The Scaling of Forced Collisionless Reconnection

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ABSTRACT: We present two-fluid simulations of forced magnetic reconnection in a collisionless two-dimensional slab geometry. In the absence of forcing, our system has Δ'=0 and as expected exhibits no reconnection. Therefore, reconnection in this study is driven by a spatially localized forcing function. This function represents a generic external forcing agent such as the solar wind. We investigate the behavior of the resulting reconnection as a function of various free parameters in the system. Consistent with previous scaling studies done on systems with relatively large Δ' we find that for sufficiently strong forcing the reconnection process becomes Alfvénic.

Introduction

The so-called GEM challenge studies featured a current sheet with an initial half-width of one proton inertial length without considering how this configuration had been achieved. In contrast, this study features a very wide initial current sheet. To drive reconnection, this ***stable*** system is then subjected to a spatially localized forcing function, representing a generic externally imposed forcing function, such as the solar wind.

Initial Equillibrium

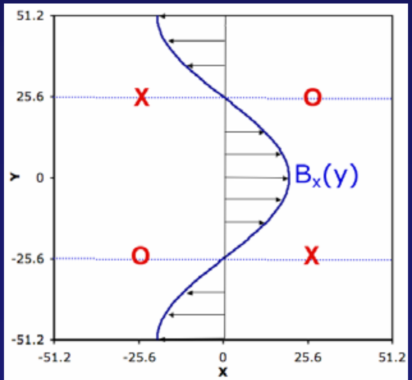

Fig 1: a schematic diagram of the initial equilibrium: a system size double periodic current sheet. We seed both current sheets with x-points as shown above to create the double tearing mode. Boundary conditions are periodic in x and y. This system is stable to all linear modes (Δ'=0.)

Forcing

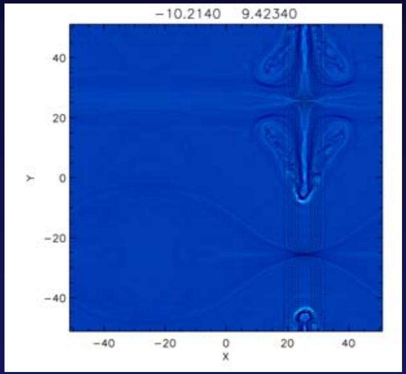

Fig 2: $F_y(x,y)$ (dashed contours and J_z (blue) The most negative current is shown in black greatest and least values of J_z are shown above the figure.

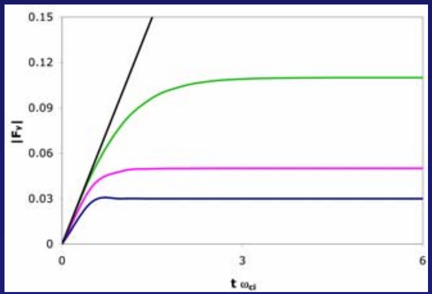

Fig 3: Time dependence of the forcing function. In each simulation the forcing is ramped up at the same rate, then held fixed at a different level. In one simulation the forcing is continuously ramped for the duration of the run.

Data

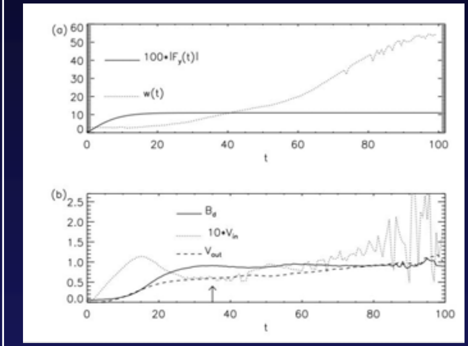

Fig 4: Time series data from a typical simulation. In (a), the strength of forcing (solid) and the island width (dotted). In (b),the upstream field B_d (solid), as well as V_{out},(dashed) and,10 V_{in} (dotted), which are explained in the figure below.

Dissipation Region

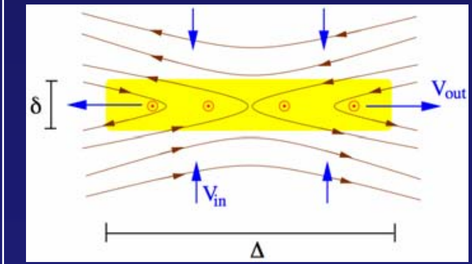

Fig 5: A schematic diagram of the current sheet and dissipation region (shaded yellow box). Magnetic fields are shown in brown, currents in red, plasma flows in blue.

$$E_r \sim \frac{\delta}{\Delta} V_{IN} B_d \sim \frac{\delta}{\Delta} \frac{B_d^2}{\sqrt{4\pi m_i n}}$$

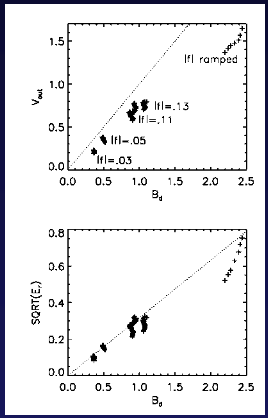

Fig 6: The scaling of V_{out} with B_d (top) and the scaling of $\sqrt{E_r}$ with B_d (bottom.) Each cluster of data is time series data from a run with a different forcing level. The reference line of slope unity in the top plot represents Alfvénic outflow based on the upstream field. The slope of the line in the bottom plot is √10, 10 being apprixmately the aspect ratio of the dissipation region Δ/δ.

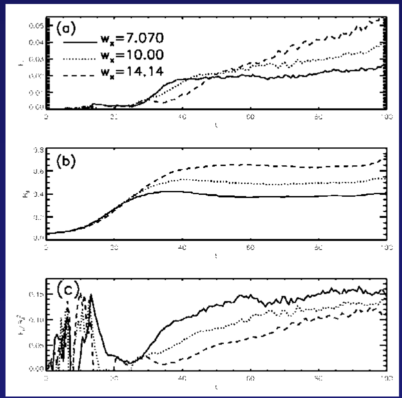

Fig 7: The scaling of E_r with varying width of the forced region, w_x. Time series of the raw reconnection rates are plotted in (a). In (c) the reconnection rates are normalized to the square of the upstream field, B_d, shown for each simulation in (b).