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Influence of environmental parameters on the Kelvin-Helmholtz instability at the magnetopause

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Motivation

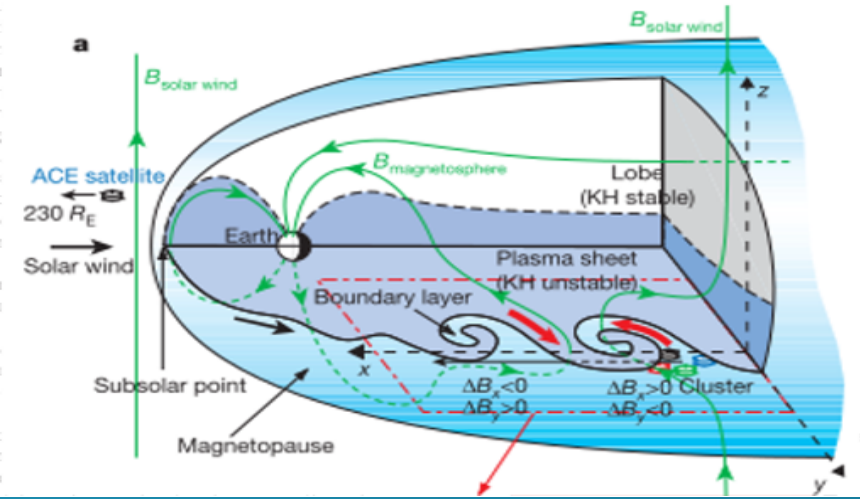
Observations

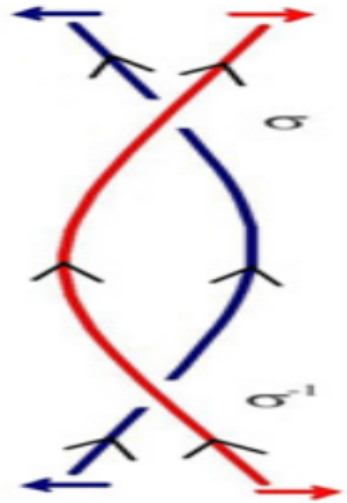
- southward IMF $\rightarrow$ reconnection at low-latitude
- northward IMF $\rightarrow$ reconnection should not be efficient

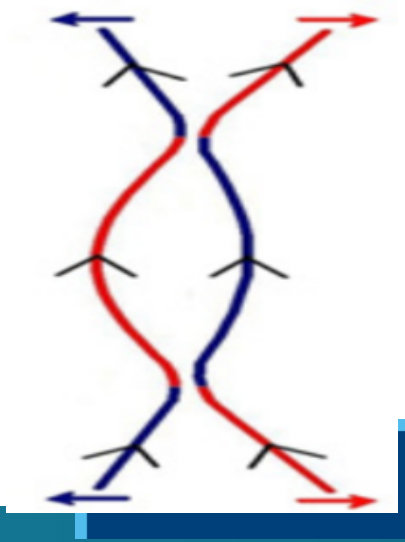
Nonetheless plasma boundary layer gets thicker during northward IMF.

Several hypothesis

- Simultaneous northern and southern cusps reconnection
- KH instability in non-linear stage enhancing mixing (supported by in situ data from spacecrafts (Cluster, THEMIS, Geotail) (Hasegawa et al., Nature, 2004)
- Double reconnection at mid-latitude



