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Kinetic turbulence generated by accelerated particles in a reconnecting current sheet with magnetic islands

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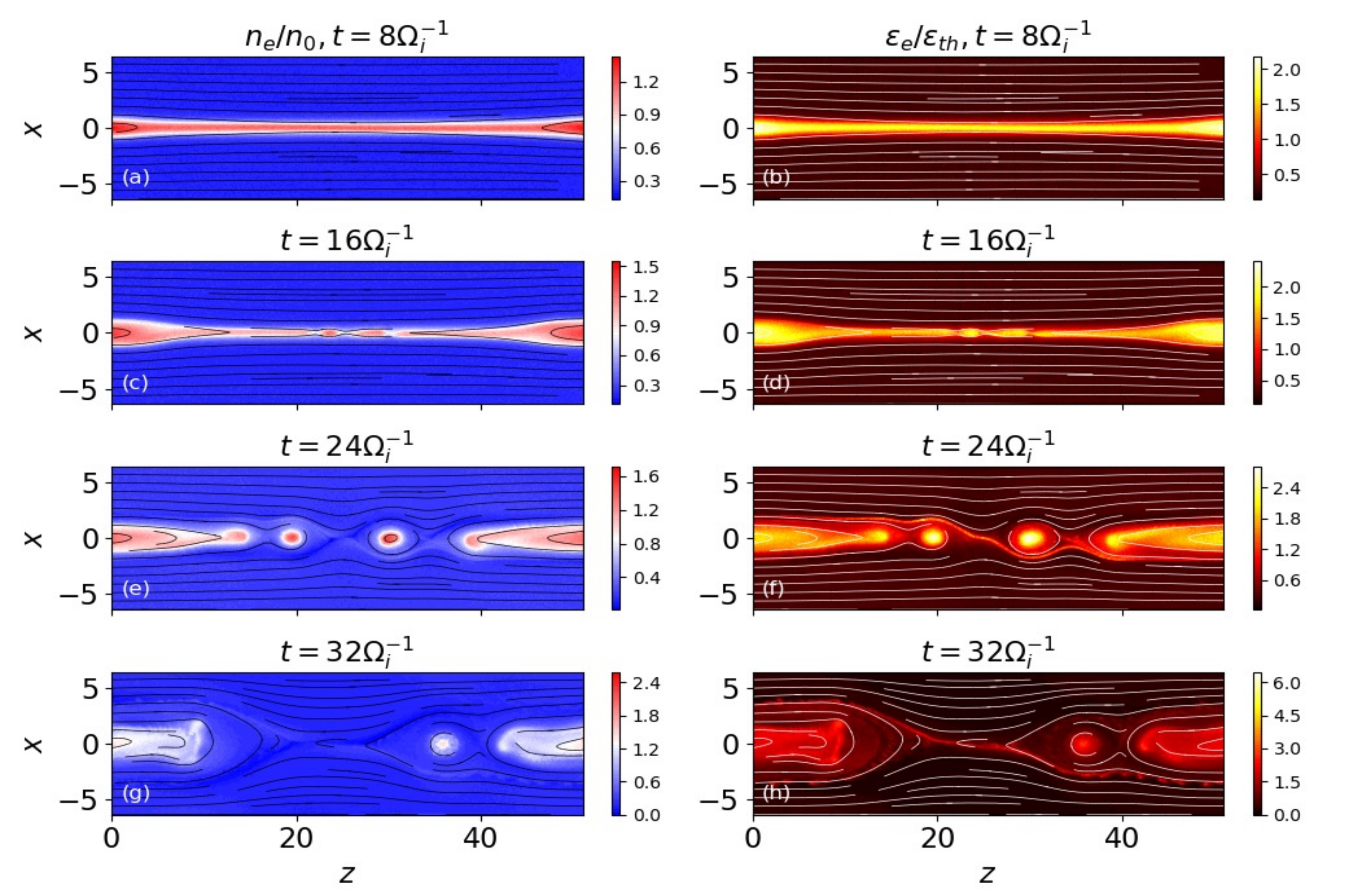
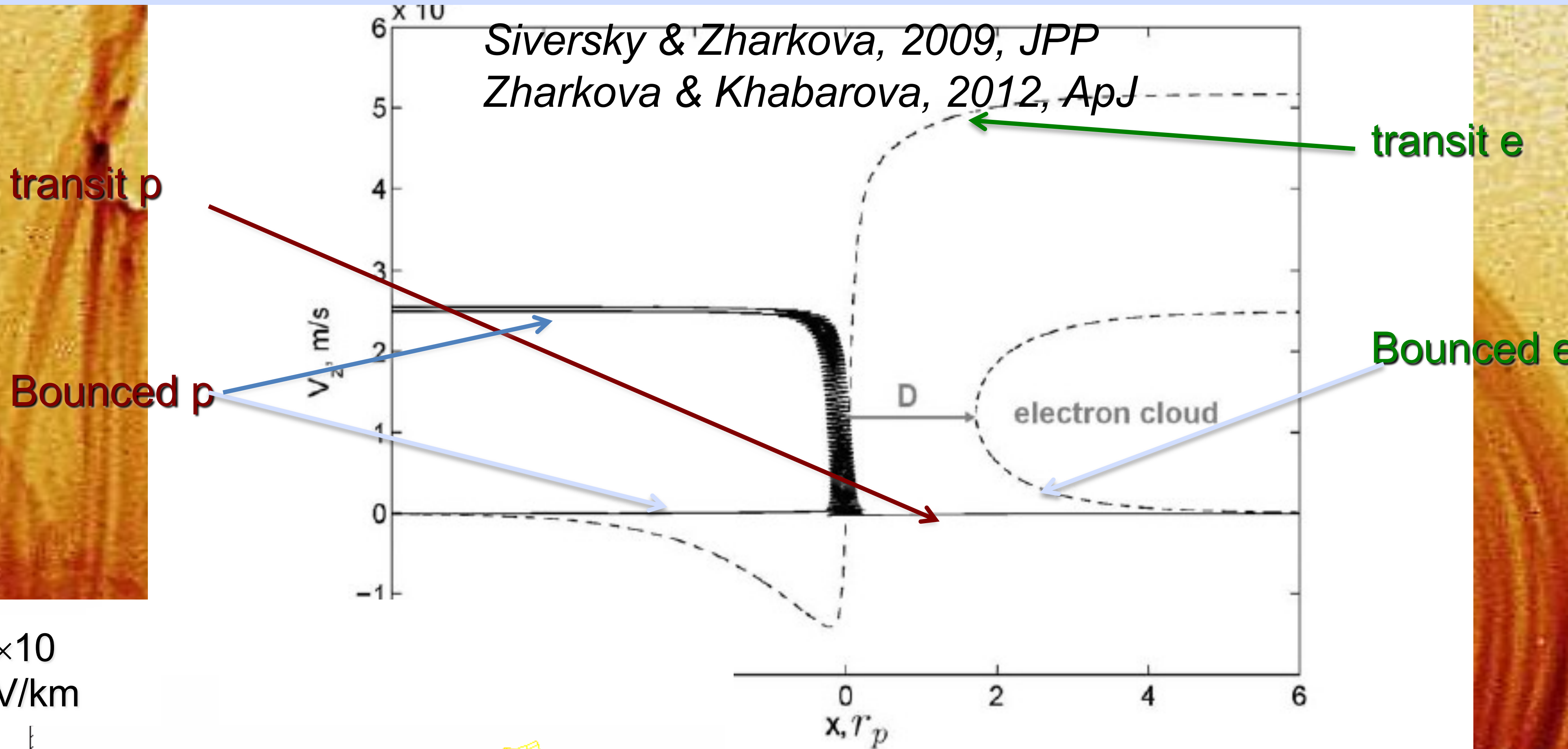


