

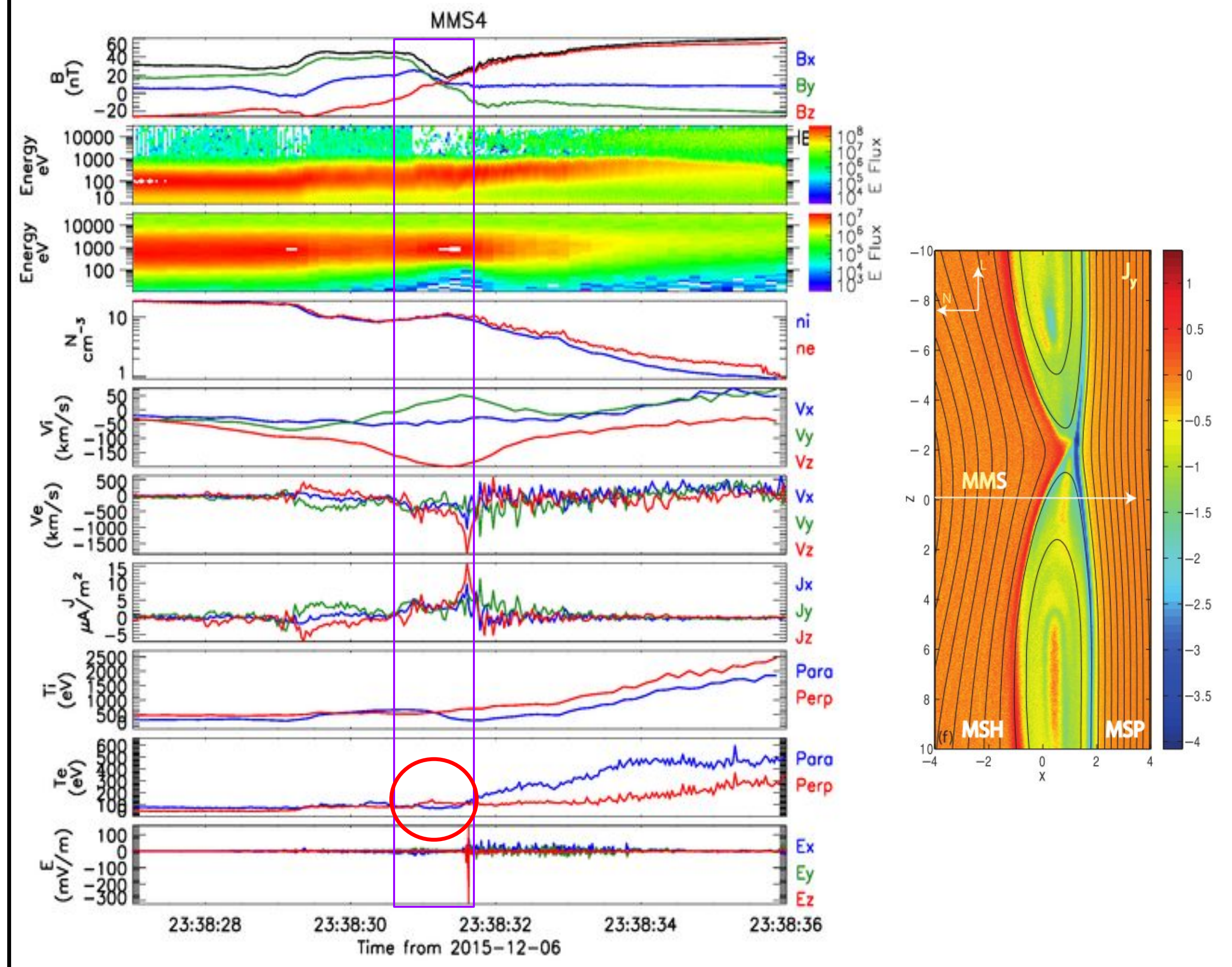
Characterization of Wave-Particle Interactions in the Flux Pile-up Region of Asymmetric Reconnection

Matthew R. Argall¹ (matthew.argall@unh.edu), K. Paulson¹, N. Ahmadi², H. Matsui¹, T. Leonard², D. Turner³, R.B. Torbert^{1,4}, O. Le Contel⁵, C.T. Russell⁶, W. Magnes⁷, R.J. Strangeway⁶, B. Giles⁸, P.-A. Lindqvist⁹, Yu. V. Khotyaintsev¹⁰, R.E. Ergun²