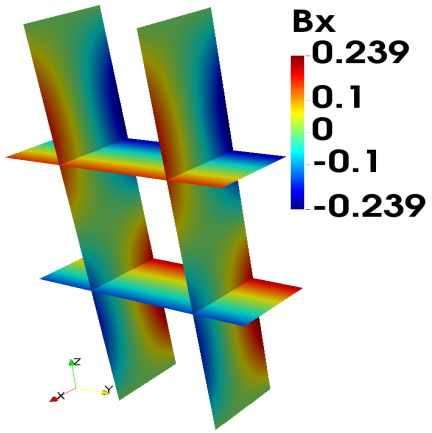


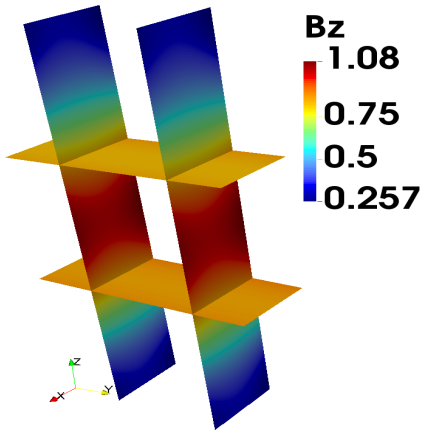


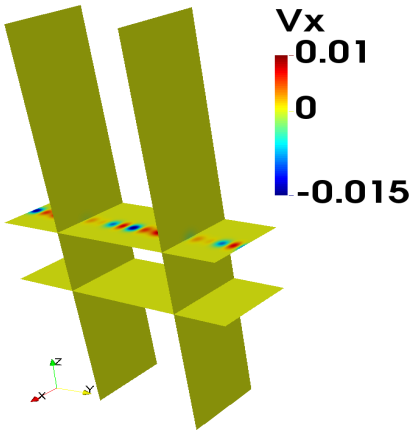
Initial and boundary conditions

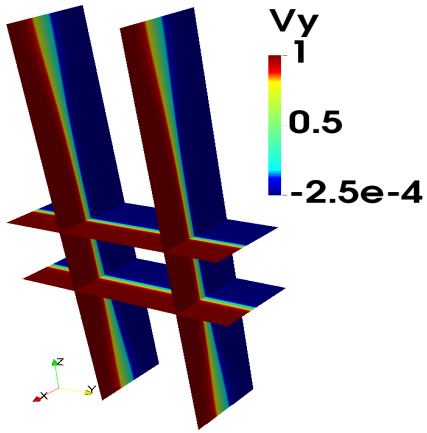
Initial setup by Faganello et al. extended here with larger domain and added features.

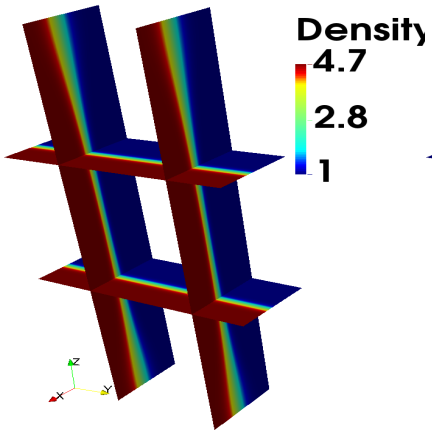
Solution of Grad-Shafranov : $A_y(x,z) = \frac{1}{2}\left(\frac{4x}{3} + \frac{L_x}{2\pi}\sinh\left(\frac{2\pi x}{L_z}\right)\cos\left(\frac{2\pi z}{L_z}\right)\right)$.

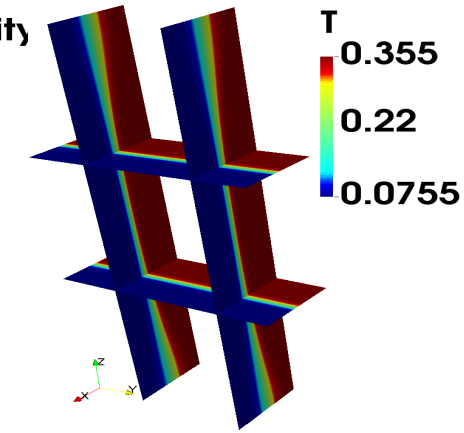












Initial parameters

$L_x = 70, L_y = 188, L_z = 377, \quad N^3 = 200^3$.
Domain large enough for two pairs of KH vortices.
y- and z-directions periodic, x-direction continuous extrapolation.

High-latitude conditions relaxed = less KHI unstable.

