Upstream Plasma Waves and Downstream Magnetic Reconnection in a Reforming Quasi-parallel Shock

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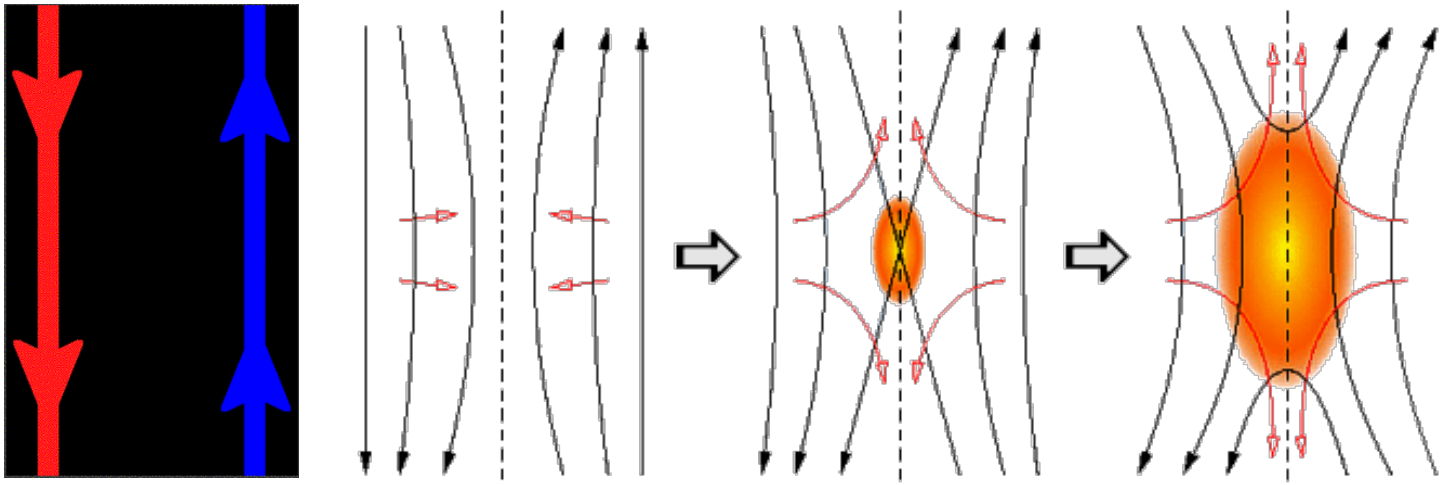
- **Magnetic reconnection in the magnetosphere**
- **Observations of reconnection in the magnetosheath**
- **Magnetic reconnection in the quasi-parallel shocked magnetosheath**
- **Summary**

Magnetic Reconnection

Magnetic reconnection, where magnetic field lines are topologically rearranged, provides a conversion from magnetic energy into plasma kinetic energy.

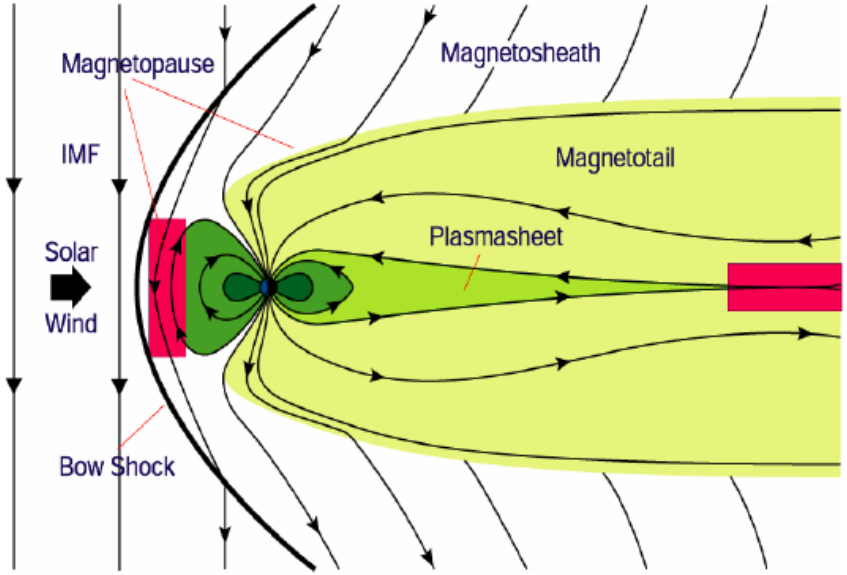


Magnetic Reconnection in the Magnetosphere

Cross-Scale

Earth's magnetosphere

Collisionless reconnection "laboratory"



- Most easily accessible place in space where in-situ observation of both plasma and fields can be performed to probe the energy release and magnetic reconfiguration process of reconnection

Magnetopause and magnetotail are two sites where reconnection occurs

[Lu, Fu, Wang, Lu, Chin. Phys. B, 2022]

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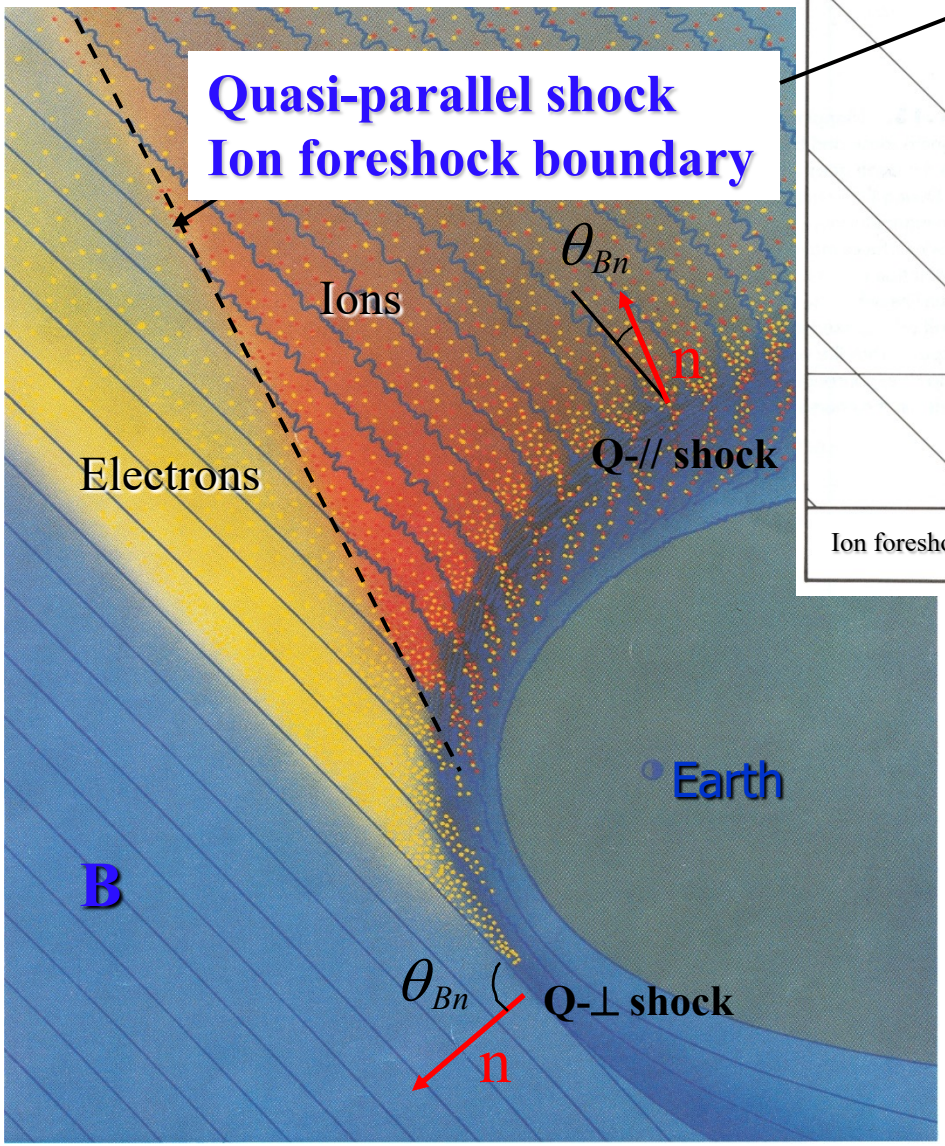
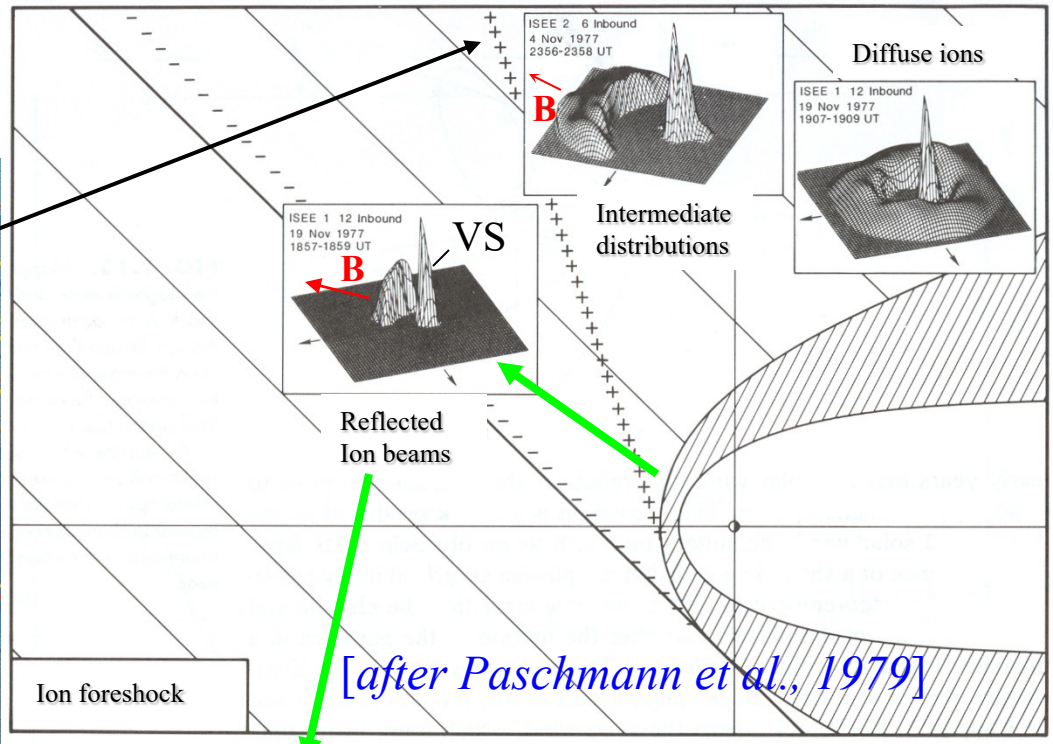
Bow shock

