North-South asymmetric Kelvin-Helmholtz instability & induced reconnection at the flanks of Earth's magnetopause

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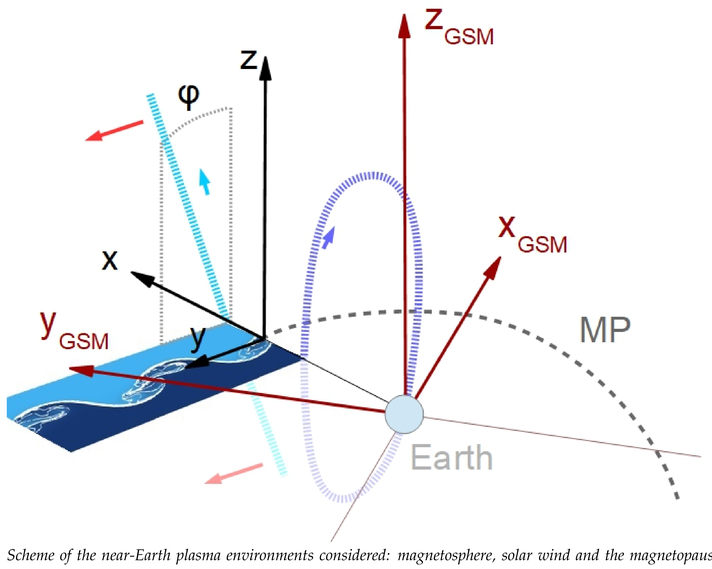
Introduction:

- SW-MS velocity shear leads to excitation of large, ideal **KH** phenomena at the MP, differing in intensity and location according to the MP geometry and outer magnetic field orientation:

Farrugia 1998

- while ideal MHD instabilities do not cause material transfer directly, yet they can provoke it through the excitation of secondary processes - in particular, **MR** is found both inside the instability (*Vortex-Induced-Reconnections*) and away from the most unstable region (*Mid-Latitude-Reconnection*):

Nakamura 2006, Faganello 2012

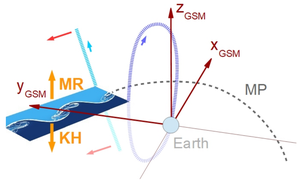


Scheme of the near-Earth plasma environments considered: magnetosphere, solar wind and the magnetopause in between (label: MP). One magnetic field line for the Earth's and one for the interplanetary magnetic field (quasi-northward configuration) have been drawn.

Summary of findings:

KH shifts away from the most unstable zones of the initial equilibrium (nonlinear effect!)

MR interpretable as VIR and MLR combined (cross-latitude extension!)

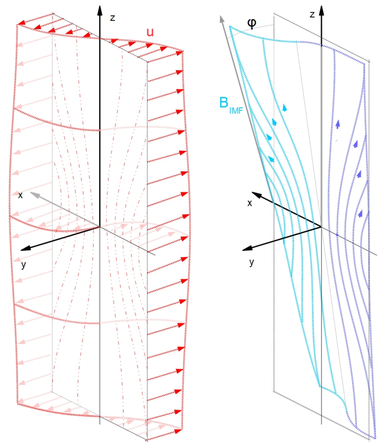


Perspectives:

- more realistic simulations (finer plasma model, more)
- confront with spacecraft data
- evaluation of mass and momentum transports
- thorough study of clock angle - tilt angle effects

Our approach:

Hall-MHD simulations of the flank MP (latitude-elongated sliding box) allow a **cross-latitude study** of **KH** and **MR**.



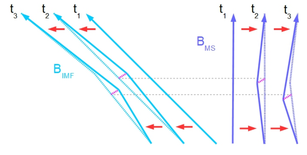
Scheme of the initial equilibrium for the fluid velocity (left) and magnetic field (right) configurations. The simulation's reference frame is aligned as reported in the leftmost picture.

- intial MHD equilibrium: we focus on the sole KH (no relaxation interferes with it)
- Latitude modulation of this configuration's instability under KH: quasi-realistic 3D dynamic

Faganello 2012

NB: a scalar quantity (*passive tracer*) initialised with peculiar values in the simulation box follows the motions of the fluid, allowing us to recognise MS and SW at each instant in time

Formation of latitude dependency in the overall magnetic shear:



Schematic representation of field-line evolution ($t_1 < t_2 < t_3$) in the MS (dark blue) and SW (light blue). The onsetting instability slows down the central portion of the material, thus bending all ideally advected field lines. The summation of this process to the initial magnetic shear leads to a latitude-asymmetric scenario ultimately influencing subsequent KH and MR developments.