Alfvén Mach number M_A=1, sonic Mach number M_c=1, $\beta = 0.7$, $L_u = 3$, $\eta = 1e^{-3}/1e^{-5}$.

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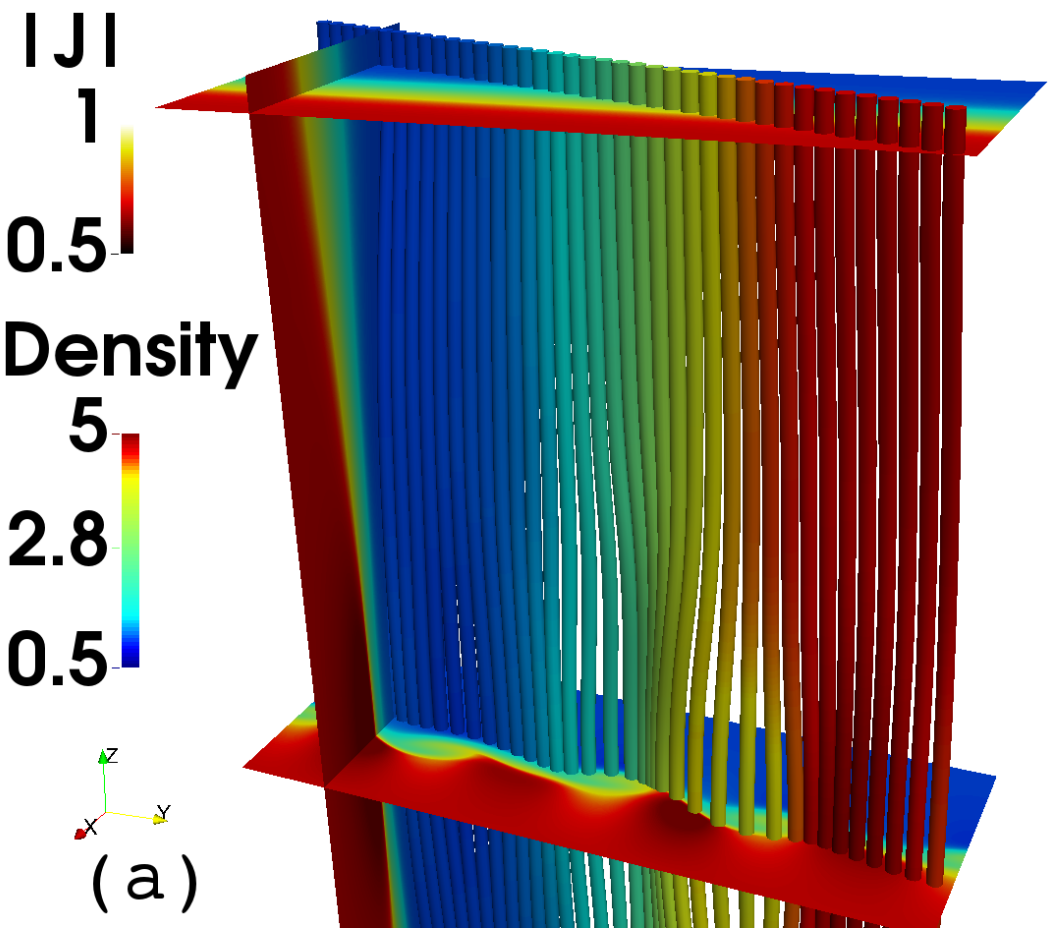
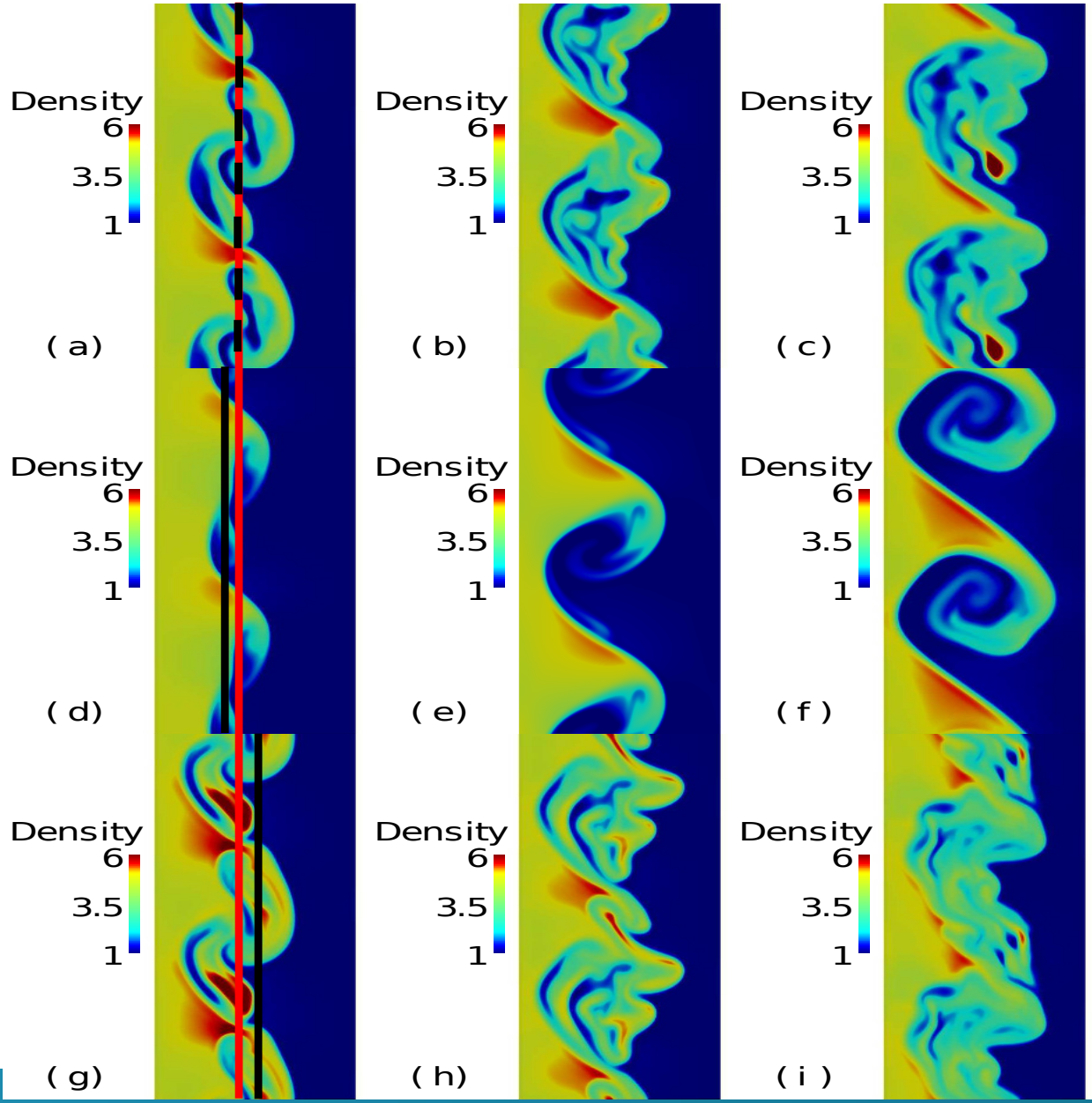
Reproduction of Faganello et al.

