Characterization of wave-particle interactions in the flux pile-up region of asymmetric reconnection

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Abstract

We investigate electron whistler wave activity in the flux pile-up region of an asymmetric reconnection event at the magnetopause. The ˜140Hz waves are right-hand polarized with a wave normal angle of ˜20 degrees and track the magnetic field strength, consistent with electron whistler waves. Poynting flux direction indicates that the waves were generated at the reconnection site. The waves modulated the flux of 500eV electrons propagating parallel and anti-parallel to the magnetic field, as observed by EDI. Only two of four MMS spacecraft observe similar wave activity, suggesting that the waves are isolated within a narrow flux tube. While it is not possible to use the wave telescope technique, current density produced by 500eV electrons provides a means of estimating the parallel wave vector, k, from a single spacecraft. In addition, we fit the FPI electron parallel energy distribution with a kappa function then use Liouville mapping with 500eV EDI electrons to determine the parallel wave potential, ?, and electric field, E. Combining this with the wave normal angle and Poynting flux direction provides an estimate for the perpendicular components of k and E.

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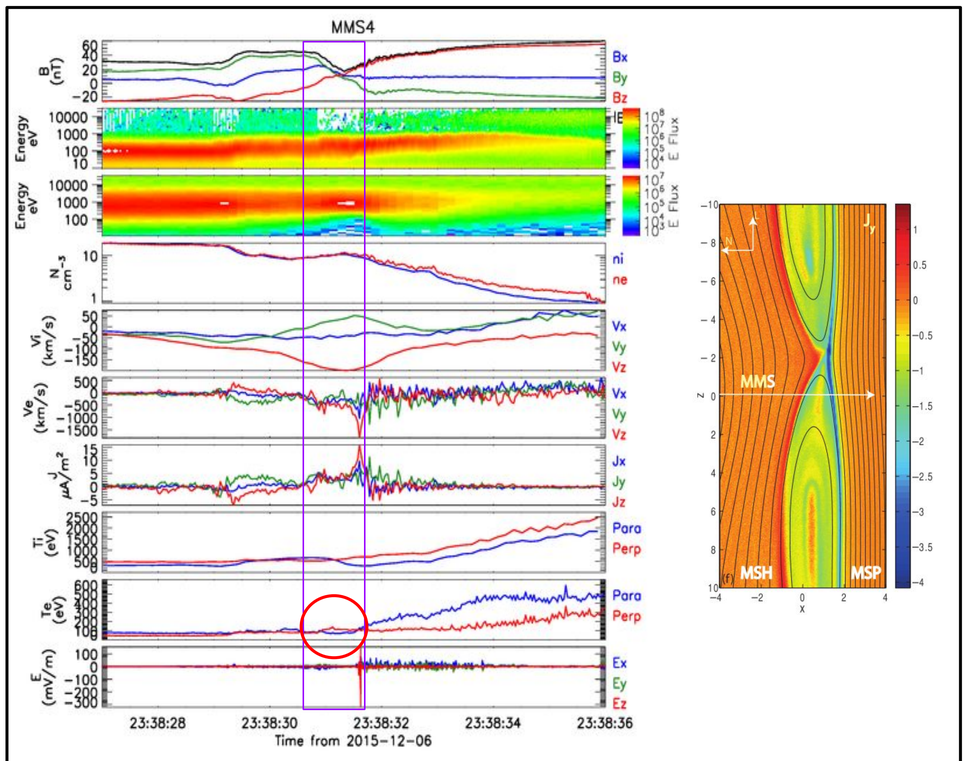
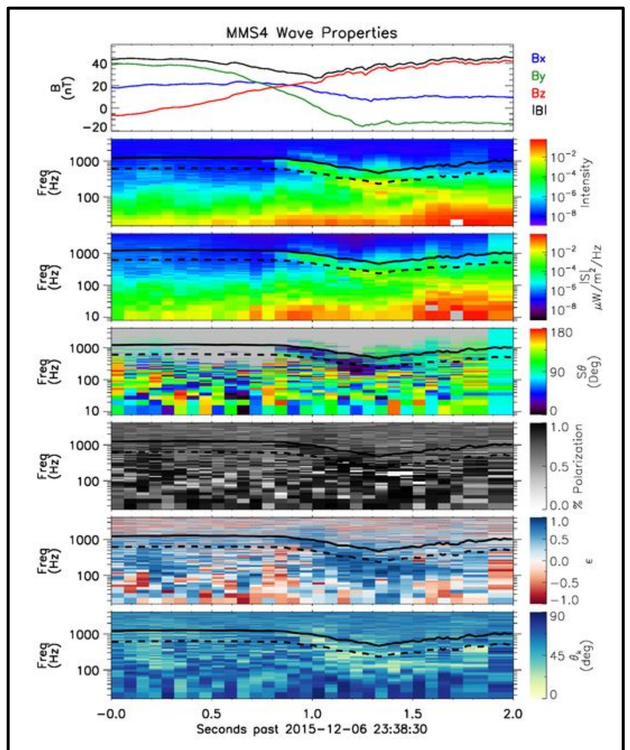
Wave Observations