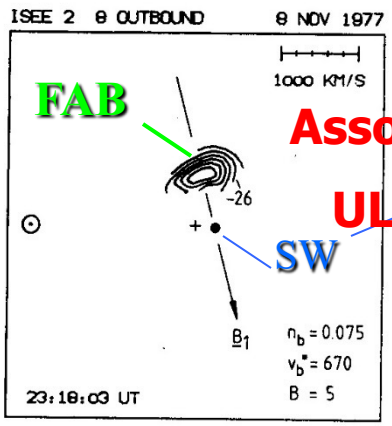


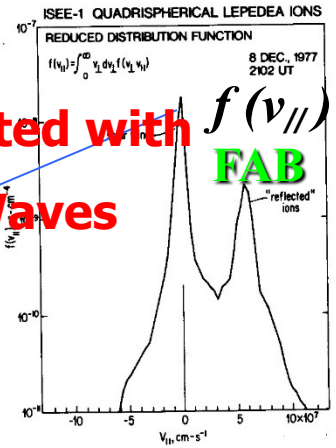
[after *Tsurutani and Rodriguez, 1981*]



[*after Paschmann et al., 1979*]

Field-aligned beams (FABs)





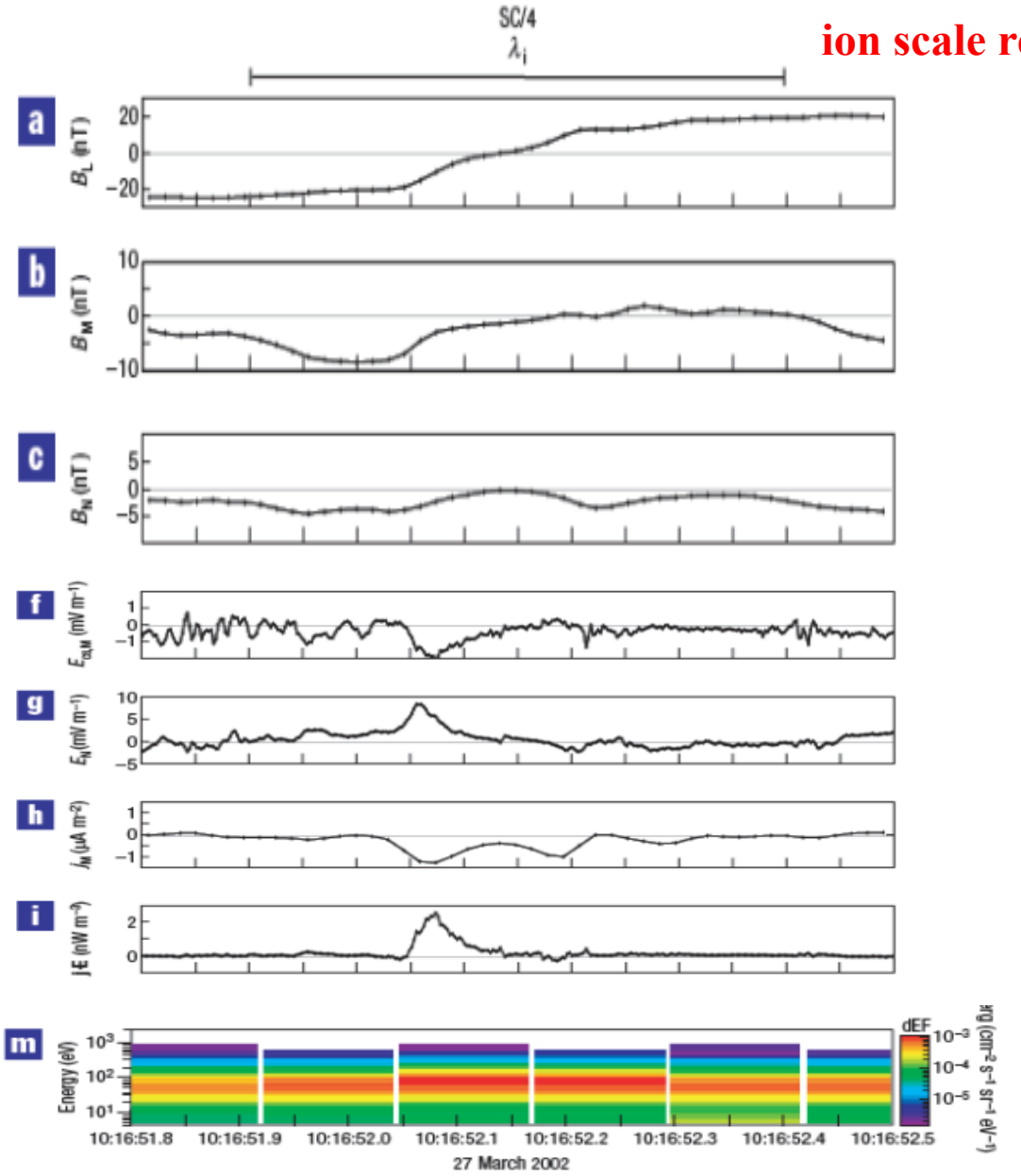
Associated with $f(v_{//})$

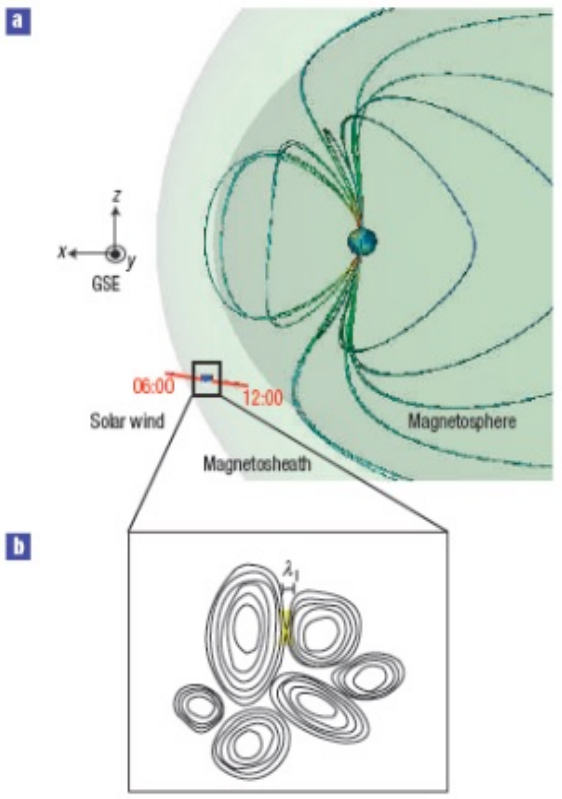
ULF Waves

[*Paschmann et al., 1981*] [*Sentman et al., 1981*]

Observations of magnetosheath reconnection

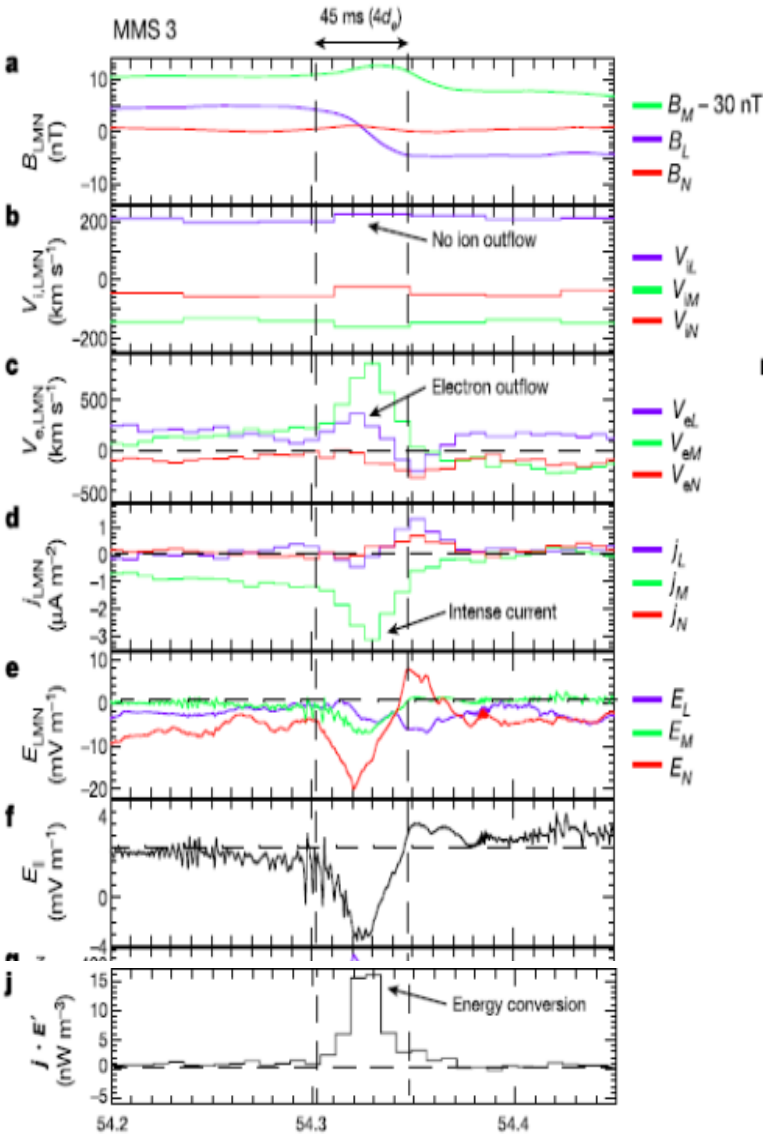
ion scale reconnection

