by the confining shocks of the collision zone. Numerical results are in line with analytical self-similarity arguments for collision zone mean properties. The spatial scale of modulation grows with the collision zone. Independent of the upstream Mach number M_u , the mean density ρ_m is proportional to the upstream density ρ_u , with $\rho_m \approx 20\rho_u$. For the root mean square Mach number (M_{rms}) we have $M_{rms} \approx 0.25M_u$. Deviations towards lower turbulence are found as the collision zone thickens, for small M_u , and in the center of the collision zone. The turbulence is inhomogeneous.
The turbulence is also strongly anisotropic. The component transverse to the upstream flow remains subsonic on average, even in the central regions of the collision zone. Line of sight effects thus may play a role in observations. The anisotropy carries over to other quantities, like the density variance - Mach number relation. The density probability function is not log-normal. Structure functions are widely different if computed either along a line of sights perpendicular or parallel to the upstream flow. Structure functions are consistent with results from homogeneous, isotropic, stationary, driven 3D supersonic turbulence if computed over a multitude of directions and if restricted to the central regions of the collision zone.
Overall, our results show that turbulence characteristics of 3D isothermal collision zones typically deviate markedly from the characteristics of homogeneous, isotropic, stationary, driven 3D supersonic turbulence. This should be kept in mind when interpreting sturbulence characteristics derived from observations.