Magnetosheath jet generation due to shock reformation

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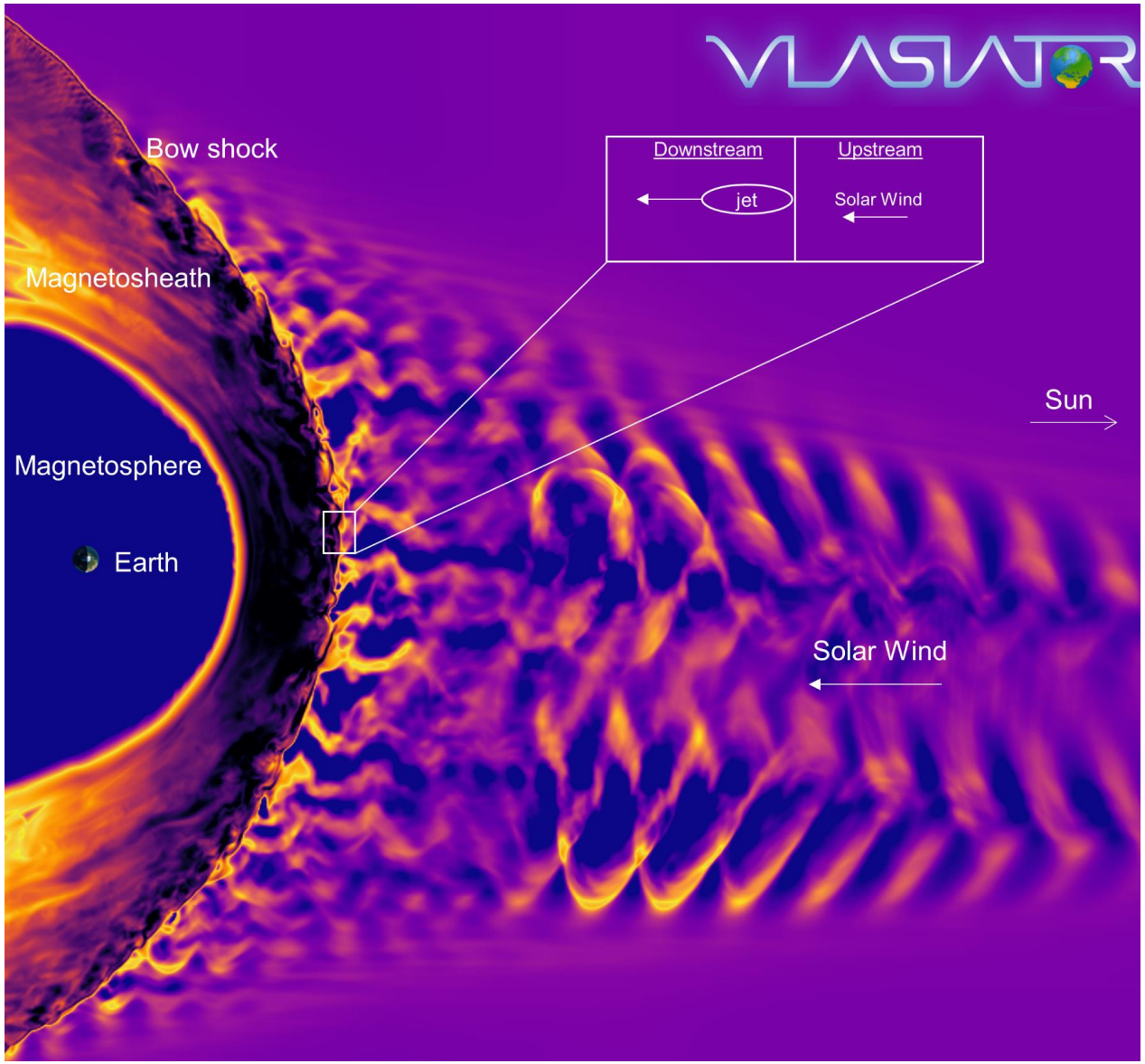
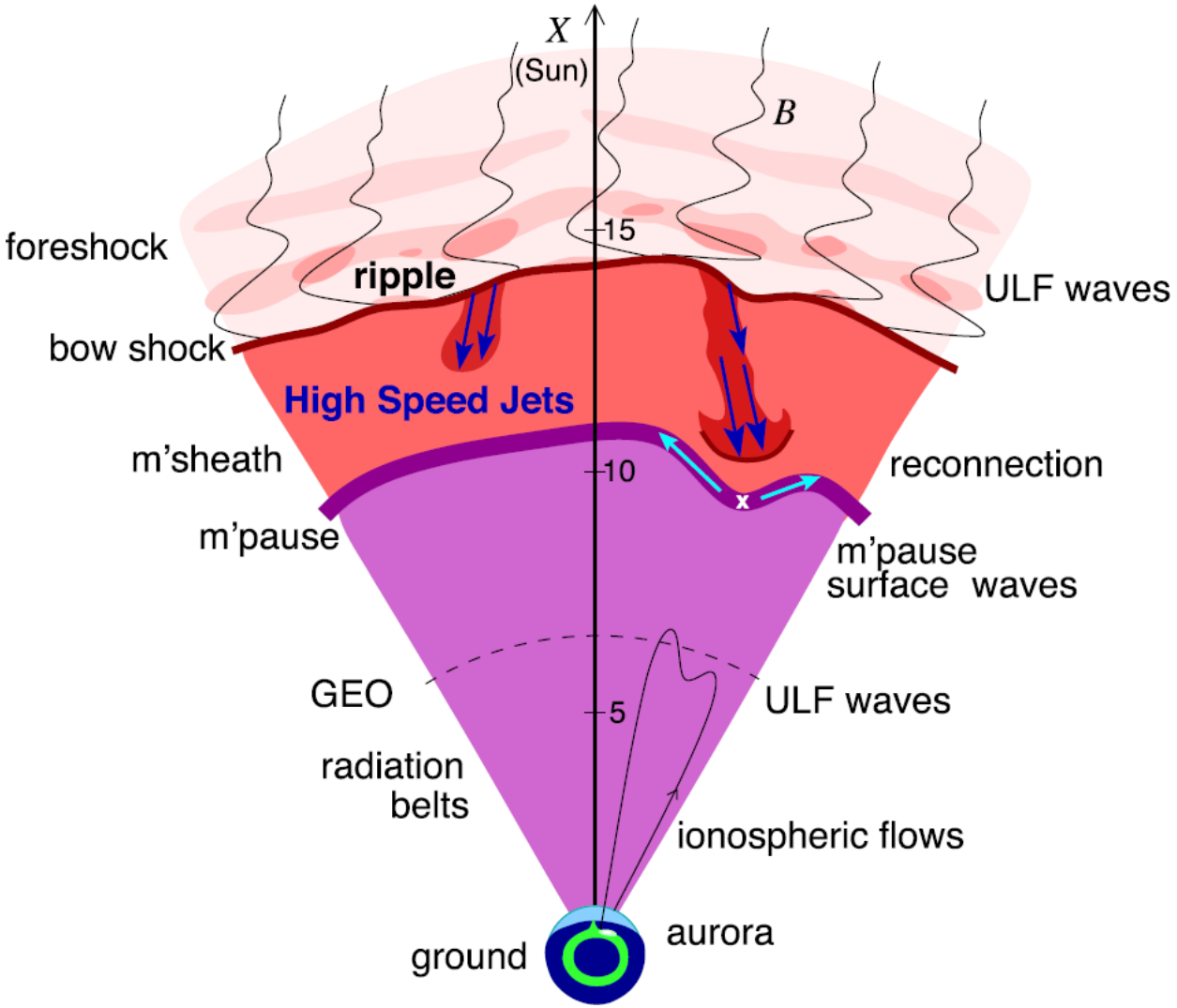
MMS SWT Tag-up Tuesday
25/01/2022

Earth’s magnetosphere



Courtesy of M. Palmroth, U Helsinki

Magnetosheath Jets



Plaschke F. et al. (2018); sketch by H. Hietala | Space Sci. Rev

Definition

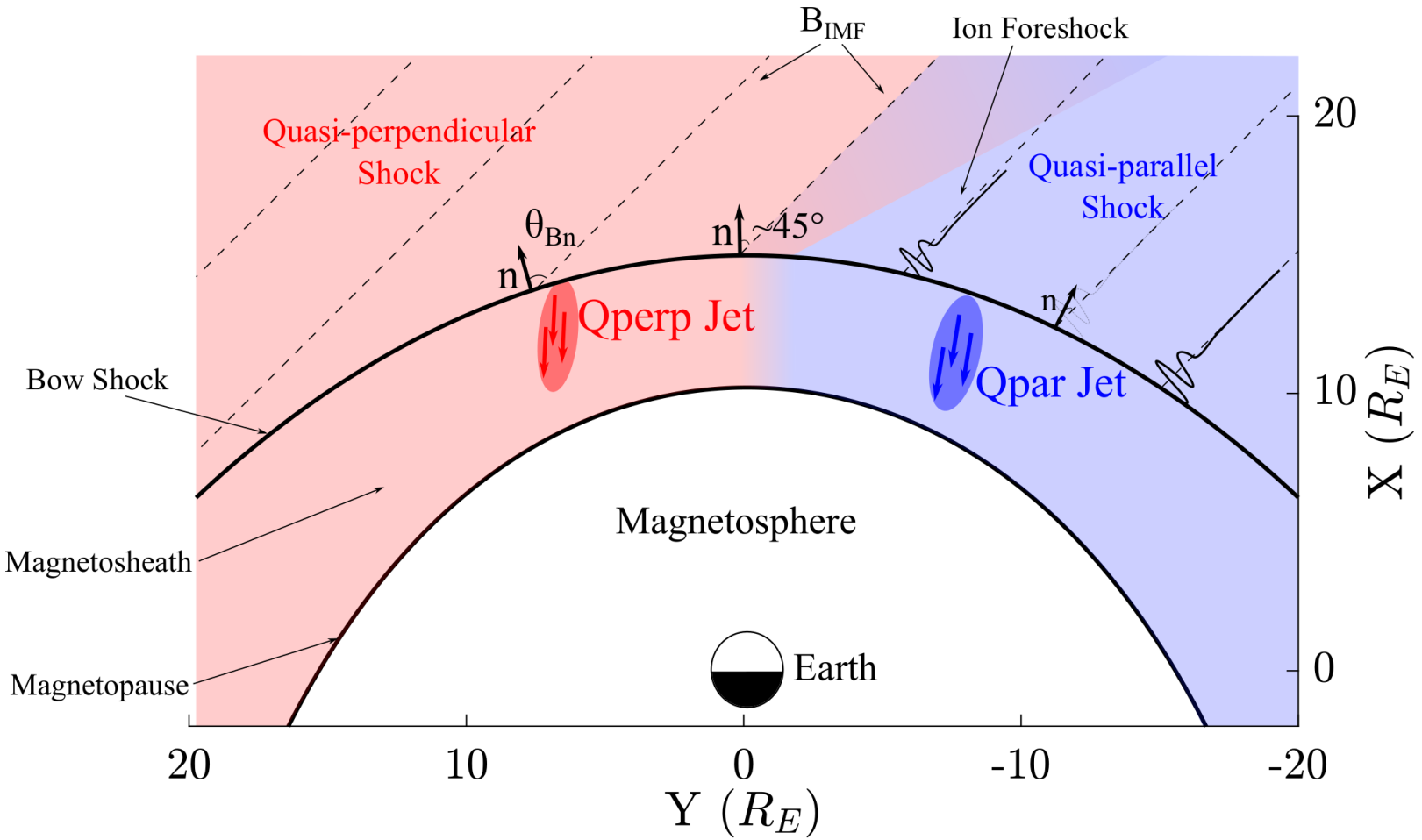
Magnetosheath jets are **transient localized enhancements** of **dynamic pressure** (density and/or velocity increase)