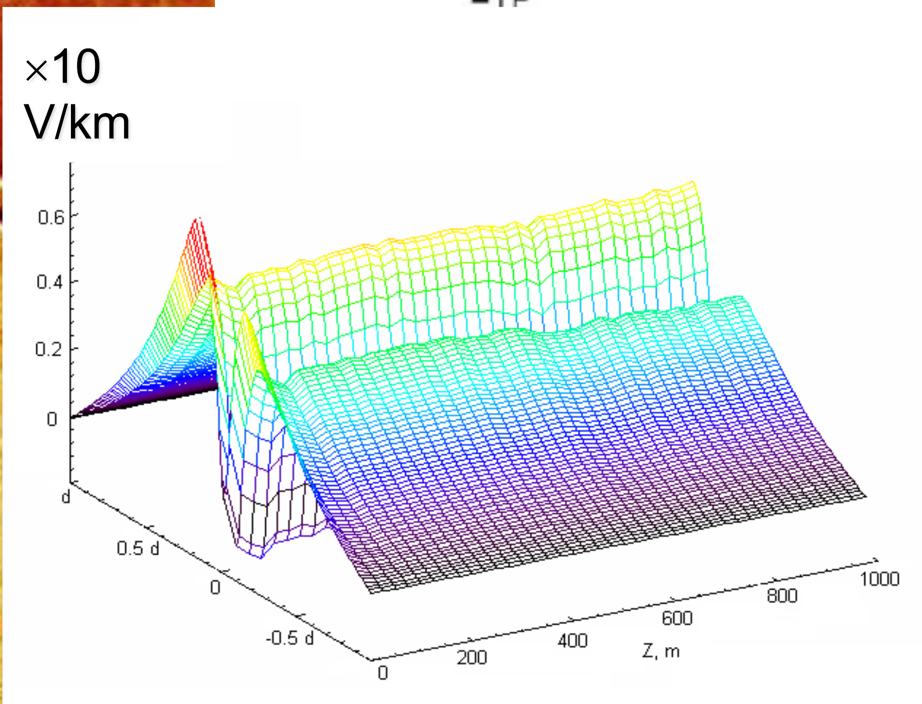
Simulations of magnetic reconnection is presented in a thin current sheet with 3D magnetic field topology affected by tearing instability → leads to formation of two large magnetic islands using particle-in-cell (PIC) approach.