Reference run with extended domain and simulation time (with regards to original Faganello et al. simulation) using MPI-AMRVAC.



Parameters exploration : Shear layers shift



Transition layers are seldom aligned.

Time increase to the right Top to bottom :

shiftn=0,+3,-3.

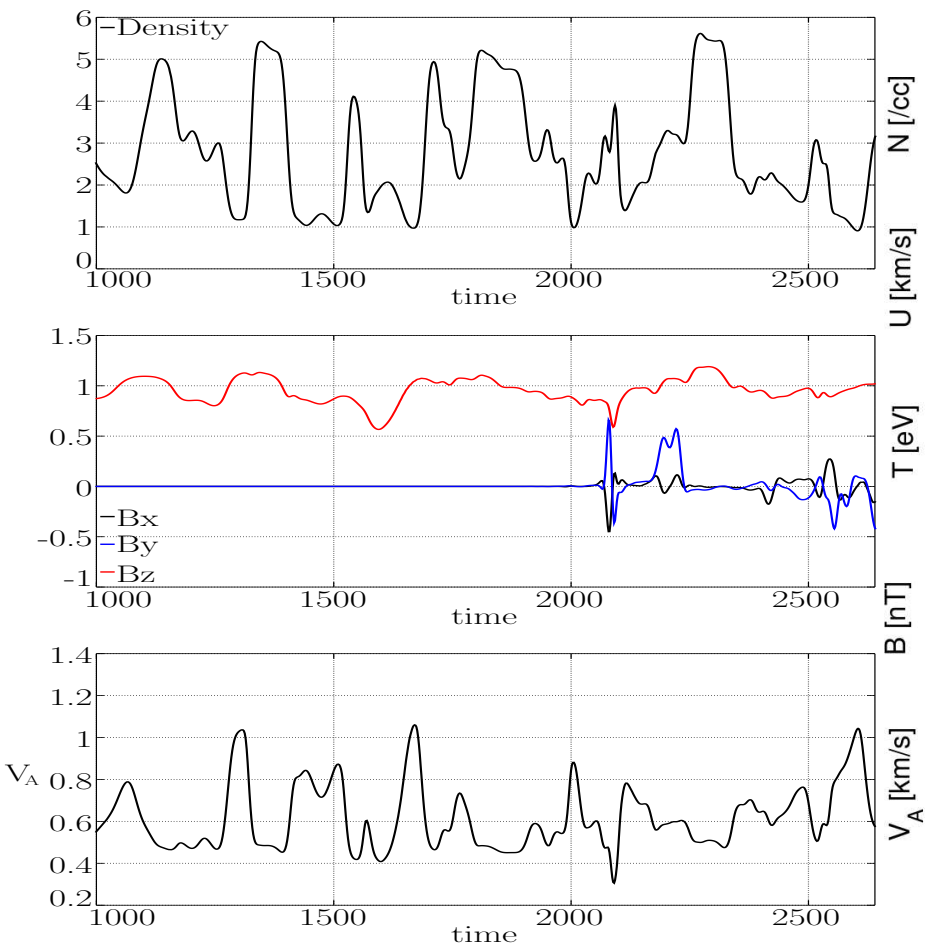
shiftn=3, more inside MS. KHI develops as if no density contrast.