e.g. 200% dynamic pressure enhancement compared to background magnetosheath

Related phenomena

Radiation belts
Aurora
Magnetopause reconnection
Magnetopause penetration
Shock acceleration
Magnetopause surface eigenmodes
ULF waves

Shock, Magnetosheath & Jet classification



"Θ_{Bn} is the angle between the IMF and the shock's normal vector"

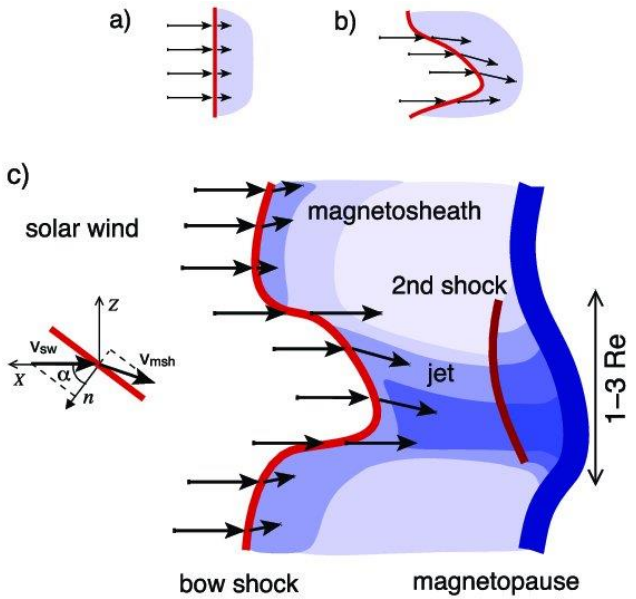
Qpar = $\Theta_{Bn} \lesssim 45°$
Qperp = $\Theta_{Bn} \gtrsim 45°$

"Jets found ~9 times more often in the Qpar MSH"

Raptis, Karlsson, et al. (2020) | JGR
Raptis, Aminalragia-Giamini et al. (2020) | Front. Astron. Space Sci
Karlsson, **Raptis S.**, et al. (2021) | JGR
Kajdič, **Raptis** et al. (2021) | GRL

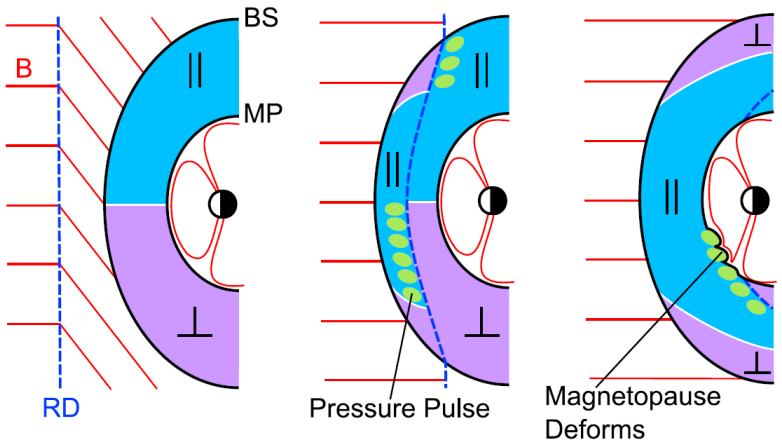
How are these jets created ?

Shock ripples



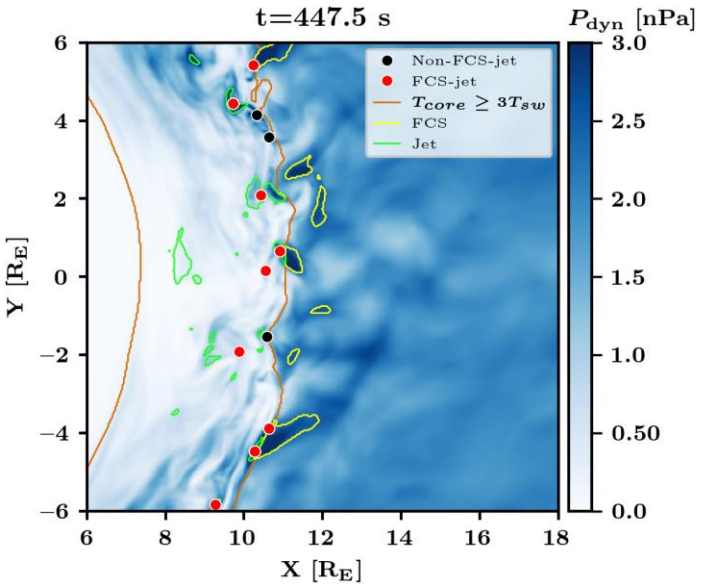
Hietala et al. (2009,2012)

SW discontinuities



Archer et al. (2012)

Foreshock Structures



Suni et al. (2021), Raptis et al. (2022)

Recent Results

Downstream High-speed Plasma Jet Generation as a Direct Consequence of Shock Reformation

Savvas Rapitis[1,*], Tomas Karlsson[1], Andris Vaivads[1], Craig Pollock[2], Ferdinand Plaschke[3], Andreas Johlander[4,5], Henriette Trollvik[1], Per-Arne Lindqvist[1]

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[2] *Denali Scientific, Fairbanks, AK, 99709, USA*

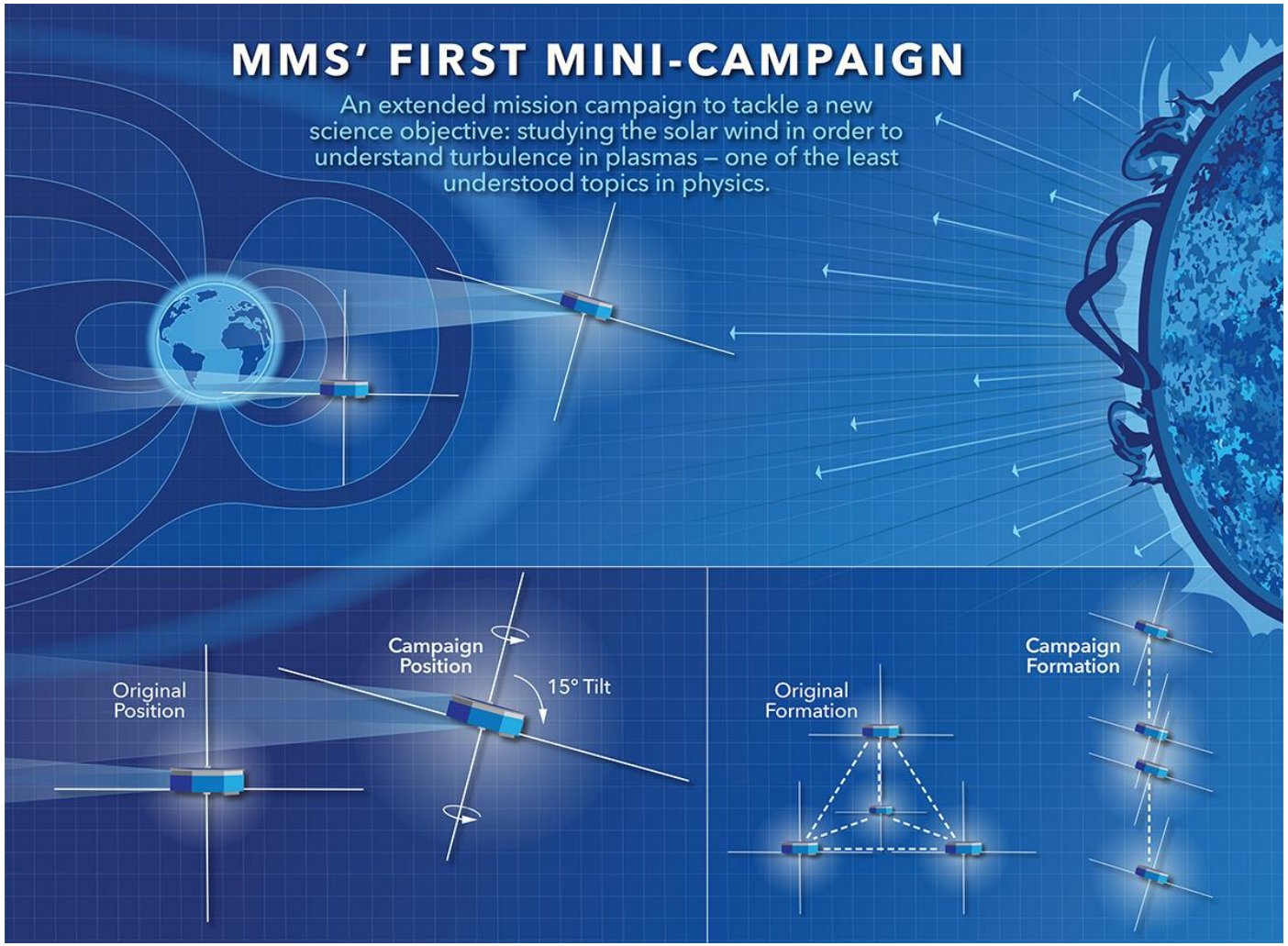
[3] *Institute of Geophysics and Extraterrestrial Physics, Technische Universität Braunschweig, Germany*

