3D Kinetic Simulations of Magnetic Reconnection Onset

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We present a number of 3D kinetic PIC simulations aimed at understanding the mechanisms behind the onset of magnetic reconnection [1]. Traditionally, the reigning paradigm has been that microinstabilities lead to anomalous resistivity and allow reconnection to progress even in collisionless systems where under ideal conditions reconnection would be severely impeded.

Our work aims at revisiting this issue using the 3D kinetic simulation tool, CELESTE. CELESTE uses an implicit time discretization of the particle equations of motion and of the Maxwell's equations allowing to resolve the scales of interest, while averaging over the smallest scales. To understand reconnection processes we need to resolve the skin depth and the particle motion in the reconnection region, but we can step over the smaller scales (Debye length, and electron plasma frequency). The overall advantage is a reduction of at least one order of magnitude in the number of cells in each direction, and one order in time.

Our analysis shows that the microinstabilities alter the initial equilibrium at a fundamental level. Besides creating a small scale turbulent fluctuating magnetic and electric field, the microinstabilities induce a macroscopic alteration of the equilibrium. Three macroscopic changes are induced. First, an anisotropic heating creates a strong temperature anisotropy enhancing the cross field temperature [2]. Second, the current layer is intensified and its profile is peaked and in cases bifurcated [2, 3, 4]. Third, a velocity shear is created [5, 6].

Each of these three effects impact profoundly the onset and evolution of reconnection. We present specific results proving the three effects and their role in the reconnection process.

References

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