Splinter #3 - Transient Processes at Earth's Magnetopause

Chairs/Organizers: Rungployphan (Om) Kieokaew, Kyoung-Joo Hwang
Co-conveners: Julia Stawarz, Benoit Lavraud, Vincent Génot

Summaries & Outbriefs

Purposes: to highlight new results and discuss key outstanding questions that we may answer with MMS and possibly in coordination with other missions

Rungployphan (Om) Kieokaew
Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse, France

Induced secondary instabilities at the edges of the KH-waves and at the vortex arms during southward IMF

Kevin Alexander Blasl, Takuma Nakamura

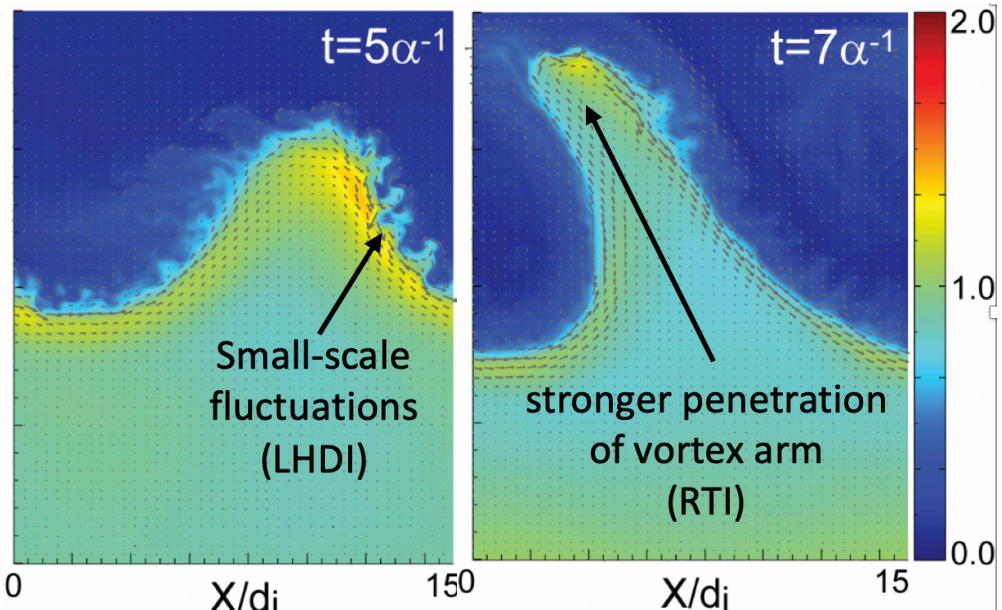
- Magnetopause crossings by MMS along duskside flank MP during southward IMF conditions
- KHI in both linear and nonlinear stages with some vortices
- Reproduced using 3D fully kinetic PIC simulations with large density and B_Z gradient
  - Rayleigh-Taylor Instability (RTI) leading to strong penetration of vortex arm
  - Small-scale Lower-Hybrid Drift Instability (LHDI) fluctuations (visible signatures in E fields with MMS)
  - RTI & LHDI lead to a quick decay of the vortex, plausible lead to rare detection

Questions

Q: What are roles of LHDI? Does it impact ion heating, etc?

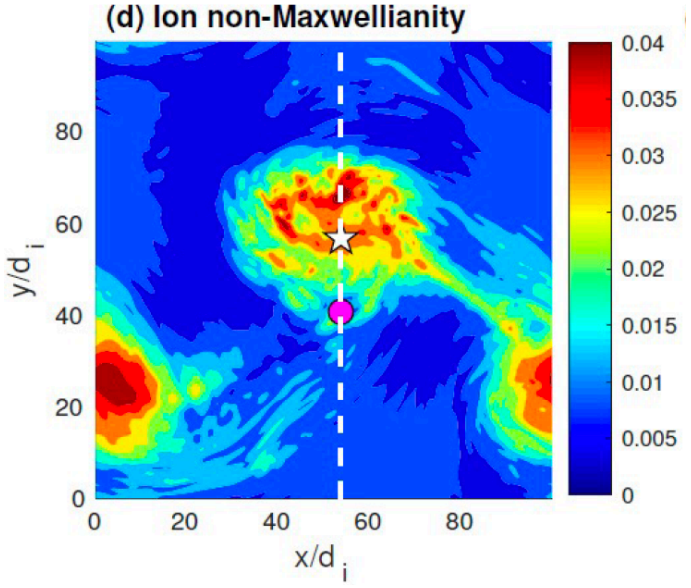
A: impacting KH signatures but unclear kinetic impacts

Q: What is the orientation of the IMF in the simulation?



