3D Kinetic Magnetic Reconnection: getting ready for the MMS mission

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We report on our work to provide theoretical support to the Magnetospheric Multiscale (MMS) Mission of NASA. We report on the results of applying our massively parallel 3D particle in cell code iPic3D [1] to the study of 3D reconnection.
Reconnection refers to the energy conversion process where magnetic field lines are broken and reconnected in a new configuration while electrons and ions are energized at the expense of the magnetic energy. The process has been extensively investigated in laboratory, in space and in astrophysical systems where it is believed to play a dominant role in shaping the development of energy in many events. The studies have preliminarily been in 2D assuming relatively idealized conditions.

Here we report on the new work where the role of the third dimension is investigated. We start from the typical 2D case and add the effects of the 3rd dimension in three steps.
First, we simply add the z-direction to a 2D run loading an initial system that simply replicates the same initial 2D state invariant of z, with the same initial perturbation also independent of z. This case is already extremely interesting showing the presence of key processes absent in 2D.Several regions of intense free energy are present (velocity shears, strong flows, density gradients) and elad to numerous instabilities. We will explain the relevance to existing observations and to the future MMS mission [2,3].

Next, we allow reconnection to develop freely an initially uncorrelated in the z dimension. Here we do not prescribe any perturbation and allow each z-plane to develop with only the spontaneous correlations naturally evolving in the system. In this case reconnection is vastly different from the 2D case leading to numerous reconnection sites that start to interact to form coherent structure: flox ropes and extended electron and ion diffusion regions.

Last, we initiate the system with configurations that are fully 3D and include to begin with a 3D topology with prescribed null lines and null points where the magnetic field is zero. The evolution is drastically different at null points and null lines.

In all three cases, we report on the evolution of the system focusing especially on:
1) the presence of instabilities,
2) the existence of non-MHD effects where electrons and ions display their kinetic nature and decouple from the frozen in condition.
3) the energetics of the process, investigating where and how energy is released.

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