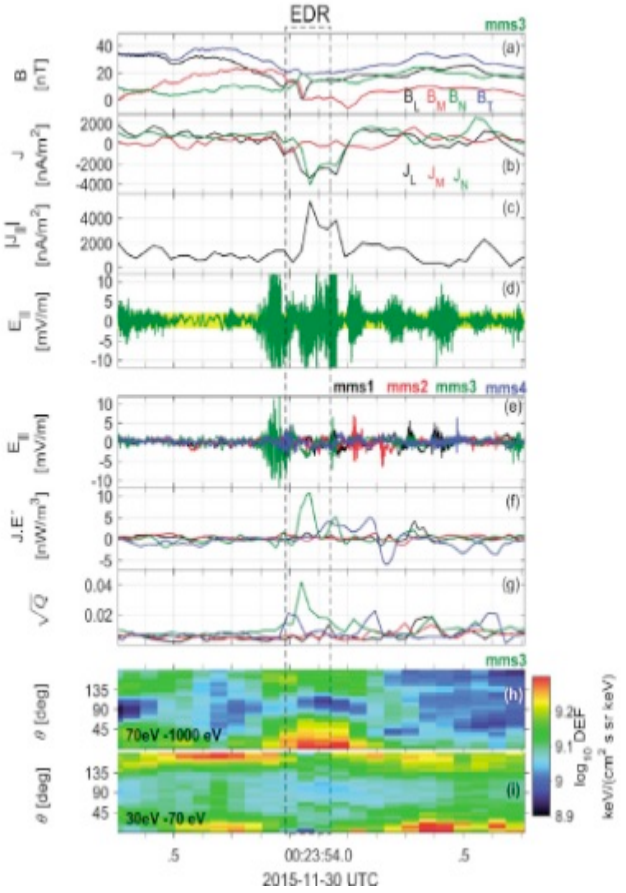




Cluster observations of magnetic reconnection in quasi-parallel shocked magnetosheath [Retino et al., 2007]

electron scale reconnection[Phan et al., 2018]





MMS observations of magnetic reconnection in quasi-parallel shocked magnetosheath [Voros et al., 2017; Phan et al., 2018; Wang et al., 2021; Xu et al. 2023]

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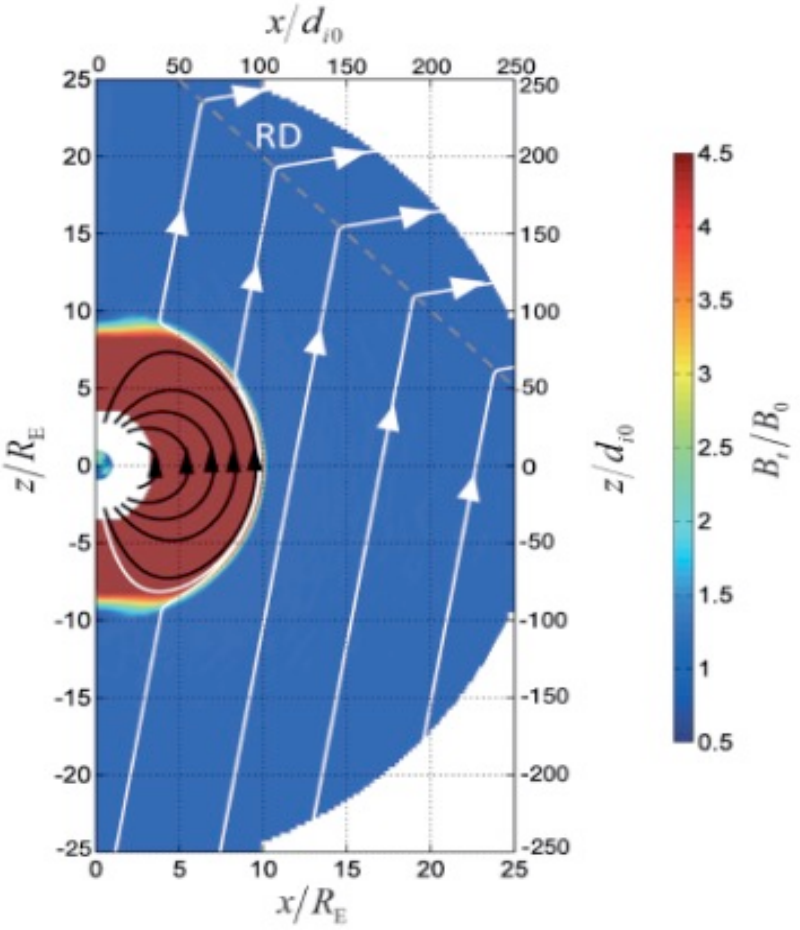
Global hybrid simulations



