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Realistic mass ratio magnetic reconnection simulations with the Multi Level Multi Domain method

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Space physics simulations with the ambition of realistically representing both ion and electron dynamics have to be able to cope with the huge scale separation between the electron and ion parameters while respecting the stability constraints of the numerical method of choice. Explicit Particle In Cell (PIC) simulations with realistic mass ratio are limited in the size of the problems they can tackle by the restrictive stability constraints of the explicit method (Birdsall and Langdon, 2004). Many alternatives are available to reduce such computation costs. Reduced mass ratios can be used, with the caveats highlighted in Bret and Dieckmann (2010). Fully implicit (Chen et al., 2011a; Markidis and Lapenta, 2011) or semi implicit (Vu and Brackbill, 1992; Lapenta et al., 2006; Cohen et al., 1989) methods can bypass the strict stability constraints of explicit PIC codes. Adaptive Mesh Refinement (AMR) techniques (Vay et al., 2004; Fujimoto and Sydora, 2008) can be employed to change locally the simulation resolution. We focus here on the Multi Level Multi Domain (MLMD) method introduced in Innocenti et al. (2013) and Beck et al. (2013). The method combines the advantages of implicit algorithms and adaptivity. Two levels are fully simulated with fields and particles. The so called ”refined level” simulates a fraction of the ”coarse level” with a resolution RF times bigger than the coarse level resolution, where RF is the Refinement Factor between the levels. This method is particularly suitable for magnetic reconnection simulations (Biskamp, 2005), where the characteristic Ion and Electron Diffusion Regions (IDR and EDR) develop at the ion and electron scales respectively (Daughton et al., 2006).
In Innocenti et al. (2013) we showed that basic wave and instability processes are correctly reproduced by MLMD simulations. In Beck et al. (2013) we applied the technique to plasma expansion and magnetic reconnection problems. We showed that notable computational time savings can be achieved. More importantly, we were able to correctly reproduce EDR features, such as the inversion layer of the electric field observed in Chen et al. (2011b), with a MLMD simulation at a significantly lower cost.
Here, we present recent results on EDR dynamics achieved with the MLMD method and a realistic mass ratio.