Injection and dissipation of energy in three-dimensional supersonic turbulence

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Abstract

Although, in the last decade there has been a lot of experimental, theoretical and computational research concerning three-dimensional supersonic turbulence, little is known on (i) the scales at which energy is injected into it, (ii) the existence of an inverse energy cascade and (iii) the Hausdorff dimension of the most dissipative structures when turbulence forcing is compressible, like point explosions acting in small regions of the domain. Previous computational work focused on incompressible forcing with some "ad-hoc" waves in Fourier space stirring up the gas in the entire computational domain simultaneously. We study supersonic turbulence by means of three-dimensional adaptive mesh refinement simulations with effective grids of 1600^3 and 2000^3 cells using the EVAF-PAMR (Evora-Vienna Astrophysical Fluids - Parallel Adaptive Mesh Refinement) code and show that: (i) there exists an inverse energy cascade, (ii) the injection scale occurs at the spectral break of the kinetic energy distribution function, (iii) the variation of the scalings $\zeta(p)/\zeta(3)$ of the structure functions with p is most consistent with a log-Poisson model for the scales at which intermittency becomes important, (iv) the most elementary structures have a Hausdorff dimension varying between 1.9 and 2.2, and (v) the dissipation of energy proceeds through an ensemble of discontinuities. We note, *en passage*, that the She-Levèque (1994) and Burgers-Kolmogorov (Boldyrev 2002) models for incompressible and compressible turbulence assume that the dissipative structures are filaments (1D) and shocks (2D), respectively. However, the geometry of those scales in supersonic turbulence does not have to represent dissipative structures (as in the case of incompressible turbulence) nor do they have to be planar. 2D in the Hausdorff sense could represent various structures, with sheets being the simplest. This is further supported by the fact that Burger's turbulence produces discontinuities, not shocks, in the sense that material can not flow through them - they just sweep up material.

Keywords: Supersonic turbulence, adaptive mesh refinement, hydrodynamics, magnetohydrodynamics, fractal dimension, shocks.

References

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