3-D global hybrid simulation

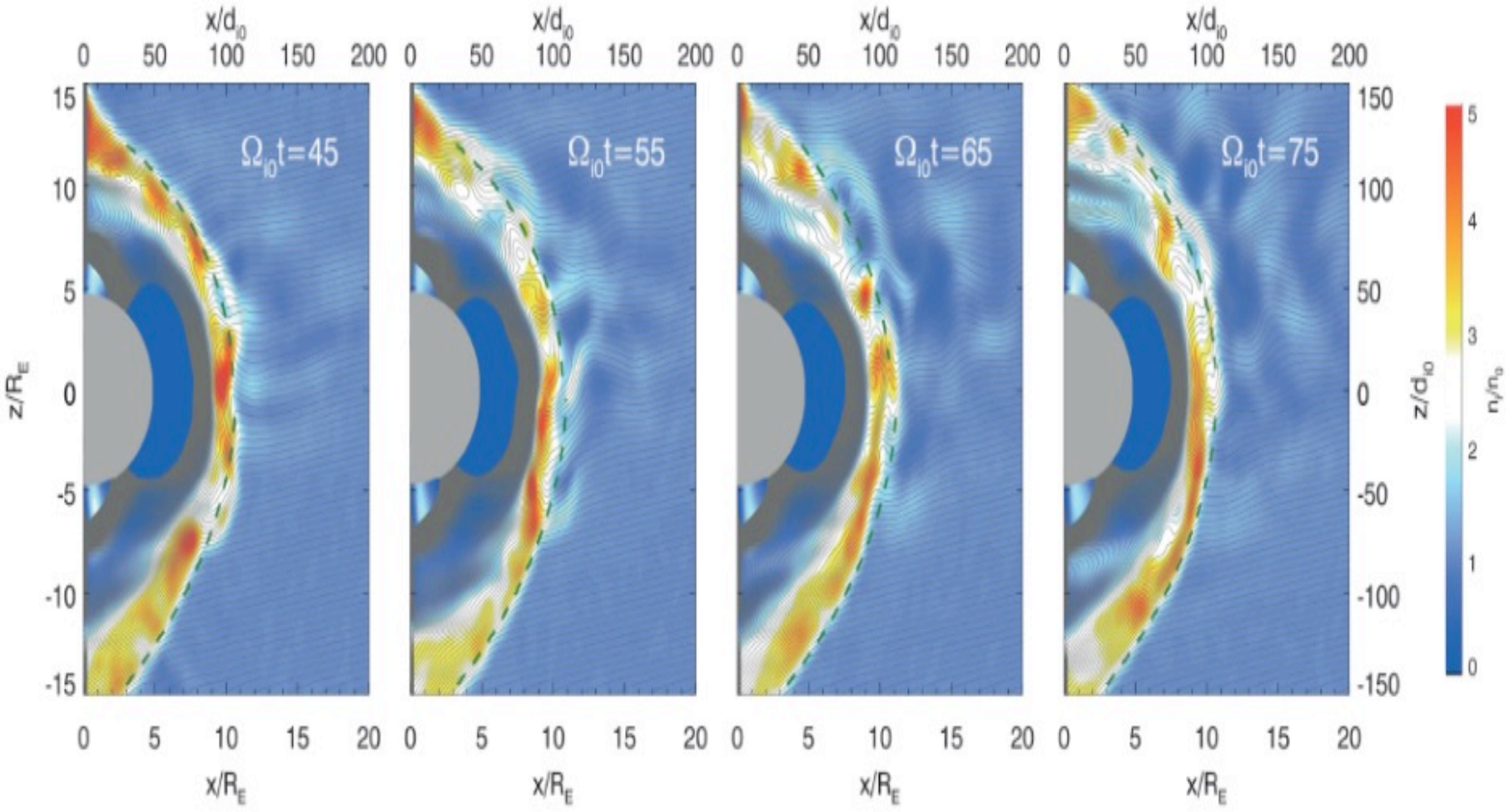
Spherical coordinate system

$$R_E = 10 d_{i0}$$

5 times smaller than the real earth

In the solar wind, there exists a rotational discontinuity to make that a quasi-parallel shock occurs around the subsolar point.
[Lu et al., GRL, 2020]