[4] *Department of Physics, University of Helsinki, Finland*

[5] *Swedish Istitute of Space Physics, Uppsala, Sweden*

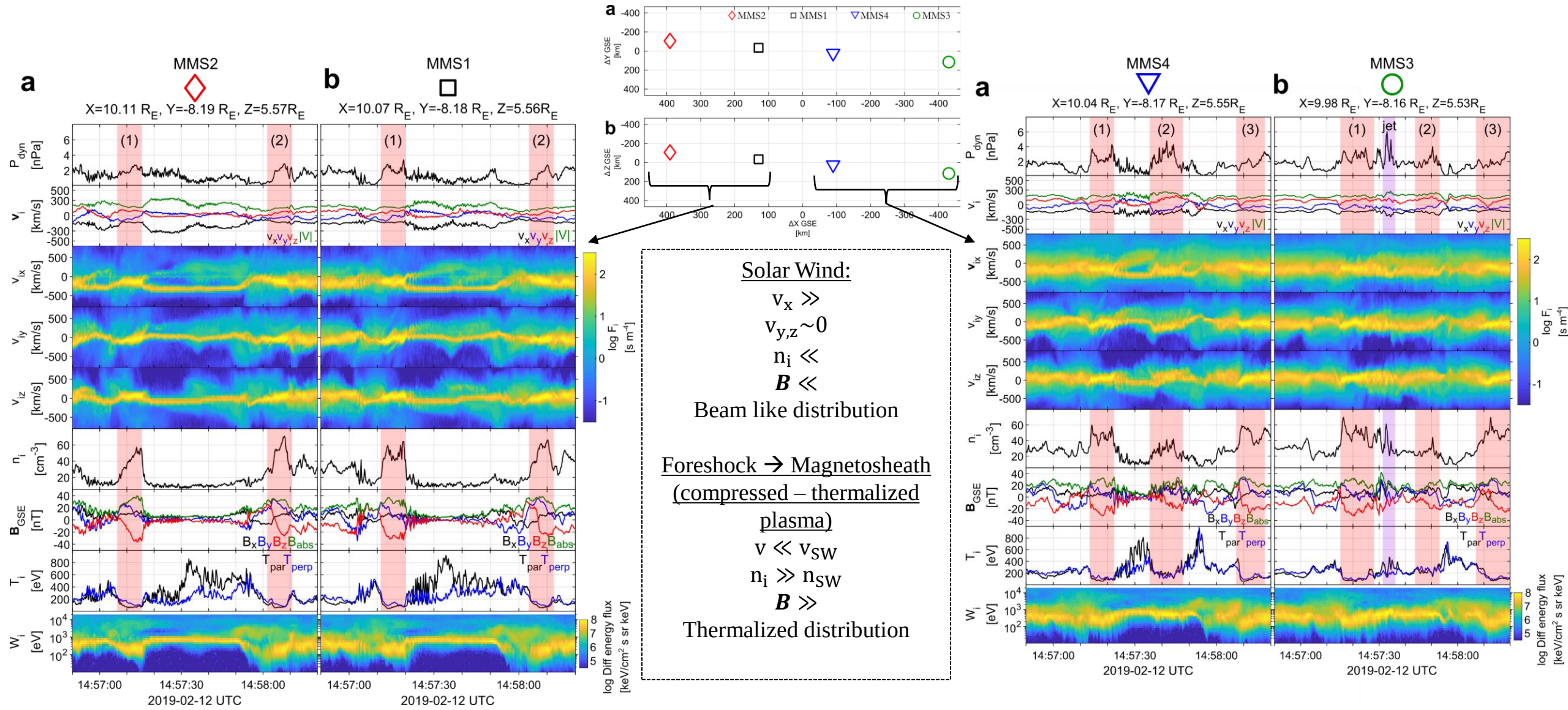
Raptis et al. (2022) “Downstream High-speed Plasma Jet Generation as a Direct Consequence of Shock Reformation”, *Nature Communications* (**accepted**)

MMS spacecraft + String of Pearl Configuration



Credits: NASA's Goddard Space Flight Center/Mary Pat Hrybyk-Keith

General Observations of MMS



Solar Wind:

$v_x \gg$

$v_{y,z} \sim 0$

$n_i \ll$

$\boldsymbol{B} \ll$

Beam like distribution

Foreshock → Magnetosheath (compressed – thermalized plasma)

