Initial conditions

large-scale, sheared Velocity field

+ Magnetic field

$$\mathbf{U}_{eq} = (U_0/2)\,\tanh\left[(x - L_x/2)/L_u\right]\hat{\mathbf{y}}$$

$$\mathbf{B}_{eq}(x, y) = B_{y,eq}\mathbf{e}_y + B_{z,eq}\mathbf{e}_z$$

Constant or sheared

Constant in plane magnetic field

$M_S = U_0/C_S = 1.0; \quad U_0 = 1.0$

$M_{A,\perp} = U_0/U_{A,\perp} = 1.0; \quad \mathbf{M_{A,||} = 20.0}\ [= U_0/U_{A,||}]$

$L_u \gg d_i$ $\quad L_u = 3 \quad L_x = 90 \quad L_y = 30\pi;$ $\quad$ **m=2** $\Leftrightarrow$ FGM

*Transparent boundary conditions** along x-axis

* K.W. Thompson, J. Comput. Phys. **68**, 1 (1987)

Plasma passive tracer and magnetic field lines: formation of two vortices by the K-H instability

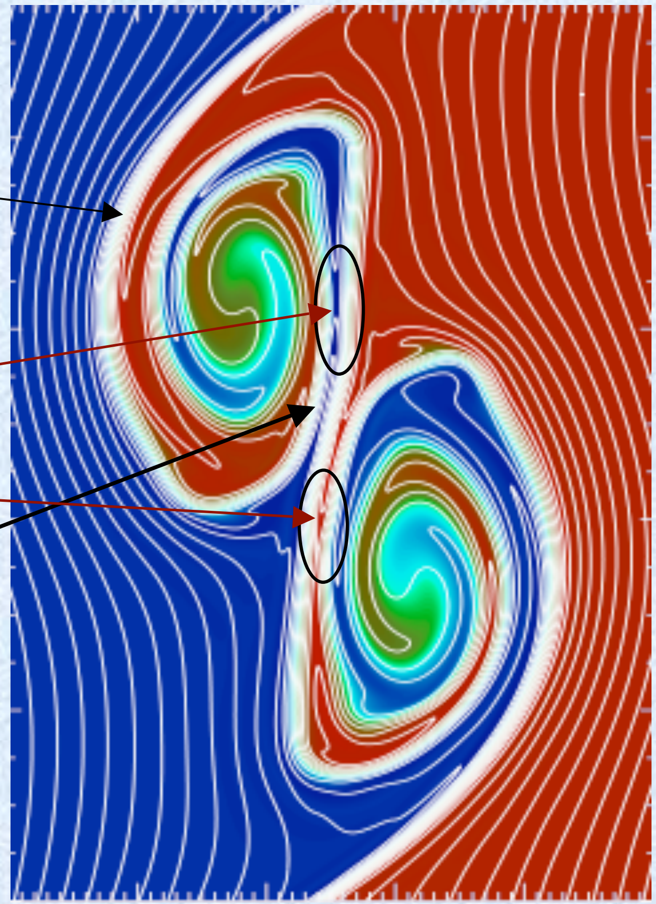
Frozen-in magnetic field lines and plasma passive tracer advected by the velocity field