Kinetic features in the Kelvin-Helmholtz instability

Adriana Settino et al.



- Hybrid simulation of the KHI
- Kinetic features of non-linear KH waves
  - Non-Maxwellianity of ions [Greco et al. 2012]
    - peaks inside KH vortices (with J peaks at vortex edges)
  - Ion Agyrotropy [Swisdak et al. 2016]
- Confirmed with MMS [Settino et al. ApJ, 2021] in a nonlinear KH event (5 May 2017, dawnside)
- Applicable to single spacecraft measurements (high resolution particle data; SolO)

Questions

Q: Did you see any temperature anisotropy developed by the KHI?

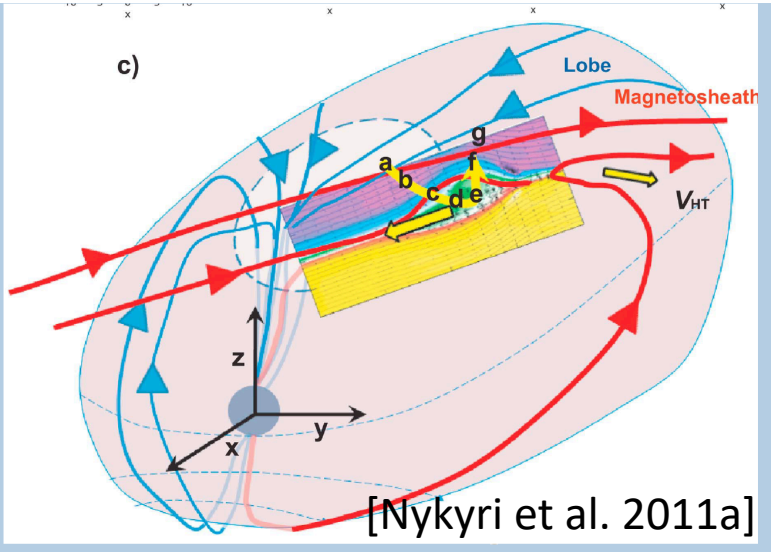
A: Yes – high Tpar inside the vortex, high anisotropy at the boundary, high Tperp outside the vortex.

Diamagnetic Cavities - High-Latitude, Dayside Source of Energetic Particles in the Earth's Magnetosphere

Katariina Nykyri

[proposal for senior review]

- Potentially significant source for magnetospheric plasma and energetic particles
- Formed by reconnection near cusps, B depression signatures, trapped particles
  - Important roles in particle acceleration
- MMS can reach high-latitudes when the dipole tilt is large!



[Nykyri et al. 2011a]

Open questions: Interaction between KH waves, mirror-mode waves, and diamagnetic cavities at high-latitudes?

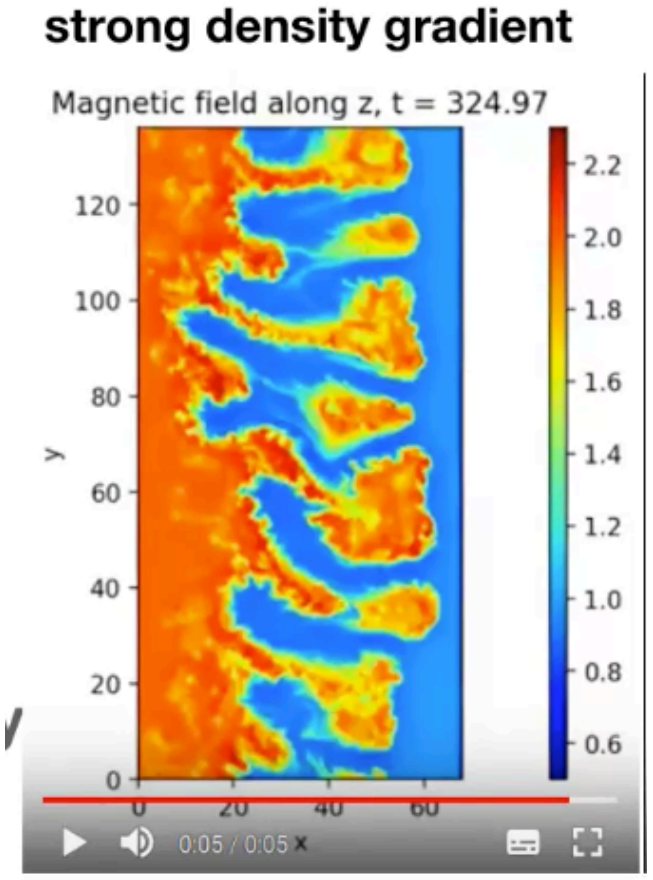
Question

Q: Roles of reconnection in particle energization up to several 100s keV?

