MMS-CLUSTER JOINT MEASUREMENTS AT THE VICINITY OF THE PLASMA SHEET BOUNDARY LAYER

Laboratoire de Physique des Plasmas

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O. Le Contel (1), A. Retino (1), A. Alexandrova (1), T. Chust (1), K. Steinvall (2), S. Alqeeq (1), P. Canu (1), D. Fontaine (1), L. Mirioni (1), I. Dandouras (3), C. M. Carr (4), S. Toledo (5), A. Fazakerley (6), N. Doss (6), S. Kiehas (7), R. Nakamura (7), Yu. Khotyaintsev (2), F. D. Wilder (8), N. Ahmadi (8), D. J. Gershman (9), R. J. Strangeway (10), F. Plaschke (7), M. R. Argall (11), D. L. Turner (12), I. J. Cohen (13), J. L. Burch (14), R. B. Torbert (11), S. A. Fuselier (14), J. Mukherjee (14) , B. J Giles (9), R. E. Ergun (8), P.-A. Lindqvist (15), P. Escoubet (16)

(1) Laboratoire de Physique des Plasmas, Paris, France, (2) Swedish Institute of Space Physics, Uppsala, Sweden, (3) Institut de Recherche en Astrophysique et Planétologie, Toulouse, France, (4) Space Magnetometer Laboratory, Imperial College, London, UK, (5) Departamento Electromagnetismo and Electronica, Universidad de Murcia, Murcia, Spain (6) Mullard Space Science Laboratory, University College London, Dorking, UK, (7) Space Research Institute, Austrian Academy of Sciences, Graz, Austria, (8) Laboratory of Atmospheric and Space Physics, Colorado, USA, (9) NASA Goddard Space Flight Center, Greenbelt, MD, USA, (10) Institute of Geophysics and Planetary Physics, Los Angeles, USA, (11) Space Science Center and Department of Physics, University of New Hampshire, Durham, New Hampshire, USA, (12) Aerospace Corporation, El Segundo, California, USA, (13) The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA, (14) Southwest Research Institute, San Antonio, Texas, USA, (15) Space and Plasma Group, Royal Institute of Technology, Stockholm, Sweden, (16) ESTEC, European Space Agency, Keplerlaan 1, 2201 AZ, Noordwijk, The Netherlands

Email address:
olivier.lecontel@lpp.polytechnique.fr

Abstract

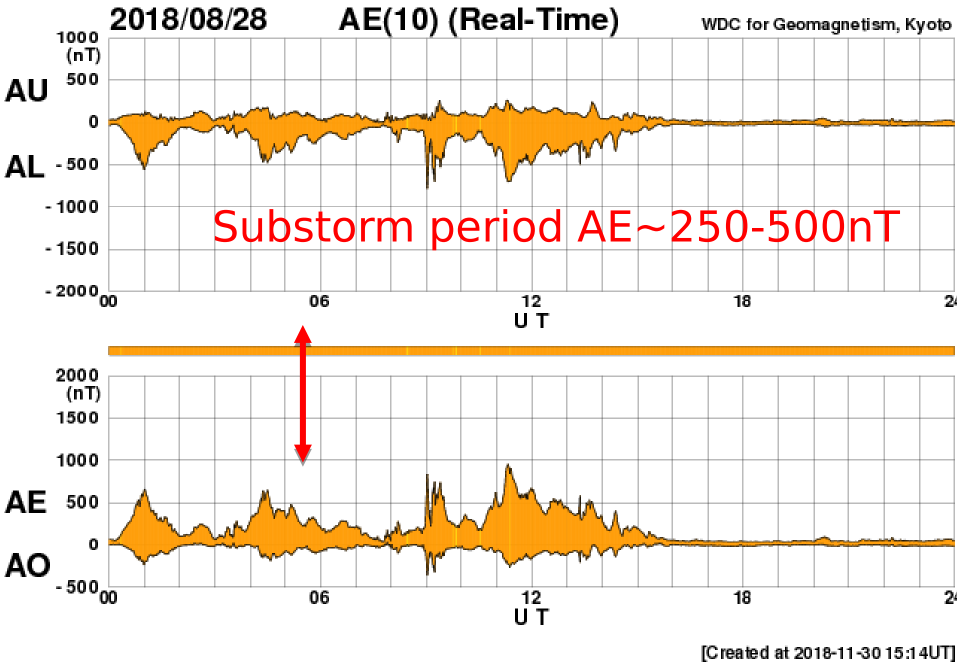
On 28th of August 2018 at 5:30 UT, MMS and Cluster were located in the magnetotail at about 16 earth radii (RE).

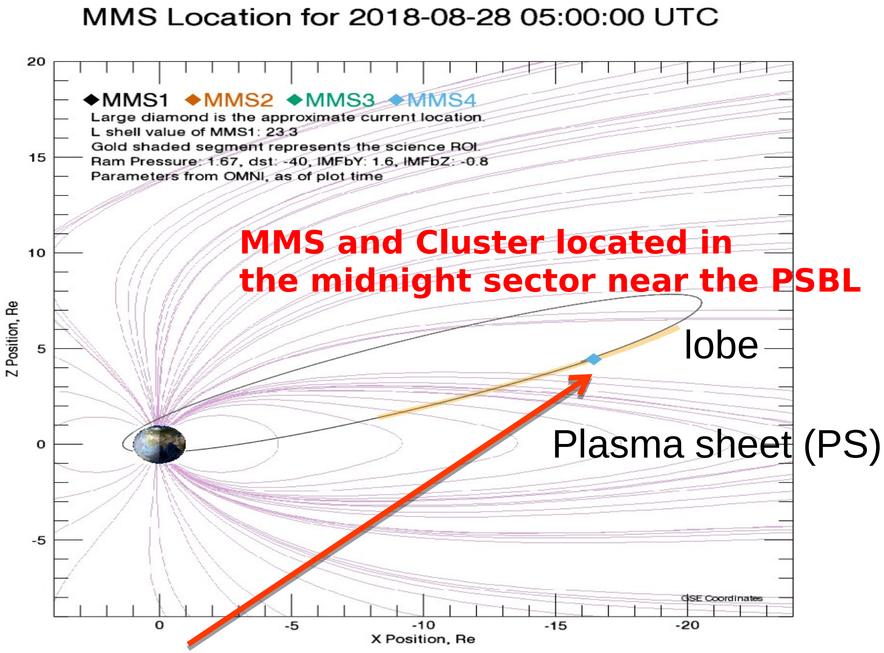
They both suddenly crossed plasma interfaces. Located in the post midnight sector, Cluster transitioned from a cold plasma sheet to a hot plasma sheet whereas MMS, located at 4 RE duskward of Cluster, transitioned from a similar cold plasma sheet to the lobe region via a very short period in a hot plasma sheet.

At 05:50 UT MMS returned to a hot plasma sheet and detected a quasi-parallel earthward flow ~ 400 km/s and increased energetic ion and electron fluxes.

We use measurements from both missions during this conjunction to describe the possible macroscale evolution of the magnetotail as well as some associated kinetic processes. In particular, we analyze fast and slow non linear electrostatic waves propagating tailward which are detected in the so called electron boundary layer as well as in the hot plasma sheet. We discuss their possible generation mechanisms and link with the large scale evolution of the magnetotail. Finally, we investigate possible effects related to the dawn-dusk asymmetry of the magnetotail.

