Probing the nature of dissipation in compressible MHD turbulence

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Turbulence affects all facets of the physics of the interstellar medium (ISM), its phase changes, its chemical evolution, its coupling to the magnetic field and cosmic rays, and even star formation. The absence of an exact mathematical description and the impossibility for simulations to reproduce the whole inertial range between the injection and dissipation scales make its role difficult to understand. An essential facet of turbulence is the spatio-temporal intermittency of the energy cascade which leads to the formation of coherent structures of high dissipation. These regions are distinguished in the diffuse MIS by a particular, so-called "hot" chemistry that allows them to be traced.

We seek to systematically study the physical nature of regions of intense dissipation in magnetohydrodynamic (MHD) turbulence. We probe turbulent dissipation using simulations of decaying isothermal compressible MHD turbulence. We take particular care in solving and controlling the dissipation: we design methods to locally recover the dissipation due to the numerical scheme. We study locally the geometry of the gradients of the fluid state variables. We develop a method to evaluate the physical nature of the dominant gradients in the discontinuities. This allows us, together with heuristic criteria, to identify them, as well as to estimate their displacement speed. Finally, we study their statistics.
We find that regions of high dissipation correspond to sheets: locally, the density, velocity and magnetic fields vary mainly in one direction. We identify these highly dissipative regions as shocks (fast or slow) or Alfvénic discontinuities (Parker sheets or rotational discontinuities). We study the effect of initial conditions that produce different footprints at short times on the relative distributions between these four categories. However, these differences fade after about one turnover time, when they become dominated by weakly compressible Alfvénic discontinuities. We show that the magnetic Prantdl number has little influence on the statistics of these discontinuities. However, it modifies the nature of the dissipation in the different structures. Finally, we show that the internal structure of the discontinuities allows us to make predictions on
the variations of the cross and magnetic helicities.

These new methods allow to consider developed compressible turbulence as a statistical collection of intense dissipative structures. This can be used to post-process the 3D turbulence with detailed 1D models that can be compared to observations. This view could also be useful as a framework for formulating new dynamical properties of the turbulence.