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

Kevin Alexander Blasl[1,2], Takuma Nakamura[1,2]

[1]University of Graz, Institute of Physics

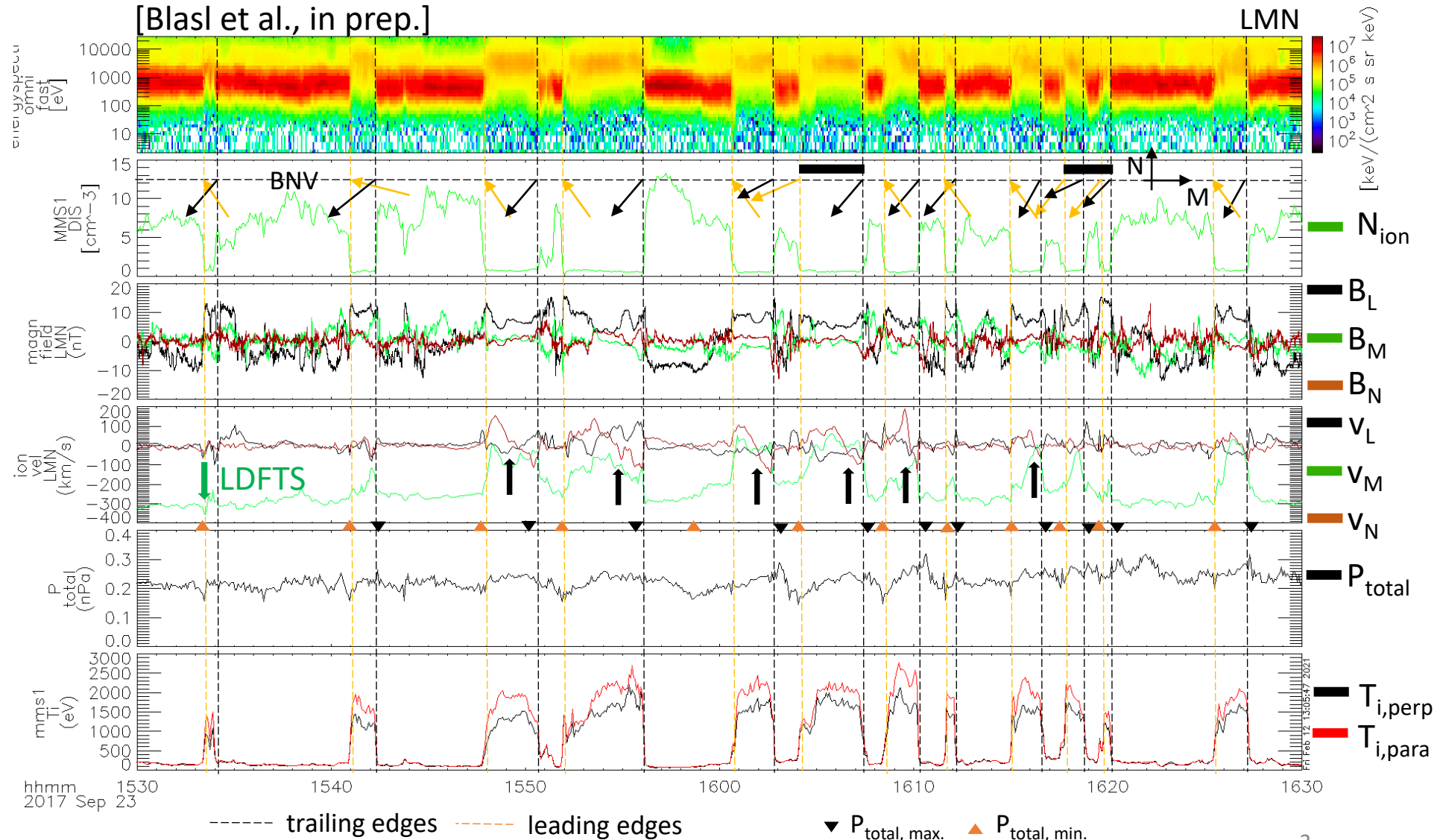[2]Space Research Institute Graz, Austrian Academy of Sciences

Collaborators: Daniel Schmid, Ferdinand Plaschke, Julia Stawarz, Martin Hosner, Martin Volwerk, Rumi Nakamura