PSBL crossings on August 28th , 2018 between 05:00-07:00 UT

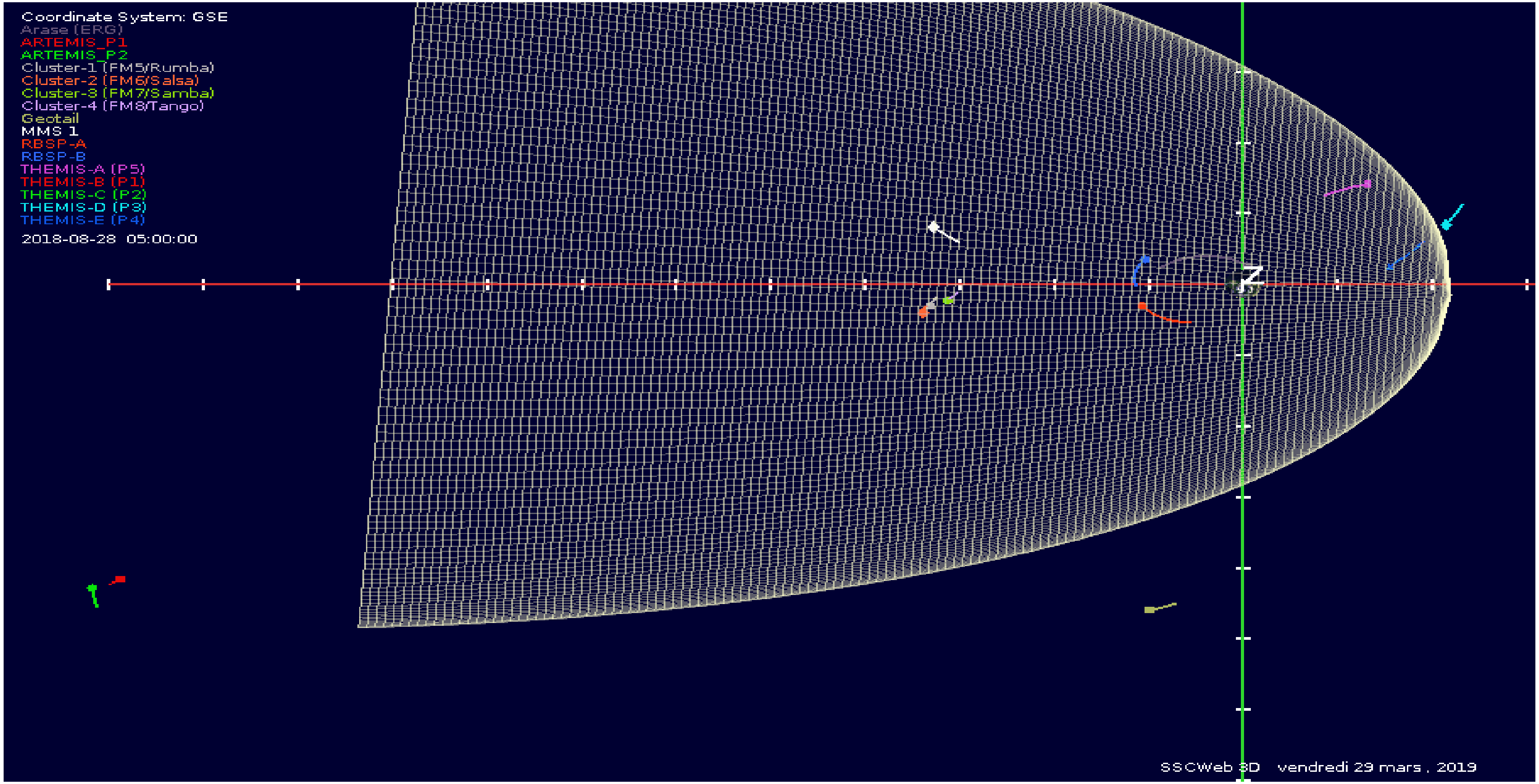




CLUSTER4 :	-15.639937 / -1.172352 / 1.854052
MMS1 :	-16.407545 / 4.041821 / 4.488390
CLUSTER1 :	-16.574538 / -1.558511 / 1.318380
CLUSTER2 :	-16.951822 / -2.015132 / 0.620120
CLUSTER3 :	-15.639673 / -1.172767 / 1.855925

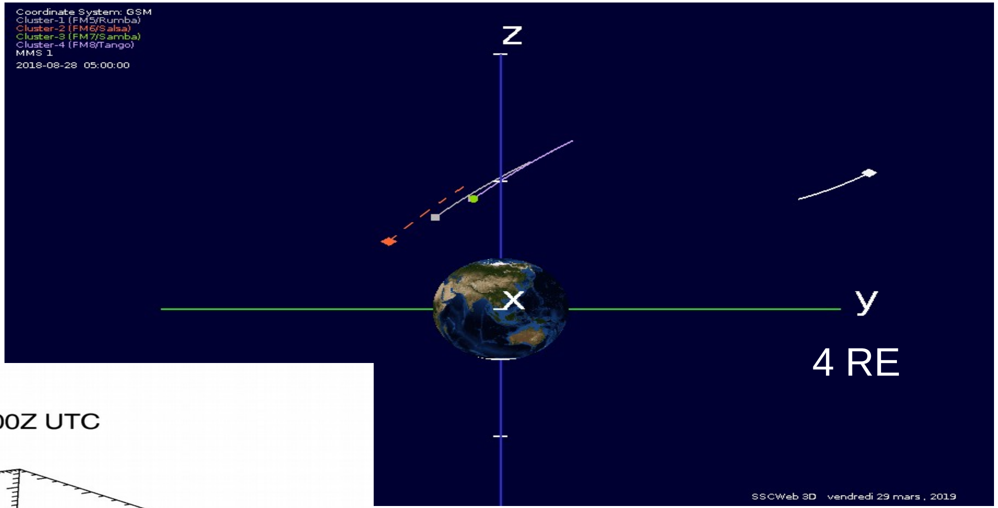
Magnetospheric Observatory on August 28th , 2018 5:00-07:00 UT

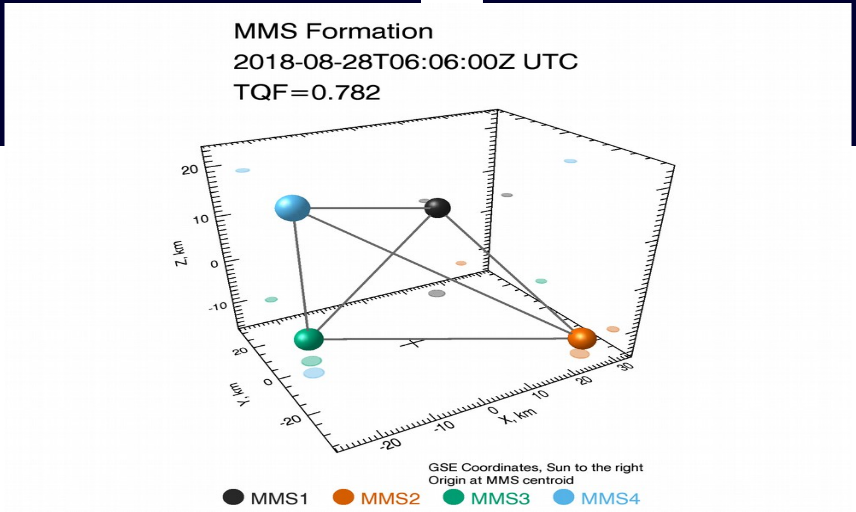
Tipsod tool (GSFC-NASA)



MMS/Cluster conjunction on August 28th , 2018 5:00-7:00 UT

Tipsod tool (GSFC-NASA)





Event overview (Cluster 4)

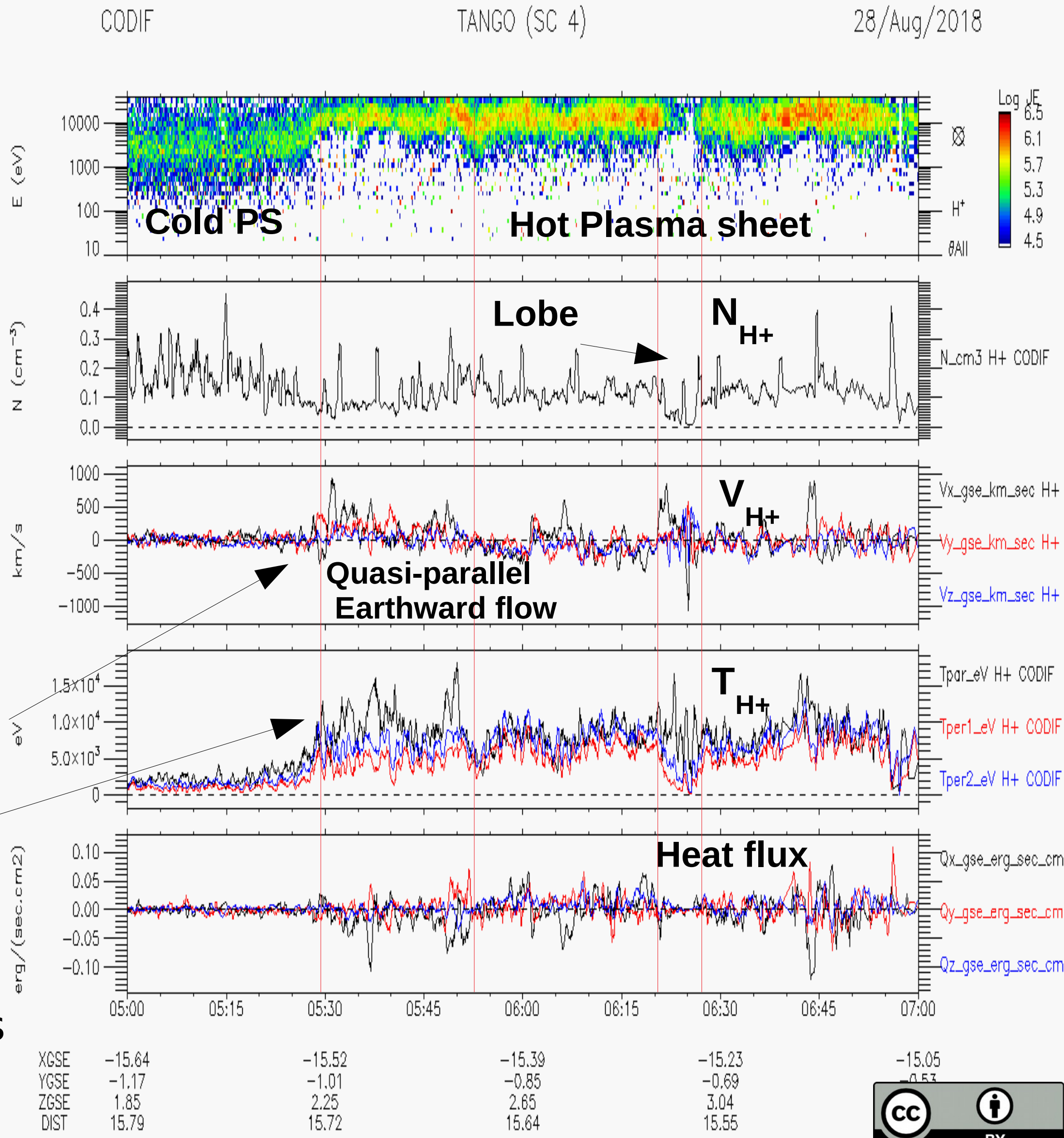
05:00-07:00 UT – Ion measurements

- Sliding average with 32 s time resolution of CODIF moments

- At 5:30 UT, Cluster 4 moved from a cold dense Plasma Sheet (CDPS)
Ni~0.2/cc Ti~ 1keV
to a hot tenuous PS Ni~0.1/cc, Ti~5-10keV
associated with a quasi-parallel earthward flow
Vx~ 800 km/s and Vy ~ 300 km/s (duskward)