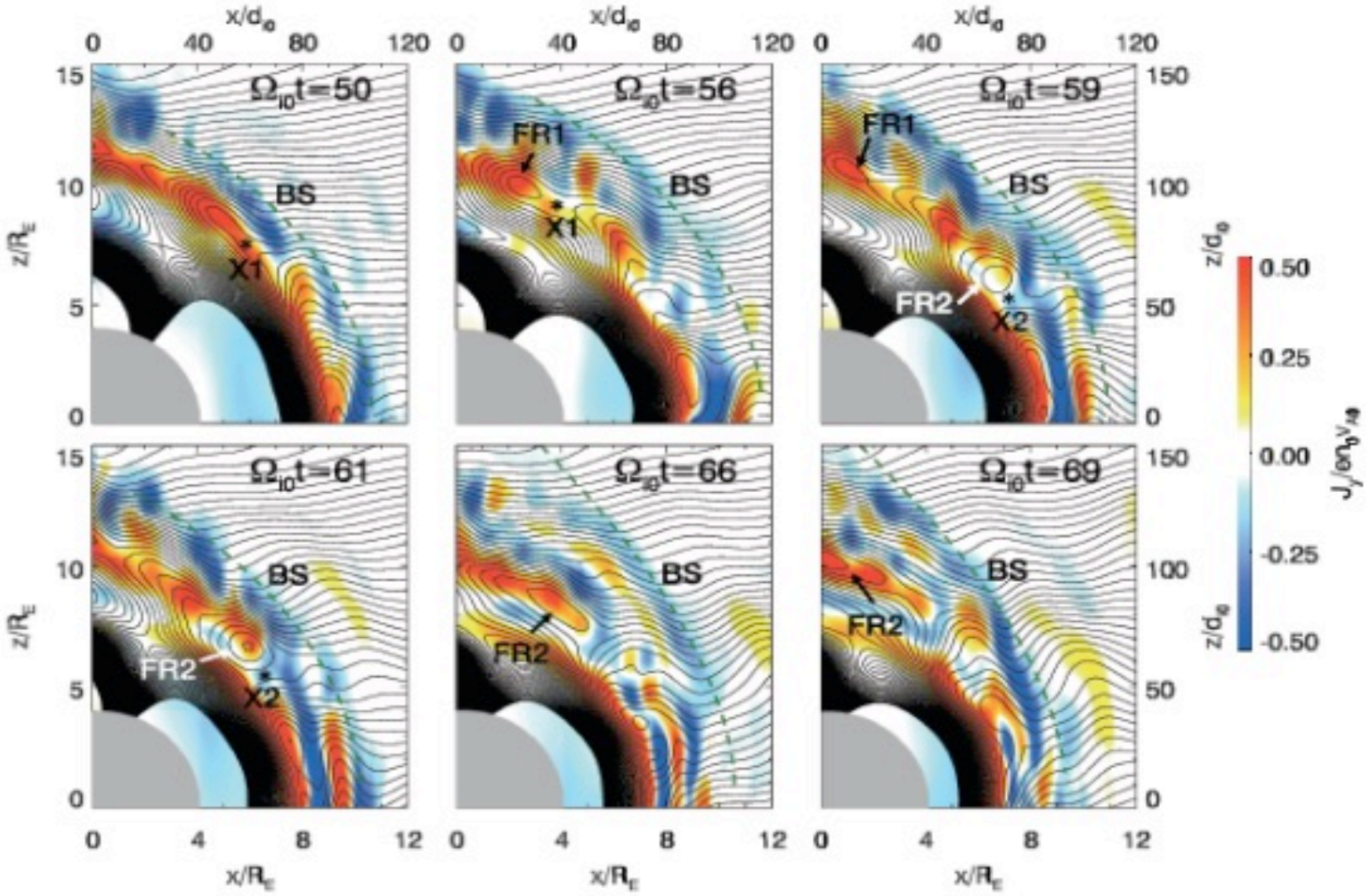
In the merdian plane



Upstream: large amplitude ULF waves

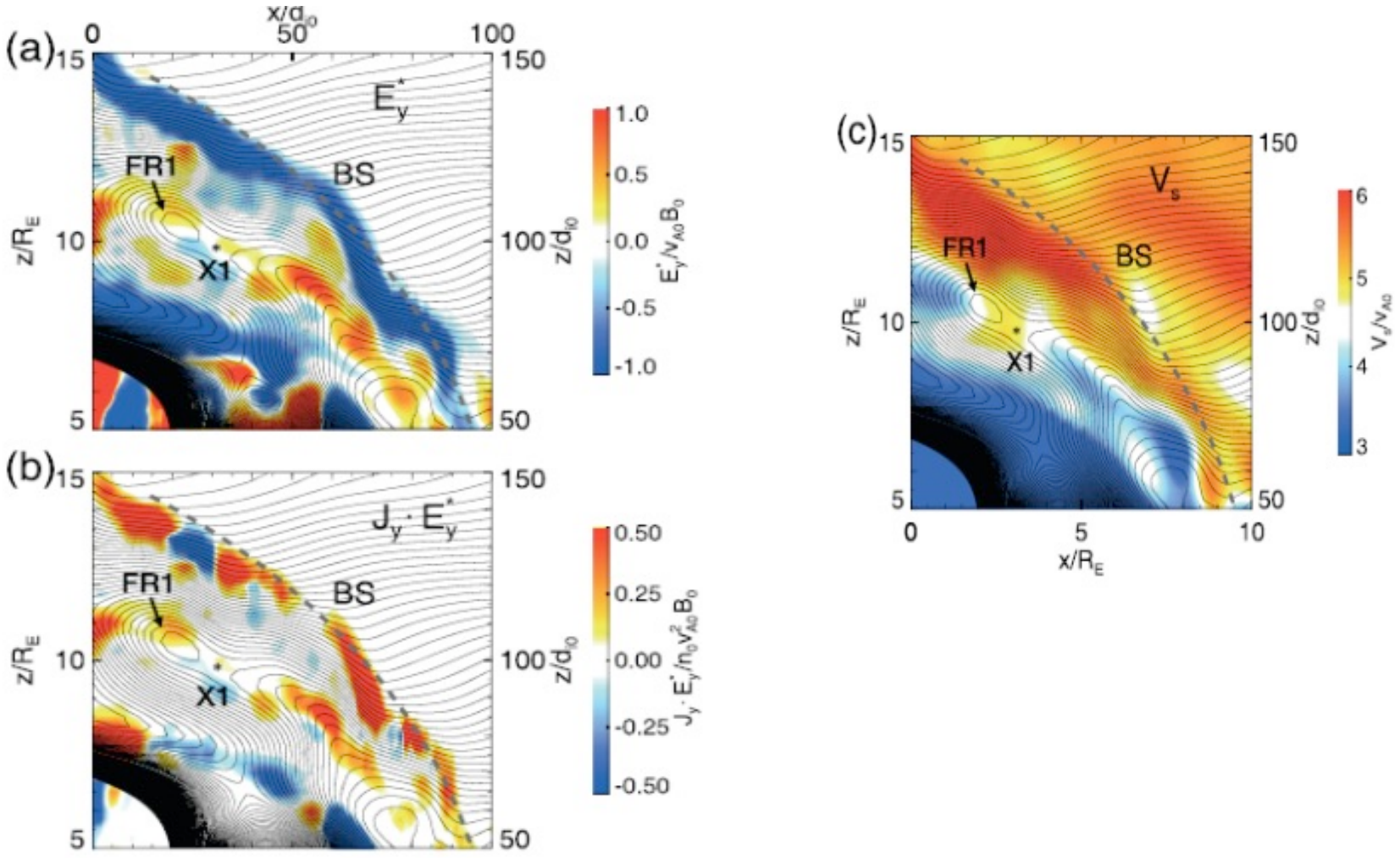
Downstream：Generation of flux ropes

In the merdian plane



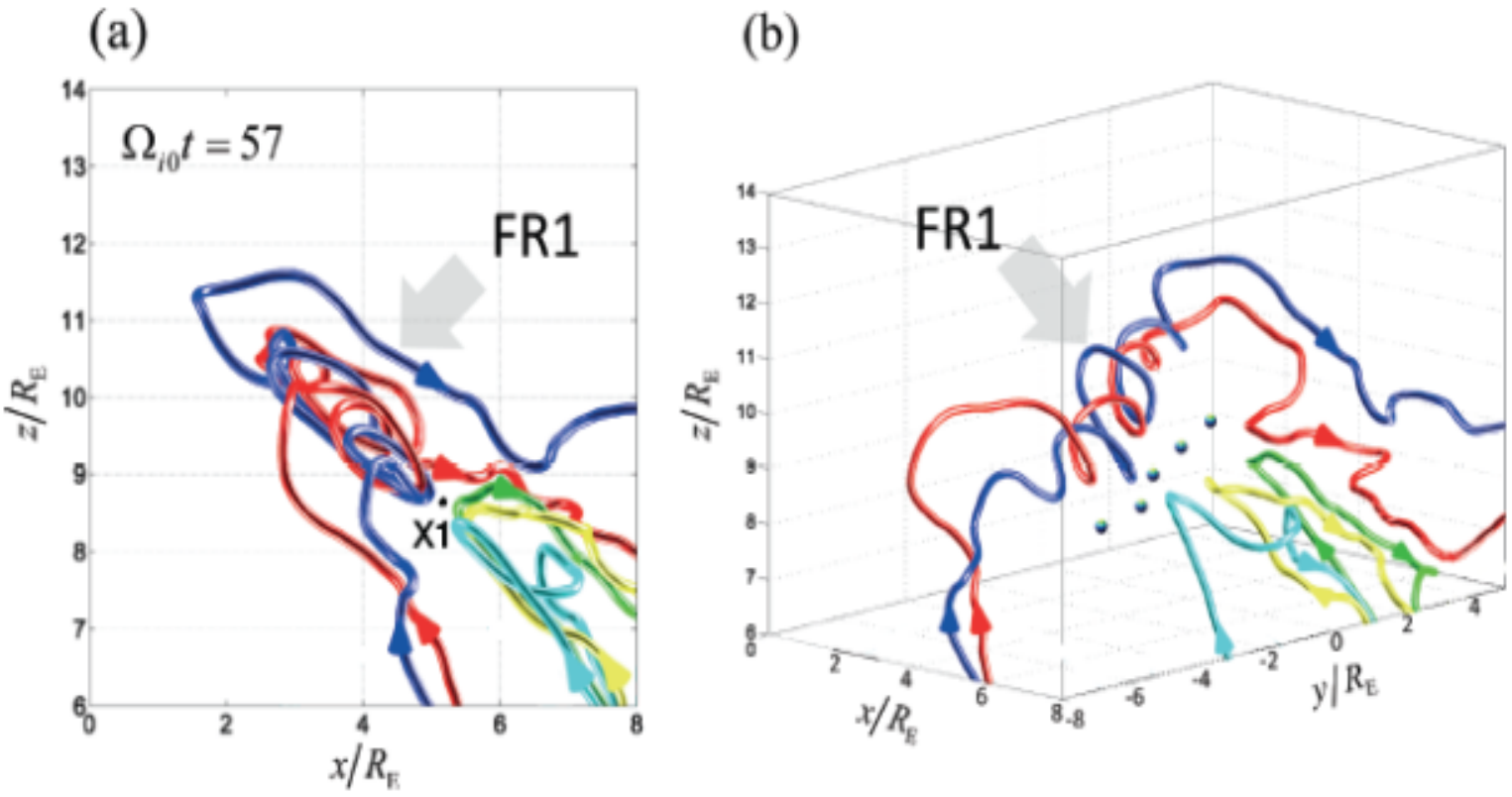
The evolution of flux ropes in quasi-parallel shocked magnetosheath. They generate around the subsolar point, and move to the auroral region.