- **Magnetopause crossings** observed by MMS on September 23, 2017 along **duskside flanks during southward IMF**
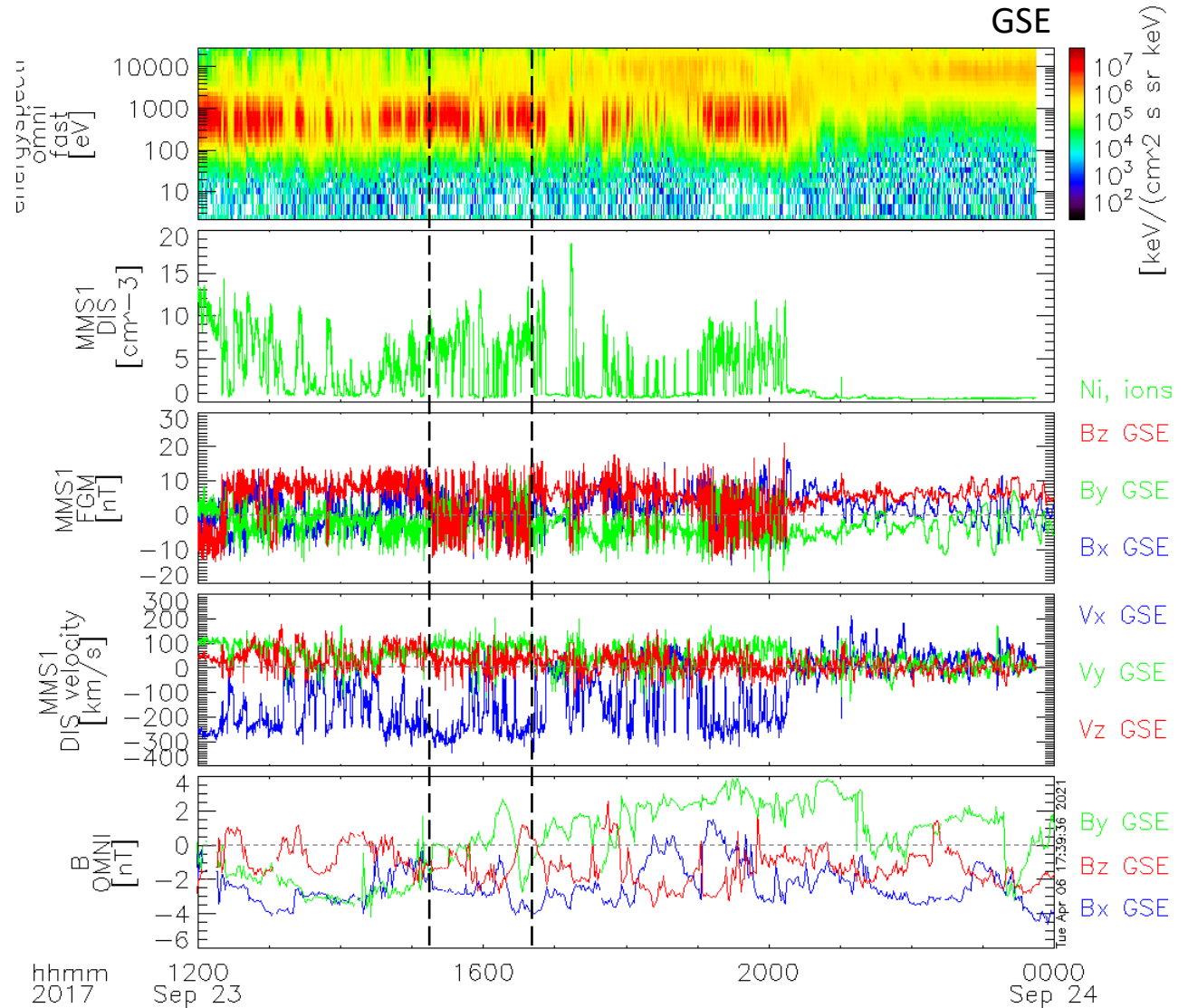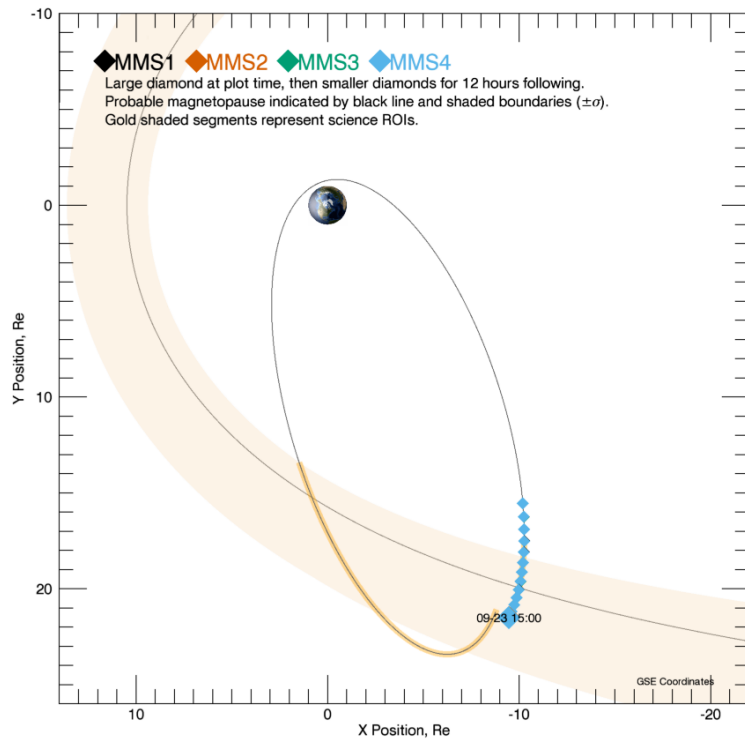
- **Boundary normal vectors** indicating linear & nonlinear ▬▬▬ waves → **coexistence** of linear & nonlinear stage waves?