Trajectories of protons and electrons in PIC model of HCS



and two electrons (dashed) on the x-V_z phase

nt sheet (TP simulations). $B_{y0} = 10^{-1}B_{z0}$, $B_{x0} =$



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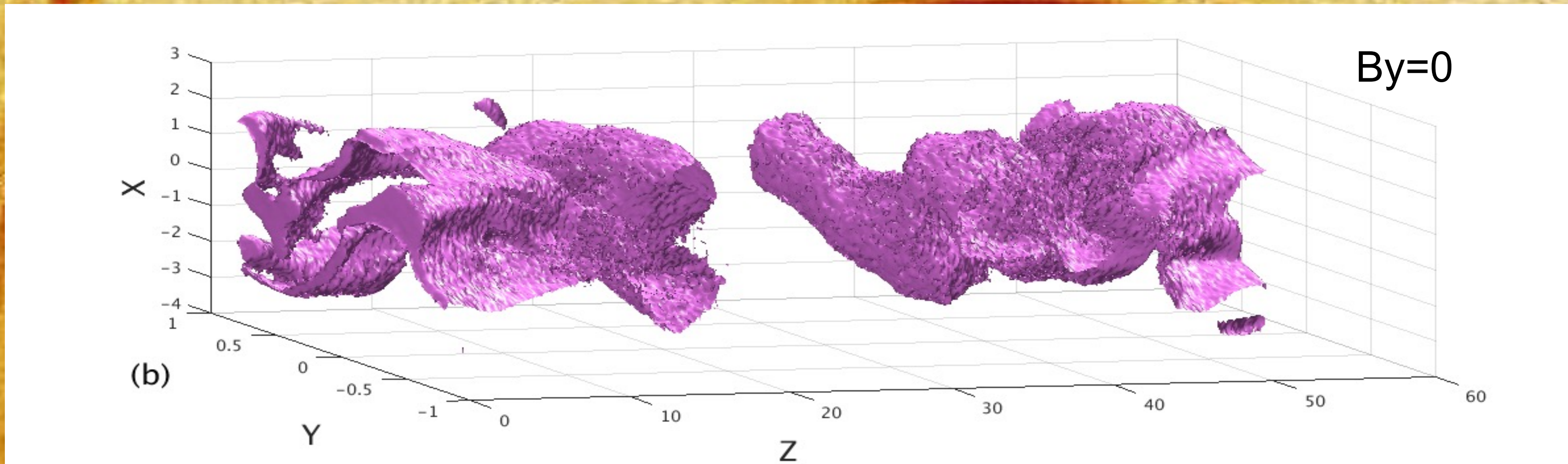
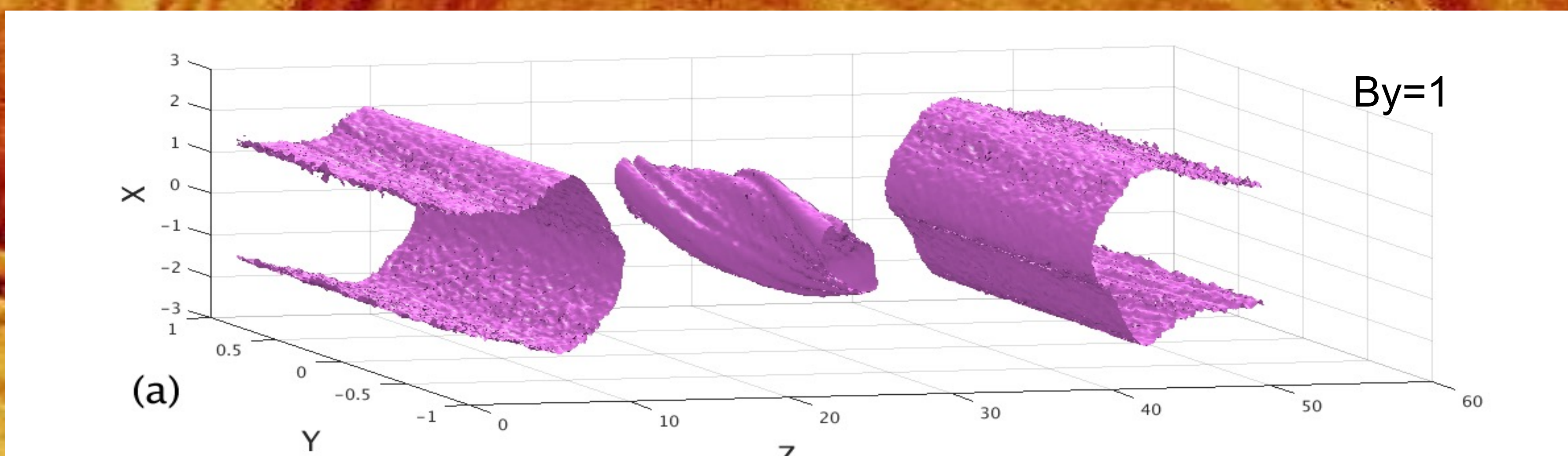
$\rightarrow 0$

Polarisation (Hall's) electric field potential induced by separation of electrons from ions (Zharkova and Agapitov, 2009, JPP)

