Shock Identification and classification in magnetohydrodynamic (MHD) Turbulence

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Compressible magnetohydrodynamic (MHD) turbulence is a common feature of astrophysical systems such as the solar atmosphere and interstellar medium. Such systems are rife with shock waves, where the fluid properties change drastically over a relatively small area. These sharp features are intrinsically linked to heating through both adiabatic (compression) and dissipative (e.g., viscous, resistive) effects. Thus understanding the role of shocks in compressible turbulence is critical for determining the energy balance of these dynamic systems.

Much of the literature that analyses shocks in turbulent MHD focus on the slow- and fast-mode shocks. However, an additional class of MHD shocks also exists: intermediate shocks. The existence of intermediate shocks, and their stability, has been controversial in the past however they are fully permissible but the MHD equations [1] and have even been observed in the solar atmosphere [2].

Here we present a recently developed model for automatically detecting and classifying the full range of MHD shocks in numerical simulations, and apply this method to study the shocks that form in the Orszag-Tang vortex.

The shock detection methodology works by first identifying candidate locations using the requirement that div.$\underline{v}$<0 (i.e., the flow is converging). The shock frame is estimated using the steady-state mass conservation equation. Shocks are then classified based on the velocity relative to the characteristic speeds of the local medium. The end result is a set of locations that satisfy shock transitions.

The vast majority of detected shocks are categorised as either fast-mode or slow-mode shocks. However, roughly 5% of shocks are classified as intermediate, which feature a reversal in the magnetic field. An interesting result is that these intermediate shocks appear to form readily near reconnection sites. The proposed mechanism is that the switch-off slow-mode shocks present in ideal models of reconnection are subject to turbulence, increasing the upstream Alfven Mach number, leading to an intermediate shock transition. Since intermediate shocks feature a reversal of the magnetic field across the interface, they may be important for quantifying the local heating and electron acceleration around reconnection sites.

The results are published in Snow et al (2021) and the shock detection code is freely available.

References
[1]L. N. Hau *et al*, JGR, 94, A6 (1989)
[2]S. J. Houston *et al*, ApJ, 892(1):49 (2020)
[3]B. Snow *et al*, Exp. Res., *2*, E35 (2021)

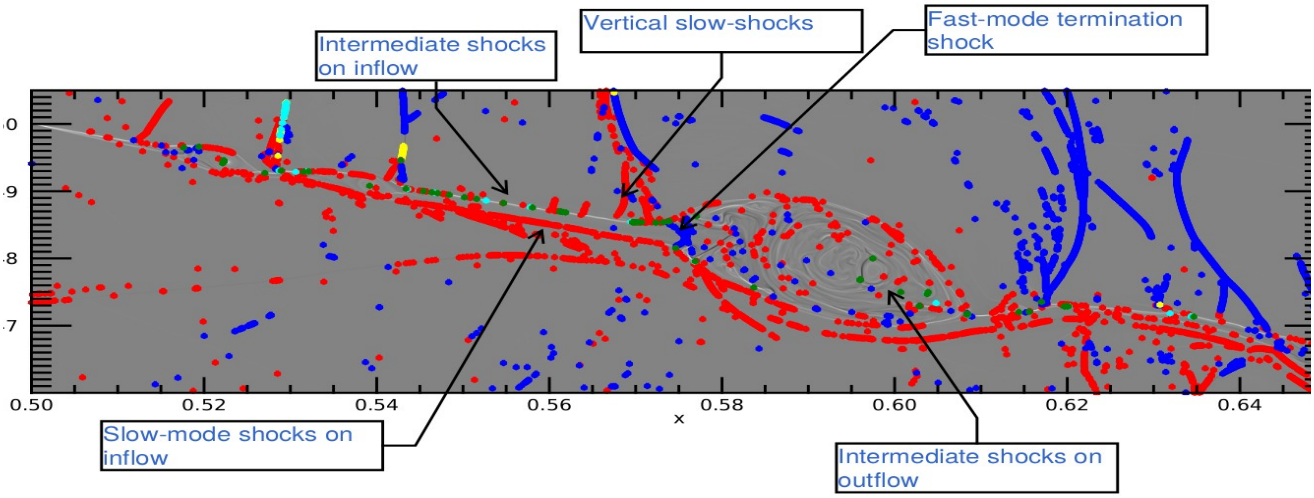

Figure 1: Shocks identified in a reconnection site in a compressible turbulent MHD simulation. Blue and red indicate fast and slow shocks respectively. Green denotes a 2-4 intermediate shock [3].