Event Overview



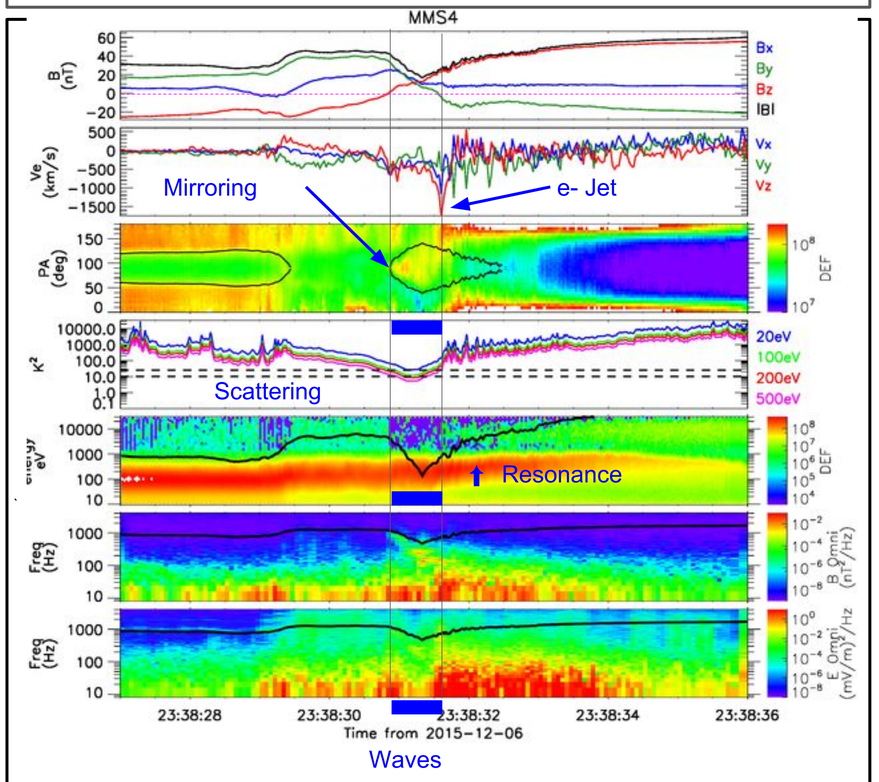
- MMS4 crossed the magnetopause from the magnetosheath to the magnetosphere
  - B_L reverses from negative to positive
  - Density transitions from high to low
- An electron-scale electron jet is embedded within the ion jet
- Electron temperature anisotropy ($T_{e,perp}$/ $T_{e,par}$ > 1) occurs within the current layer

Wave Properties



- Anisotropy leads to wave growth
- Electron whistler waves (f ~ f_{ce}/2)
  - Right-hand polarized
  - Wave-normal angle of ~20°
- Poynting flux directed away from the X-line