- Larger increase of the ion parallel temperature

- Then Cluster remained almost always in the PS until the end of the joint observations except a brief entry in the lobe region around 06:25 UT



Event overview (Cluster 4)

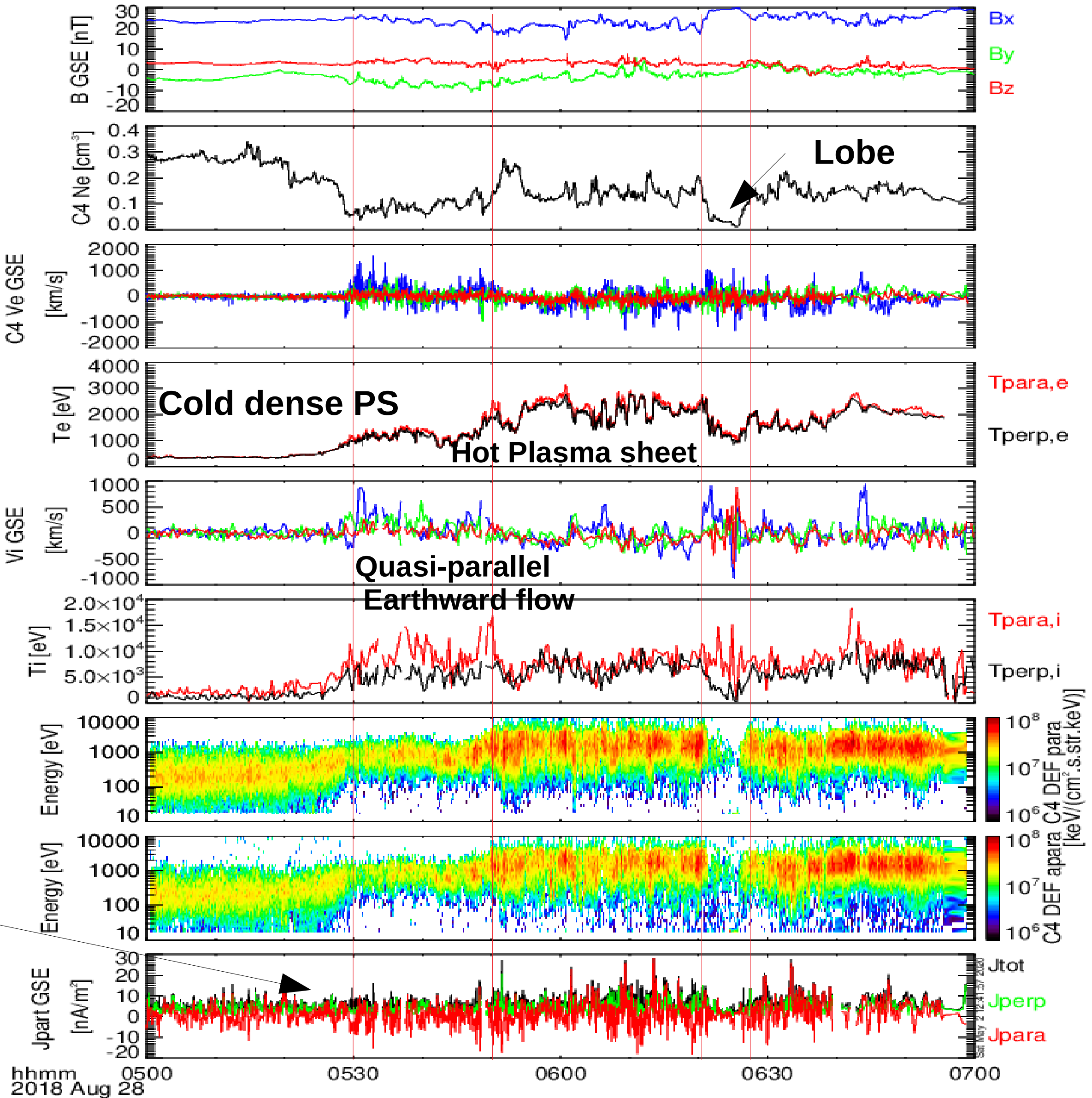
05:00-07:00 UT

- Consistent electron PEACE moments

- At 5:30 UT, Cluster 4 moved from a cold dense Plasma Sheet (CDPS)
 Ne ~0.3/cc,Te~350eV
to a hot tenuous PS
Ne~0.05-1/cc, Te~1-2keV
associated with a quasi-parallel earthward flow Vx~ 500-1000 km/s

- Tpara,i>Tperp,i while Tpara,e~Tperp,e

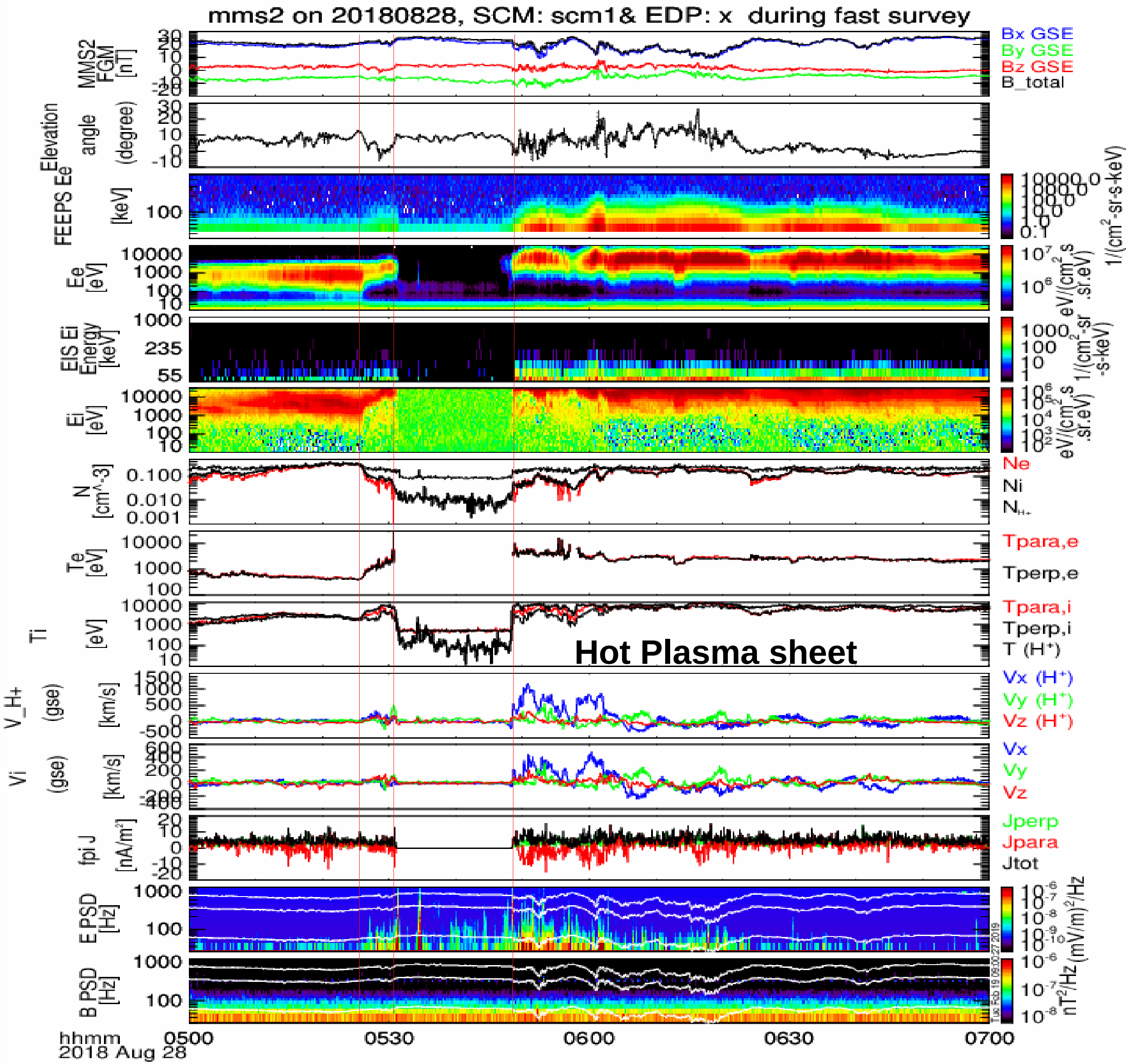
- Mostly anti-parallel (updward) current only short periods with Jpara>0 even around the lobe region



