Observations of Plasma Waves in the Multiple X-line Reconnection at the Magnetopause

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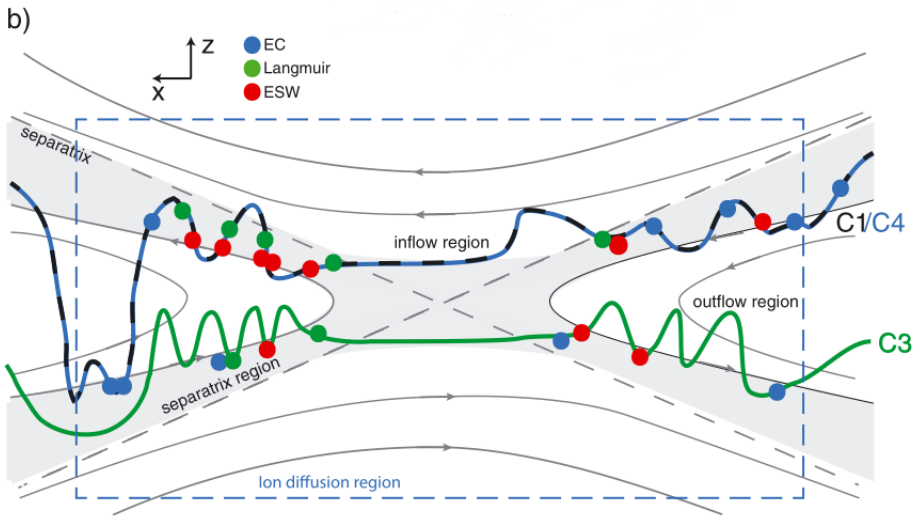
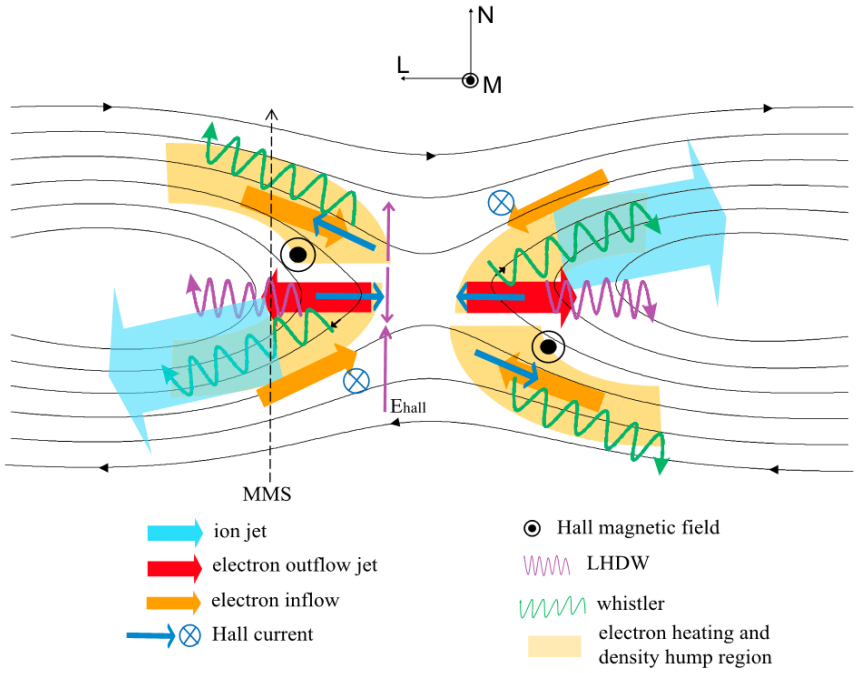
Introduction