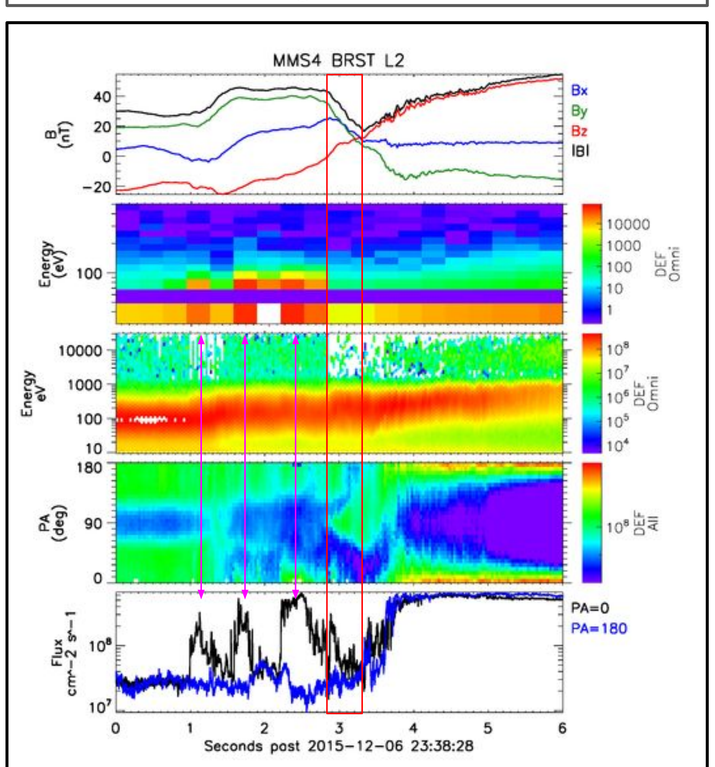
Wave Generation



- Pitch-angle focusing toward 90° at mirror point in 40nT field
- Field line curvature scatters electrons
- Resonant energy dips into bulk energy of the plasma
- Combined result is whistler wave growth