¹University of New Hampshire, Durham, NH, USA; ²Laboratory of Atmospheric and Space Physics, Boulder, CO, USA; ³The Aerospace Corporation, El Segundo, California, USA; ⁴Southwest Research Institute, San Antonio, TX, USA; ⁵Laboratory of Plasma Physics, Paris, France; ⁶University of California, Los Angeles, Los Angeles, CA, USA; ⁷Space Research Institute, Academy of Science, Graz, Austria; ⁸Goddard Space Flight Center, Greenbelt, MD, USA; ⁹Royal Institute of Technology, Stockholm, Sweden; ¹⁰Swedish Institute of Space Physics, Uppsala, Sweden

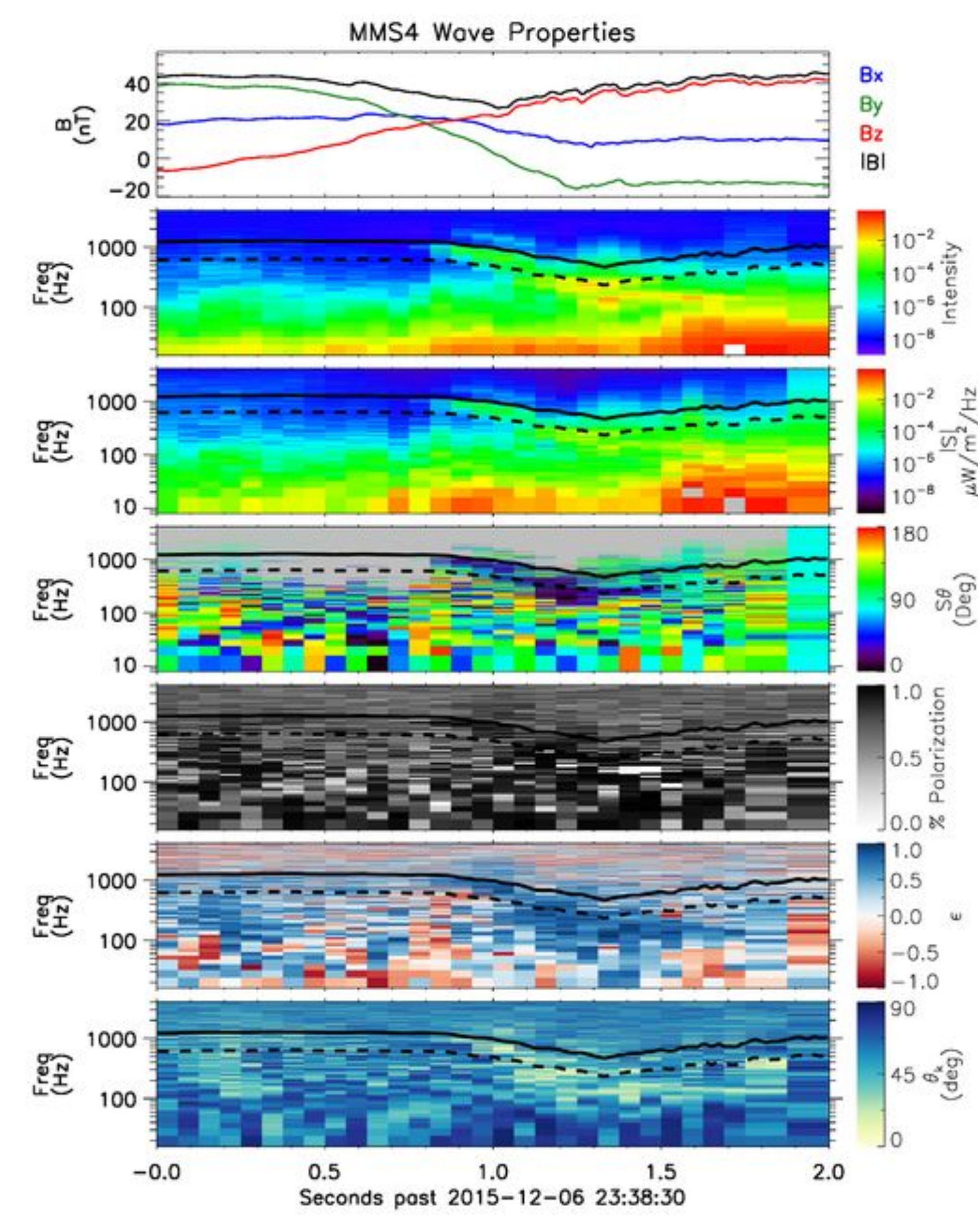
Wave Observations

Event Overview



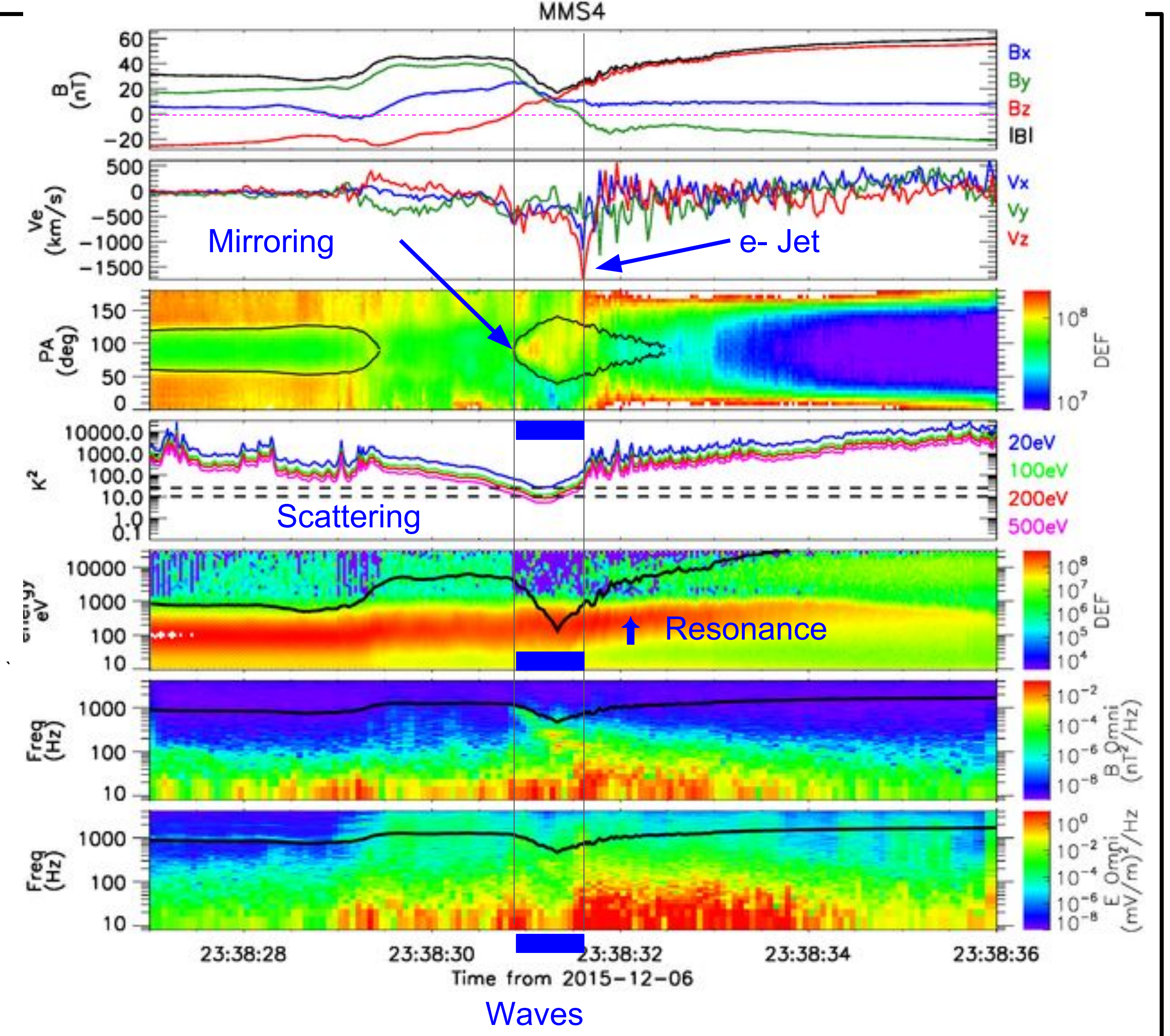
- MMS4 crossed the magnetopause from the magnetosheath to the magnetosphere
 - B_L reverses from negative to positive
 - Density transitions from high to low
- An electron-scale electron jet is embedded within the ion jet
- Electron temperature anisotropy ($T_{e,perp}/T_{e,par} > 1$) occurs within the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

