Three-Dimensional Dynamics of Magnetic Reconnection in Space and Laboratory Plasmas

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Abstract
The physics of collisionless magnetic reconnection remains one of the most challenging and far-reaching problems in plasma physics. This research effort will lead to ground breaking new advances in this field by combining three unique innovations. First, the highly optimized 3D kinetic plasma simulation code VPIC has already been ported to the Roadrunner architecture, allowing calculations 100x larger than any competing group in world. Second, in order to mimic the large open systems found in nature, we will employ a new open boundary method [1] that permits the structure of the reconnection layer to develop more realistically over dynamically interesting time scales. In recent large-scale 2D kinetic simulations [1,2], this approach has already demonstrated that the basic structure and time dependence of a reconnection layer is radically different than what was previously understood based on small-scale periodic studies. Third, we have a clear path for validating these simulations through our close interactions with one of the leading laboratory reconnection experiments (MRX). This robust validation effort will combine realistic boundary conditions for the experiment along with the inclusion of binary Coulomb collisions. These developments will place this research effort at the forefront of the field, by permitting first-principles 3D simulations to understand the influence of current aligned plasma instabilities on the reconnection dynamics.