Comparative simulations of Kelvin-Helmholtz induced magnetic reconnection at the Earth's magnetospheric flanks

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Context

This study employs two 3D simulations to study the Kelvin–Helmholtz instability (KHI) dynamics at Earth's magnetospheric flanks during northward interplanetary magnetic field periods. By comparing nearly identical simulations without (run A) and with (run B) initial magnetic shear, we investigate the impact of different magnetic field orientations on plasma dynamics and magnetic reconnection events, focusing on changes in the latitudinal distribution of KH vortices, current sheets, and reconnection events. Of particular interest is the competition between various magnetic reconnection event types, such as (double) mid-latitude reconnection (MLR) and Type I vortex-induced reconnection (VIR).

Simulations setup

- Resistive Hall-MHD quasi-neutral model (Faganello et al., EPL, 2012)
- Boundary conditions:
  - X: outflow (non-reflective)
  - Y, Z: periodic
- $\lambda_{KH} \simeq 50 d_i$
- Run A: $\phi = 0$ & Run B: $\phi \simeq 18^\circ$

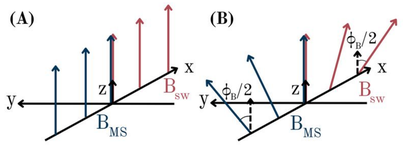


Fig 1: magnetic field configuration

- Box size and resolution:

$$L_x = 90\ d_i$$
$$L_y = 2\ \lambda_{KH}$$
$$L_z = 8\ \lambda_{KH}$$
$$n_x = 600$$
$$n_y = 512$$
$$n_z = 512$$

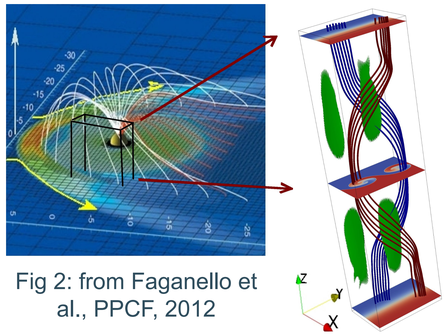


Fig 2: from Faganello et al., PPCF, 2012

Reconnection events

- Run A: twice-reconnected lines dominate and are ~ twice the number of once-reconnected lines
- Run B: dominance of once-reconnected lines until late nonlinear phase

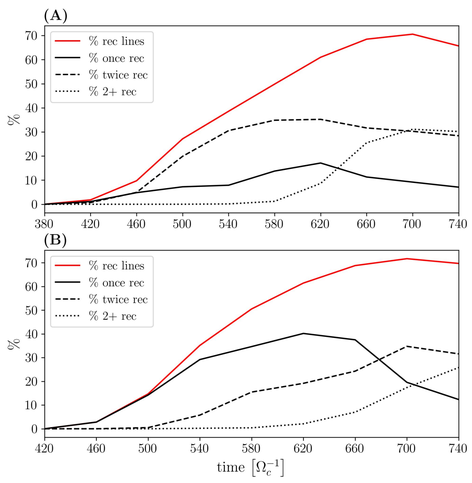


Fig 6: count of reconnecting field lines for both runs

Mixing layer

- $\langle \Delta\psi^2 \rangle$ is the maximal perpendicular displacement of a magnetic line with respect to its position following an ideal evolution
- Linear growth ⟶ diffusive-type widening of the mixing layer
- Effective magnetic diffusion coefficient of order $\sim 10^{10}\ m^2 s^{-1}$