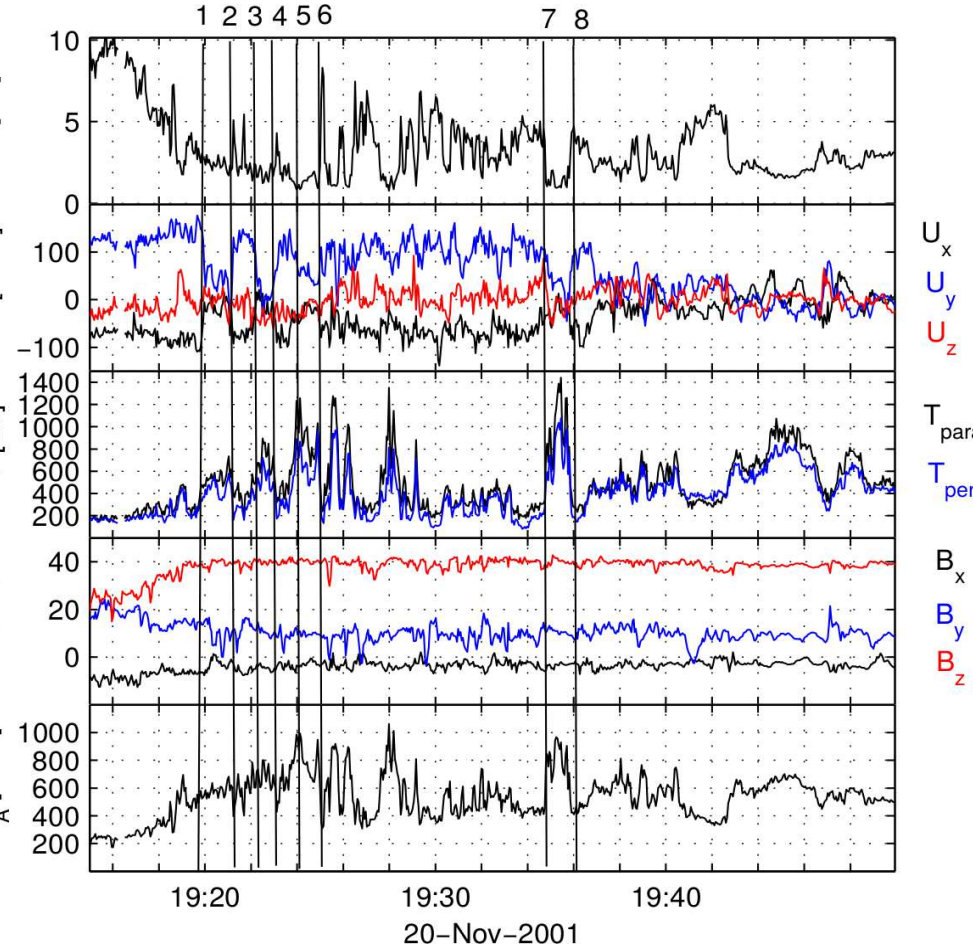
shiftn=-3 same structure than shiftn=0. Mixing enhanced = larger boundary layer.

Significant difference can be noted only when the shift is equal or larger than L_u.

Simulated spacecrafts

KHI on equatorial plane not incompatible with DMLR.

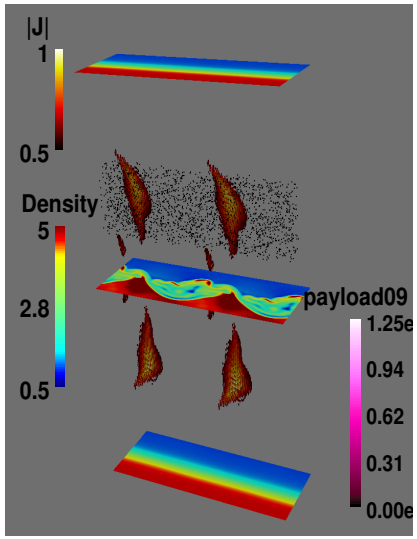


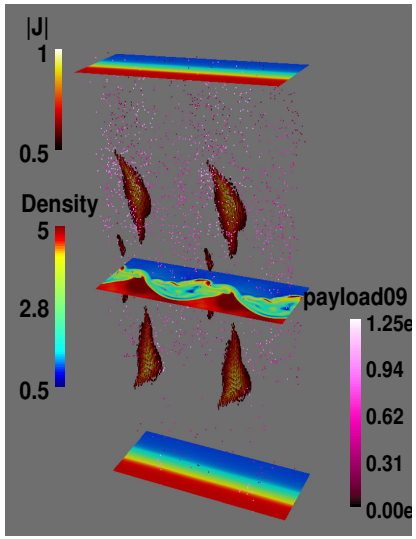


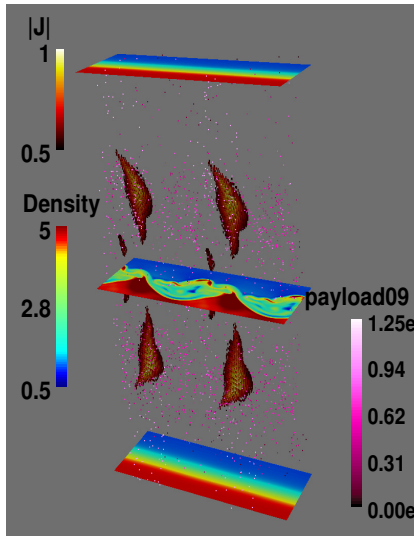
But need high/mid latitude data to differentiate between 'simple' KHI and DMLR.