Strong guiding field suppresses kink instability along By direction

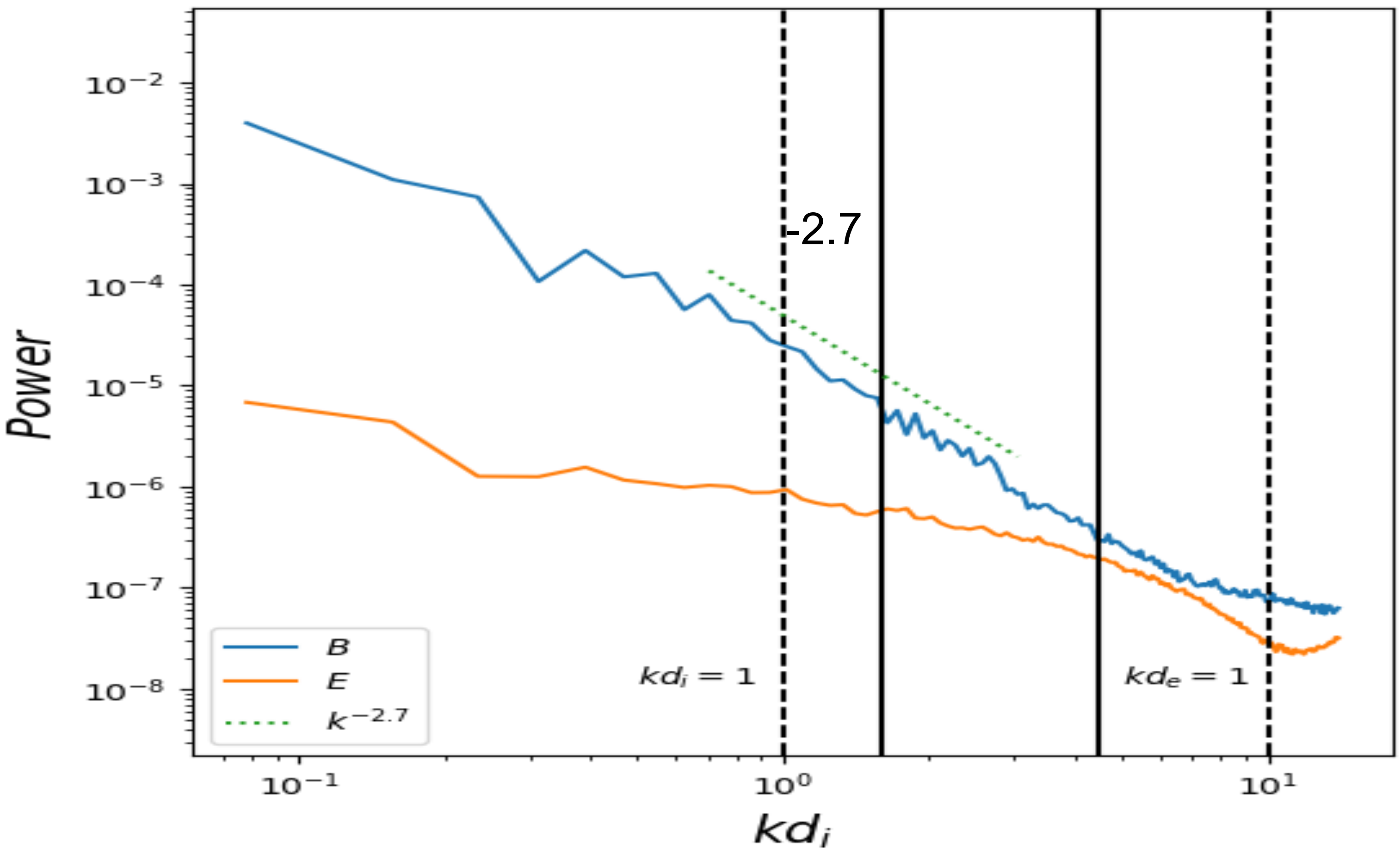




Isosurface of the electron energy distribution (the 35 \% contour of the max energy) for a strong guiding field (B_y=1) in the simulation box