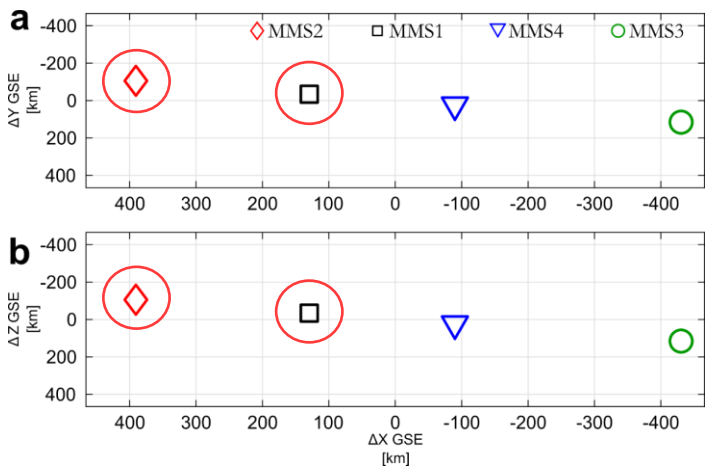
$v \ll v_{SW}$

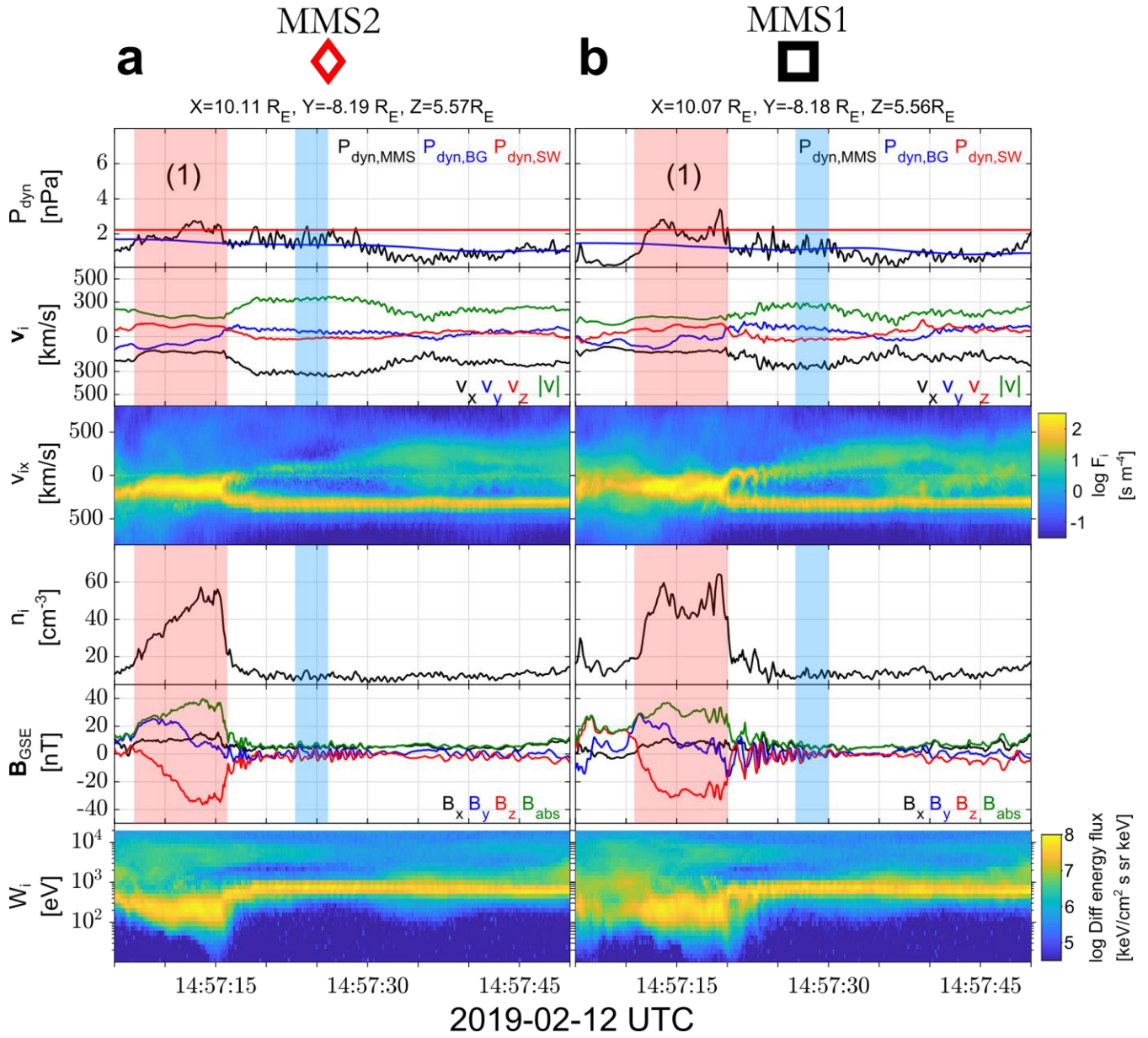
$n_i \gg n_{SW}$

$\boldsymbol{B} \gg$

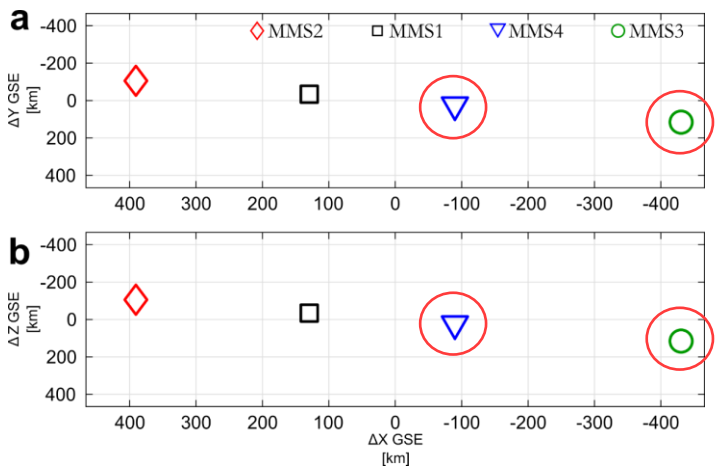
Thermalized distribution

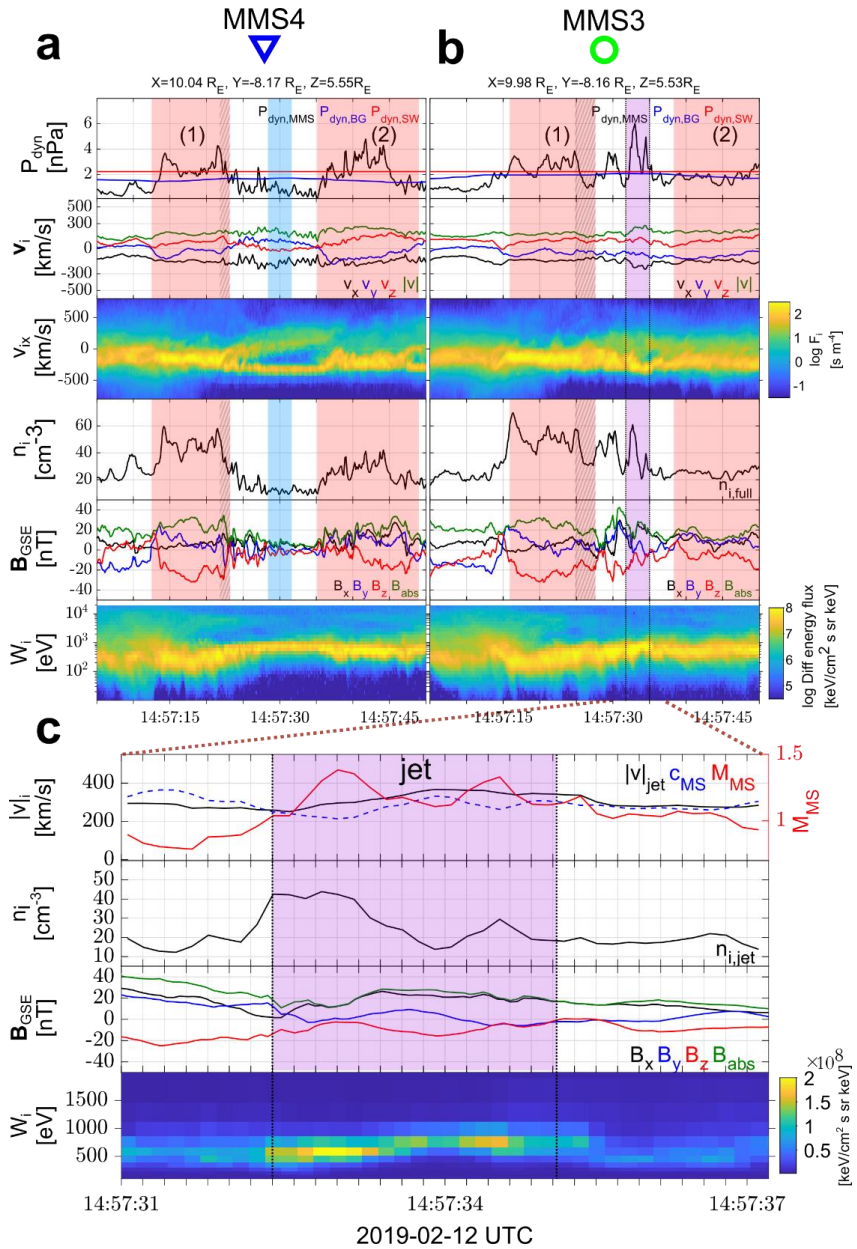
MMS outer-spacecraft observations



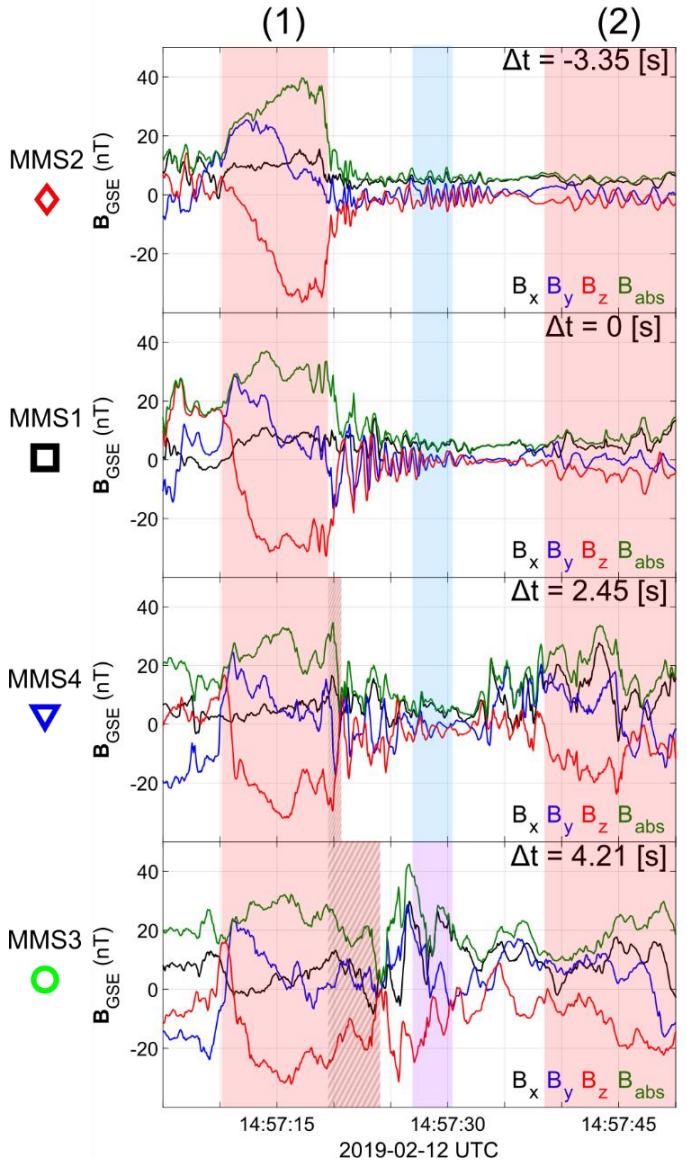


MMS inner-spacecraft observations