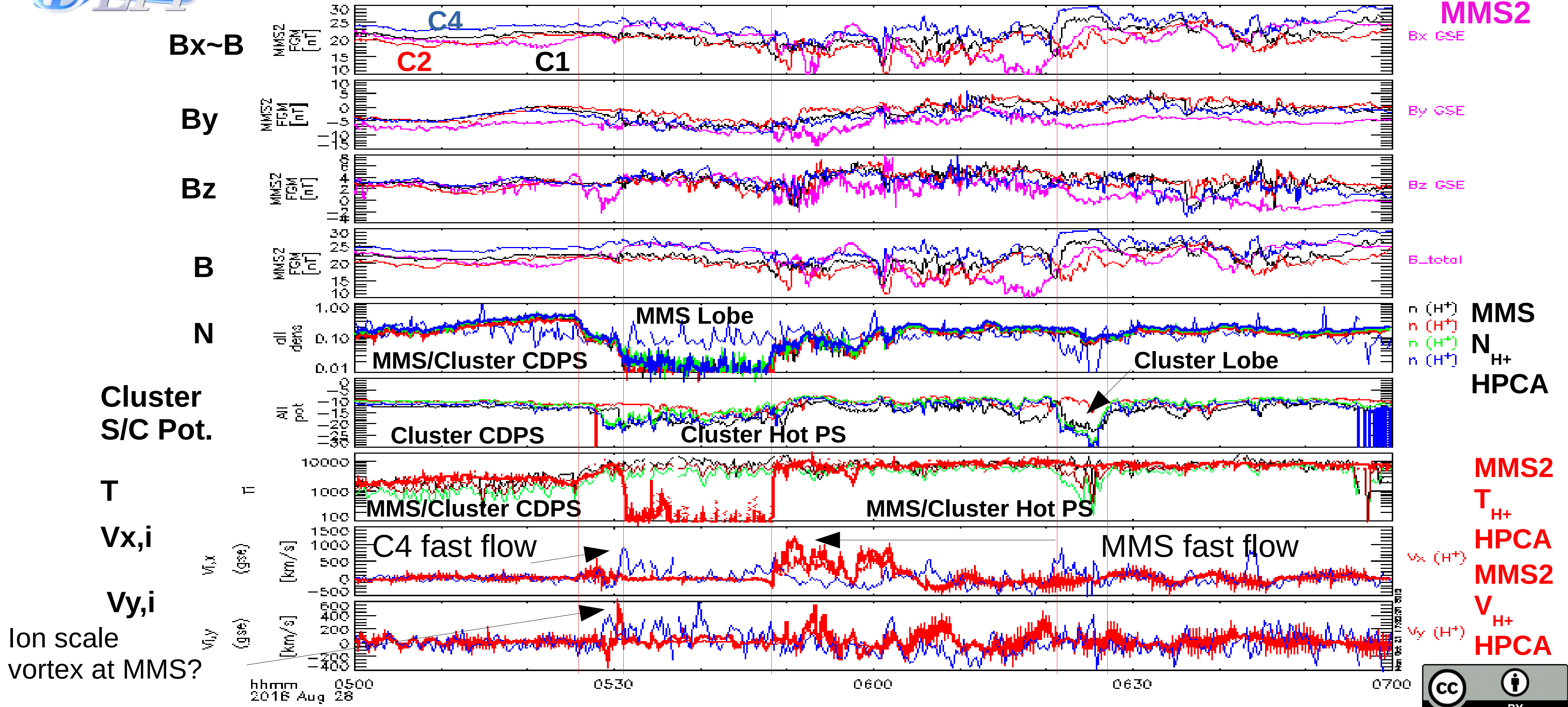
Event overview (MMS2)

05:00 UT- 07:00 UT

- Elevation angle <10°
- MMS moved from a cold dense PS
to the lobe region ~ 05:30 UT
via a brief period of hot PS
- returned to a hot PS around 05:48 UT
associated with a quasi-parallel
earthward flow (18 min later than Cluster)
Vx~ 400 km/s (FPI)
~ 800 km/s (HPCA)
- Increasing of energetic ions and
electrons
- Mostly anti-parallel (upward) currents
as on Cluster [e. g. Nakamura et al., 2004]
- High-frequency electric fluctuations
are detected near the PSBL
crossings [e.g. Onsager et al., 1993]



Event overview
MMS2 and Cluster 1234 (GSE)

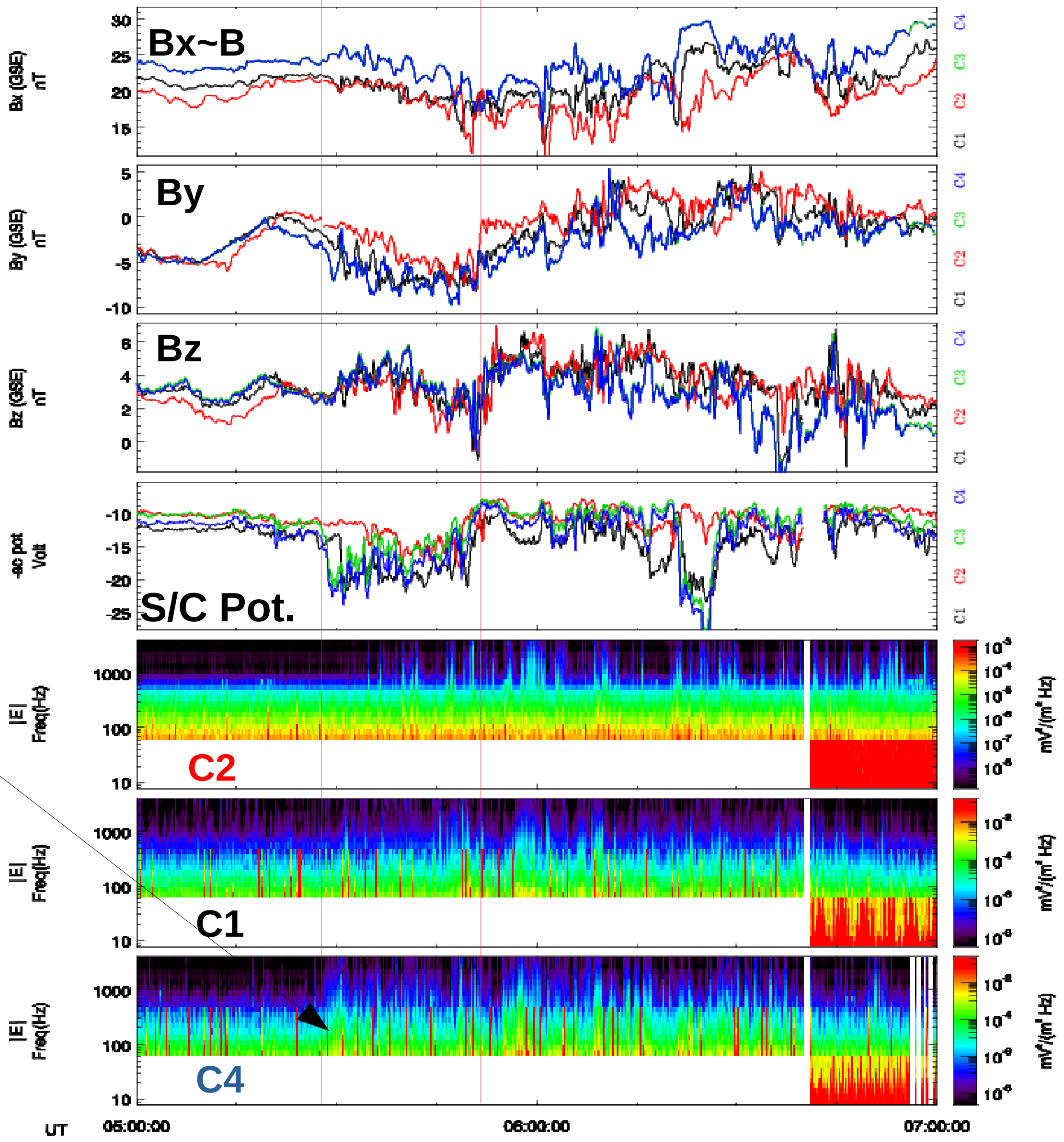


Cluster

FGM & STAFF-SA

- More intense E field fluctuations at high frequency (F>100 Hz) at the edge of the PS (C4) when the earthward flow starts
Also true on WHISPER
(not shown)