- v_N indicates wave structures in magnetospheric intervals

- **Maxima** of P_{total} near trailing edges
- **Minima** of P_{total} near leading edges/centres

- **Instability criterion fulfilled** → vortex evolution possible

[Blasl et al., in prep.]

LMN

N_{ion}
B_L
B_M
B_N
v_L
v_M
v_N
P_{total}
$T_{i,perp}$
$T_{i,para}$

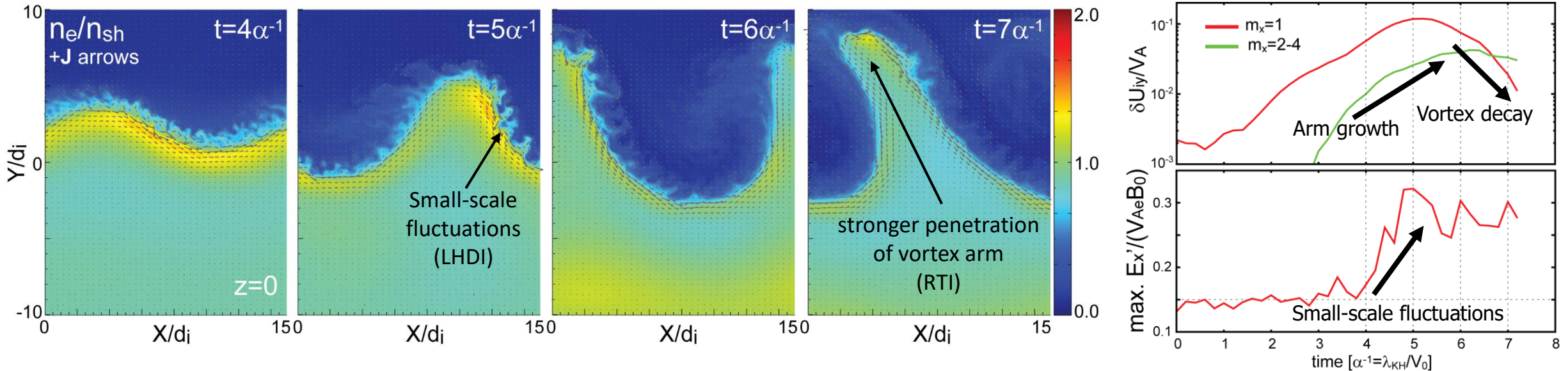- - - - trailing edges   - - - - leading edges   ▼ $P_{total, max.}$ ▲ $P_{total, min.}$

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3D fully kinetic PIC simulation

Signatures for secondary instabilities

Large density and magnetic (B_z) gradient

3D fully kinetic PIC simulation

- Differences to low-density northward IMF event:
  - **Rayleigh-Taylor Instability (RTI):** Stronger penetration of high-density arm into low-density region leading to quicker vortex decay
  - **Lower-Hybrid Drift Instability (LHDI):** Small-scale fluctuations along vortex edge, flattening the edge layer and diffusing, e.g., peaks in the total pressure or ion density