A: Electrostatic potential, particle-wave interactions near reconnection X-line

Discussion and short presentations

Impacts of Lower-Hybrid Drift Instability (LHDI) on a growth of the KHI for a strong density gradient across the shear layer (i.e., at Mercury) by Federico Lavorenti.

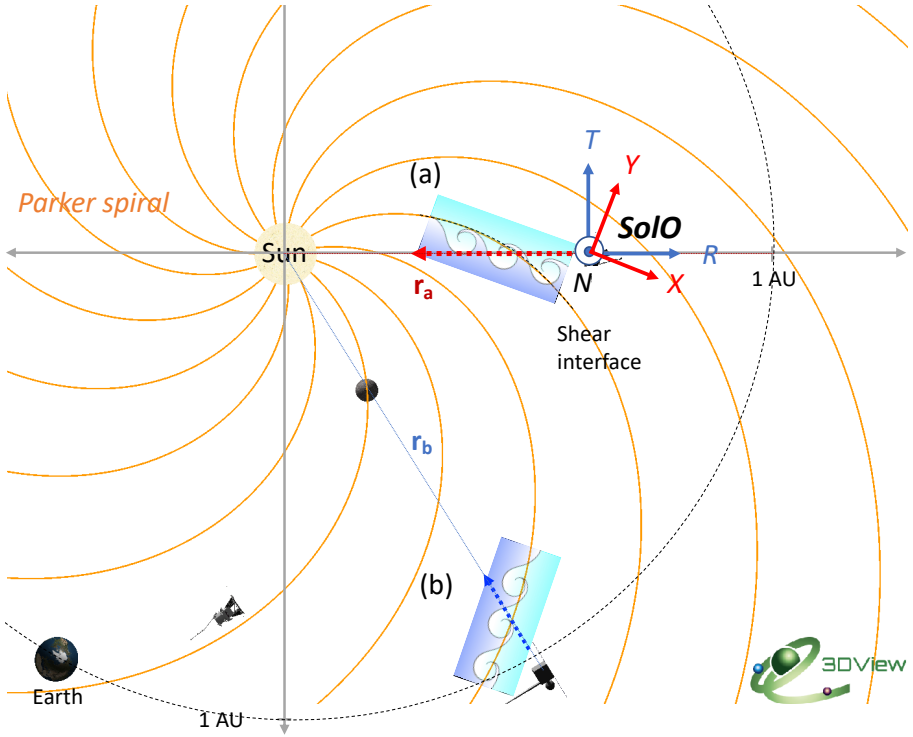


Dargent et al. (2019) PoP

Solar Orbiter observations of the KHI in the solar wind with implications in driving of solar wind fluctuations by Rungployphan Kieokaew.