- Probably more intense E field fluctuations at low-frequency (F<100 Hz) closer to the magnetic equator (C2)



[CSA quicklook]

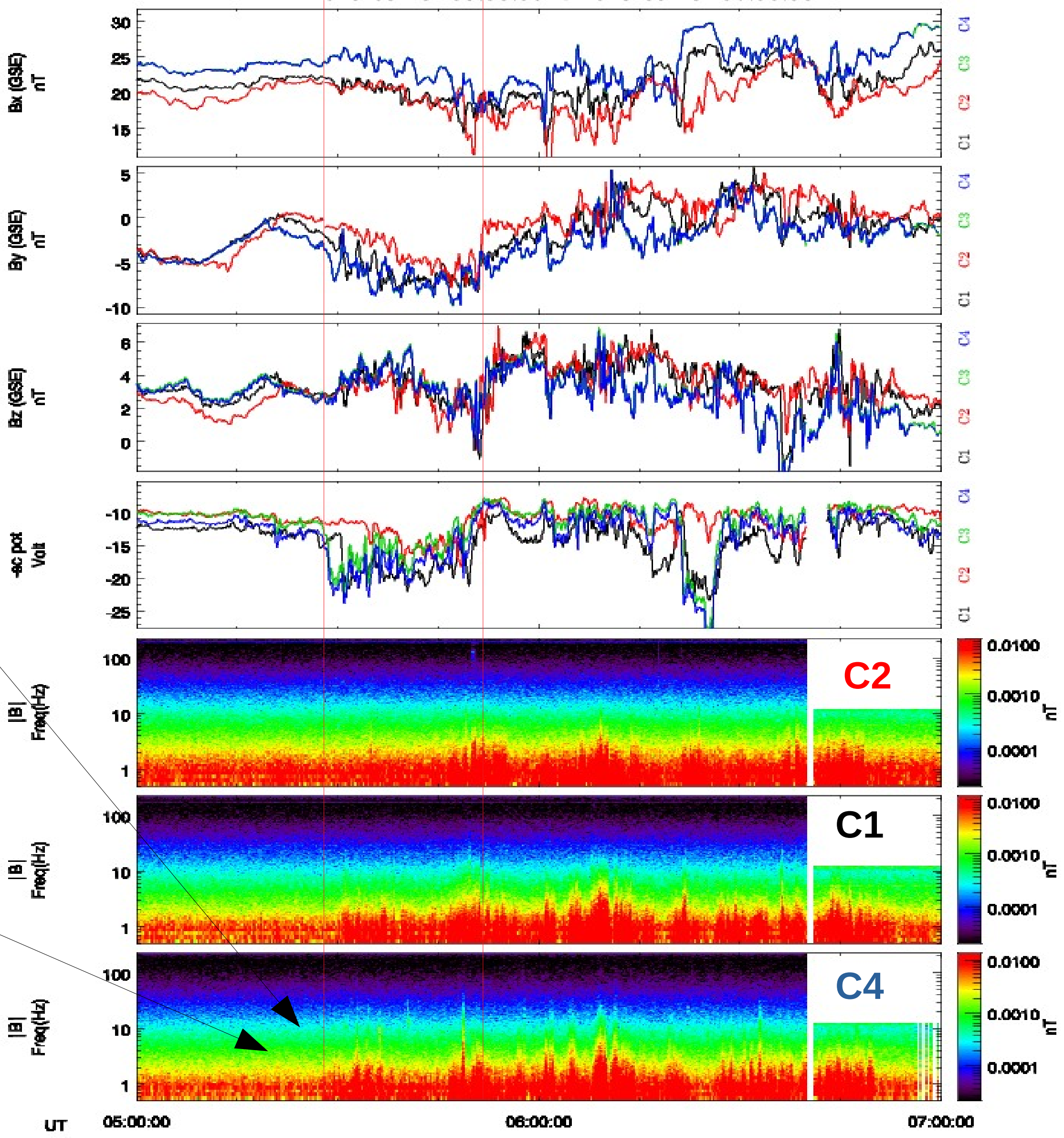
Cluster

FGM & STAFF-SC (HBR)

- More intense B field fluctuations (F<10 Hz) are associated with the fast Ion flow and Tpara,i>Tperp,i

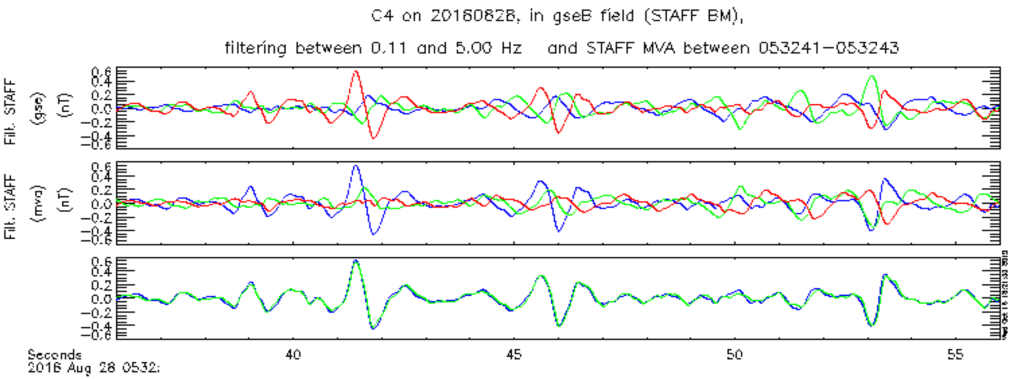
- **Fire hose instability which could reduce the flow?** [Hellinger&Matsumoto, 2000, Haggerty et al. 2018, Alexandrova et al., 2020, submitted] **KAW ?** [Chaston et al., 2012]

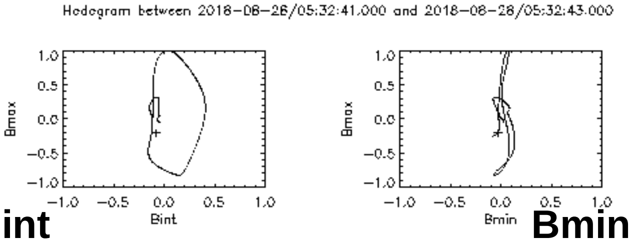
- **More intense at the PS edge (C4) than closer to equator (C2)**



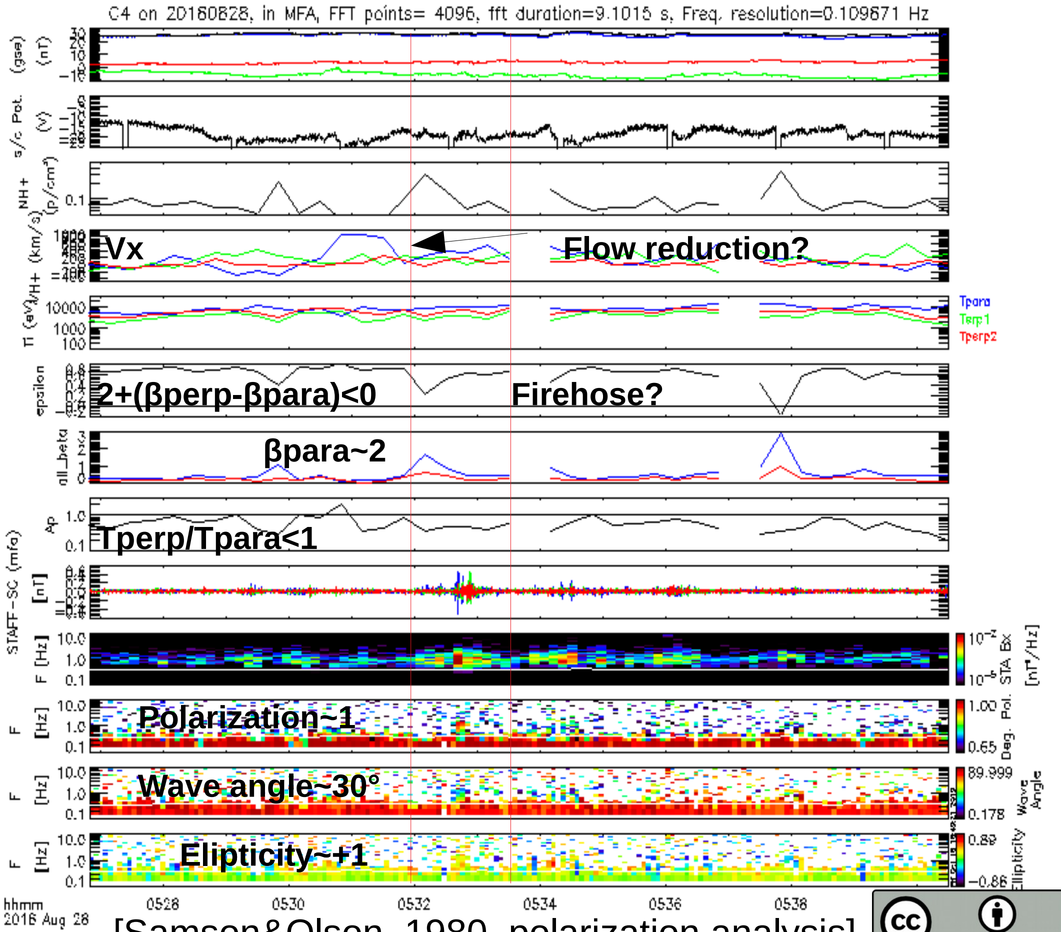
[CSA quicklook]