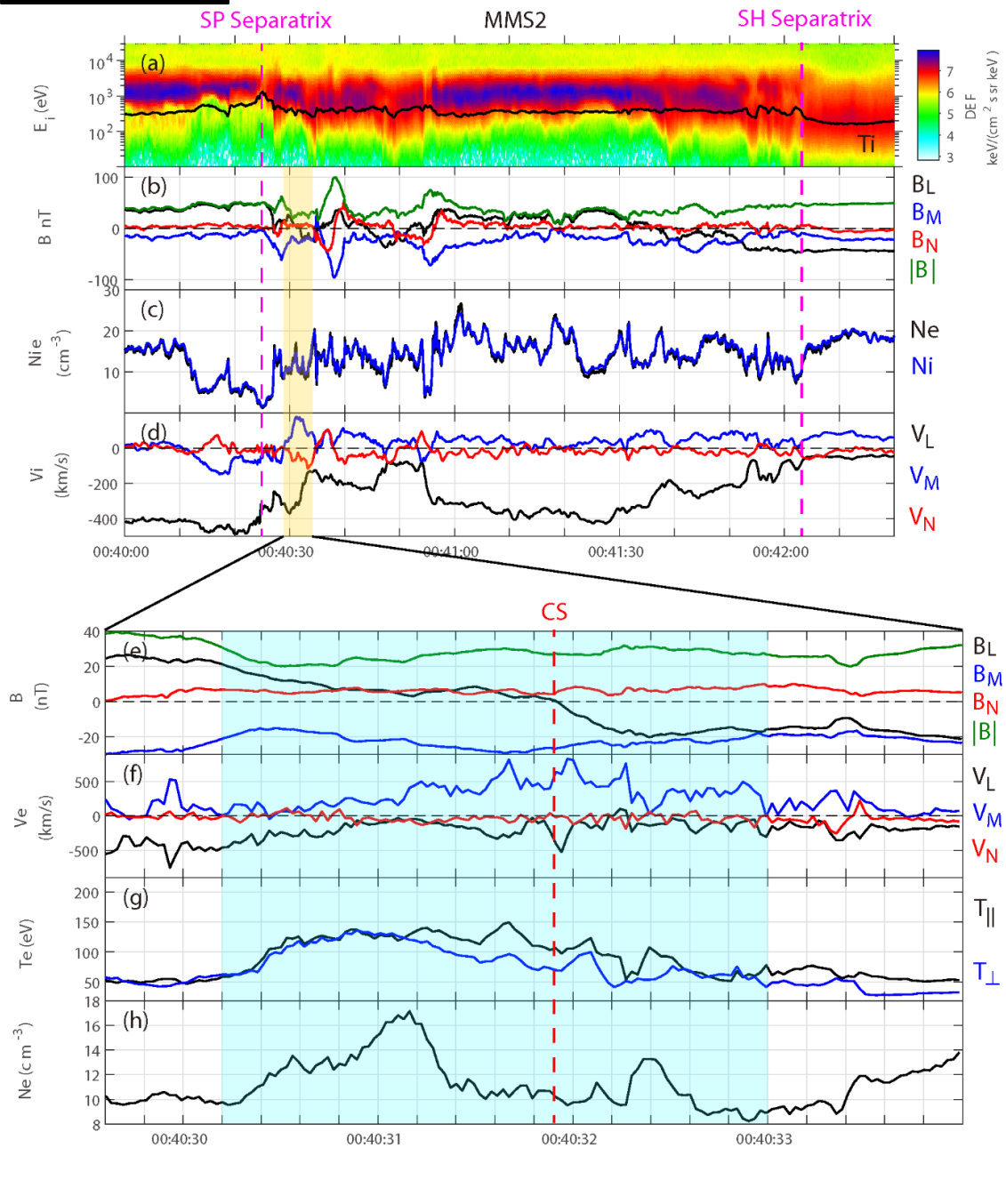
- Plasma waves are one of the important products of the magnetic reconnection process. Plasma waves can produce particle heating, diffusion, and anomalous effects, which can potentially affect magnetic reconnection.
- We investigate the evolution and properties of plasma waves during a multiple X-line reconnection event.



[Viberg et al., 2013]