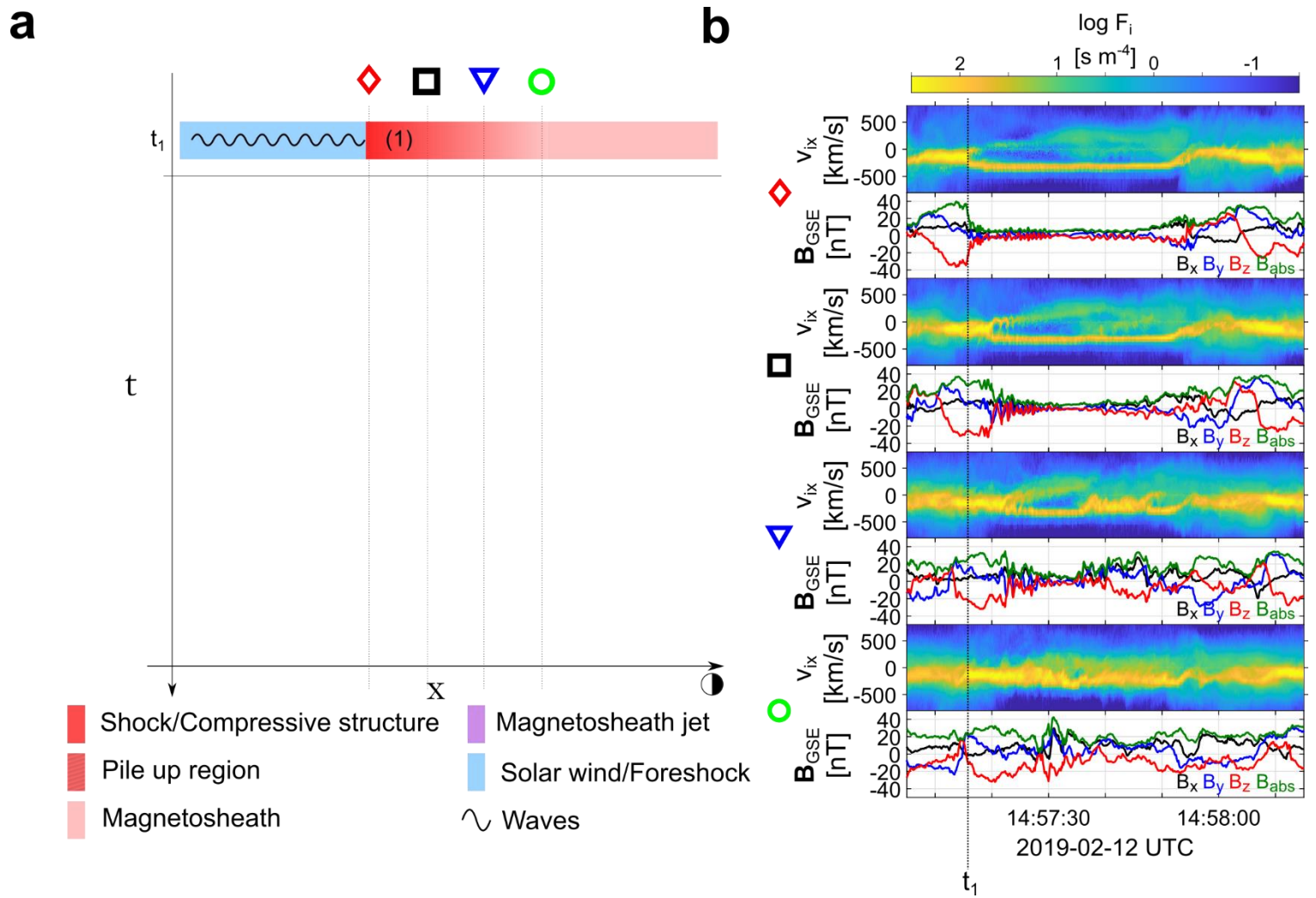




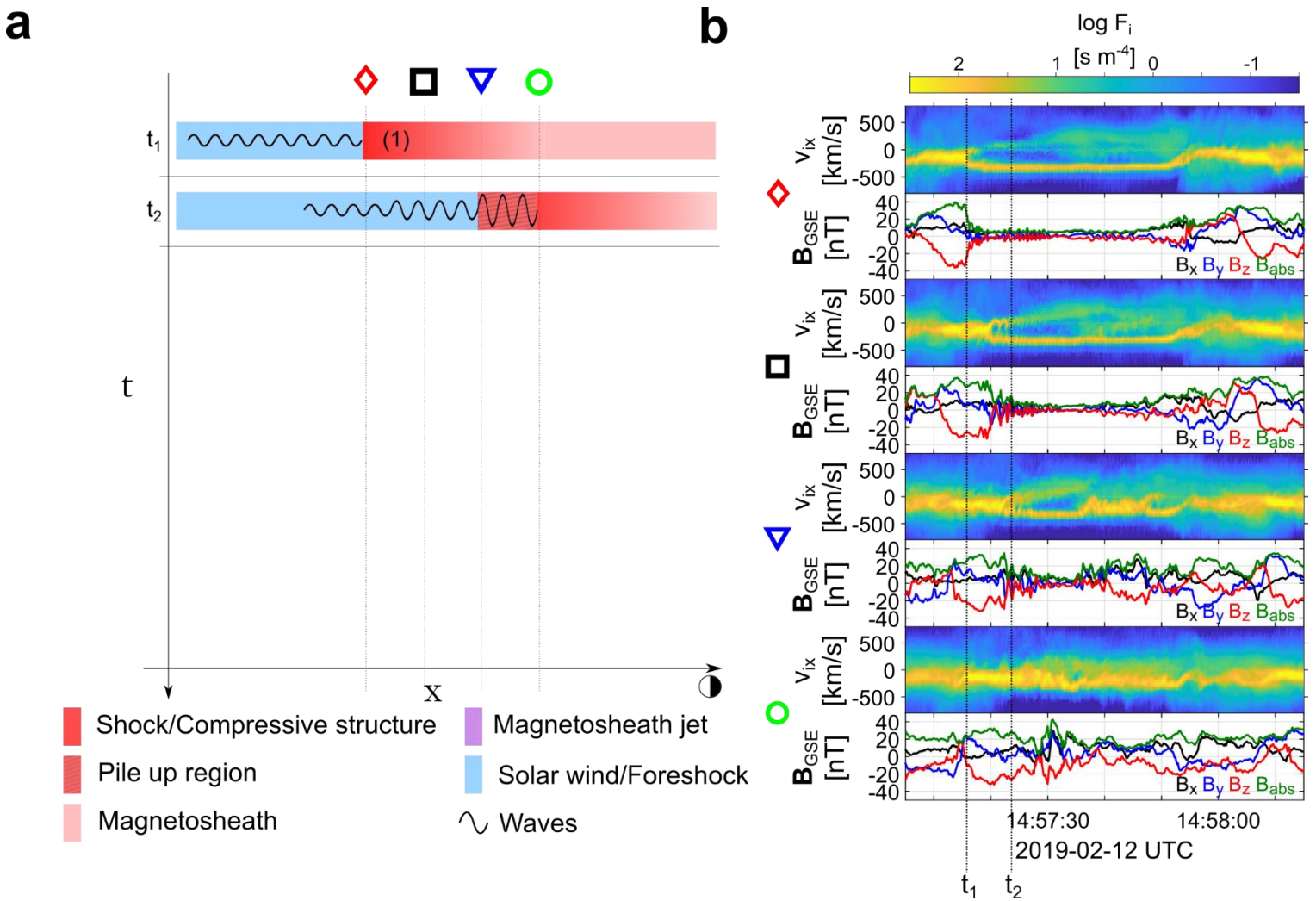
SLAMS & wave activity co-moving picture



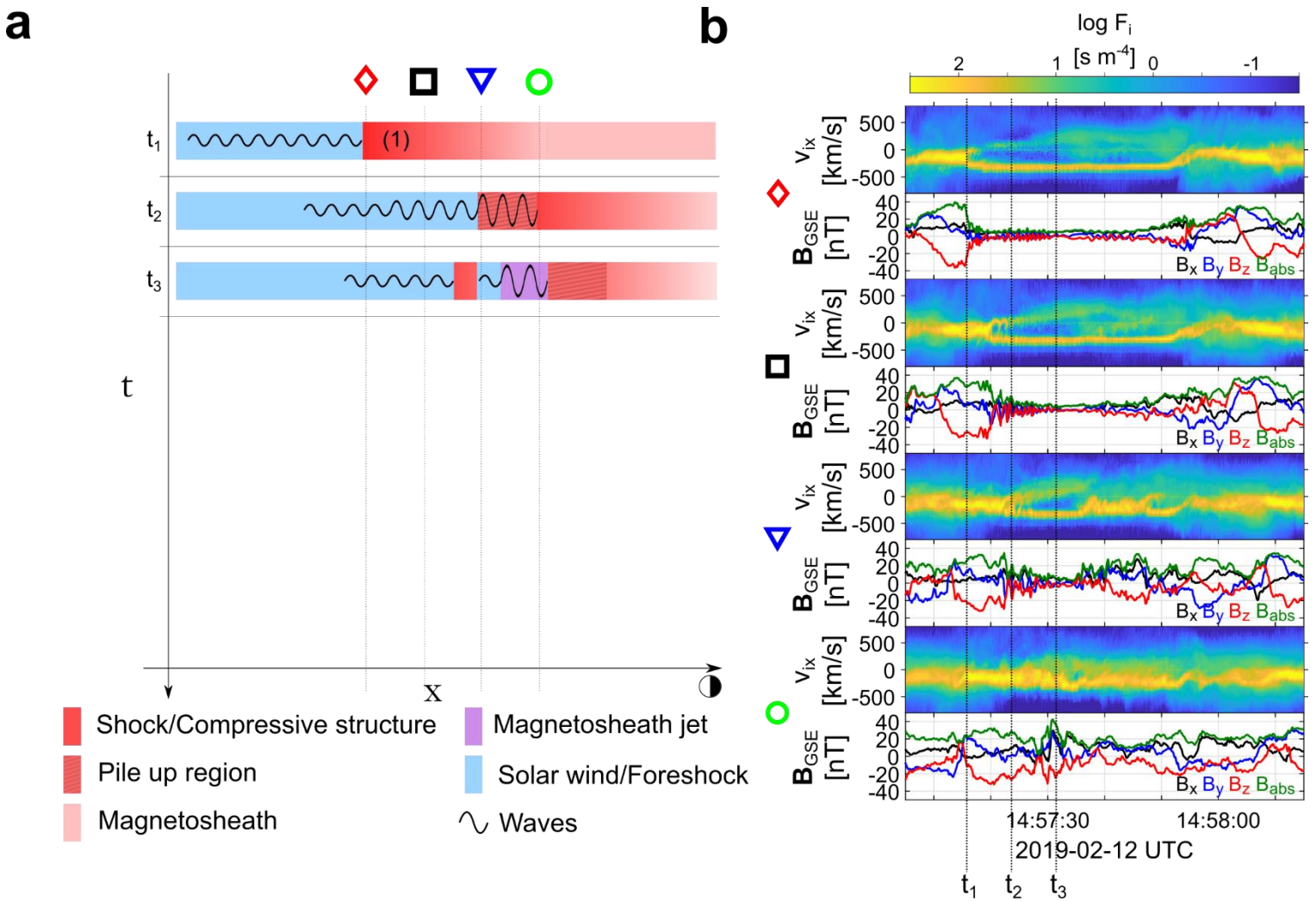
Formation mechanism



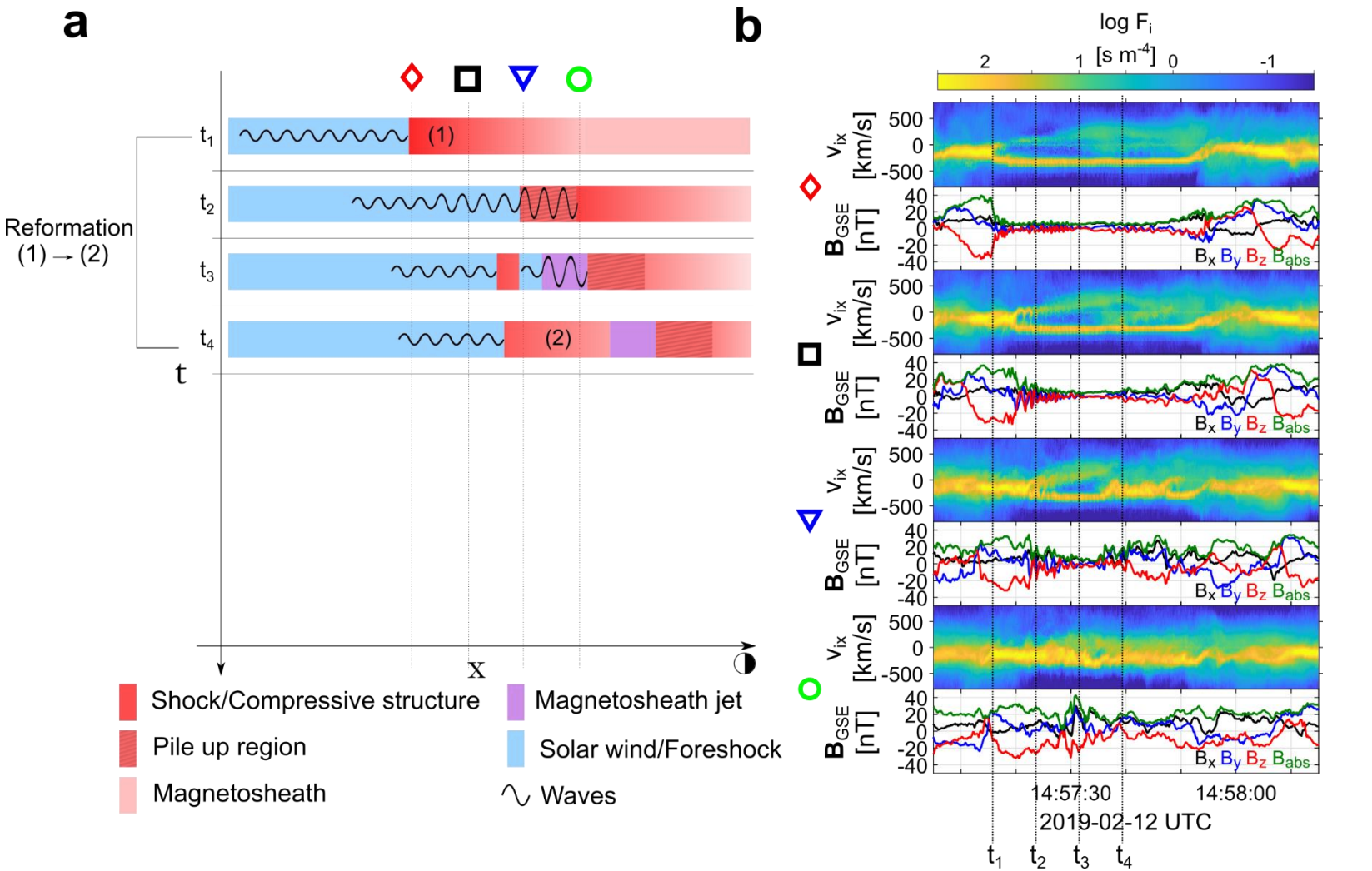
Formation mechanism



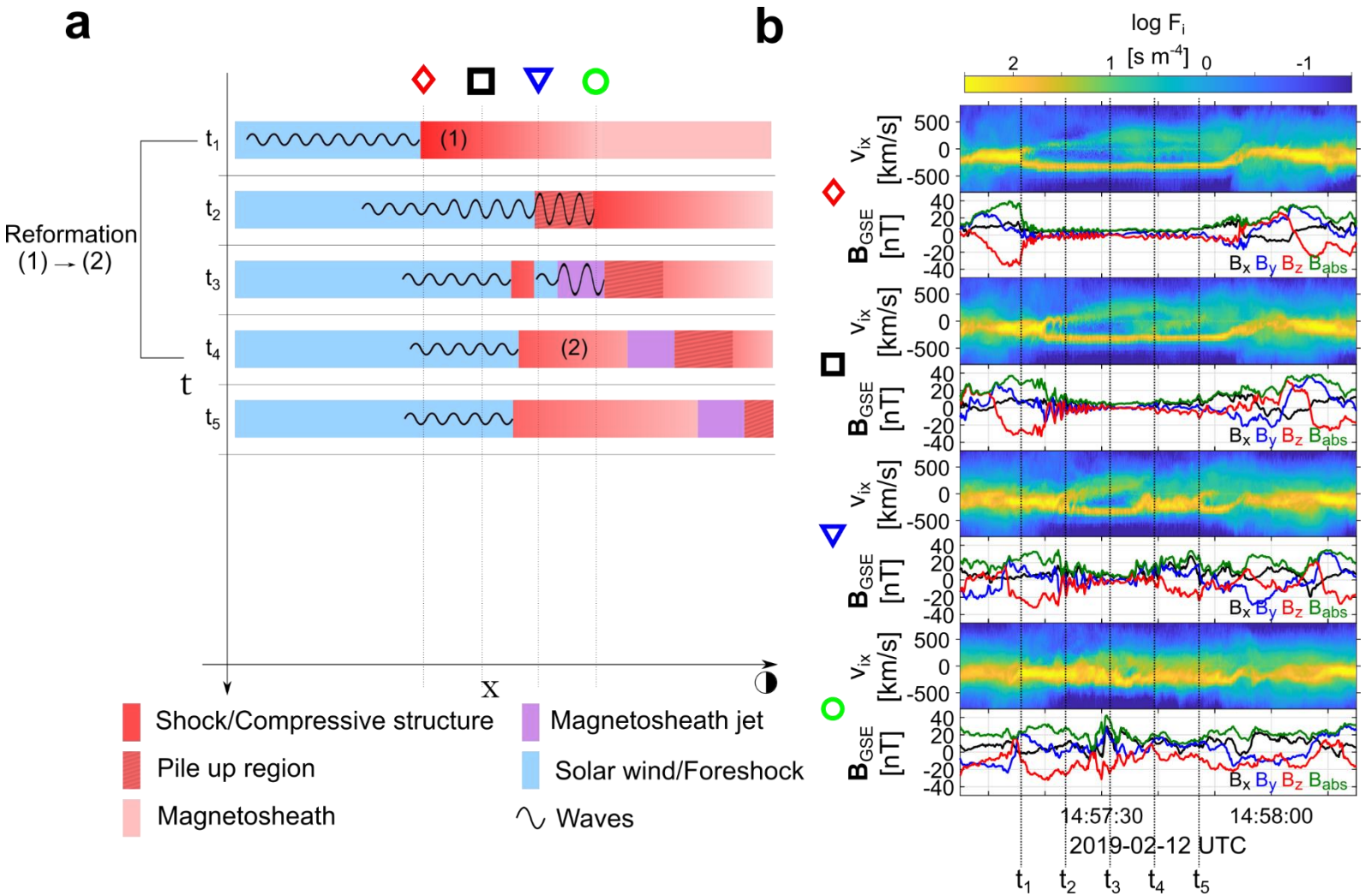
Formation mechanism



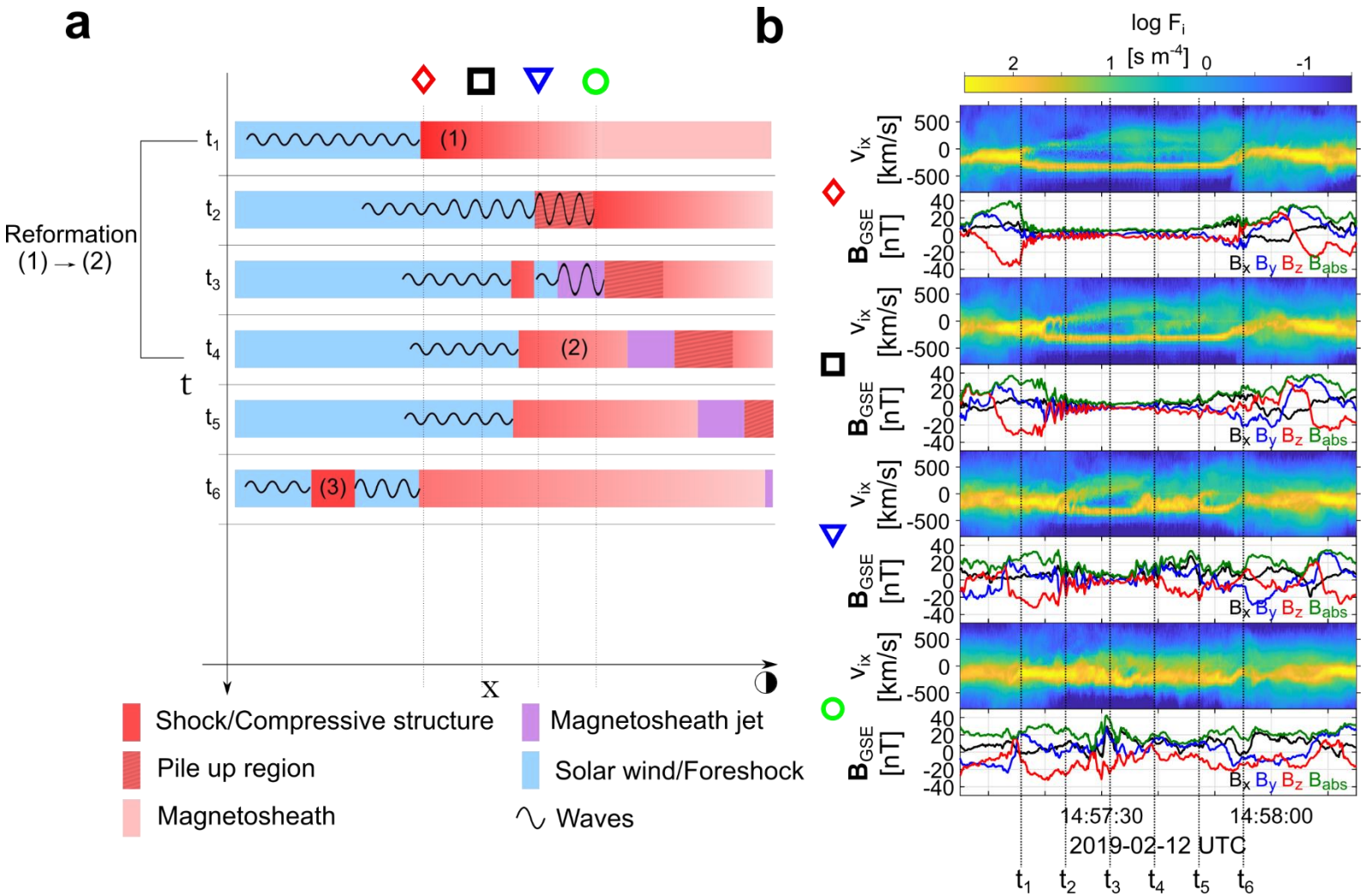