In the merdian plane

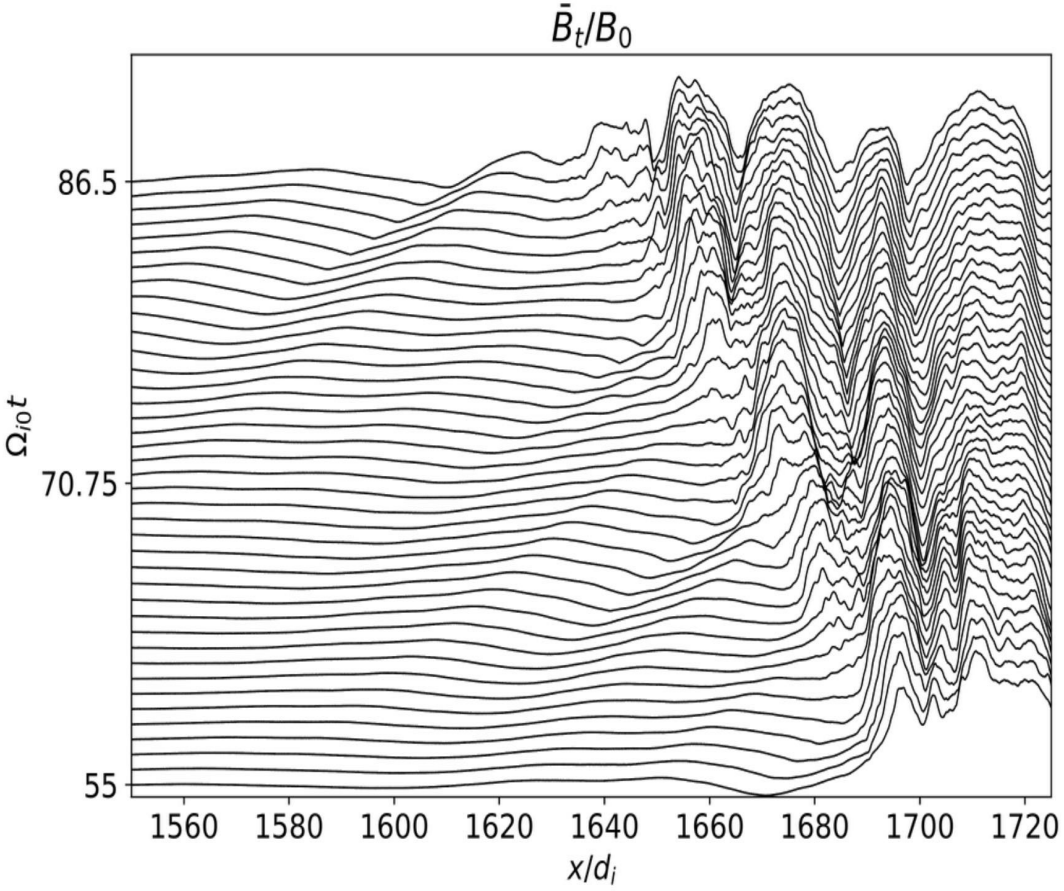


The electromagnetic structure in reconnection: energy dissipation around the X line, and high-speed outflow.

3D structure of flux ropes



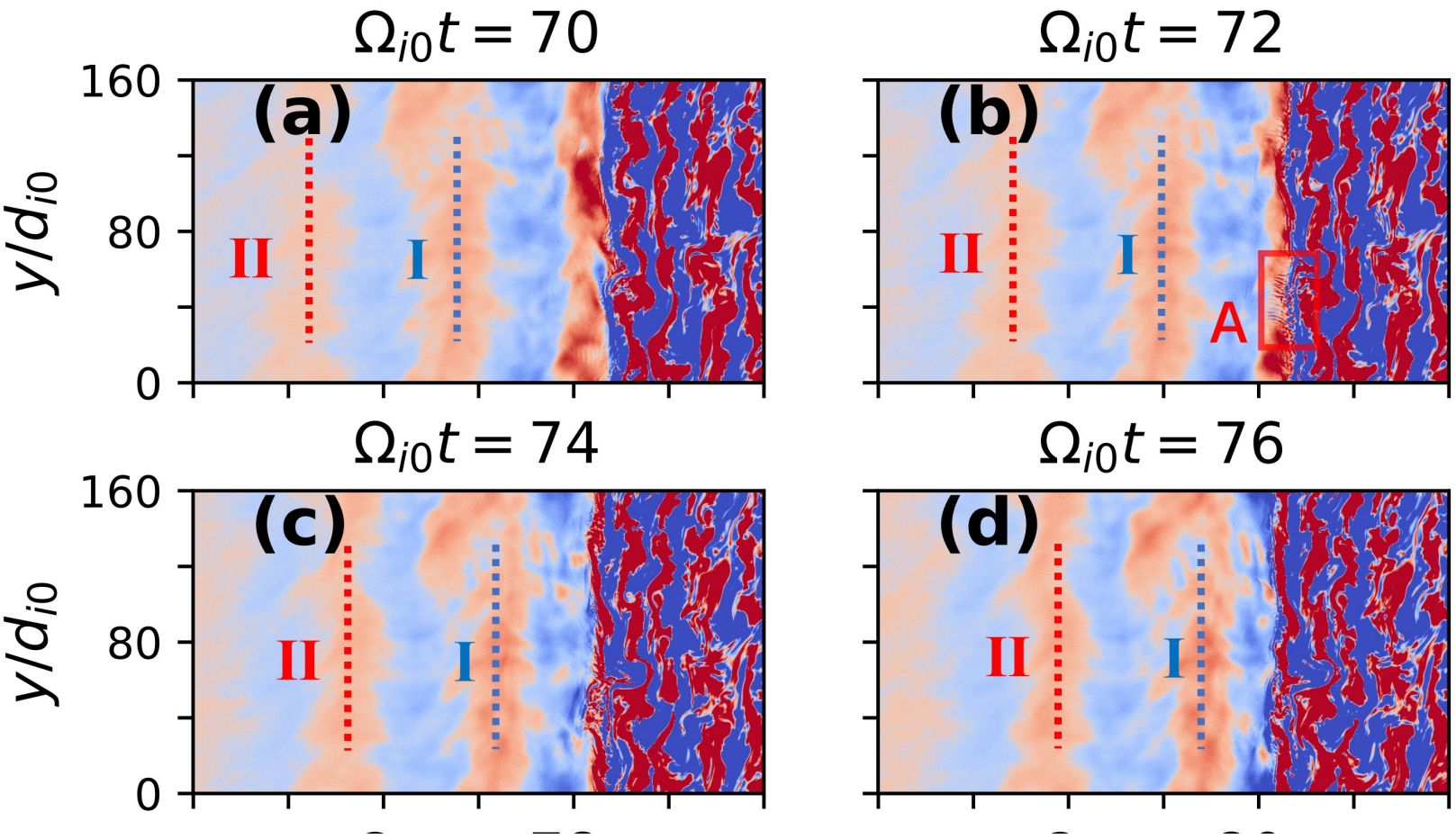
Three structure of generated flux rope and X line, and the extension of the X line is about several R_E (tens of ion inertial lengths) in the y direction. [Lu et al., GRL, 2020]



