Alfvénic wave packets collisions in a kinetic plasma

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The problem of two colliding and counter-propagating Alfvénic wave packets has been analyzed in detail since the late Seventies due to its pivotal role in driving magnetohydrodynamics (MHD) turbulence. Within the context of incompressible MHD, it has been shown that nonlinear interactions can develop only when the two packets overlap [1].

Here we investigate a similar problem in several theoretical frameworks by means of compressible MHD, Hall-MHD and kinetic simulations performed with two different hybrid codes: an Eulerian Vlasov-Maxwell code and a Particle-In-Cell code. Due to the huge computational cost, we consider only a 2D-3V phase space (two dimensions in the physical space, three dimensions in the velocity space). The most relevant nonlinear effects occur during the overlapping of the two packets, as in the MHD description. The inclusion of compressive, dispersive and kinetic effects maintains the gross characteristics of the simpler classic formulation. However it reveals intriguing features that go beyond the pure MHD treatment [2].

By focusing on the Eulerian Vlasov-Maxwell simulation, we analyze in detail the production of non-Maxwellian features in the proton distribution function and the characteristics of the turbulence generated by the collision. We observe intense non-Maxwellian structures in the proton distribution function [3], ranging from regions characterized by temperature anisotropies and agyrotropies to the detection of a clear beam along the direction of the magnetic field, similarly to some recent solar-wind *in-situ* observations.

A detailed analysis of the turbulence generated by the collision reveals the coexistence of subdominant, low-energy fluctuations, that are consistent with Kinetic Alfven Waves, immersed in a strongly turbulent environment, characterized by the presence of quasi-stationary turbulent structures and by a significant weakening of clear dispersion relations [4]. Figure 1 illustrates the complexity generated by the collision of the Alfvénic wave packets.

References

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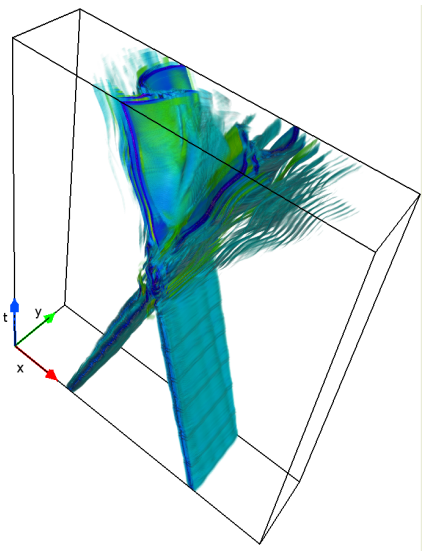

Figure 1. Space-time representation of Alfvénic packets collision by means of the iso-surfaces of the current density $j_z(x,y,t)$ [4]. After their collision, wave-packets are strongly distorted due to nonlinear interactions. Small-amplitude ripples propagating almost purely along x are a signature of Kinetic Alfven Waves like fluctuations.