Vortex merging

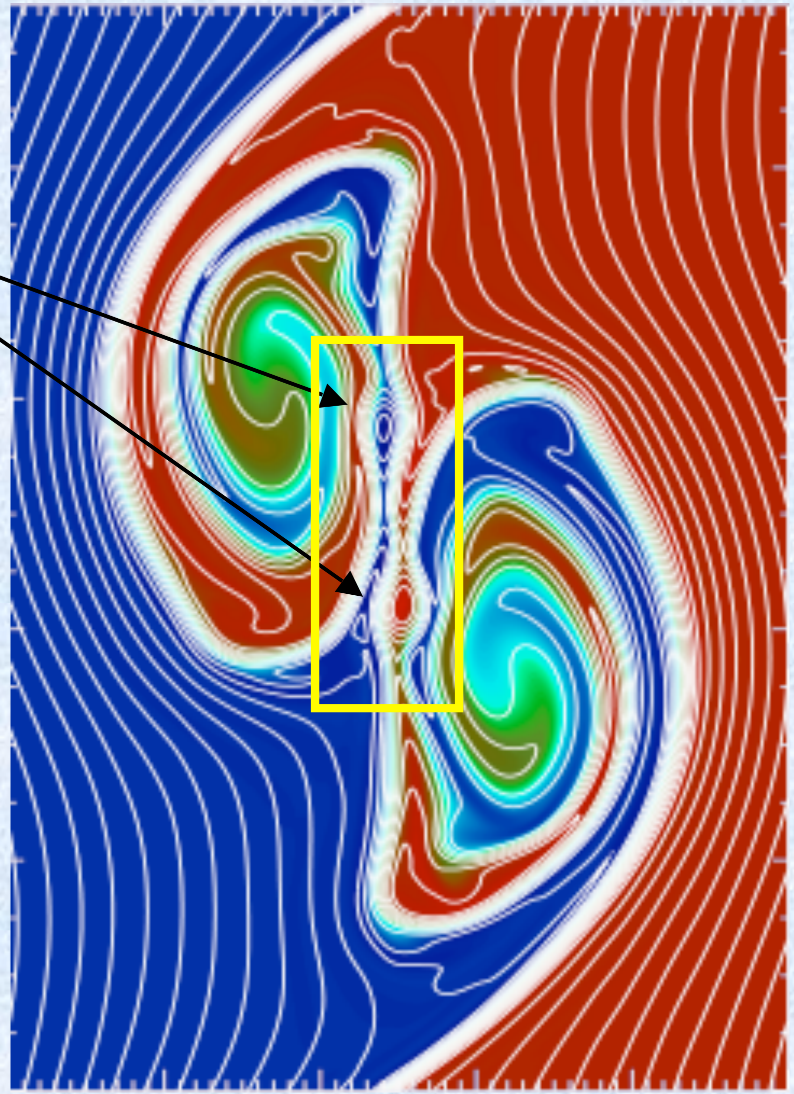
The blue and the red domain are well separated by a (rolled-up) ***ribbon*** of nearly parallel, compressed magnetic lines.

(first couple) X-points

Two **current layers**
(local magnetic inversion lines).



Magnetic reconnection develops at the X-points

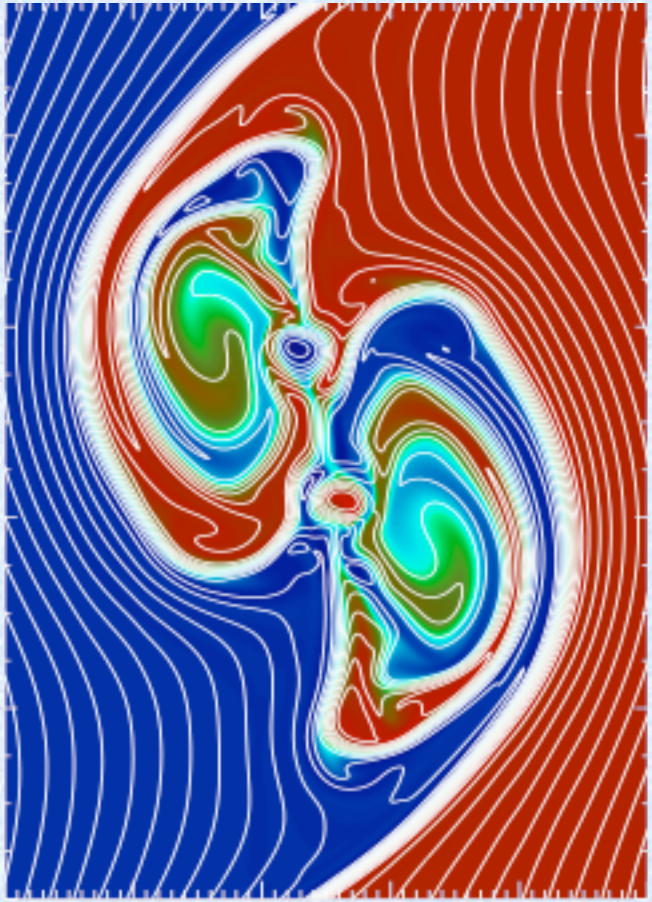


magnetic islands

typical size ~ d_i

The inflow plasma velocity at the X-points is $\sim 0.1\ c_{A,\ local}$ (as expected for *fast magnetic reconnection*[*]) $\Rightarrow$ $\gamma \sim 0.1\ c_A / L_{B,\ local} \sim 0.15$ compatible with d\ln E_z / dt at the X-point.