Power spectrum from the whole RCS region vs wavenumbers

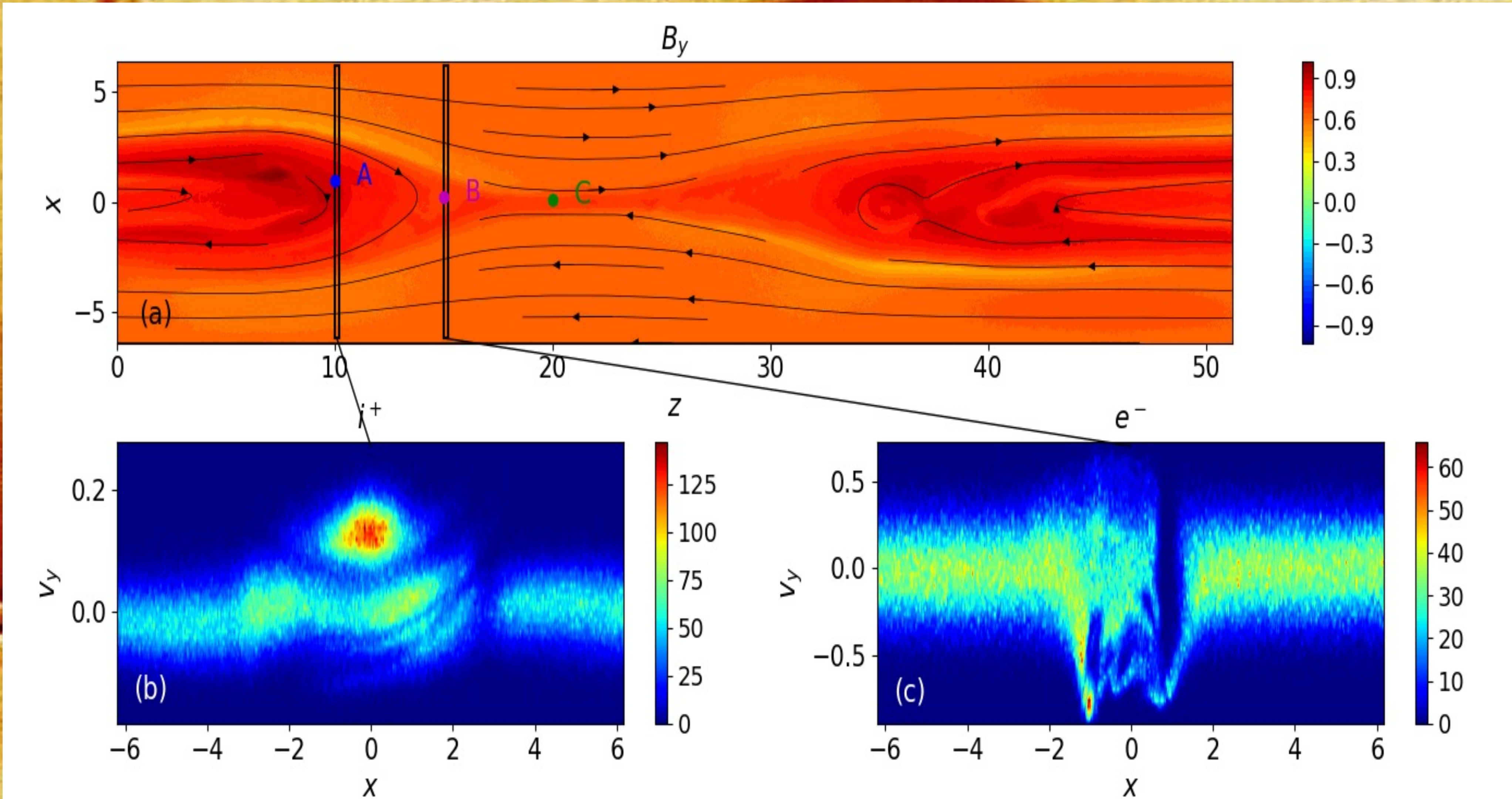
The solid lines indicate the ion gyroscale (left) and electron inertial scale (right)



In a wavenumber space the spectral index of the turbulent magnetic field near the ion inertial length is found to be -2.7 that is consistent with other estimations and measurements