Unique to southward IMF case:

Enhanced RTI and LHDI by the additional current flow in x-direction, produced by the current between the northward and southward magnetic field across the layer

MMS data

Wave power analysis
Power Spectral Density analysis

High resolution of MMS: search for LHDI signatures

- Electric field in field-aligned coordinates
  → **x, y**: perpendicular / **z**: parallel

- Characteristic features:
  - $\delta E_{perp} > \delta E_{para}$
    → on low-density side of wave edges

  - $\nabla P_{el.} \neq 0$ near density gradients
    Electron pressure gradient associated with electron drift due to density gradient

  - Strongest wave power between
    $f_{ci\,(<1\,Hz)} < f_{waves} < f_{LHD}$

  - Wavepower (B) << Wavepower (E)
    → electrostatic character
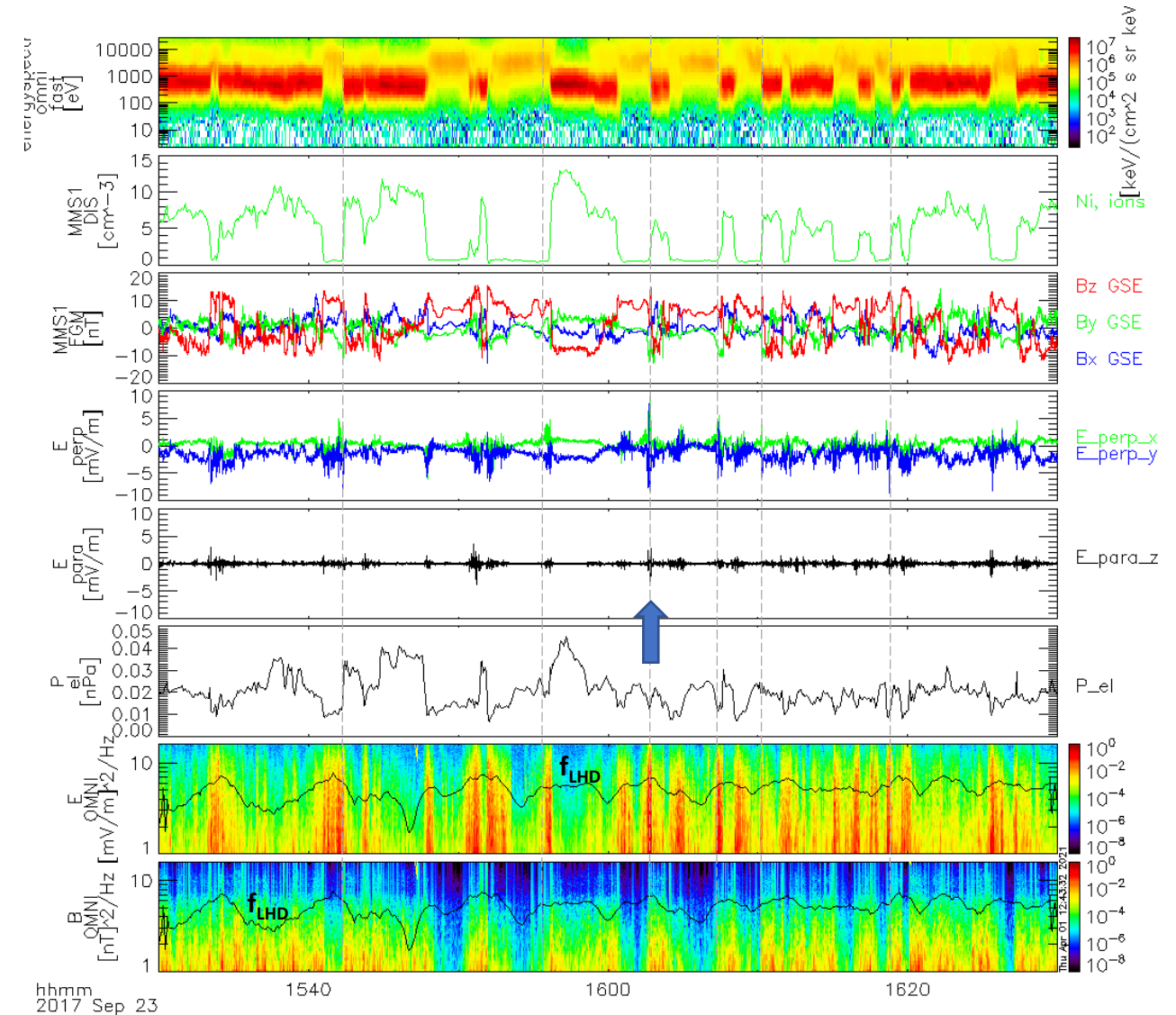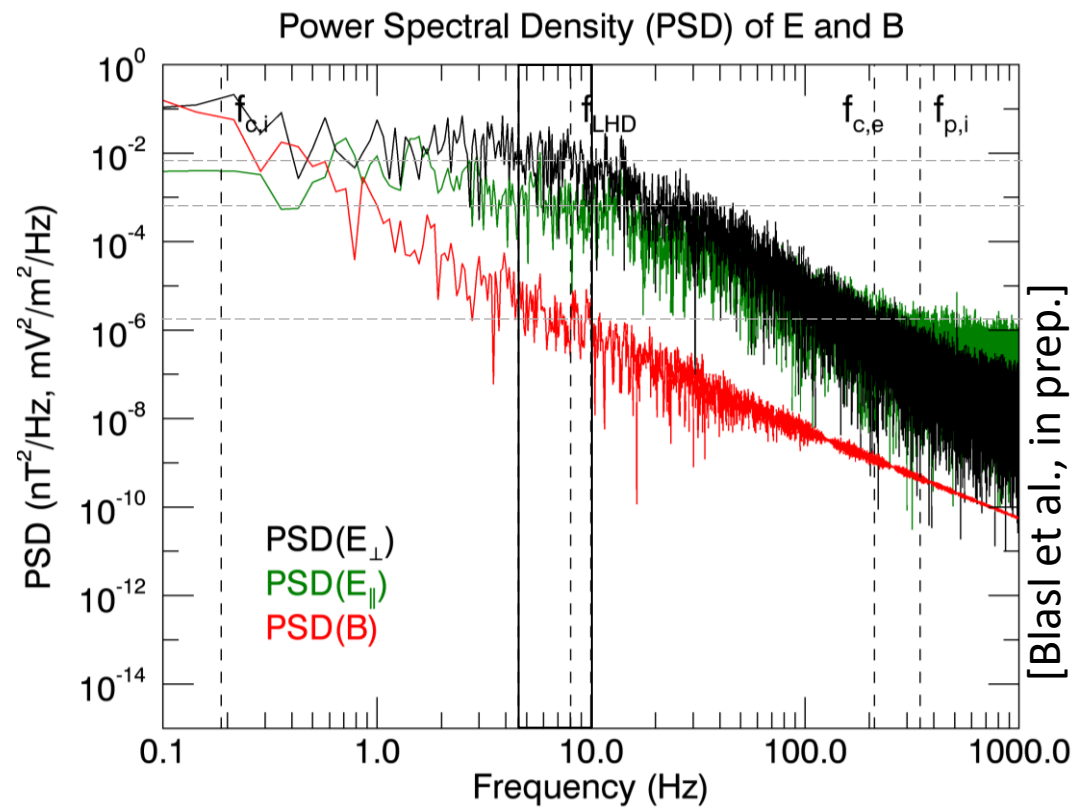
LHD wave analysis
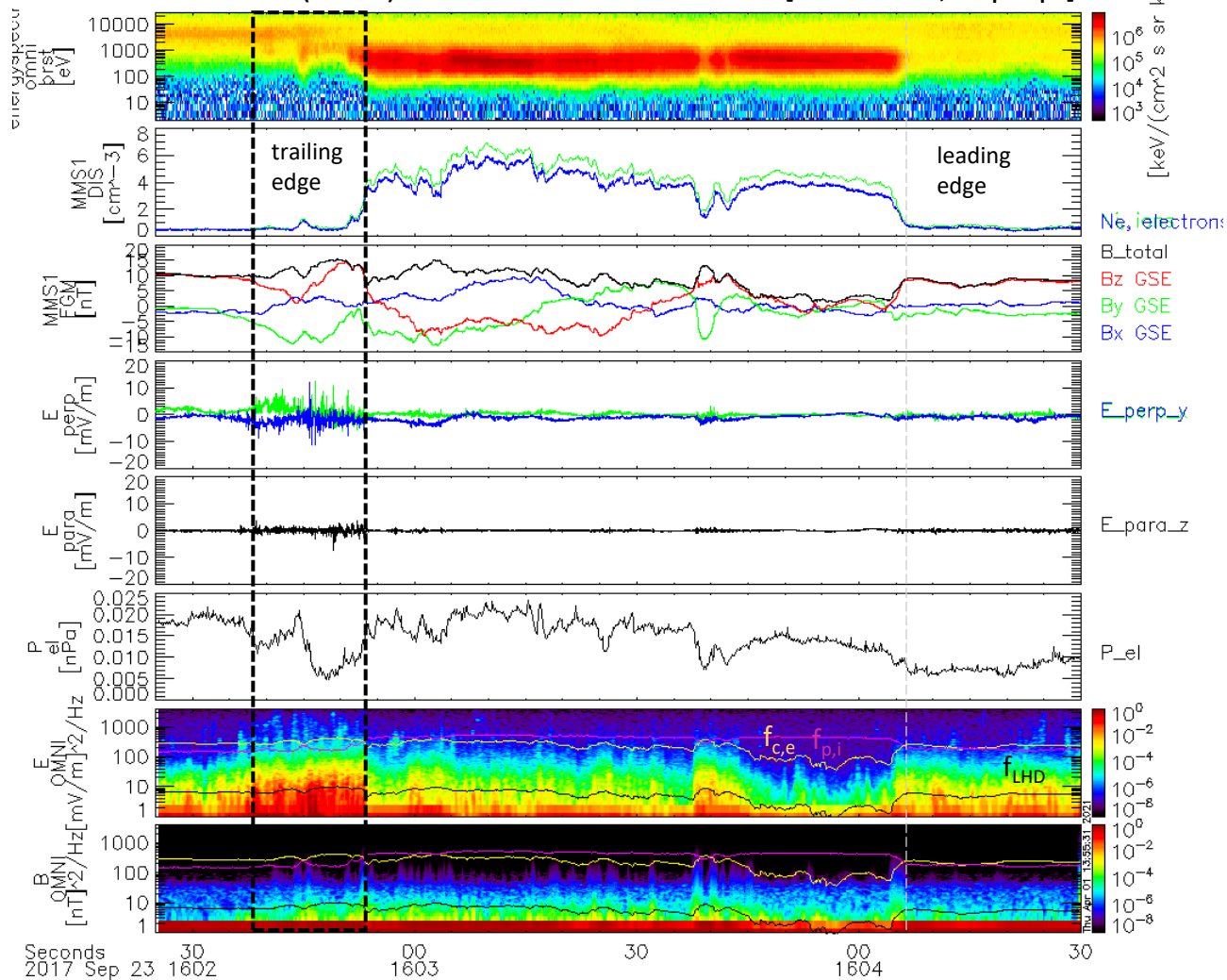
[Blasl et al., in prep.]