$\gamma \sim 0.15$



In the time interval of a few growth times the two vortices can only rotate by a few degrees

⇩

The plasma displacement and the current rearrangement due to vortex rotation are

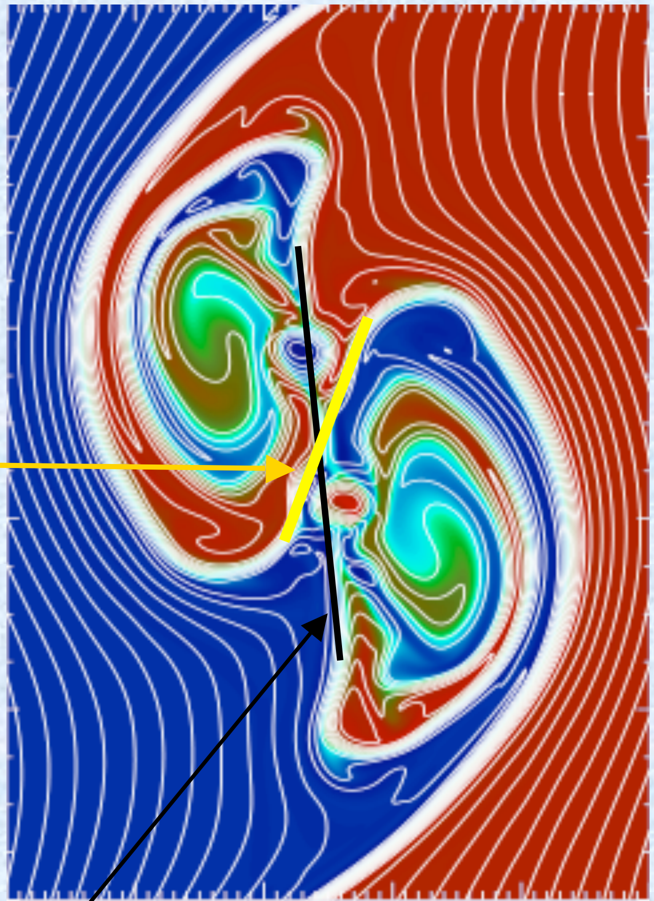
not sufficient rapid to interfere with the reconnection process.

⟹ ***"fast" reconnection***

[*]M.A. Shay *et al*., J. Geophys. Res. **103**, 9165 (1998))

Change in the large scale magnetic field topology

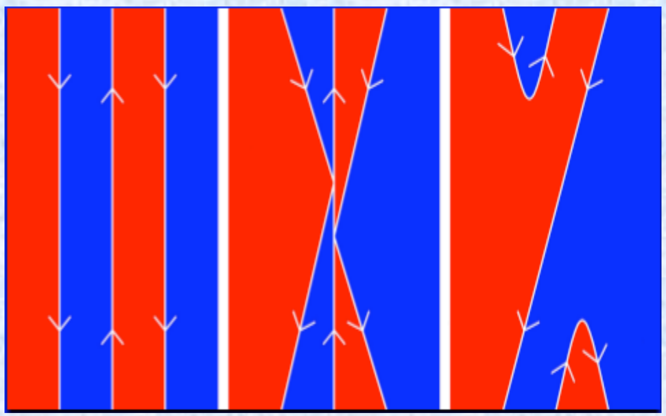
The field line ribbon shrinks and finally opens up



A **new ribbon** of field lines appears which no longer separates the red and the blue plasma regions

Significant portions of the red plasma have been engulfed in the form of "blobs" into the blue plasma region and viceversa.