The 2-D local PIC simulation is performed in x-y plane

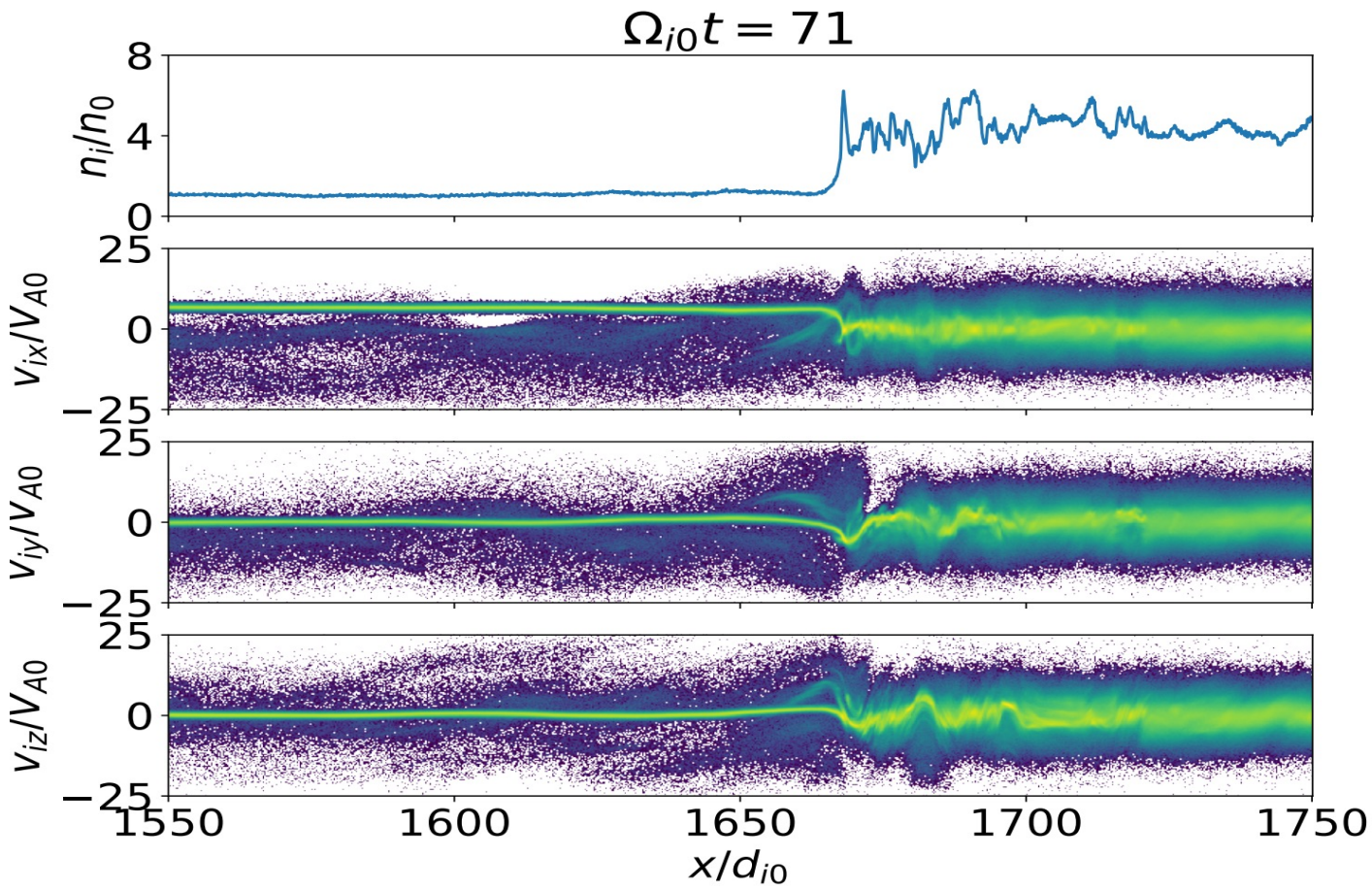
M_A~8-9, $\theta_{Bn}=20^o$, $m_i/m_e=100$, $L_x=1800d_i$, $L_y=160d_i$

The reformation of a quasi-parallel shock and the upstream ultrao-low frequency(ULF) waves.[Lu et al., ApJ, 2023(in revision)]



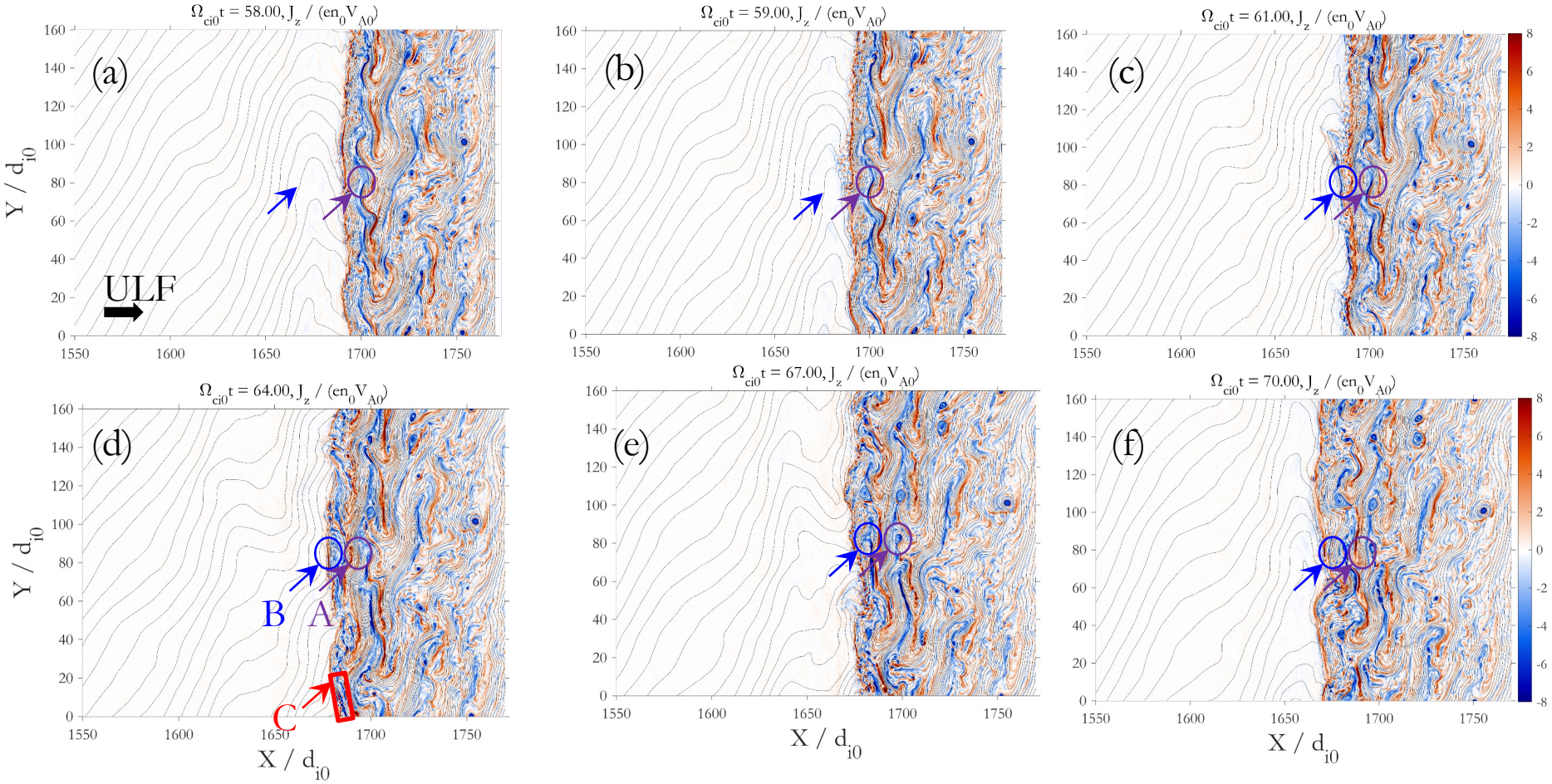
The upstream ULF waves excited by the ion-ion beam instability due to the reflected ion by the shock front.

The wavelength is about 75 ion inertial lengths. The wave propagate at about 1.8 Alfven speed to the left in the plasma frame, and frequency is about 0.15 ion gyrofrequency.



