3D Kinetic Effects in Collisionless Reconnection

Giovanni Lapenta

Katholieke Universiteit Leuven

We report the latest results of the theory effort in support of the Magntospheric Multiscale Mission (http://mms.gsfc.nasa.gov/). We have developed a 3D massively parallel particle in cell code based on the implicit moment method to study 3D reconnection on large scales including an accurate description of all scales from the smallest electron scales to the global system sizes.
We will focus on three processes.
First, how is energy converted in 3D kinetic reconnection (the speed, the break up in bulk flow and thermal energy and the fraction going to different species)? 3D results differ quantitatively and qualitatively from the 2D case we are accustomed to and 3D reconnection can be much more effective. But most importantly comes the question as to where is the energy being released? Not in the electron diffusion region as it is typically assumed, but rather in the downstream front (in space physics called dipolarization front). A shift of focus must than take place, of key importance to the MMS mission.
Second, how is the topology of 3D kinetic reconnection? A lot of progress has been made in MHD reconnection as to the role of null points, separatrix surfaces and separators. We have recently conducted the first study of null point reconnection with full kinetic models. The results are very surprising in terms of energy rate but also in terms of the relative role of null points and singular null lines. But the most interesting point in 3D kinetic topology is what are the structures of the kinetic electron and ion diffusion regions around a null point. We are used to the famous two boxes in 2D kinetic reconnection, the inner electron box where the electron decouple from field lines and the outer ion region where the ions decouple. Previous 3D studies have reported the tendency of null lines to extend in 3D kinetic simulations (similarly to fluid models based on Hall-MHD). But in truly 3D isolated null points this point has not been investigated previously.
Finally, in 3D kinetic reconnection we report on the natural tendency of reconnection to transition to a chaotic regime where the diffusion regions tend to break into a plethora of site of different sizes. A clear transition towards turbulent reconnection, previously observed in MHD reconnection but now also being investigated in kinetic reconnection by several groups.