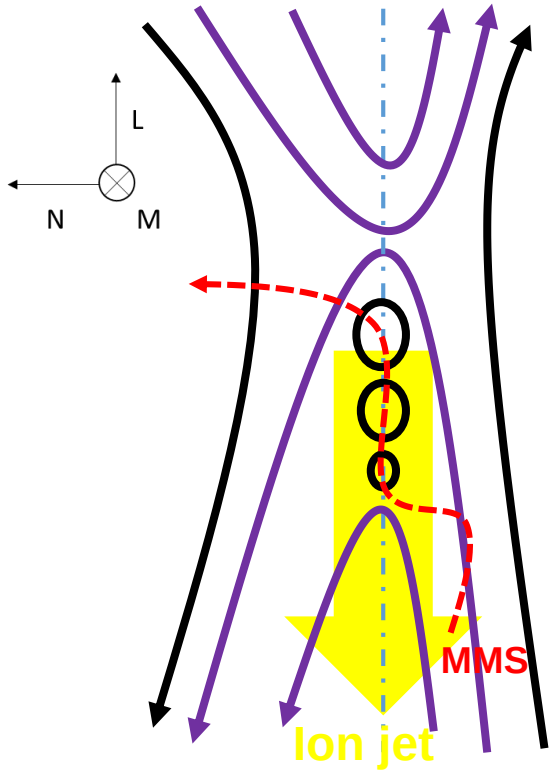


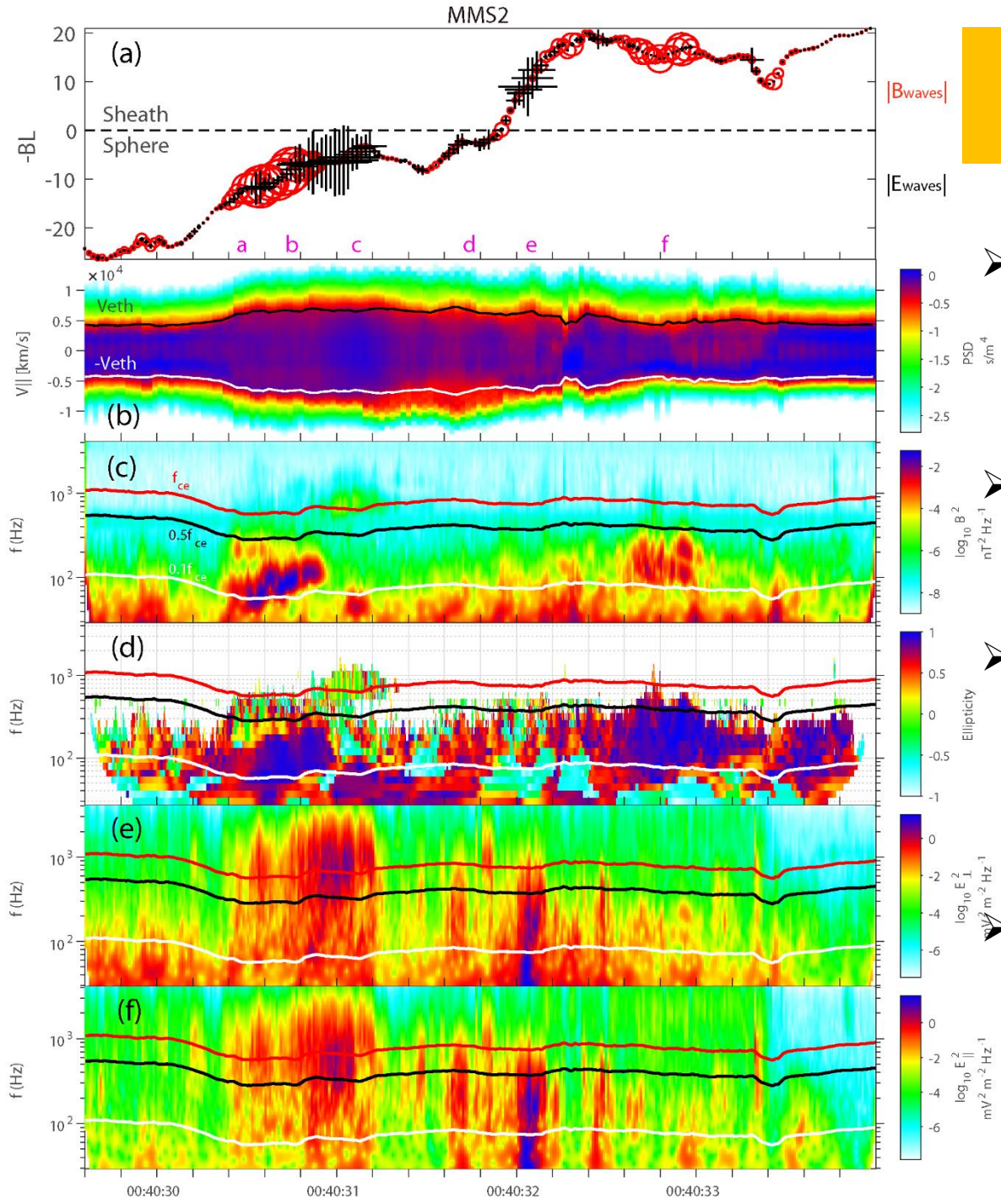
[Zhou et al., 2018]



Event Overview

- Three ion-scale FRs were observed within the south exhaust of magnetopause reconnection.
- MMS crossed a reconnecting current sheet between the first two FRs.