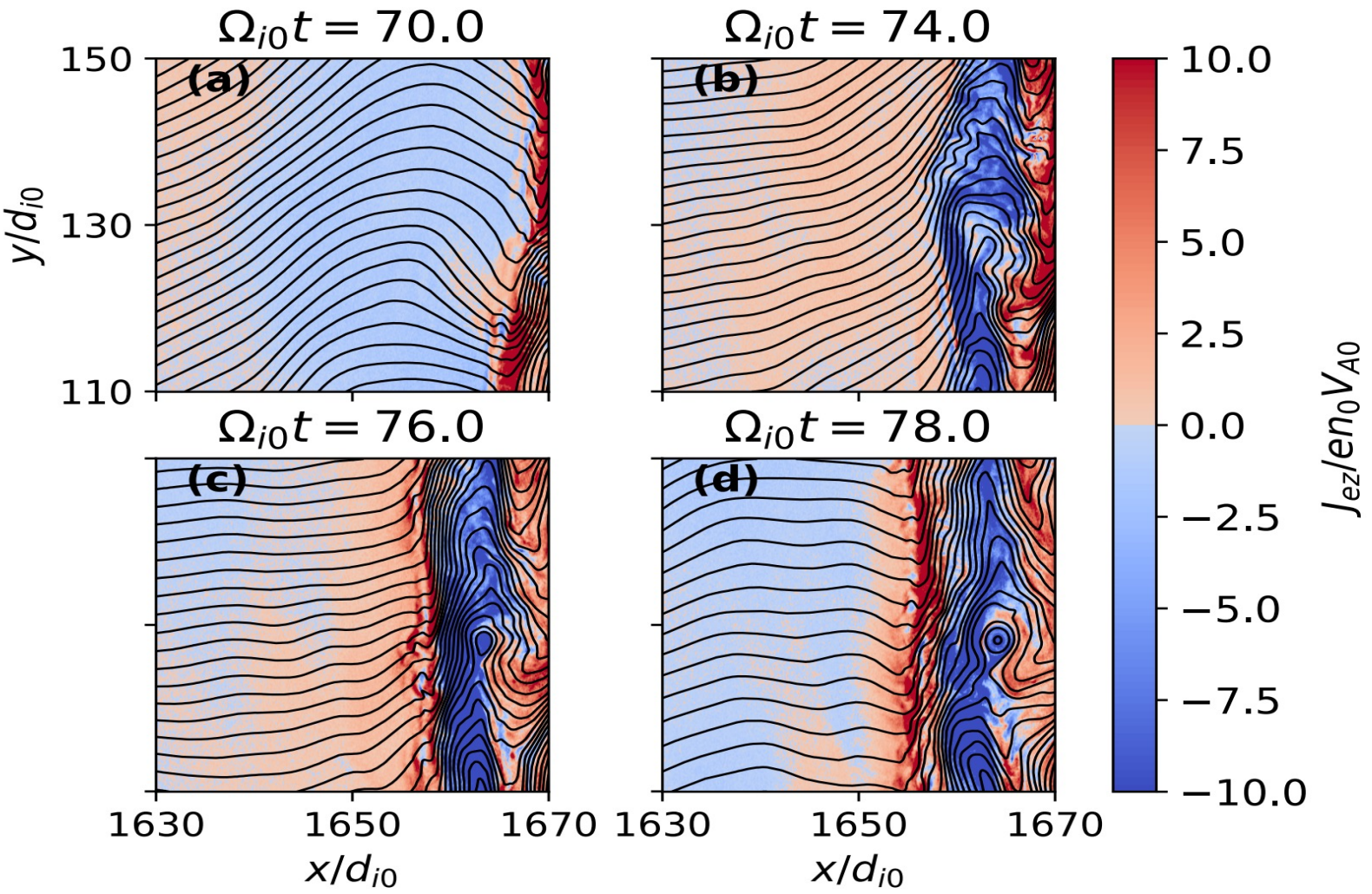
About 4% upstream ions are reflected by the shock, and the relative speed between the reflected ions and upstream plasma is about 13.1 Alfven speed. The resonant condition is satisfied.

in one reformation cycle

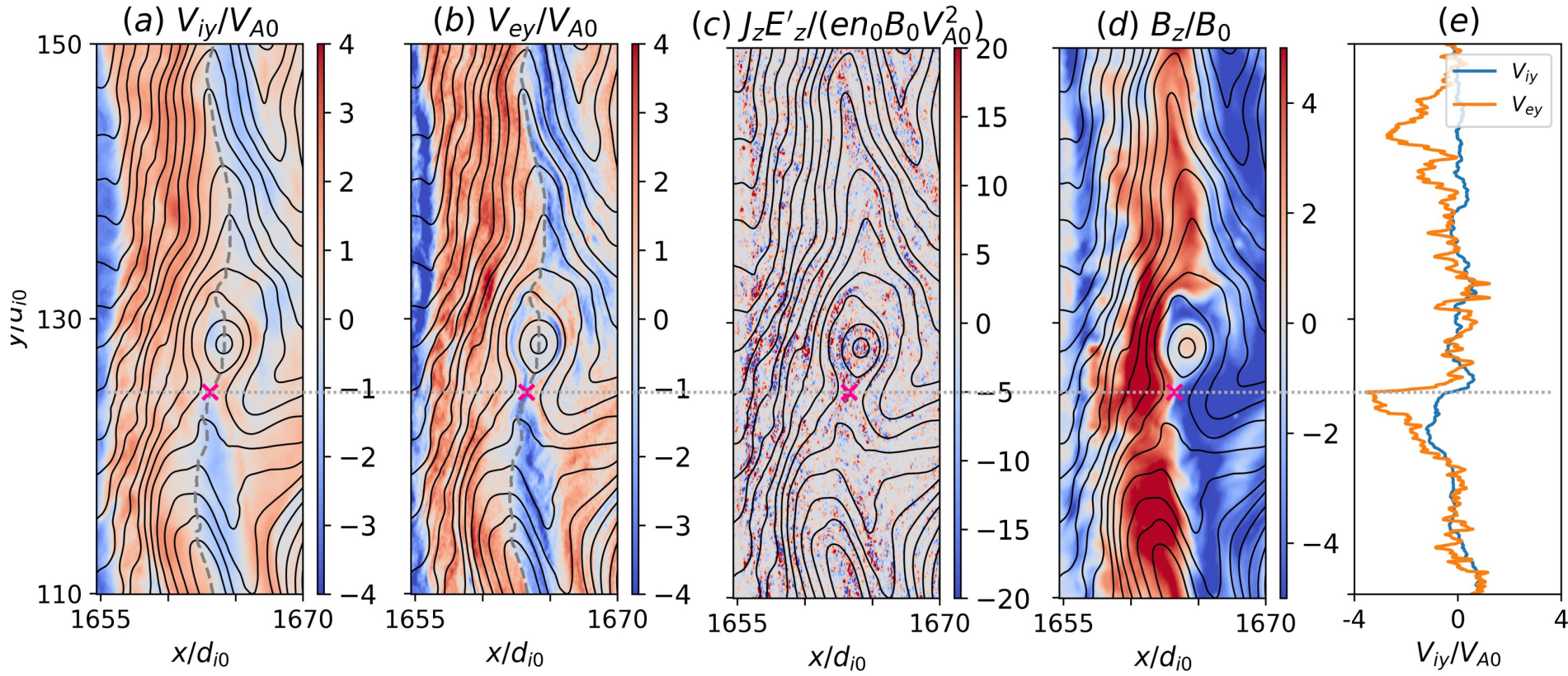


The current in the z direction in one reformation cycle. A current sheet is formed when the upstream waves approach and then penetrate the shock.

Magnetic reconnection occurs in the current sheets downstream of the shock.



The evolution of magnetic reconnection in the magnetosheath



The characteristics of downstream magnetic reconnection

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- **Magnetic reconnection can occurs in the downstream of a quasi-parallel shock.**

- **Current sheets are formed in the downstream after the large amplitude low frequency waves in the upstream penetrate the shock front to the downstream.**

Thanks for your attention!