* Lessons learned from MMS can be carried forward

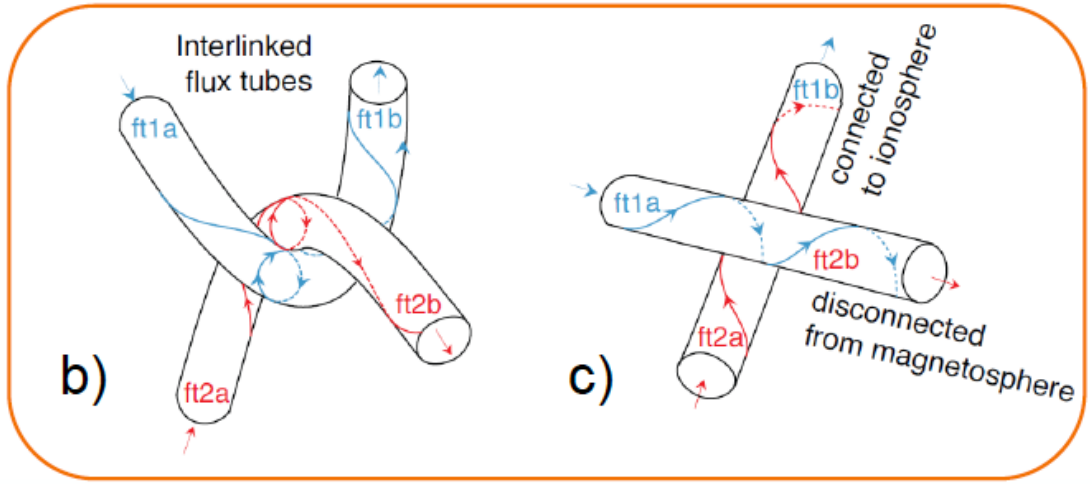
Kieokaew et al. (submitted) arXiv



Flux rope interactions in the magnetosphere and beyond Yi Qi et al.

- Flux tube entanglement (interlinked flux tubes; IFTs) in magnetosphere and solar corona (i.e., important roles in flares, X-ray bright points)
- With MMS, temporal evolution of flux tube entanglement is characterized into early, mid, and late stages (Qi et al. 2020).
- Hall MHD simulations confirm that reconnection can occur between IFTs (Jia, Qi, et al. 2021) => this then allow reconnected flux tubes to evolve into untangled flux ropes

  + Future collaboration with solar observation team



Question:

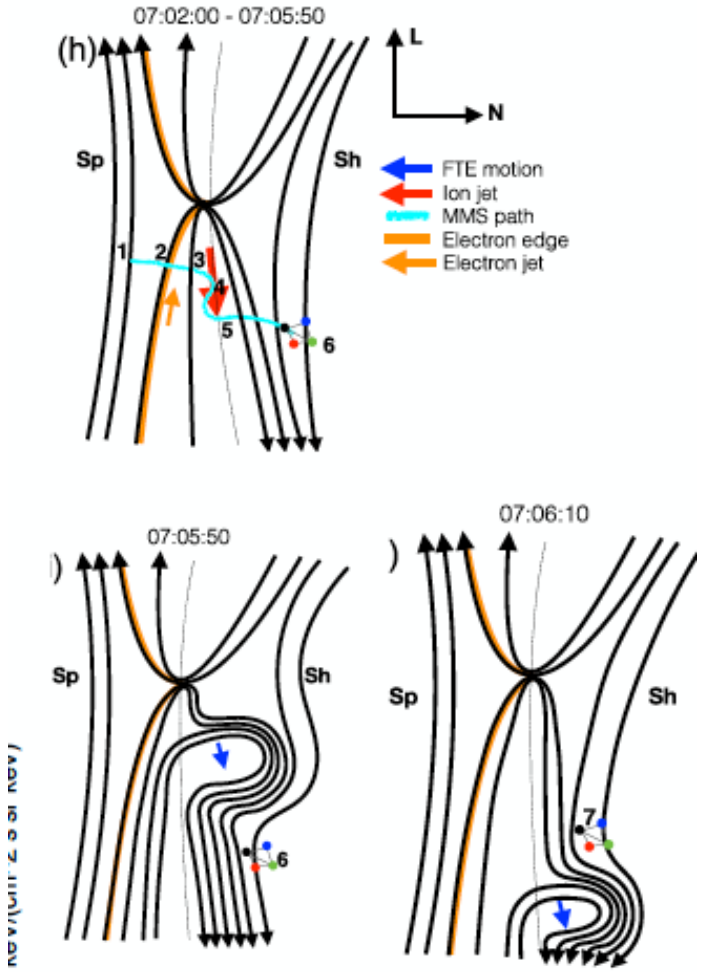
Q: Electron or ion acceleration, jet formation observed during the events?

A: Yes, there's an ion acceleration.

+ Similar events observed in the solar wind!

Flux transfer event with an electron-scale substructure observed by the MMS Marcos Silveira

- MMS observations of an outbound magnetopause crossing with magnetic reconnection
- A very small FTE (~4 ion gyroradii) is observed near the reconnection, likely generated by an intensification of reconnection at a preexisting X-line, which became bursty.
- The region is not large enough to affect the ion behavior but it does for electrons. The FTE's core is an electron-scale structure.