old ribbon

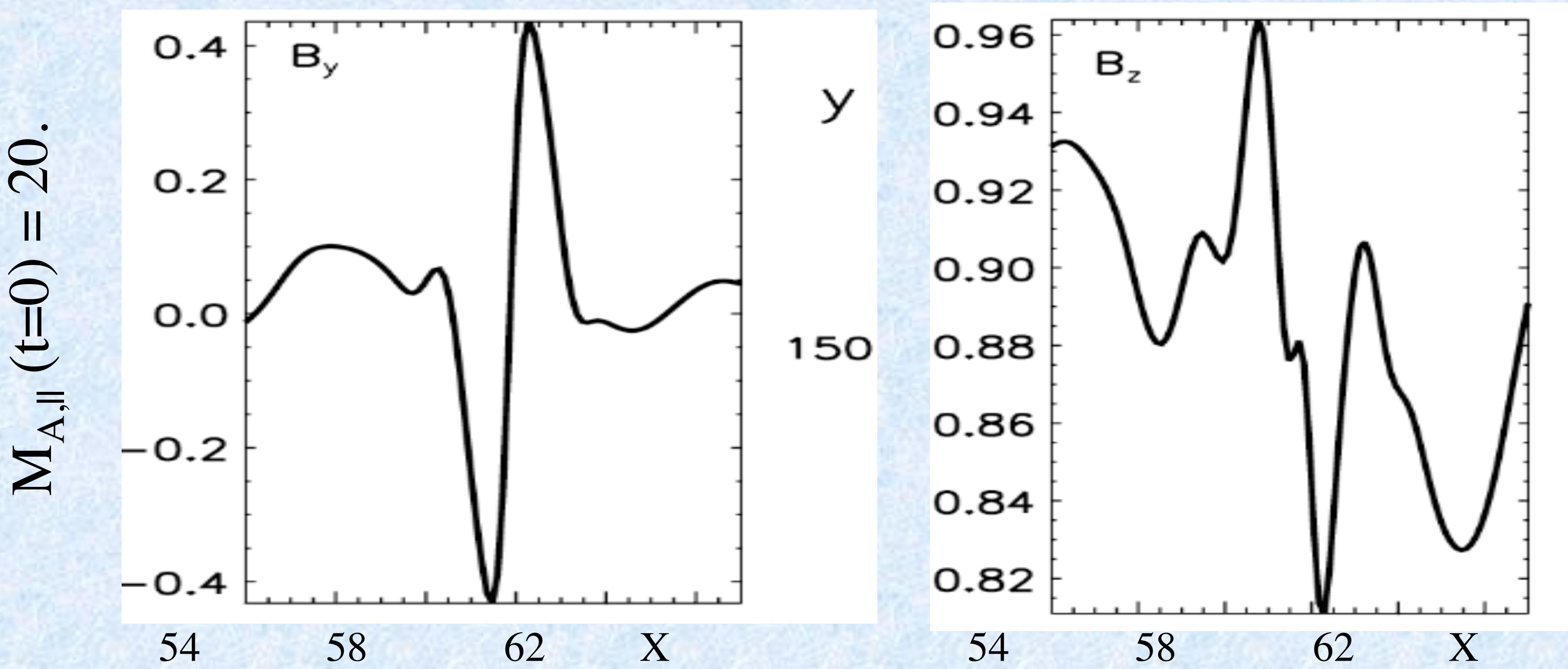


Schematic representation of the magnetic field lines in the region between the two pairing vortices

The value of the in-plane magnetic field inside the current sheet is strongly enhanced by the compressional motion of the vortices.

In the reconnection region $B_{in\text{-}plane}$ and B_{gf} are comparable !