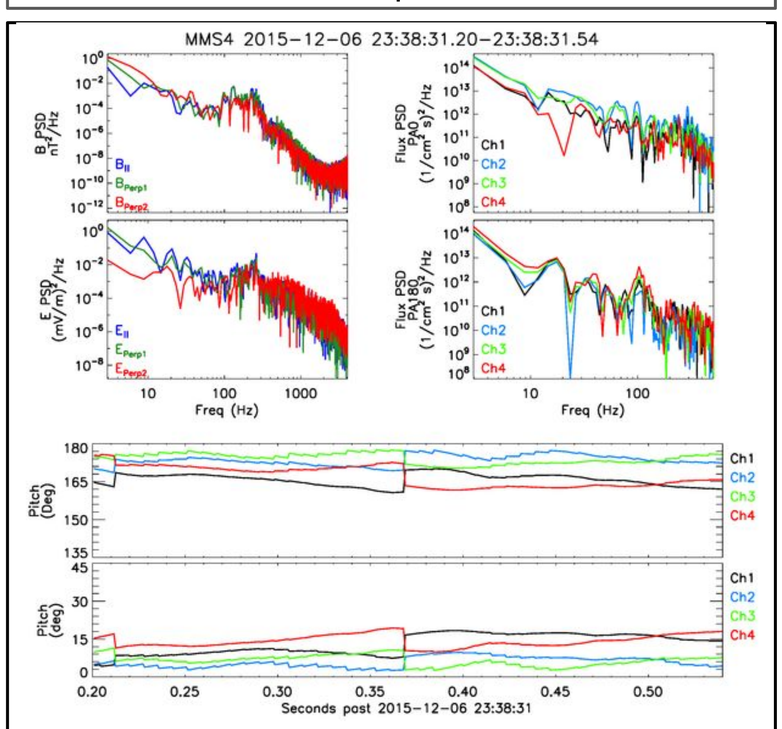
Wave-Particle Interactions

Opening of Field Lines



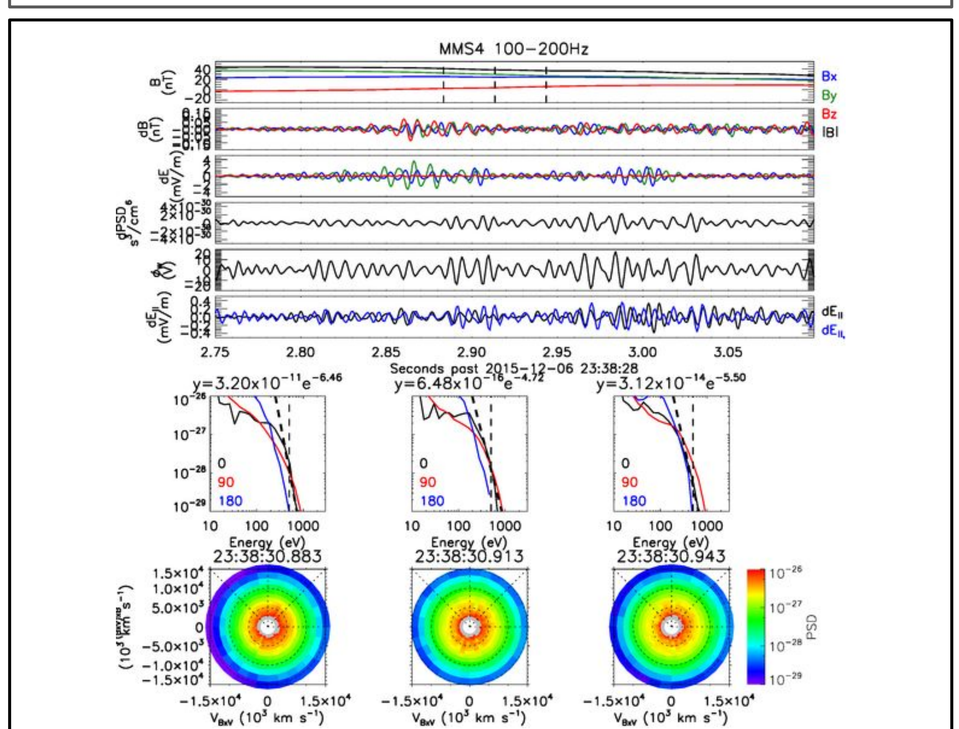
- Magnetospheric plasma is visible in magnetosheath along newly reconnected flux tubes
  - Increase of 500eV, 0° electrons indicate cross to south
  - ~100keV electrons present with whistler waves on separatrix

Power Spectrum



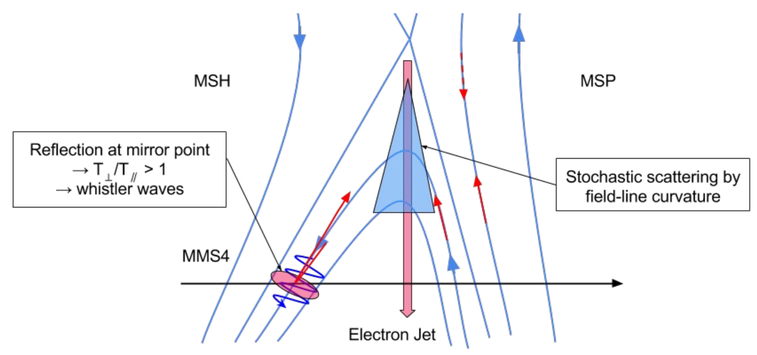
- Magnetic and electric fields show wave power from 100-400Hz
- EDI fluxes modulated from 70-200Hz
  - ~160° PA resonate strongest, in agreement with θ_k

Wave Electric Field



- Parallel-component of whistler waves modulates field-aligned electron fluxes
- Louiville mapping of 500eV fluxes provides wave potential and $E_{||}$
  - ϕ_W ~ 20 V
  - $dE_{||}$ is 10x greater than the measured field (plot is scaled), out-of-phase
  - More careful examination needed

Conclusions



- Inflowing, field-aligned electrons are scattered towards 90° PA by increased field line curvature
- They are then accelerated in the out-of-plane direction by the reconnection electric field
- Upon ejection from the current layer, they re-magnetize and mirror within the exhaust
- Focusing toward 90° PA, among other factors, spurs whistler wave growth

References

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