Tentative polarization analysis (Cluster 4 data)





Bmax **Bint** **Bmin**



[Samson&Olson, 1980, polarization analysis]

MVA analysis on band-path filterered (0.1-5 Hz) AC B (STAFF-SC) data:

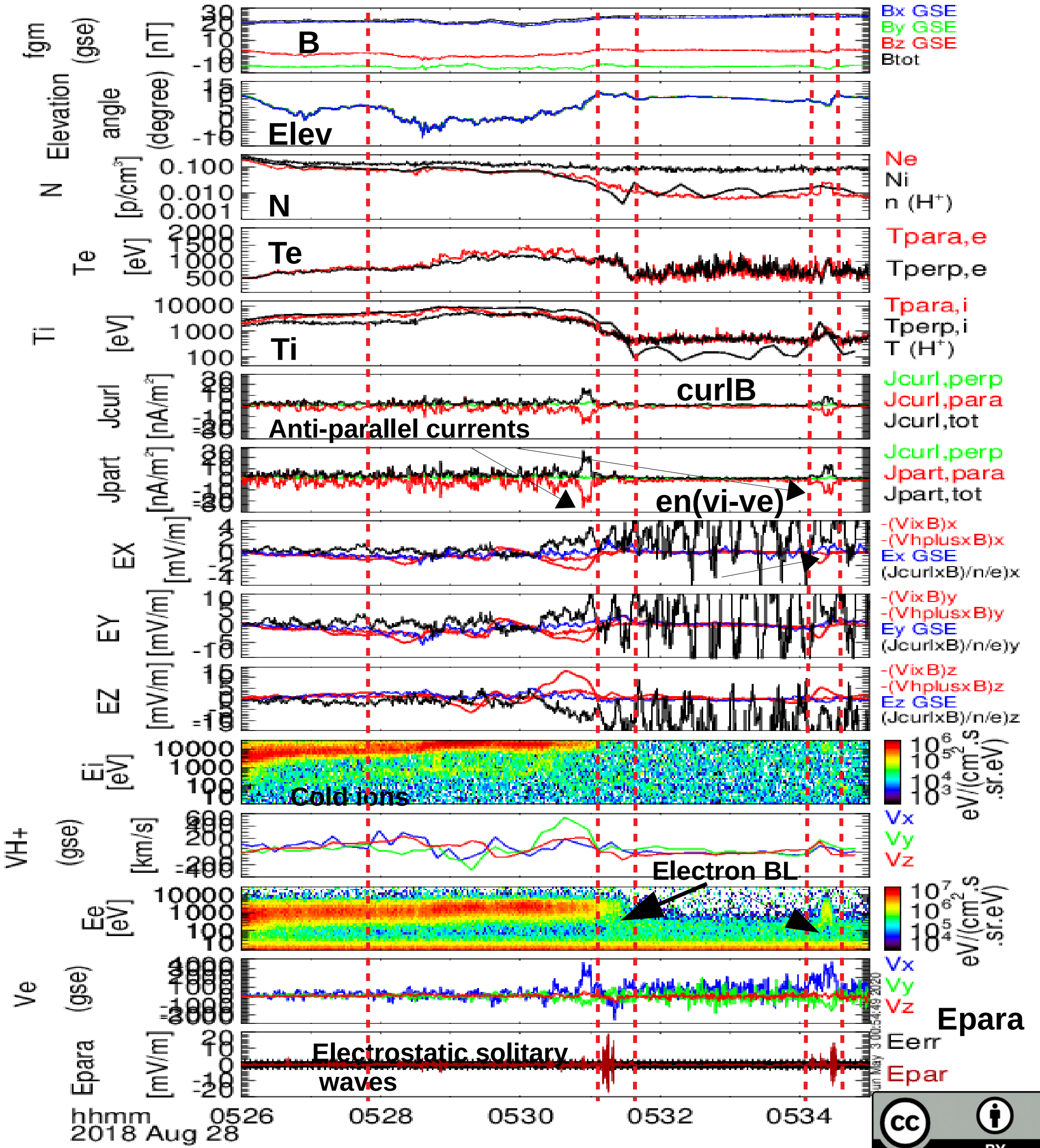
- Right-handed hodogram
- k~ Varmin [0.81, 0.50,0.30]
- λmax/λint=7.7 and λmax/λint = 7.9
- Wave angle ~42° => Oblique propagation
  => both analysis consistent with whistler fire hose (tbc)

MMS 1st PSBL Xing

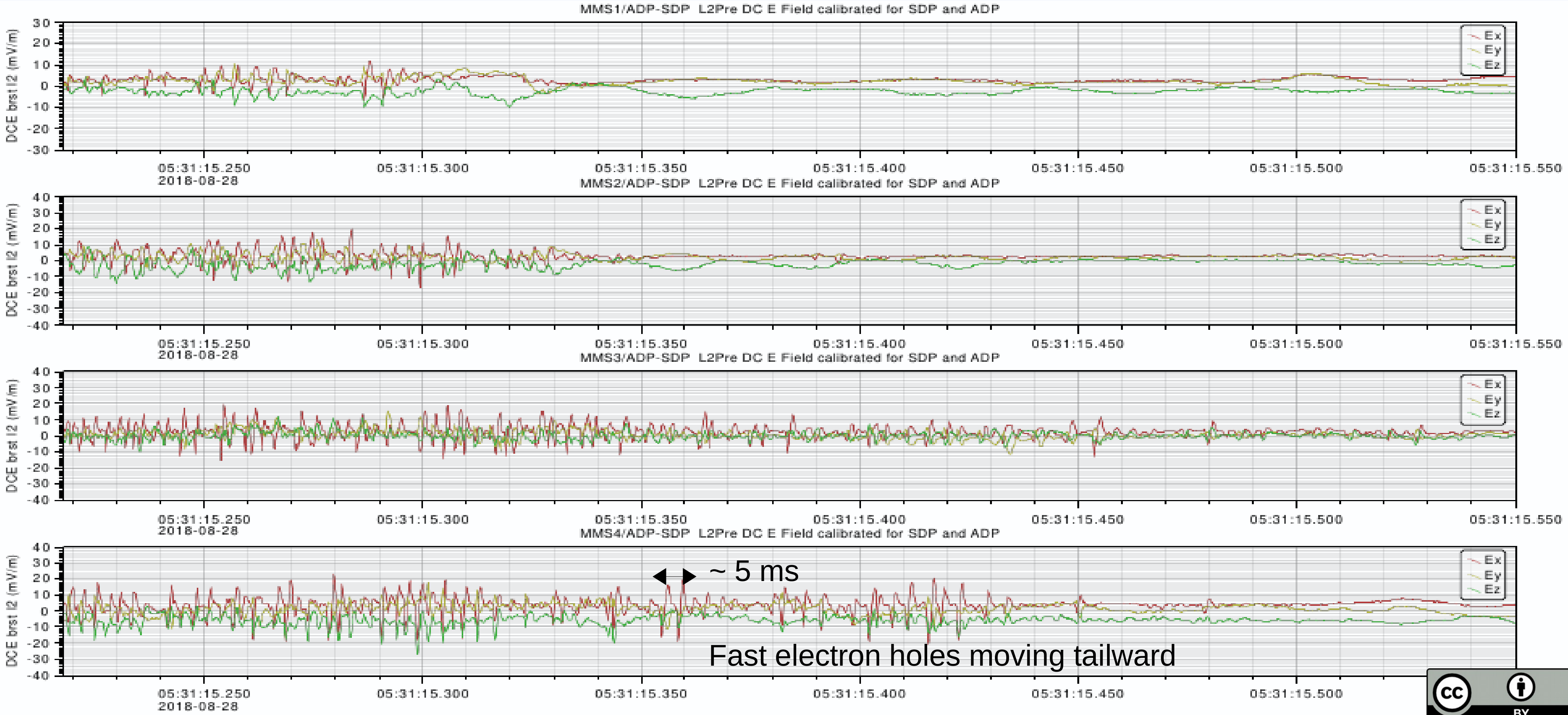
0526-0535 UT (MMS2)

- Elevation angle increases from 0 to 10°
- Increase of Te and Ti just before Xing
- **Anti-parallel (upward) current** signatures from **curlB** and from particles (en(**V**i-**V**e)) ~ -20 nA/m² just before the Xing
- Despite small perpendicular currents, ions are decoupled from B due to Hall field (JxB)/n/e just before PSBL Xing
- First Earthward flow (200 km/s) at 05:28 UT followed by a bipolar Vy,i -200/+600 km/s : ion vortex just before Xing ?
- **Inside the electron BL** (no ions, see e.g. [Varsani et al, 2017])