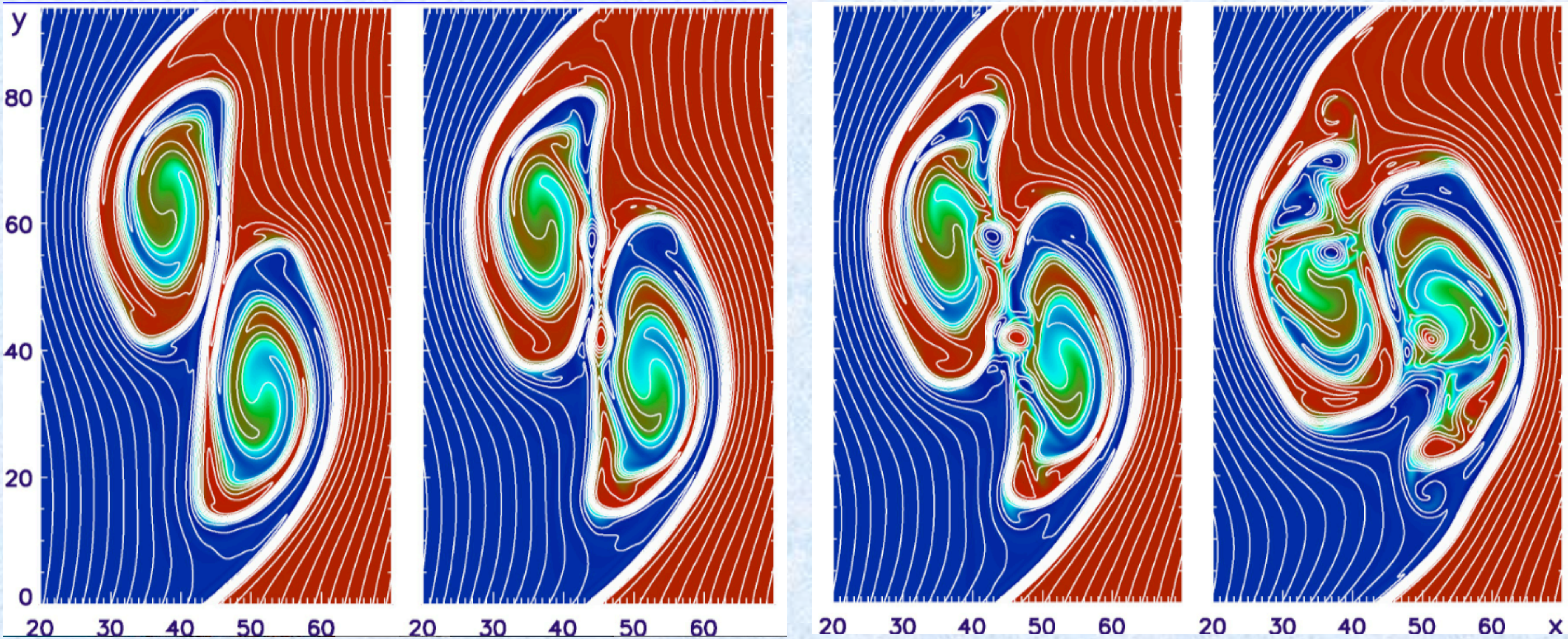
Initially $B_{gf}/B_{in\text{-}plane}$ was more than a factor of ten.



The y and z component of the magnetic field along x (y = 142.5, t = 385)

Thus, in this region, we expect the Hall term to be comparable to the UxB term in Ohm's law.

