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Towards Realistic Solar Flare Models

Solar flares are complex multiscale phenomena that demand modeling strategies capable of precisely capturing processes at both the microscale and macroscale. At the microscale, kinetic models such as the Particle-In-Cell (PIC) method are crucial for an accurate depiction of physical phenomena, especially particle acceleration near reconnection sites. However, the extensive computational demands of full-scale PIC simulations necessitate a more practical approach. A hybrid system is employed wherein Magneto Hydrodynamics (MHD) governs the large-scale dynamics, while PIC is strategically applied to model the critical reconnection processes.

We have developed a PIC solver and integrated it within the DISPATCH framework. DISPATCH organizes the simulation domain into smaller, manageable 'patches'. Each patch operates semi-autonomously, updating based on local conditions, thereby enabling simulation across diverse time and spatial scales. This modular approach not only achieves near-perfect strong and weak scaling but also enables dynamic solver switching, a critical feature for efficiently addressing the vast scale discrepancies characteristic of solar flare phenomena.

Here, we show the initial validation results of our explicit PIC solver, along with our ongoing efforts towards its integration with MHD. We will underscore the significant advancements in our hybrid modeling approach, demonstrating its potential to enhance our understanding and simulation capabilities of solar flares.

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