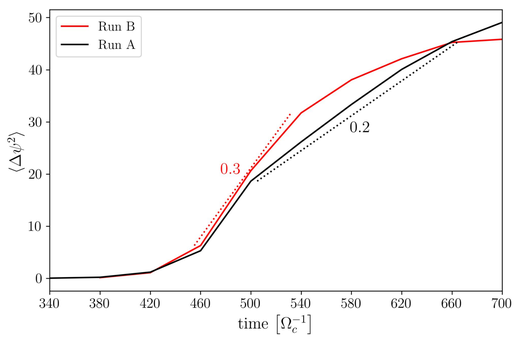


Fig 7: mixing layer widening

Latitudinal distribution of vortices and reconnection events

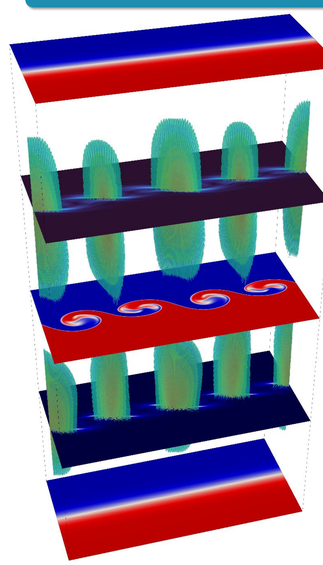
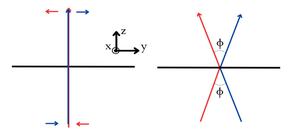
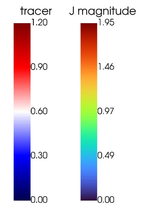


Fig 3: 3D box view of Run A





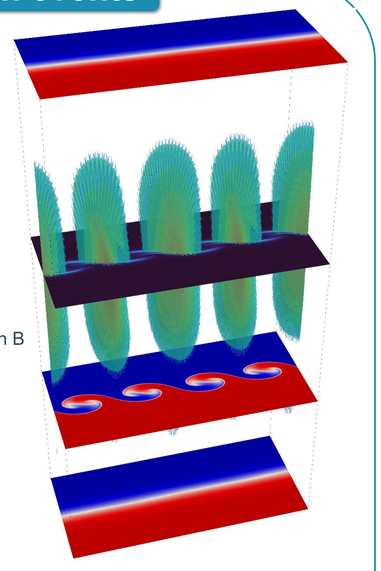
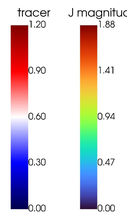
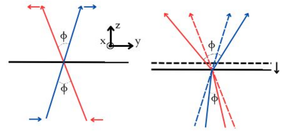


Fig 4: 3D box view of Run B





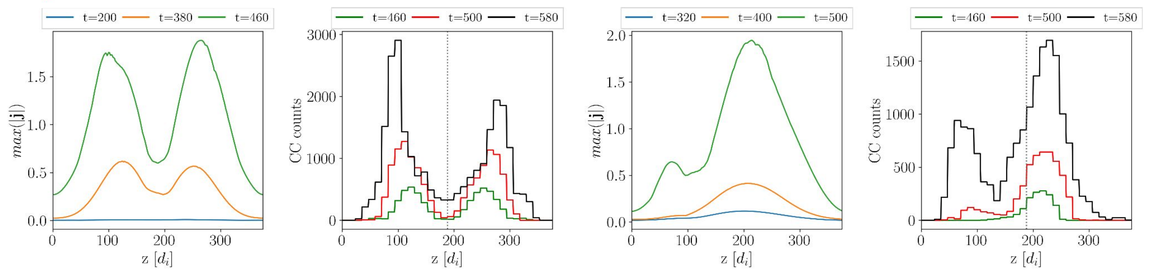


Fig 5: latitudinal distribution of current density and histogram of the connection changes (CC) count for both runs

Conclusions

The introduction of a rotation in the magnetic field significantly impacts the latitudinal distribution of vortices, current sheets, and reconnection events. Notably, the percentage of lines undergoing single, double, or multiple reconnections remains consistent across both configurations during different phases of the KHI evolution (vortex formation, merging, and disruption). Moreover, the presence of an initial magnetic rotation minimally affects the formation of the mixing layer, with comparable final magnetic diffusion coefficients observed for both configurations.