Questions

Q: Did you focus only on kinetic scale flux ropes? A: No

Q: Can you explain electron-scale structures within the FTE? A: It's visible in E_N

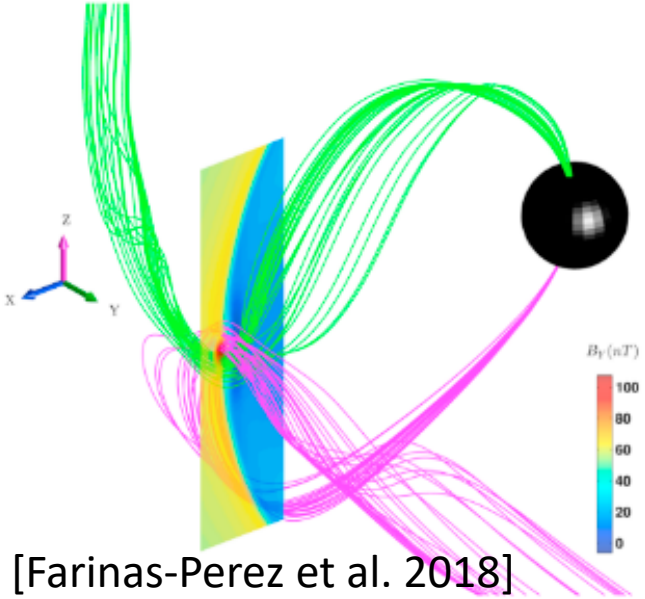
Q: Is the E_N variaion consistent with V_E because this may be consistent with electron vortices? A: It's unclear whether it's bipolar or unipolar.

Q: Do the sketch field lines (?) on Slide 5 indicate that FTEs are open (not closed flux ropes) structures? A: Yes, based on particle signatures.

Overview and recent advances in flux rope and flux tube studies in magnetospheric environments

Rungployphan Kieokaew

- Overview of FTE flux ropes and generation mechanisms
- Recent discovery of reconnection within FTEs indicating a different structure called “Interlinked Flux Tubes (IFTs)”
- Proposed formation mechanisms (open issue)
  - Patchy reconnection
  - Strong guide-field reconnection
  - Global configuration of dayside reconnection
- Relation between IFTs and FTEs (open issue)
  - Flux tube entanglement (i.e., Qi et al. 2021)
- Space weather impacts of IFTs (future work)



[Farinas-Perez et al. 2018]

Recent research complied by Kyoung-Joo Hwang

Recent findings from MMS observations

1) Ion-scale secondary flux ropes generated by dayside reconnection [Eastwood+, 2016; Dong+ 2017; Teh+, 2017; Hwang+, 2018a]
2) Multi-layered substructures/temporal evolution of an FTE [Hwang+, 2016; Russell+, 2017; Teh+, 2017; Akhavan-Tafti+, 2018; 2019a, b; Silveria+, 2020]
3) Electron- or ion-scale current layers at the interface of two coalescing FTEs [Zhou+, 2017; Wang+, 2017; Alm+, 2018]
4) Reconnection between colliding reconnection jets in a compressed current sheet at the center of an FTE [Øieroset+, 2017]
5) Reconnecting current sheet between interlinked flux tubes [Kacem+, 2018; Øieroset+, 2019; Fargette+, 2020; Russell&Qi, 2020; Qi+, 2020; Jia+, 2021]
6) The formation of an FTE driven by the electron vortex [Zhong+, 2017]
7) The formation of an (interlinked) flux rope via KH vortex-induced reconnection [Nakamura+, 2017; Kieokaew+, 2020; Hwang+, 2020]
8) IMF By effect on the helicity of FTEs [Kieokaew+, 2021]

+ Discussion on recent work about dayside reconnection under strong IMF Bx conditions
+ More explanation of particle energization by diamagnetic cavities

Summary

- **Recent advances in transient processes at the Earth's magnetopause**
- Great participations of recent research by early career researchers
- Highlight work on how MMS can address plasma phenomena (i.e., diamagnetic cavities) near the cusps that are potential sources of energetic particles in the magnetosphere [proposal to senior review]
- **New, exciting sciences as allowed by MMS**
  - Signatures of secondary instabilities (LHDI) at the KH edges with E field measurements
  - Kinetic signatures of the KHI thanks to high-resolution particle measurments
  - Reconnection and kinetic signatures leading to a better understanding of flux rope and flux tube studies
- More exciting research to come!