Wave Properties



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

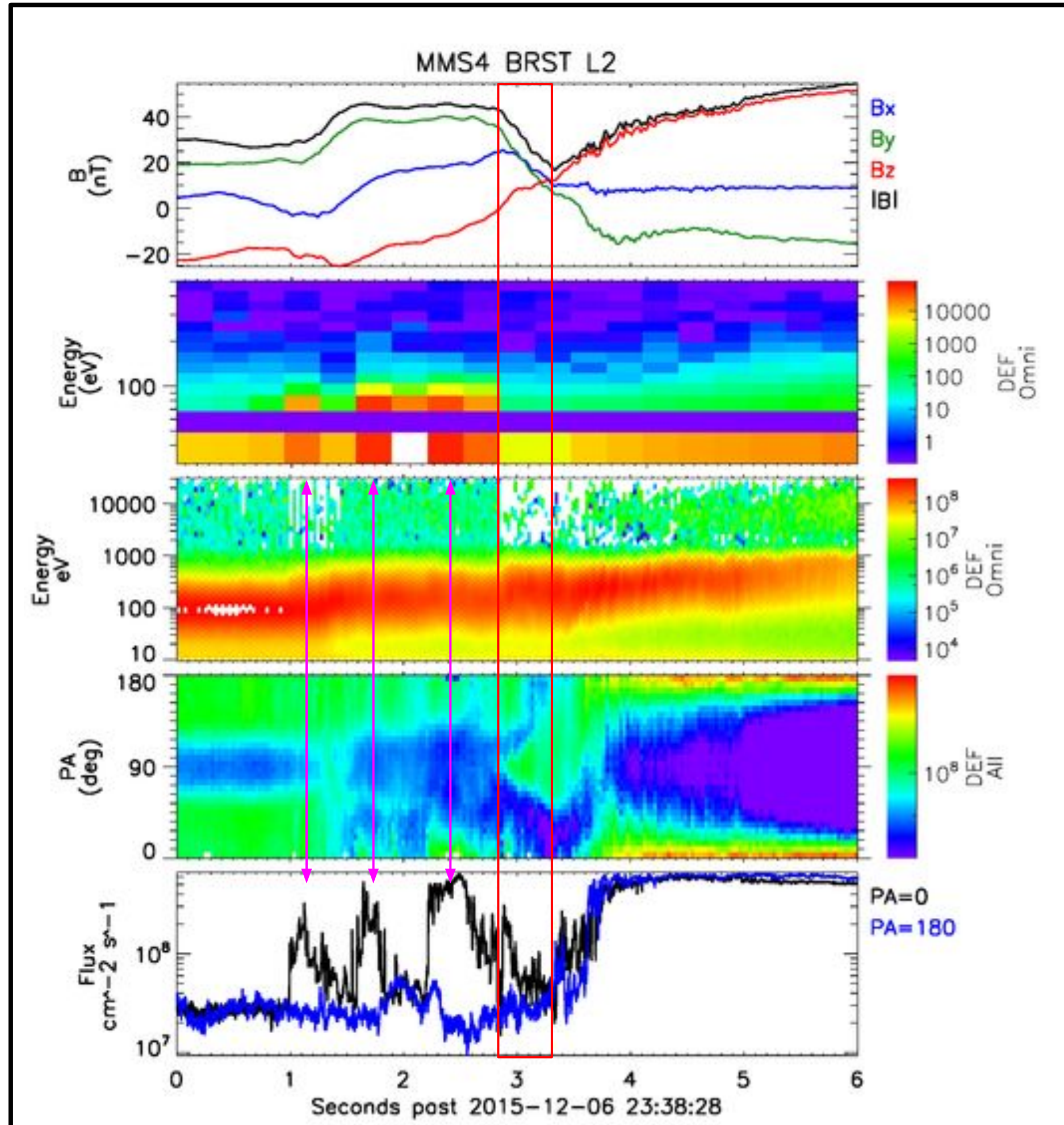
Wave Generation



- 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

