Magnetic Reconnection: effects of the 3rd dimension

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Abstract

Understanding 3D reconnection is a challenge. For two reasons.
First, the simulations are very expensive. To obtain reliable first principle results one has to rely on kinetic PIC simulations that are prohibitively expensive in 3D. The widely different time and length scales of electrons and ions prevents explicit formulations from being able to study systems of sufficient size for sufficiently long times at realistic mass ratios. We have a solution to this problem: implicit PIC [1]. Implicit PIC allows us to remove the following three constraints: 1) the need to resolve the electron plasma frequency; 2) the need to follow the speed of light propagation; 3) the need to resolve the electron Debye length. For reconnection studies, we are not concerned by any of these three scales and yet explicit PIC has to resolve them to prevent instability and loss of energy conservation. But implicit PIC can step over the scales above and worry only about the true scales of interest: the time step is selected to resolve the electron cyclotron frequency (allowing time steps 40 times larger than in explicit codes) and the electron skin depth (allowing grid spacing 10 times larger than in explicit codes). Previous studies have compared explicit and implicit PIC [2]. The accuracy of implicit codes is limited for high frequency and short wavelength processes but is as accurate as that of explicit codes for the larger scales processes involved in reconnection. Second, the wealth of physics presence in 3D simulations is breathtaking. Yet recently some new insight has occurred, like the coupling of the lower hybrid drift instability with the presence of kinking of current sheet (probably a Kelvin-Helmholtz instability, KHI) [3], the existence of KHI driven reconnection [4], the existence of reconnection waves [5] and electron holes [6] propagating in the current direction.
In the present work, we report the conclusions of our simulations in this field focusing particularly on two issues: 1) the difference between 2D and 3D reconnection induced by waves and instabilities propagating in the current aligned direction; 2) the effect of the guide field on such differences, showing that some 3D effects are suppressed by the guide field.

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