Electrostatic waves (ESW) are detected with parallel Efield signatures up to ± 10 mV/m consistent with Onsager et al., 1993 suggesting that **ESW are generated by plasma sheet electrons** and not by ion beams



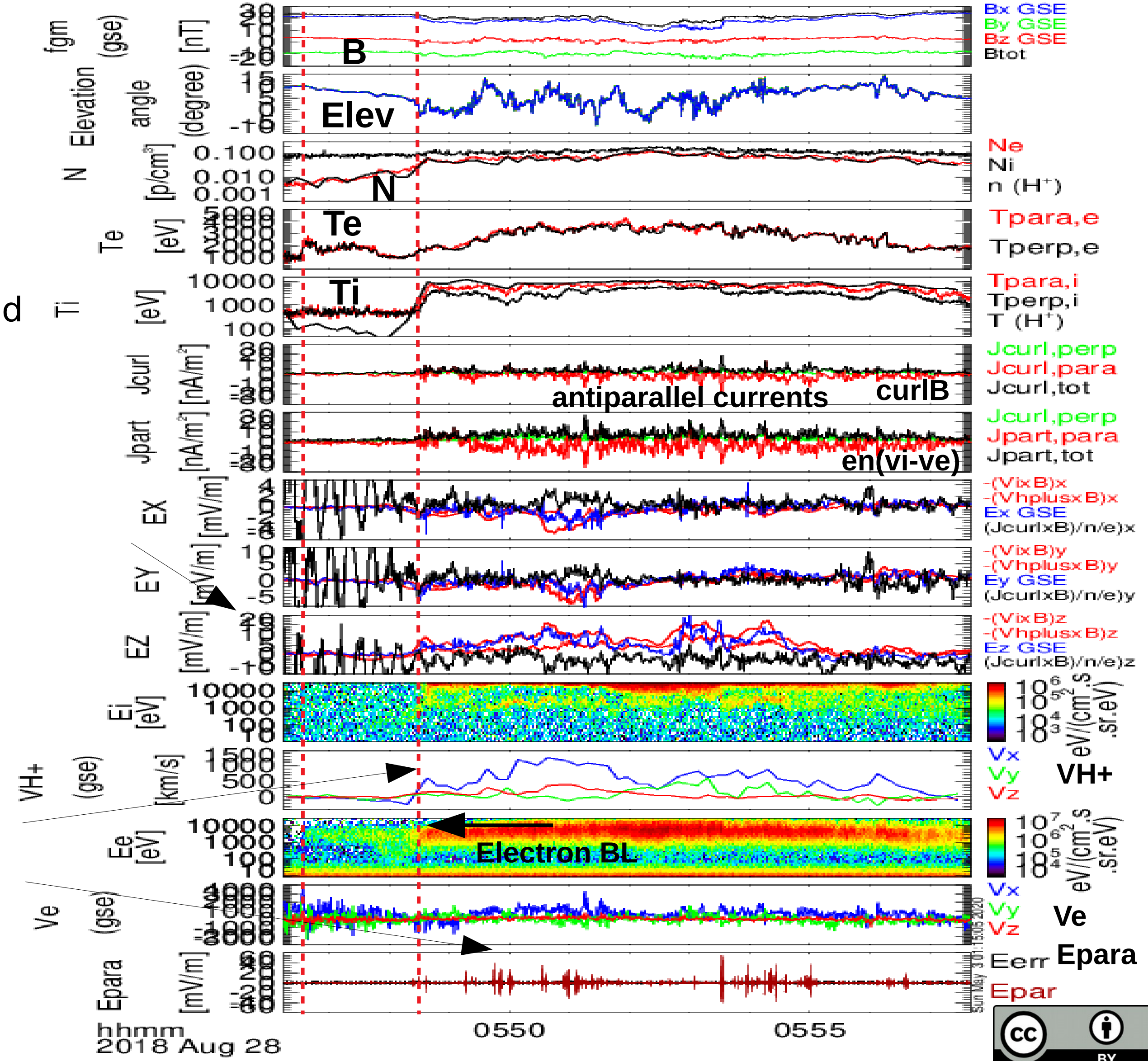
Zoom in to large Eperp ~ Epara (ESW) in the electron boundary layer



MMS
2nd PSBL Xing

0546-0558 UT (MMS2)

- Elevation : CS oscilations with 60 s period
- Mostly anti-parallel (upward) current fluctuations from **curlB** and particles en(**Vi-Ve**) ~ -20 nA/m²
- Some periods of decoupled ions due to Hall field
- Presence of « cold » ion beams ~ 1 keV coming from the ionosphere ?
- Quasi-parallel earthward flow ~1000 km/s at 05:48 UT
- **No ESW inside the electron BL but numerous ESW signatures up to ± 40 mV/m in the PS and associated with the fast flow**