- $\delta E_{perp} > \delta E_{para}$ (mostly perp. waves on magnetospheric side)
- $\nabla P_{el.} \neq 0$ near density gradient
- Strongest wave power between $f_{ci\ (<\ 1Hz)} < f_{fluc.} < f_{LHD}$
- PSD(B) < PSD(E) : on order of 10^3 near f_{LHD} mainly el.static waves

Power Spectral Density (PSD) of E and B

PSD($E_\perp$)
PSD($E_\parallel$)
PSD(B)

[Blasl et al., in prep.]

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- <u>Simulation results:</u>

  - **Secondary RTI and LHDI** are induced at the density gradient layer located along the vortex edge, leading to a quick decay of the vortex [Nakamura et al., in prep.]. The LHDI also flattens the edge layer and diffuses, e.g., peaks in the total pressure or ion density

- <u>MMS event:</u>

  - Wave activity at $f_{c,i} < f_{fluc.} < f_{LHD}$
  - Fluctuations on **low-density side** of the boundary
  - Mainly **electrostatic** waves
    PSD(E) > PSD(B)
  - **Electron** pressure gradient
  - **Density** gradient
  - **Magnetic** field gradient
  - No high frequency or E_{para} bursts
  - $\delta E_{perp} > \delta E_{para}$

  } LHDI signatures

> → **Clear KH wave/vortex structures are expected to be observed only in a limited growth phase during southward IMF**
>
> → consistent with observations [Hwang et al., 2011; Kavosi & Raeder, 2015]

[Blasl et al., in prep.]

Thank you