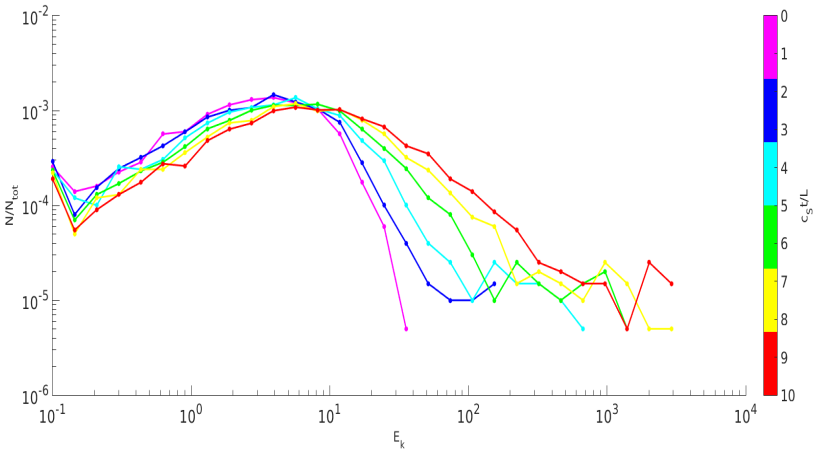
Particles populations

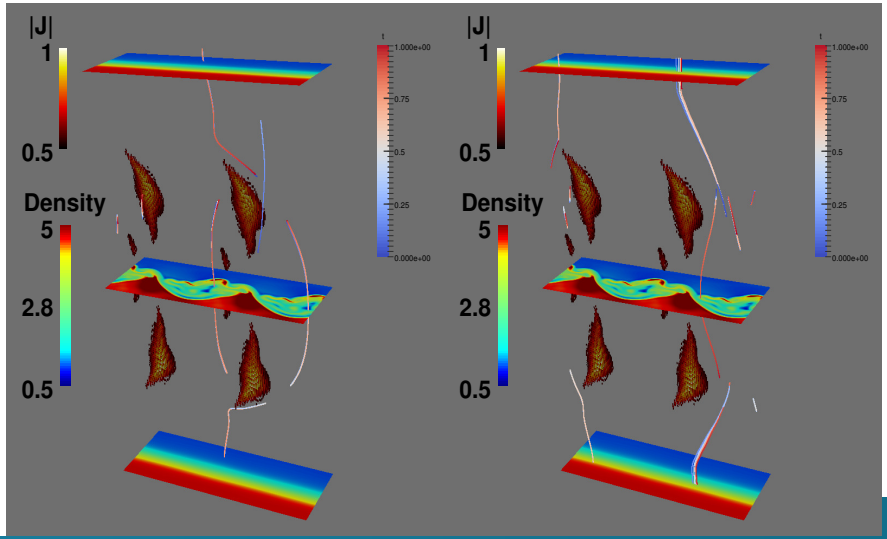
Most of the particles accelerated along fields lines and trapped in 1 of 3 regions.











Conclusion

- Shear layer width and relative position
  $\rightarrow$ different KHI evolution (dawn/dusk asymmetry ?)
- Full study in PoP 24 (M.H.J. Leroy, R. Keppens).
- Q-maps / characterization of reconnection / Evaluation of mass exchange.
- Improve simulation of spacecrafts (trajectories, initial fields) / Particle populations in narrower areas.

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Thank you for your attention.

open-source MPI-AMRVAC :

`gitlab.com/mpi-amrvac/amrvac`

personal website :

`matthieu-leroy.com`

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