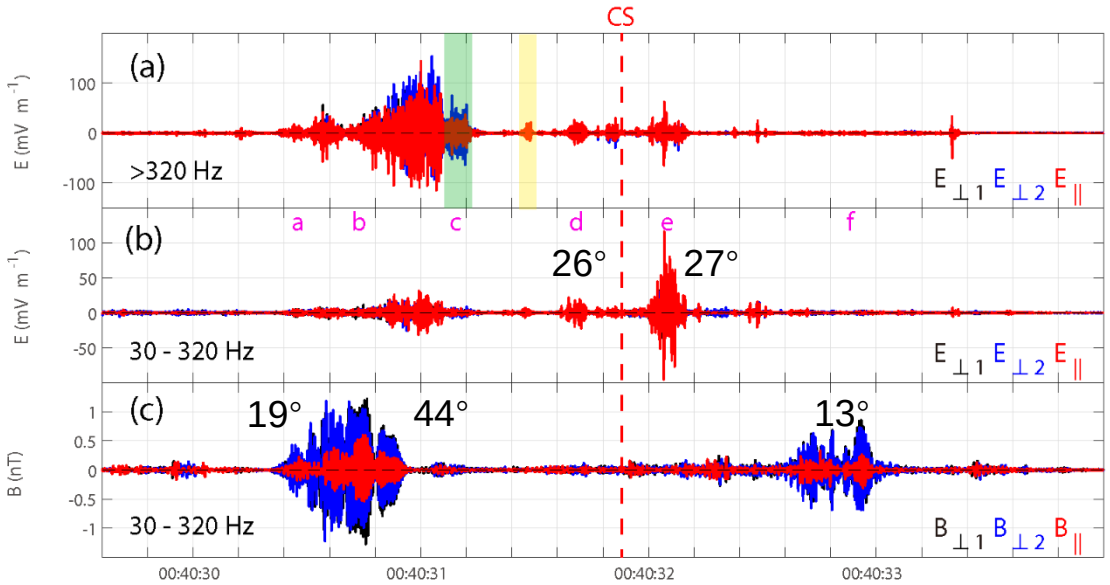


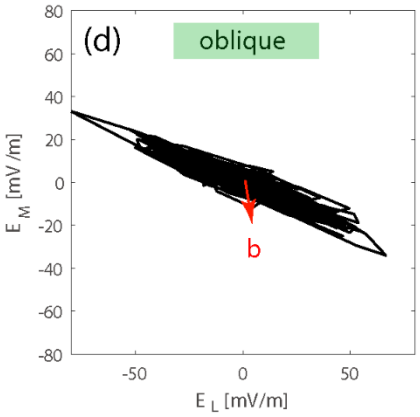


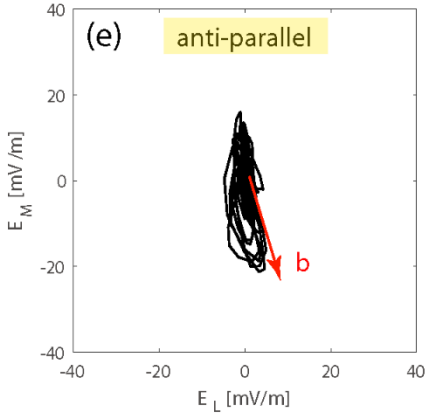
Detailed Analysis

- The broadband large-amplitude (> 100 mV/m) electrostatic waves were observed with frequency above $0.5*f_{ce}$.
- The whistler waves were observed with frequency between $0.1*f_{ce}$ and $0.5*f_{ce}$.
- The electrostatic waves occurred near the center of the reconnecting current sheet, while the electromagnetic waves occurred outer side.
- This evolution and properties of plasma waves correspond to the electron dynamics around the reconnecting current sheet.