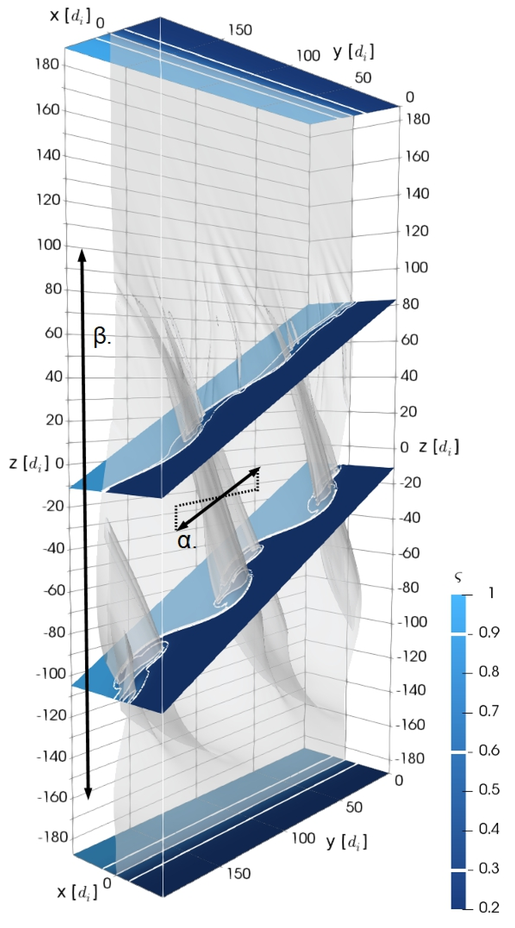
Kelvin-Helmholtz phenomena:

α . Tilt of unstable wave-modes, away from the horizontal flow plane

NakamuraDaughton 2014; Adamson 2016

β . Latitude sliding of unstable band, away from latitudes of initial maximum vorticity zone (around $z = 0$): the formation of a latitude dependency in the overall magnetic shear leads to an asymmetric development of the KH, enjanced in less sheared regions.

NEW!



Snapshot of the simulation box at $t = 460$, presenting fully nonlinear KH vortices in advanced pairing.

Magnetic reconnection processes:

Cross-latitude distribution of MR events, both:

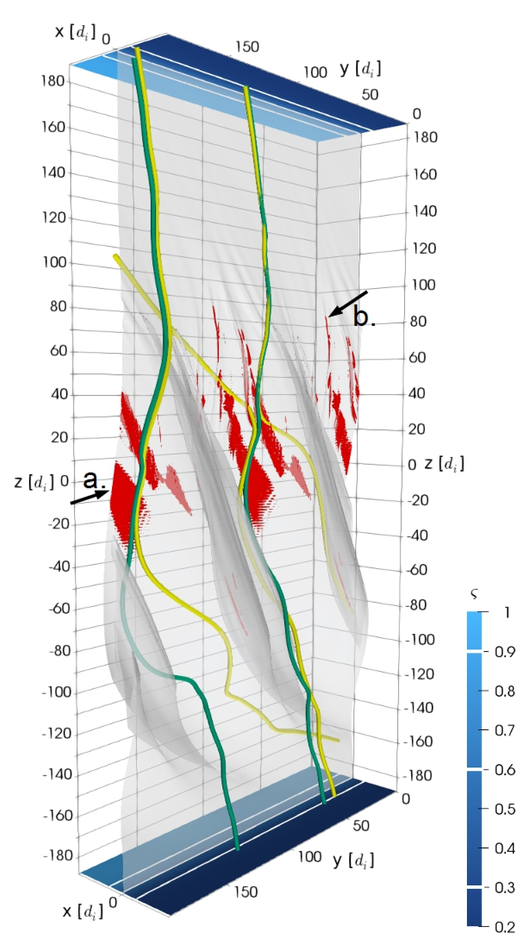
a. at hyperbolic point of principal KH (interpretable as VIR when inside the vortices and MLR when above KH!)

b. inside small secondary structures

The latitude-asymmetric MR pattern follows from the development of latitude-dependent shear, as enhanced shear enhances MR - and vice-versa.

This scenario is compatible with the findings of

Vernisse 2016



Snapshot of the simulation box at $t = 460$, with some unreconnected (green) and reconnected (yellow) lines highlighted. The red regions defined by ion-electron decoupling, are where we expect MR to occur.

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