Formation mechanism



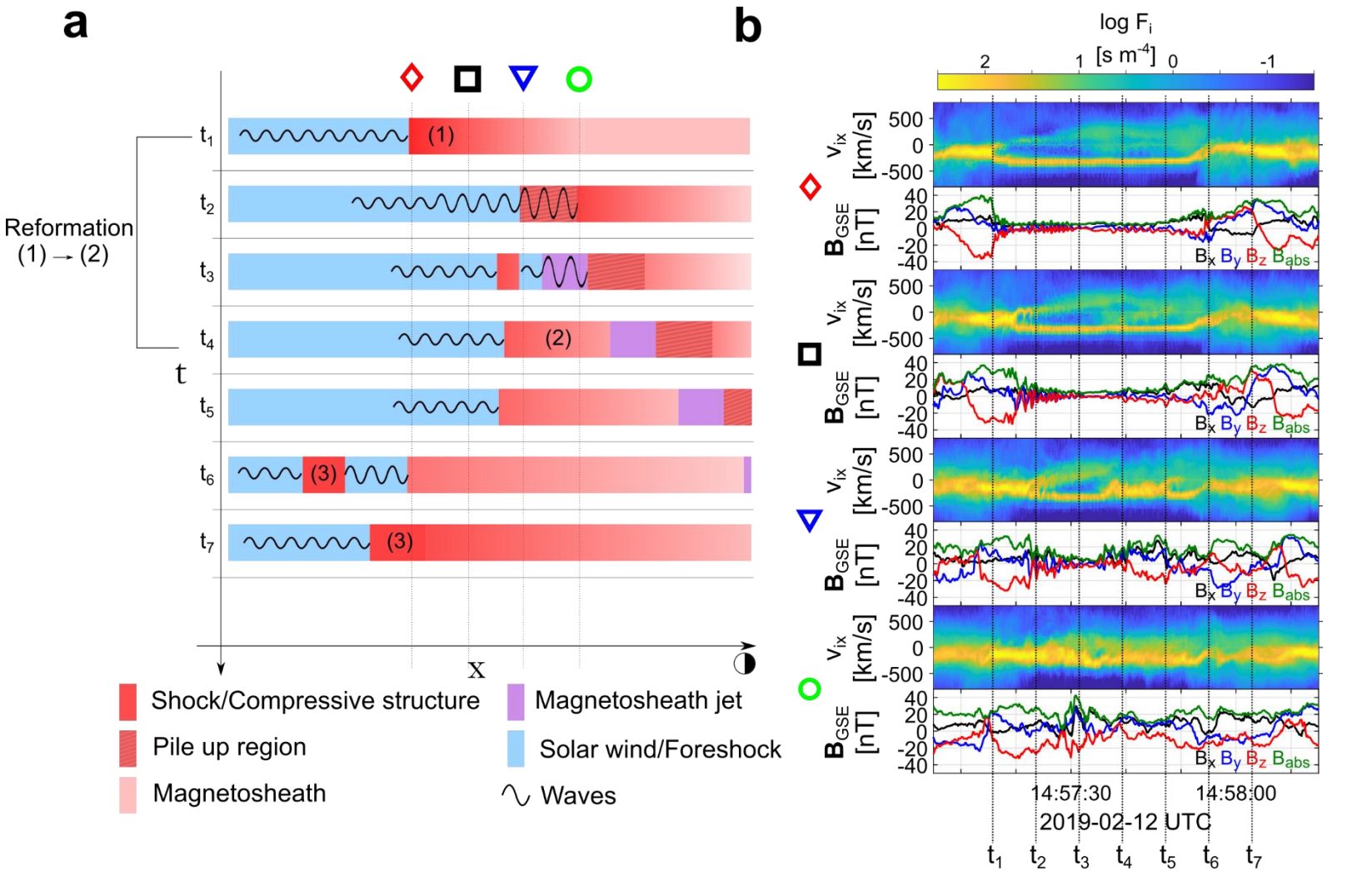
Formation mechanism



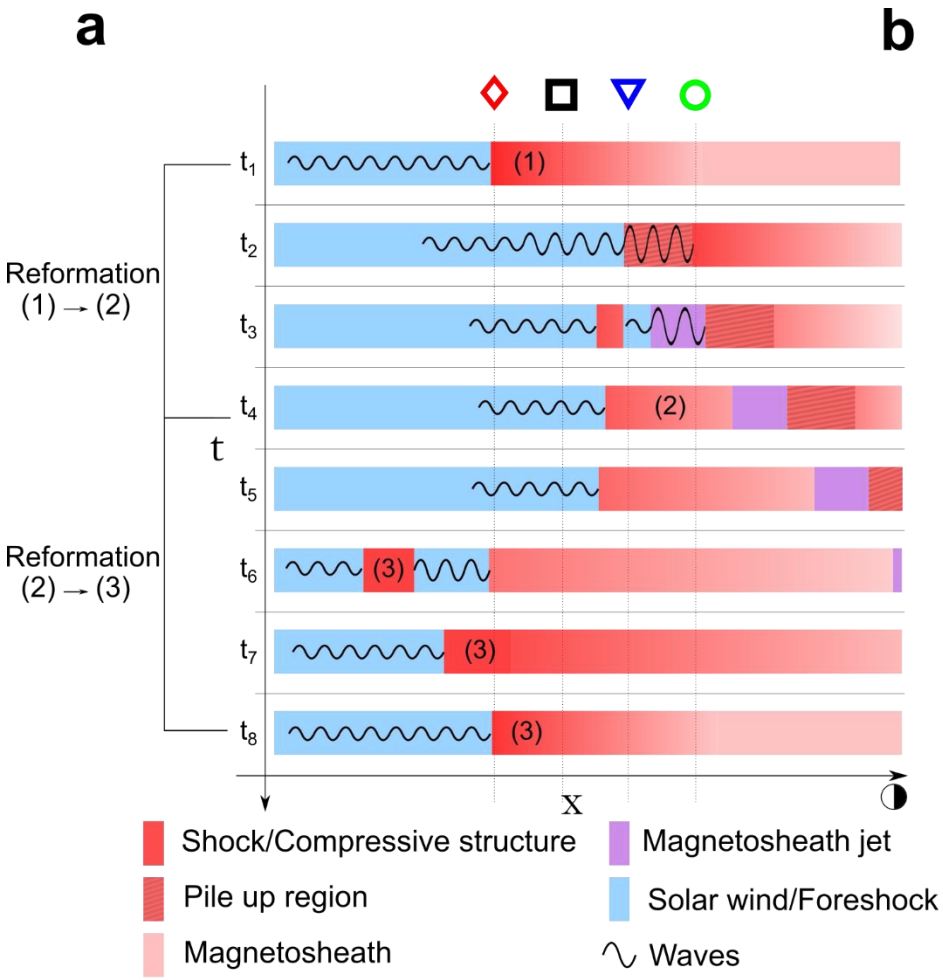
Formation mechanism

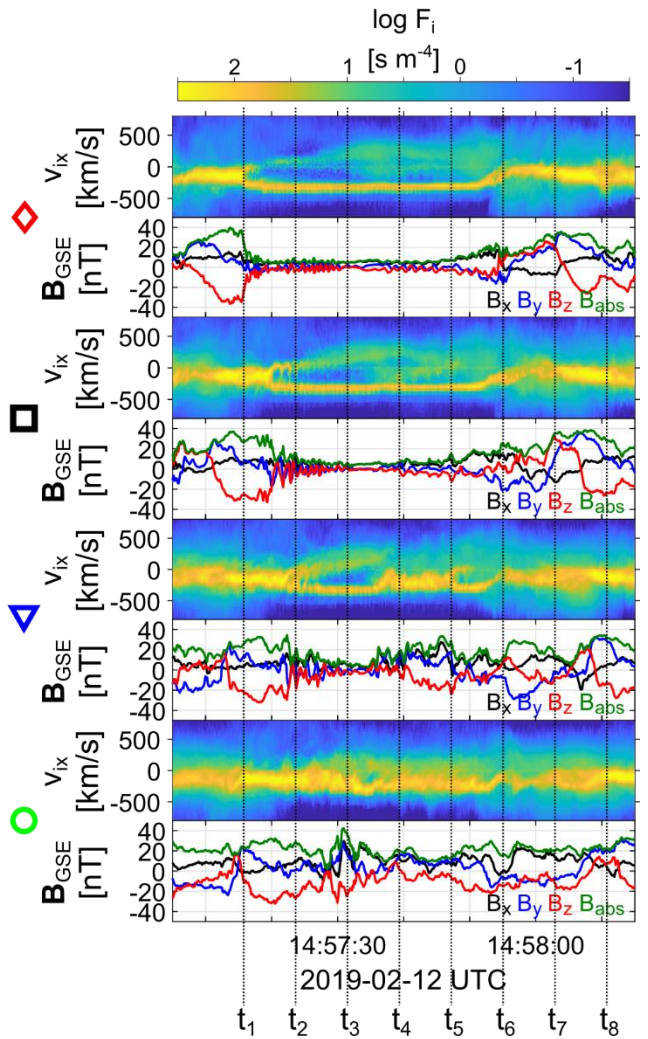


Formation mechanism



Formation mechanism





Summary & Conclusion

Main points

- ***In-situ* observations** of shock fronts (**SLAMS**) becoming "**embedded plasmoid**s" (density enhanced downstream regions).
- ***in-situ* observations** of **jets** forming by the dynamical evolution of collisionless shock (**reformation**)

Implications

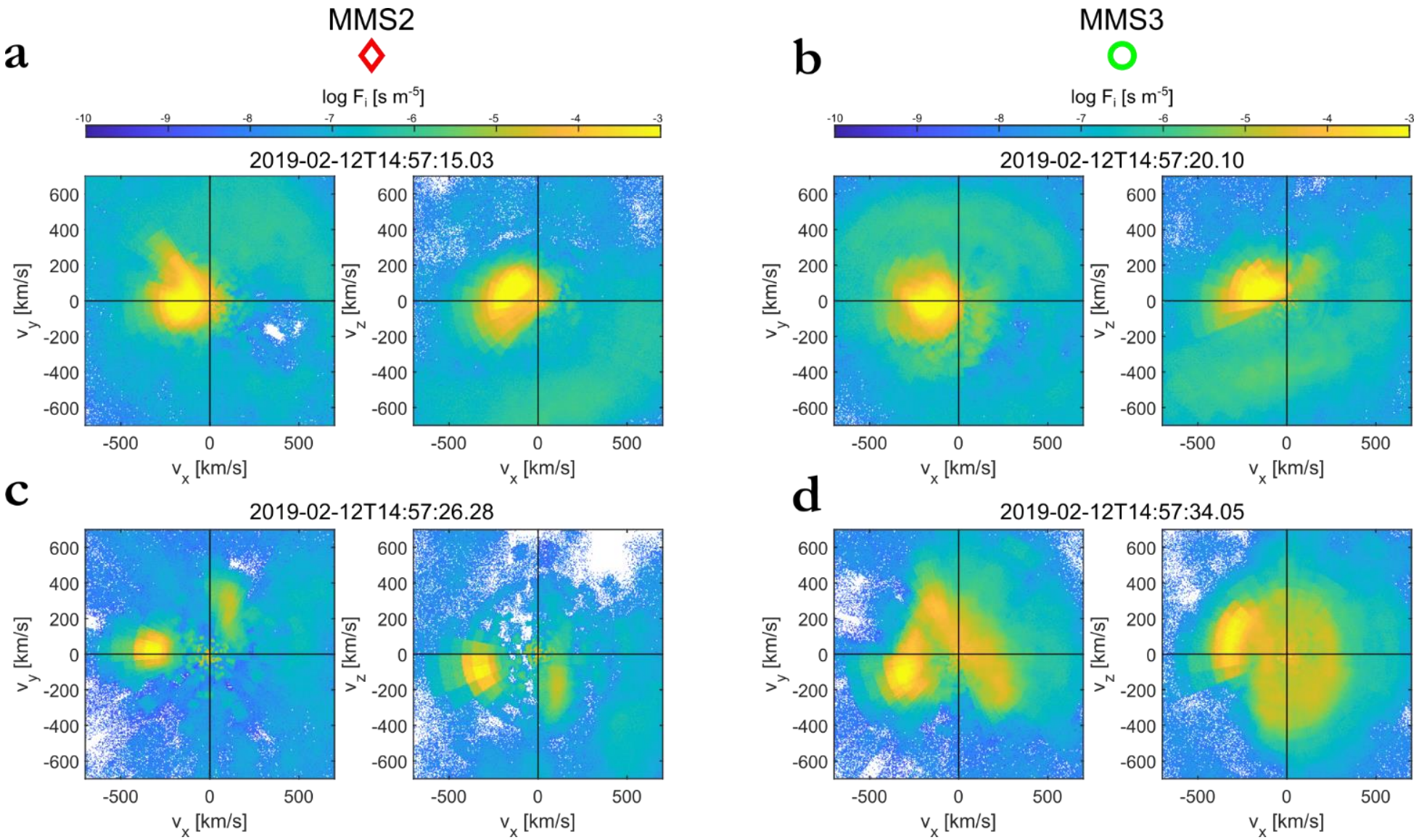
- Possibly a general process of collisionless shocks that can be found in planetary, astrophysical and laboratory shocks.