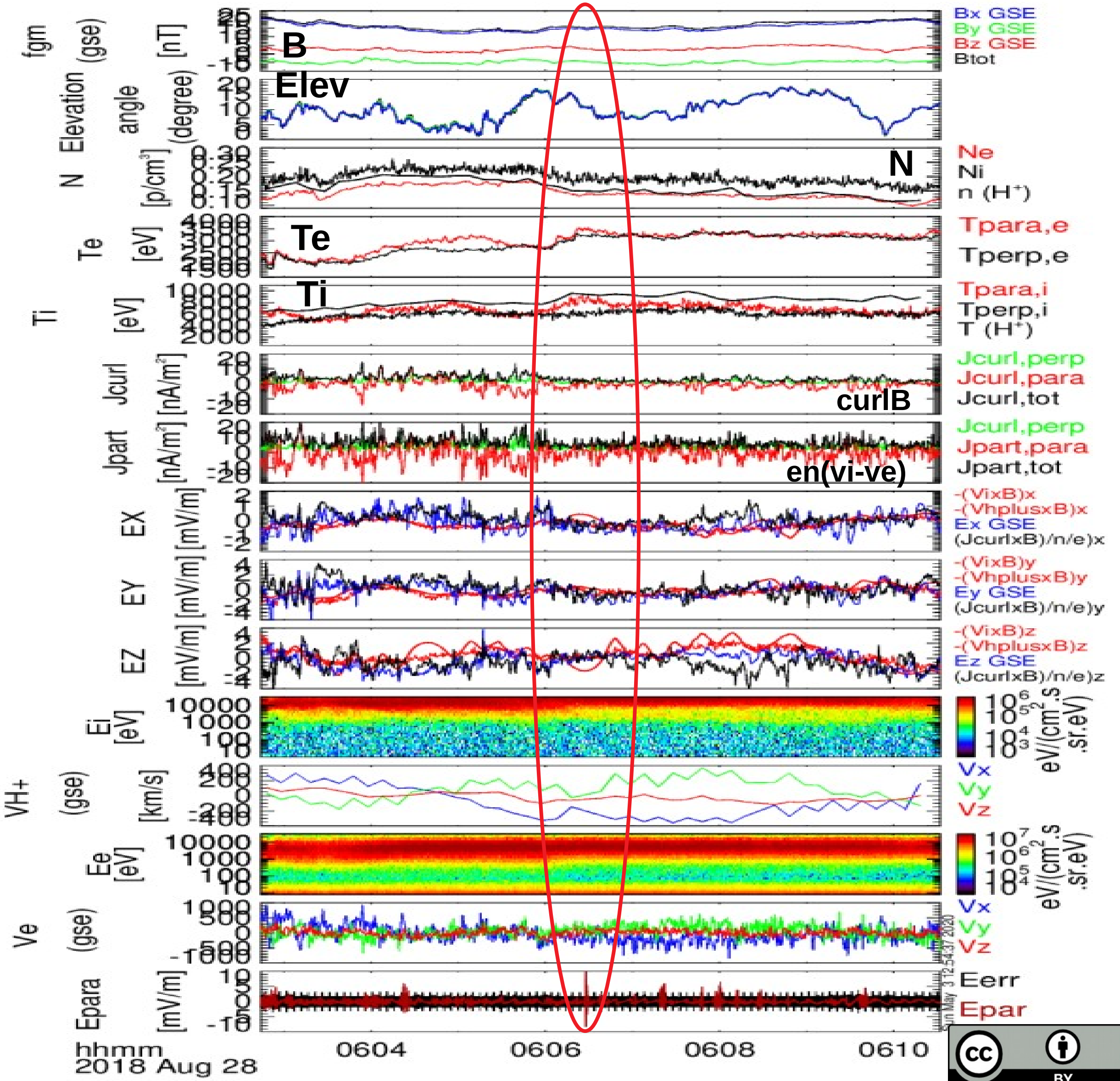


ESW in the PS

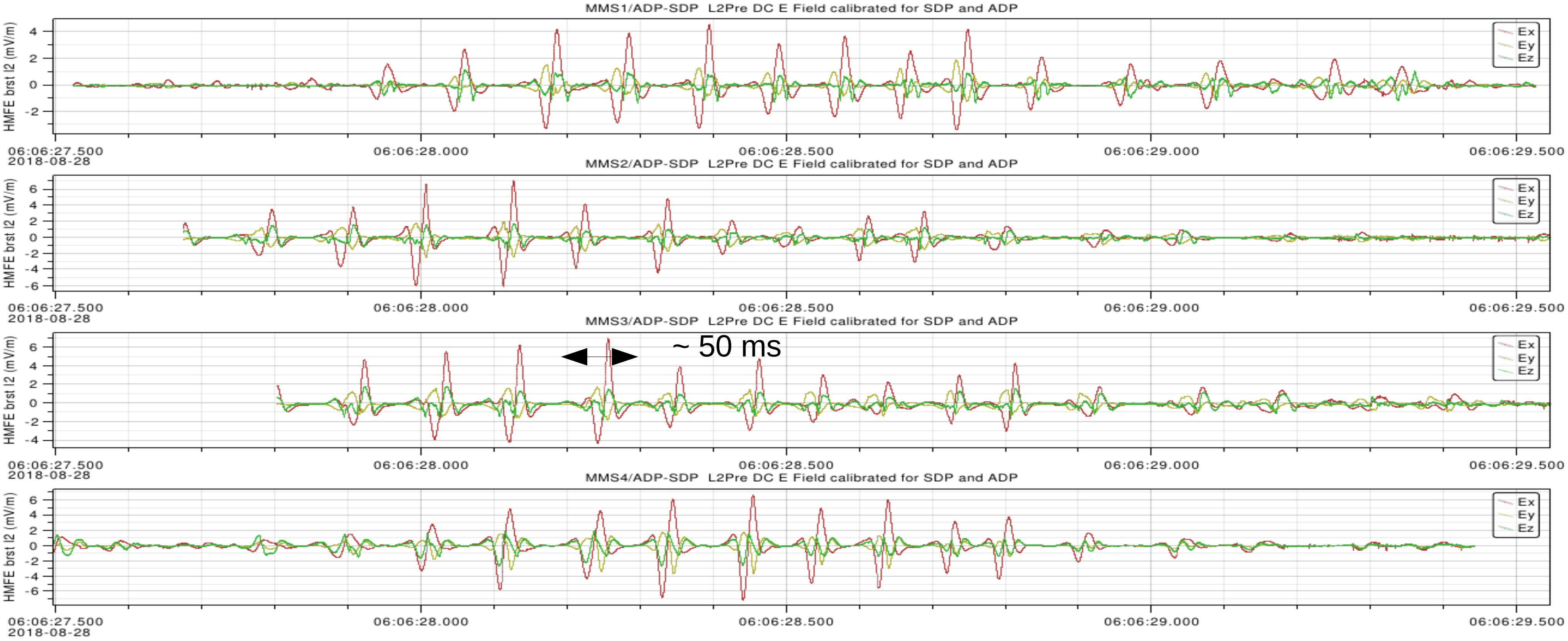
0603-0610 UT (MMS2)

- Isolated ESW detected well inside the PS

- Ion and electron anisotropies $T_{\parallel} > T_{\perp}$
- Quasi-parallel tailward ion flow ~ -200 km/s

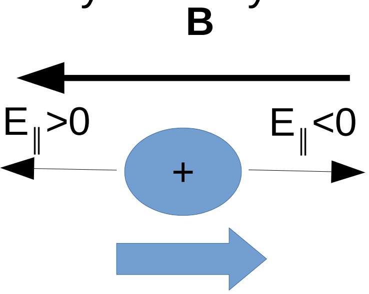


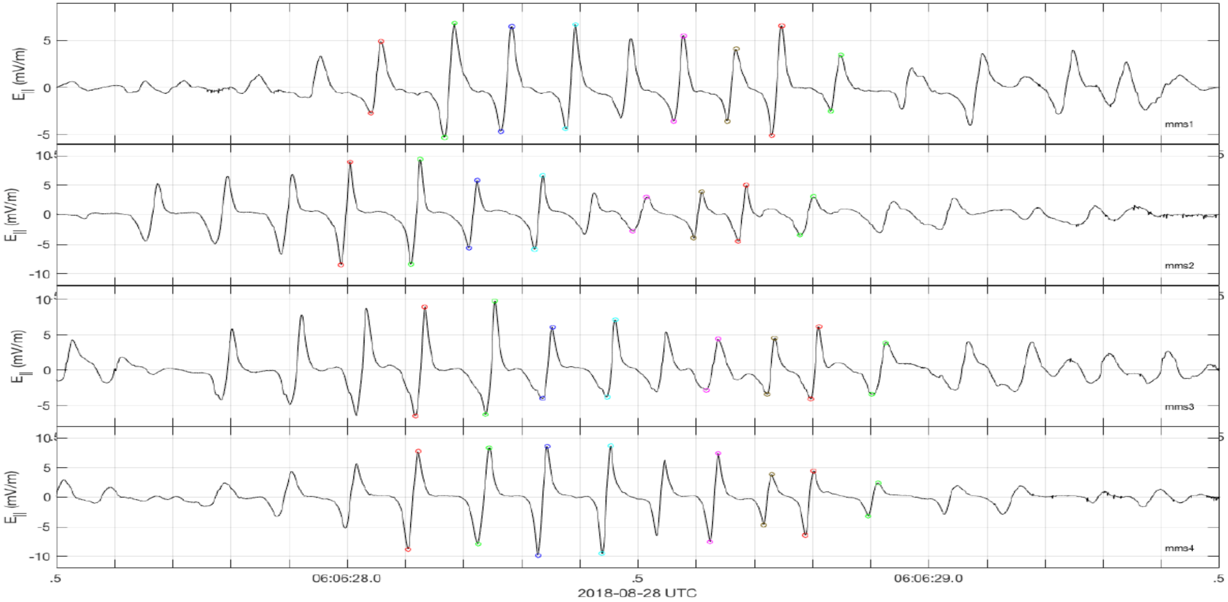
Electrostatic solitary waves (ESW)



Slow ESW moving tailward : electron holes

Timing Analysis (by pair) performed
From **Konrad Steinvall**
Phd student supervised
By Y. Khotyaintsev (IRFU)





Vx~ -400 km/s
$L_{\parallel}$~ 20 km~ c/ω_{pe}
~ $20\lambda_{De}$

Event nr	$v_{1\to2}$	$v_{1\to3}$	$v_{1\to4}$	$v_{2\to3}$	$v_{2\to4}$	$v_{3\to4}$
1	-0.4367	-0.4002	-0.3786	-0.4151	-0.4056	-0.5084
2	-0.3933	-0.4307	-0.4100	-0.4135	-0.4016	-0.5463
3	-0.3946	-0.4352	-0.3874	-0.4163	-0.3916	-0.8035
4	-0.4129	-0.4426	-0.3928	-0.4277	-0.4012	-0.8599
5	-0.3536	-0.5178	-0.3951	-0.4318	-0.3695	2.5080
6	-0.3994	-0.4496	-0.3868	-0.4253	-0.3921	-1.1427
7	-0.3877	-0.4692	-0.4232	-0.4291	-0.4053	-0.7667
8	-0.4880	-0.3863	-0.3674	-0.4257	-0.4158	-0.4978

Summary (I)

Large scale dynamics

- MMS and Cluster were located in the midnight sector separated by 4RE in Y GSE during a substorm period (AE~ 250-500 nT
- Both MMS and Cluster plasma measurements corresponded to a cold dense plasma sheet (CDPS)
- First signature corresponded to an earthward flow Vx~ 200 km/s detected by MMS at ~ 05:28 UT
- Then a bipolar Vy signature -200/+600 km/s (ion scale vortex ?) was detected by MMS associated with a brief hot plasma sheet transition whereas Cluster detected a duskward flow of 200 km/s
- At 05:30 UT, Cluster transitioned from a CDPS to a hot PS associated with a fast quasi-parallel earthward flow which could be reduced by whistler firehose instability (e.g. Alexandrova et al., JGR, 2020, submitted)
- At the same time, MMS located 4RE duskward transitioned to the Lobe region which could suggest that the PS was thinner (or thinning) or moving vertically due to a large scale (4 Re) dawn-dusk oscillation of the magnetotail
- Then MMS returned to a hot PS detecting a fast quasi-parallel earthward flow 18min (~ 05:48 UT) later than Cluster
- MMS and Cluster kept measuring an active PS until 07:00 UT, Cluster briefly exploring the Lobe region ~ 06:25 UT indicating a still relatively thin current sheet.
- While both MMS and Cluster crossed the PSBL during this event, only antiparallel (upward) currents were detected.

These MMS/Cluster joint measurements can hardly be interpreted with a large scale perturbation invariant in the dawn-dusk direction. They suggest a complex plasma dynamics combining fast earthward plasma flow with dawn-dusk plasma sheet oscillations

Summary (II)

Kinetic scales

- Electrostatic waves (ESW) were detected inside the electron boundary layer [Onsager et al., JGR, 1993] but not always and also inside the plasma sheet
- Fast electron holes moving tailward were detected in the electron boundary layer related to hot PS electrons.
- Slow (~ 400 km/s) electron holes (~ $20\lambda_{De}$) moving tailward were also detected in the PS and possibly related to counter streaming beams

To be continued.