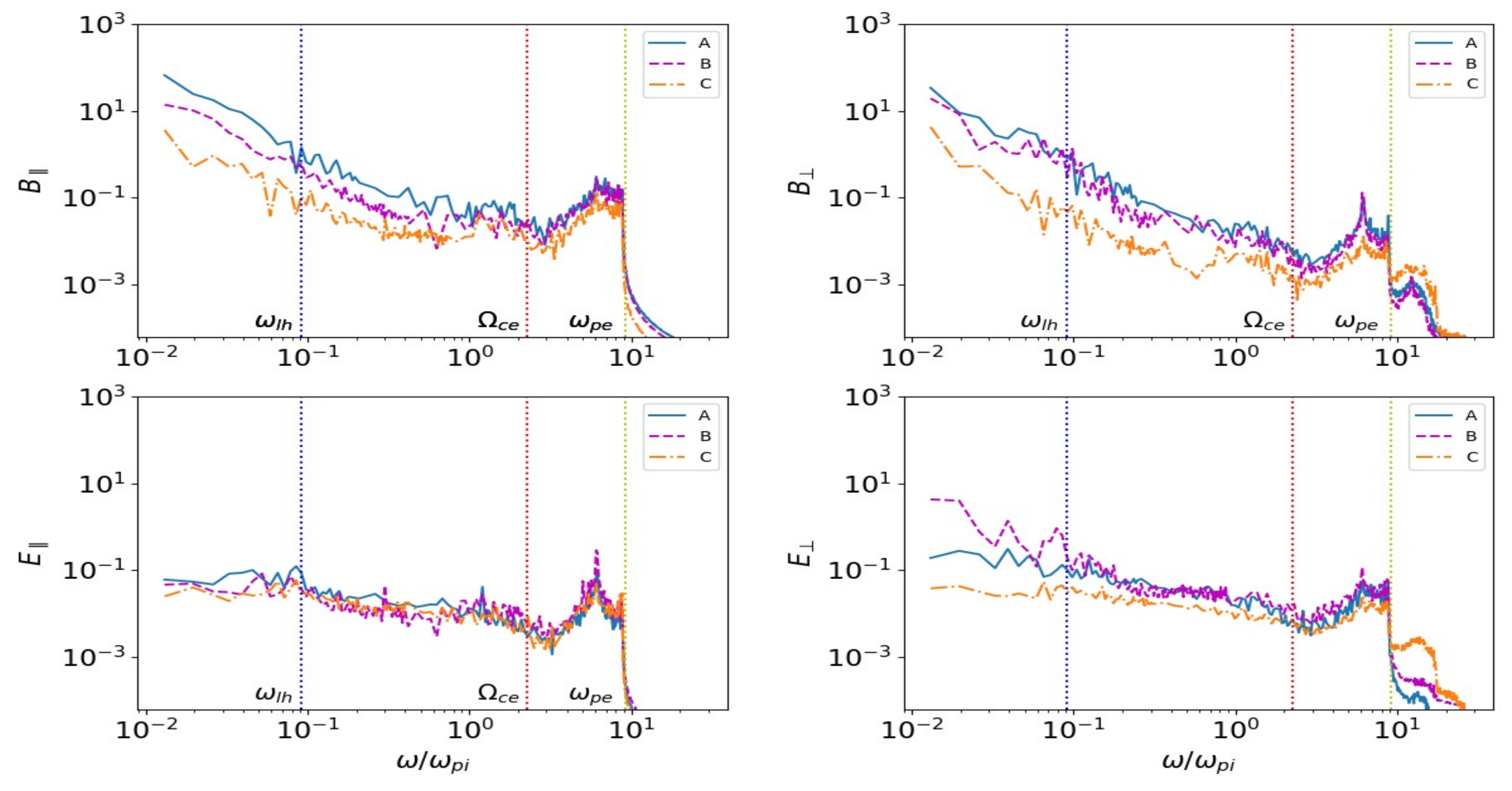
Gather turbulence when it is become stable in this topology

RCS with X and O-nullpoints



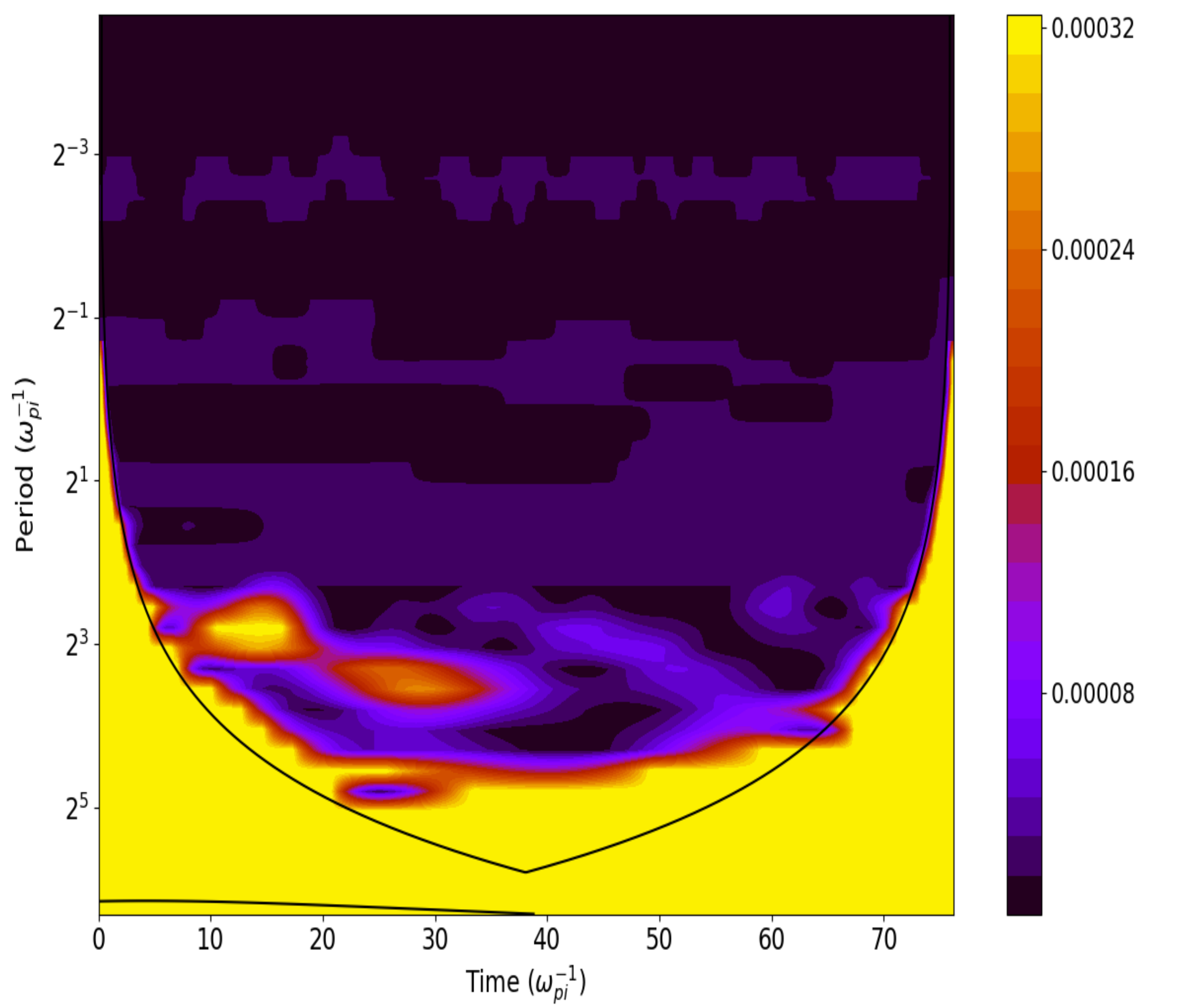
Kinetic turbulence is mainly generated by accelerated particle beams, which are found to evolve later into a phase-space hole indicating the beam breakage: at a distance of ~7d_i for electron and 12d_i for proton beams (d_i is a proton inertial length).