Future work

- *Simulation* comparison (connection with foreshock structures & reformation)
- *Statistics* (need more events, currently found 3 of similar signatures)
- *Modeling* (can this process explain jets close to MP ? Are these just a subset of small jets ?)

Extras

VDFs


MMS2
MMS3
a
b
c
d
log F_i [s m^-5]
-10 -9 -8 -7 -6 -5 -4 -3
2019-02-12T14:57:15.03
2019-02-12T14:57:20.10
2019-02-12T14:57:26.28
2019-02-12T14:57:34.05
v_y [km/s]
v_z [km/s]
v_x [km/s]
600 400 200 0 -200 -400 -600
-500 0 500

Jets database of MMS

Fast/Survey

9/2015 - 9/2020

Subset	Number	Percentage (%)
Quasi-parallel	2458	26.7
Final cases	**901**	10.1
Quasi-perpendicular	542	5.9
Final cases	**214**	2.3
Boundary	781	8.5
Final cases	**191**	2.1
Encapsulated	80	0.9
Final cases	**60**	0.7
Other	5335	58.0
Unclassified/Uncertain	3789	41.2
Border	1500	16.3
Data Gap	46	0.5

Jets with full burst data →

Useful to study early properties & generation

Burst

Qpar	423
Qperp	34
Boundary	35
Encapsulated	31
Close to BS / MP	495
Others	428

Raptis S., Karlsson T., et al. (2020) | JGR
Raptis S., Aminalragia-Giamini S., et al. (2020) | Frontiers
Palmroth M., **Raptis S**., et al. (2021) | Annales
Kajdic P., **Raptis S**., et al. (2021) | GRL

Raptis, Karlsson, et al. (2022) | Accepted
Raptis, Karlsson, et al. (2022) | Ongoing

Fast/Survey MMS data

	Resolution (samples/s)
FGM (magnetic field):	0.0625
FPI (plasma moments | ions):	4.5
EDP (electric field):	0.0313

Pros

- ✓ Always available
- ✓ Decent resolution
- ✓ Can be good for statistics due to availability

Cons

- ✖ Not suitable for small scale studies especially these related to ion moments
- ✖ Could be misleading close to boundary surfaces (Magnetopause, Bow shock etc.) due to very similar observational signatures

Burst MMS data

Resolution (samples/s)
0.0078
0.15
0.00012218

Pros

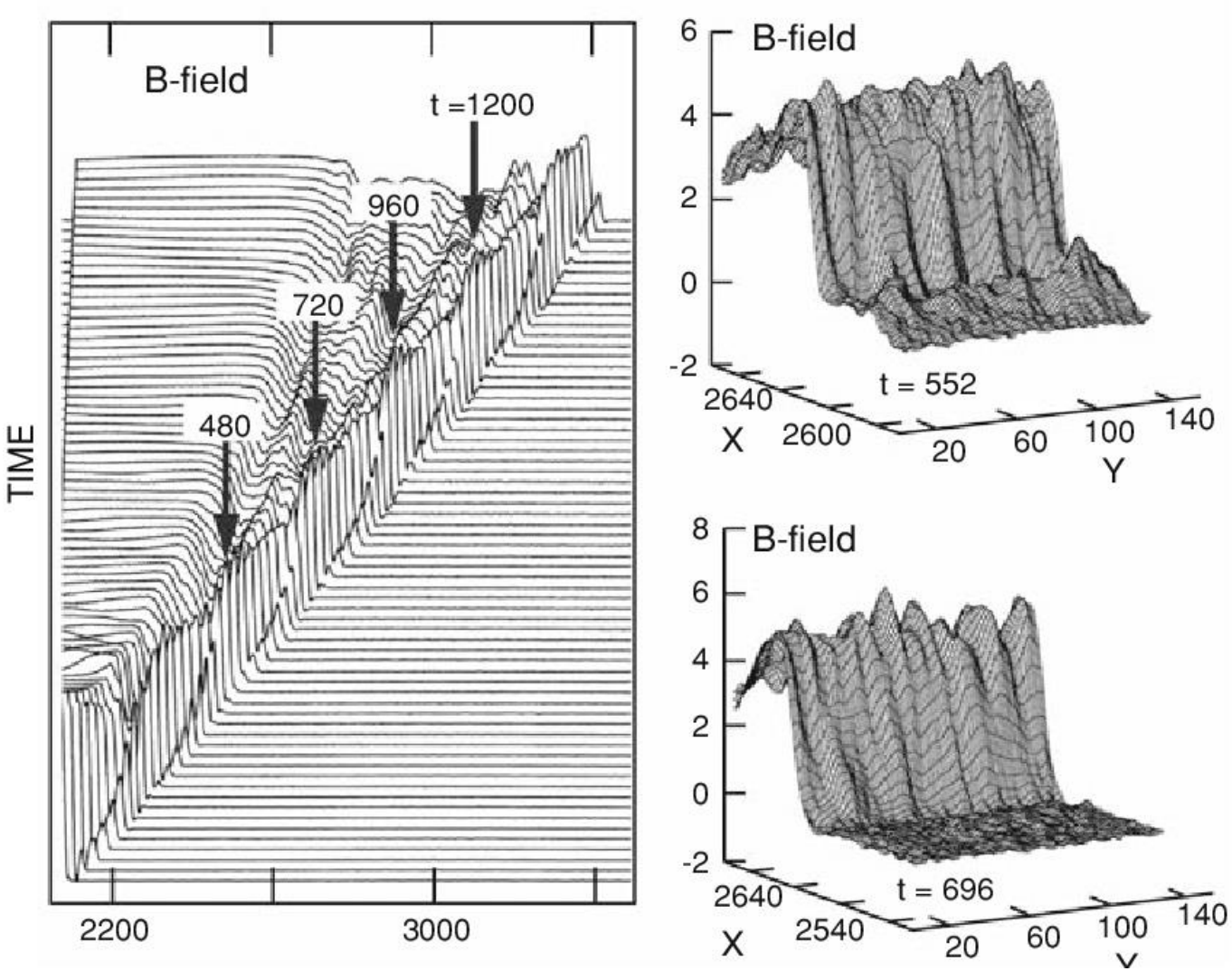
- ✓ Very high resolution
- ✓ Able to resolve structures close to boundary surfaces (e.g. mix of plasma close to magnetopause, bow shock, foreshock etc.)

Cons

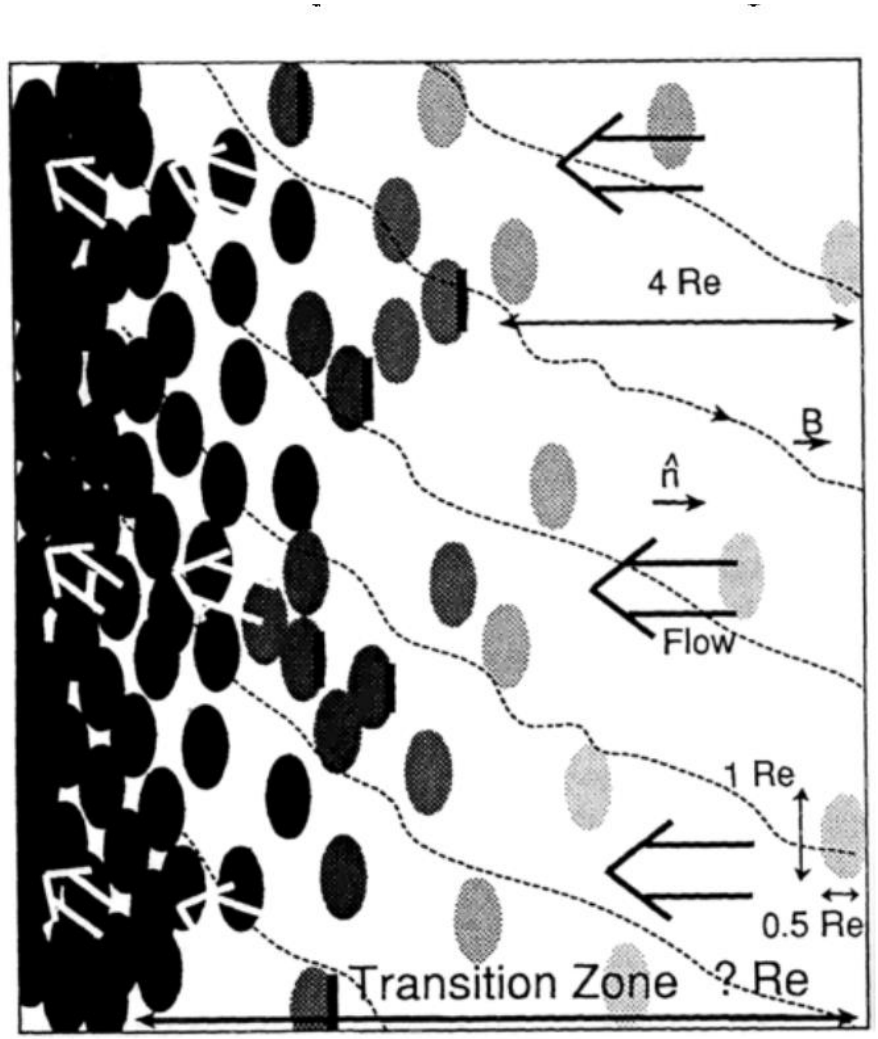
- ✖ Not available all the time, mostly available close to vital mission objectives (magnetopause, diffusion regions, shock transitions etc.)
- ✖ Hard to do proper large scale statistics due to biases generated from specific availability and manual choice of intervals

More information: Baker, et al. (2016) | Space Sci Rev 19

Shock Reformation idea



Lembège and Savoini 2002



Schwartz, 1990