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Interplay between long and short wavelength instabilities feeding the microturbulence within the foot of a quasi-perpendicular supercritical shock: 2D PIC numerical simulations

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In supercritical shocks a substantial fraction of ions is reflected at the steep shock ramp. The beam of reflected ions carries a considerable amount of energy and is a main source of microturbulence in the shock's foot. For quasi-perpendicular geometries the speed of the reflected ions is mostly directed at 90° to the background magnetic field $\mathbf{B_o}$. This enables streaming instabilities excited by the relative drifts between incoming ions, reflected ions, and electrons across $\mathbf{B_o}$.

We investigate the resulting microturbulence by means of a spectral periodic 2D PIC code that solves the full Maxwell-Poisson equations in the presence of three plasma distributions. The simulation is carried out in the center of mass frame and is initiated by loading one electron population and two ion populations that move in opposite directions representing the incoming core and the reflected beam. The two-dimensional grid $[x, y]$ includes $\mathbf{B_o}$ along $\hat{\mathbf{y}}$ and the relative drift along $\hat{\mathbf{x}}$, so that the waves can propagate at all angles versus $\mathbf{B_o}$. A snapshot of the electrostatic field component E_{LX} and the perturbed magnetic field components B_Y and B_Z is shown in Figure 1.

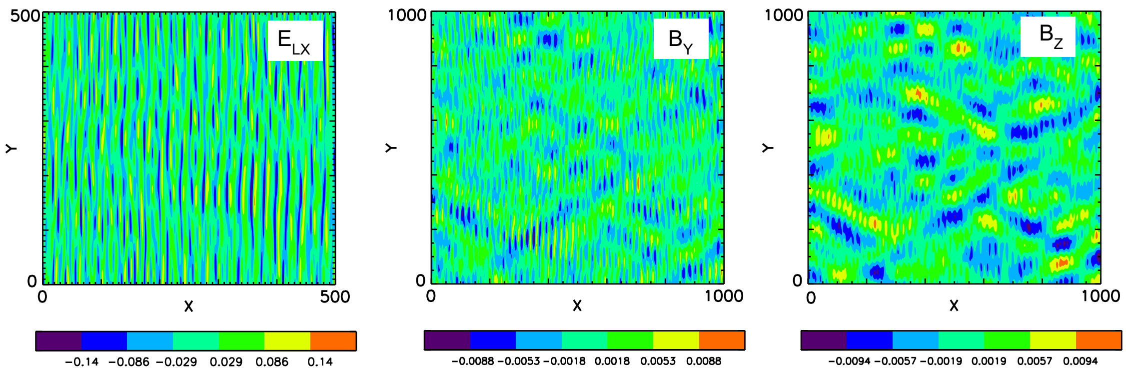

Figure 1. Snapshot of some field components shown on a portion of the simulation grid ($\mathbf{B_o}$ parallel to y).

At least 2 spatial scales can be identified: a short scale with wavefronts parallel to y and a much longer scale with oblique wavefronts. From previous studies we know that the former is due to Bernstein waves [1] whereas the latter is due to whistler waves in the lower-hybrid frequency regime [2]. Here, we perform several times the simulation with exactly the same initial conditions. What changes between the various runs is that a spectral filter is applied to eliminate specific wave modes. By combining (adding and subtracting) results from the runs we can pinpoint what is non-additive in the generated microturbulence, hence what self-consistent interplay takes place between the long and short types of modes during the linear/nonlinear phases of the different instabilities.

References

[1] L. Muschietti and B. Lembège, "Microturbulence in the electron cyclotron frequency range at perpendicular supercritical shocks", *J. Geophys. Res.*, **118**, 2013, pp. 2267–2285, doi:10.1002/jgra.50224

[2] L. Muschietti and B. Lembège, "Two-stream instabilities from the lower-hybrid frequency to the electron cyclotron frequency: application to the front of quasi-perpendicular shocks", *Ann. Geophys.*, **35**, 2017, pp.1093–1112, doi:10.5194/angeo-35-1093-2017.