Electrostatic waves

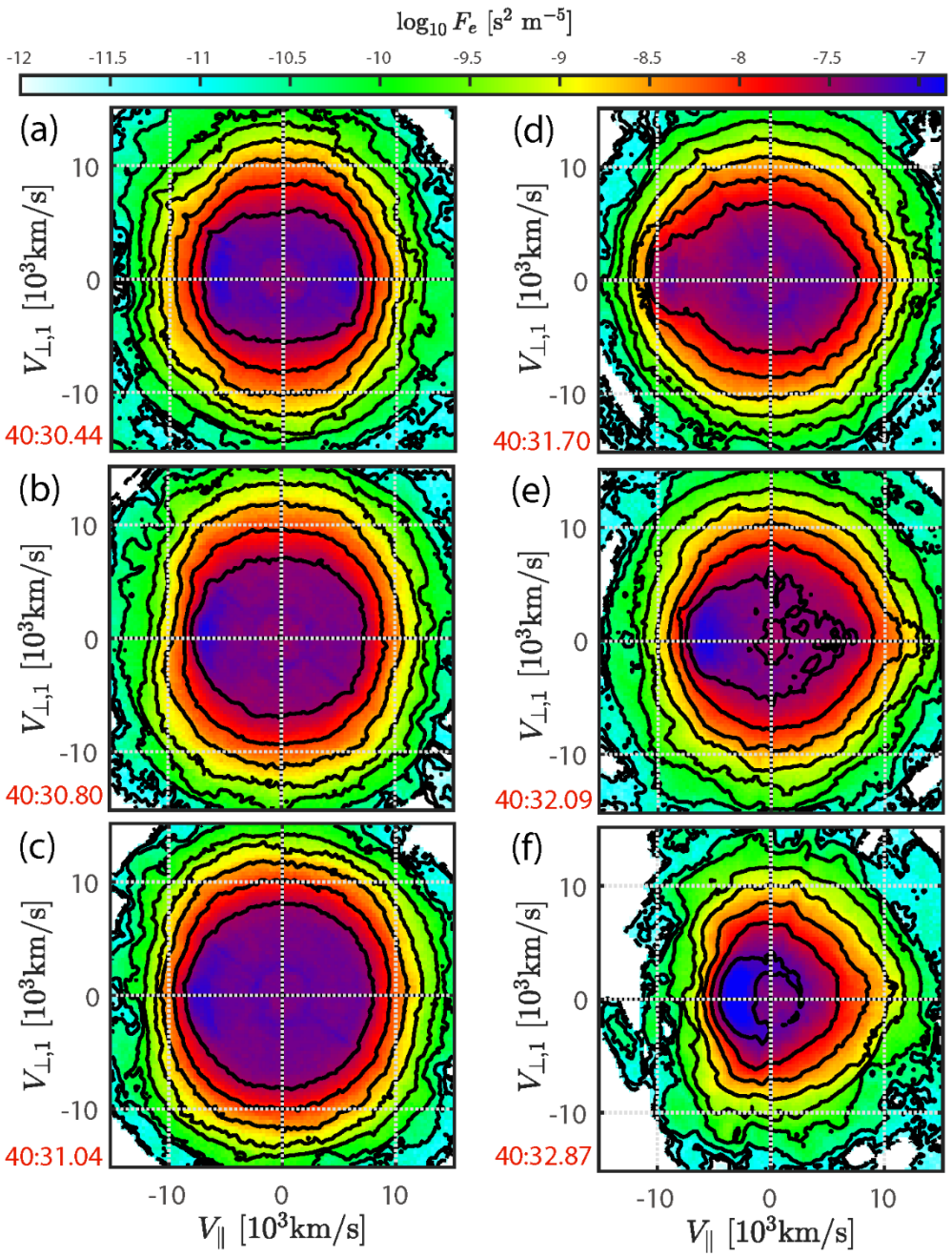






- The broadband electrostatic waves (> 320 Hz) combined by two components: oblique waves and anti-parallel waves.
- $K_{oblique}$ was almost along the L direction, while $K_{anti\text{-}parallel}$ was almost along the M direction in LMN coordinates.
- The oblique electrostatic waves: electron Bernstein waves?
- The anti-parallel electrostatic waves: Buneman waves?

Whistler waves



- The quasi-parallel whistlers corresponded to regions with significant anisotropies or loss cones.
- The oblique whistlers were generated by the electron beams.
- When the cold beams were accelerated to higher energies, the oblique whistlers become stronger, while the quasi-parallel whistlers disappeared since the anisotropy or loss cone distributions became less apparent.

Summary

1. The whistler waves and broadband electrostatic waves were observed around the current sheet of multiple X-line reconnection.
2. The electrostatic waves occurred near the center of the reconnecting current sheet, while the electromagnetic waves occurred outer side.
3. Both quasi-parallel and oblique whistlers were observed. quasi-parallel whistlers were generated by electron loss cone distribution or temperature anisotropy, while the oblique whistlers which present more electrostatic were generated by the electron beams.
4. The broadband electrostatic waves include two wave modes. Lower frequency mode was quasi-parallel, while the higher frequency was oblique.