Plasma passive tracer and magnetic field lines

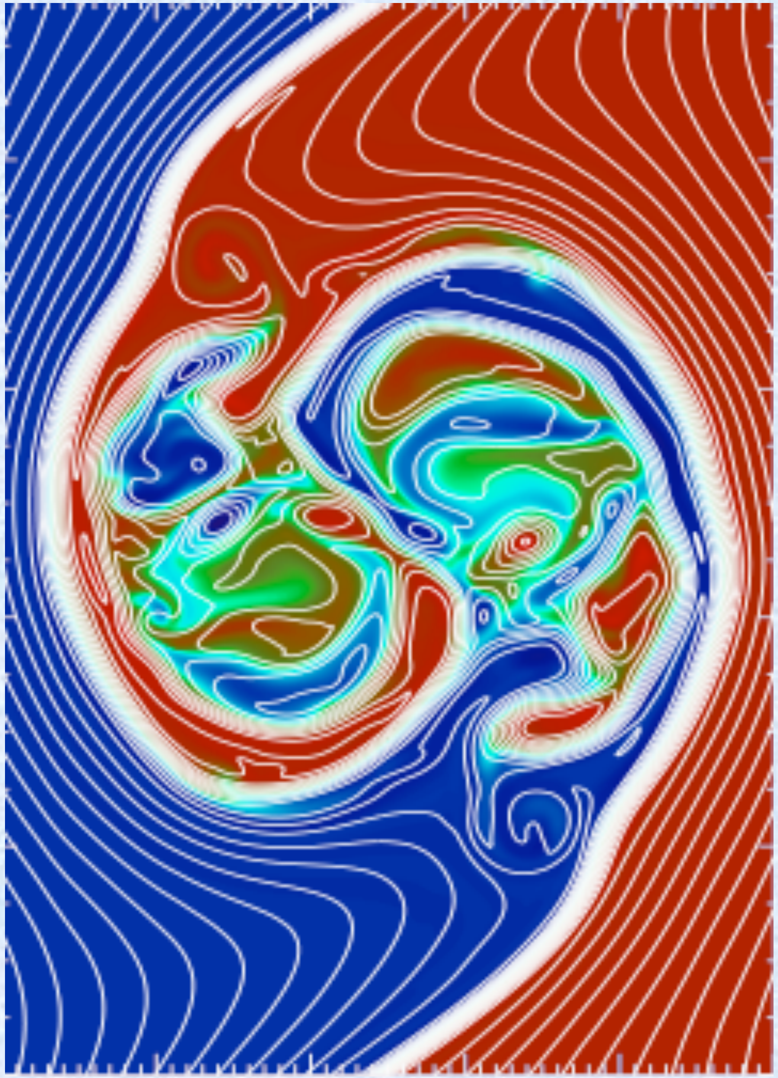


Generation of coherent magnetic structures

typical size comparable to the ion inertial scale, much smaller than the system dimensions but much larger than the electron inertial scale.

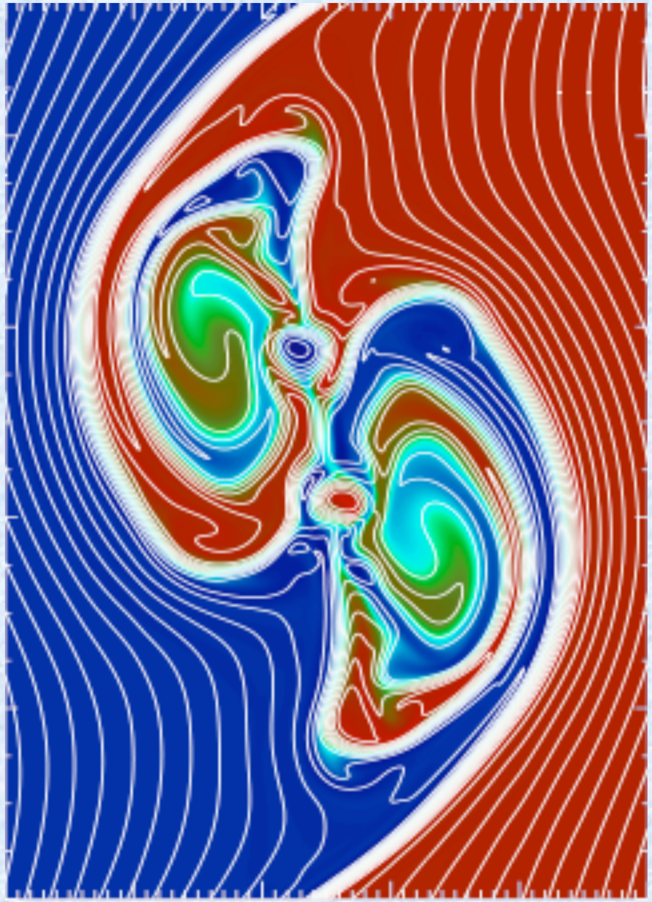
$$\mathbf{L} \gg \lambda_{c.s.} \sim \mathbf{d}_i \gg \mathbf{d}_e$$

These magnetic structures are further advected in the plasma by the velocity field in a complex pattern, but *remain stable over a time interval much longer than their formation time.*



The Hall term

We are interested in establishing the effect of the Hall term in a **collisionless reconnection regime** that is **produced dynamically** through the MHD evolution of a plasma with a sheared flow, i.e., in



regimes where sub-d_i scales are not imposed from the start

but develop self consistently.

$L_u \gg d_i$ => *electrons and ions both initially magnetized*