Frequency analysis



- The spectra of kinetic turbulence as functions of frequency in points A,B and C
- Noticeable lower-frequency turbulence occurring at lower hybrid frequency → oblique whistler waves (?).
- High-frequency fluctuations of perpendicular electric field, or upper hybrid waves, to occur in vicinity of or not far away from X-nullpoints

Wavelet power spectrum



Local wavelet power spectrum of B_x (the purple point B at z=15, x=0.25). The solid dark curve encloses the regions of > 95\% confidence.

The lower-hybrid waves are seen in both frequency and wavelet analysis. Lower hybrid turbulence – bottom purple and yellow-red patterns, high hybrid turbulence – top two purple strips

Conclusions

- In order to suppress substantial kink turbulence in the off-plane direction, a strong guiding field approach is used leading to a significant polarisation electric field generated across the current sheet by separated particles with the opposite charges.

- Particles of the same charge (transit and bounced) accelerated in 3D current sheets form the `bump-on-tail' velocity distributions in different locations of RCS and generate plasma turbulence owing to two beam instabilities.
- From the phase space analysis →kinetic turbulence is mainly generated by accelerated particle beams, which are found to evolve later into a phase-space hole indicating the beam breakage: at a distance of ~7d_i for electron and 12d_i for proton beams (d_i is a proton inertial length).
- In a wavenumber space the spectral index of the turbulent magnetic field near the ion inertial length is found to be -2.7 that is consistent with other estimations and measurements.
- From the frequency spectra of electric and magnetic field of kinetic turbulence it was found that the high-frequency fluctuations of perpendicular electric field, or upper hybrid waves, to occur in vicinity of or not far away from X-nullpoints
- Turbulent fluctuations near X-nullpoints or on the edges of magnetic islands are consistent with Langmuir or Bernstein waves generated by electrons when they move across the magnetic field lines.
- The frequency spectra of turbulent waves generated in parallel and perpendicular directions to local magnetic field → noticeable turbulence at lower hybrid frequency

- The lower-hybrid waves are seen in both frequency and wavelet analysis.
- The fluctuations of the perpendicular electric field component of turbulence is consistent with a generation of oblique whistler waves on density fluctuations of accelerated particles.