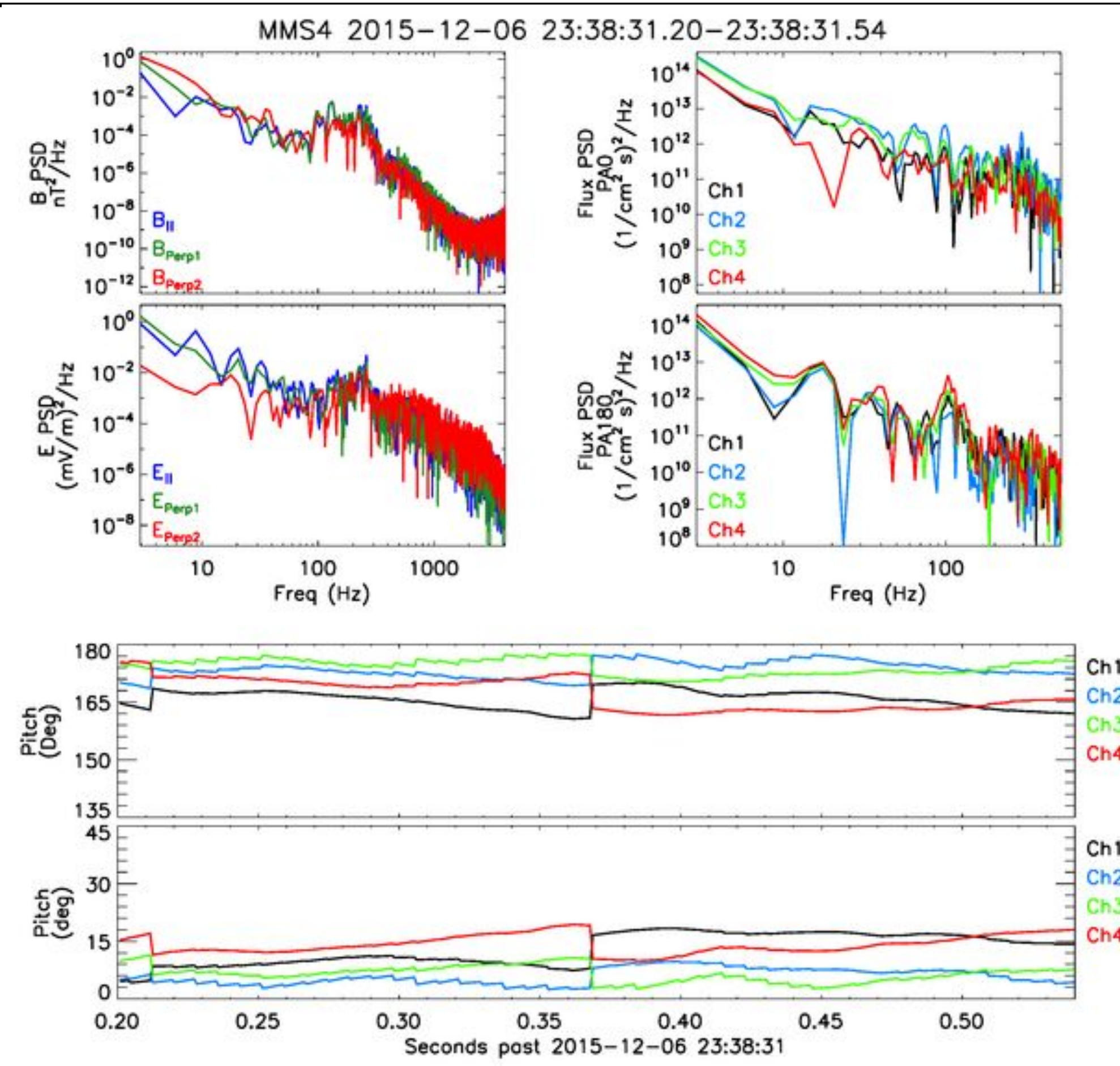
Wave-Particle Interactions

Opening of Field Lines



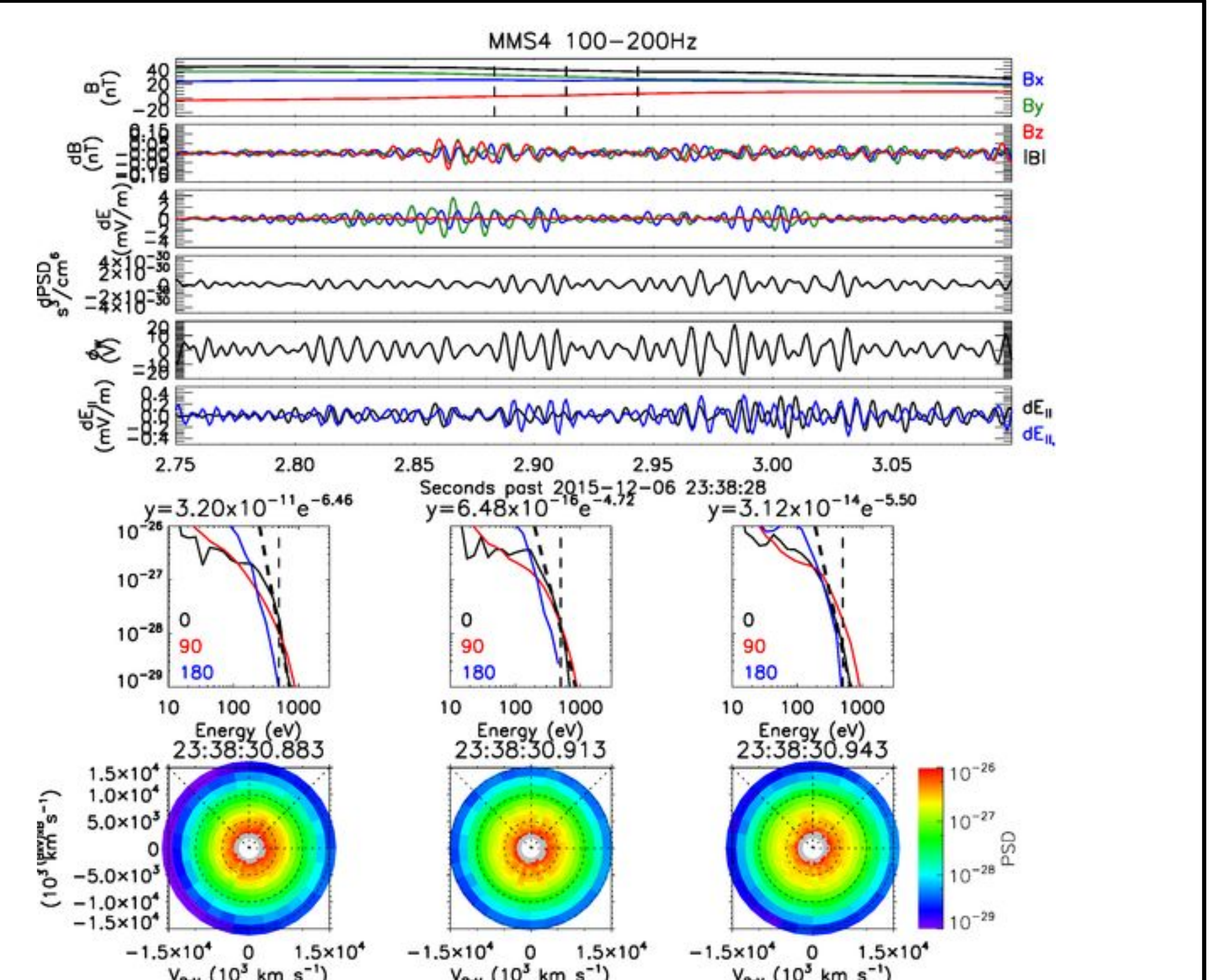
- Magnetospheric plasma is visible in magnetosheath along newly reconnected flux tubes
 - Increase of 500eV, 0° electrons indicate cross to south
 - ~ 100 keV electrons present with whistler waves on separatrix

Power Spectrum



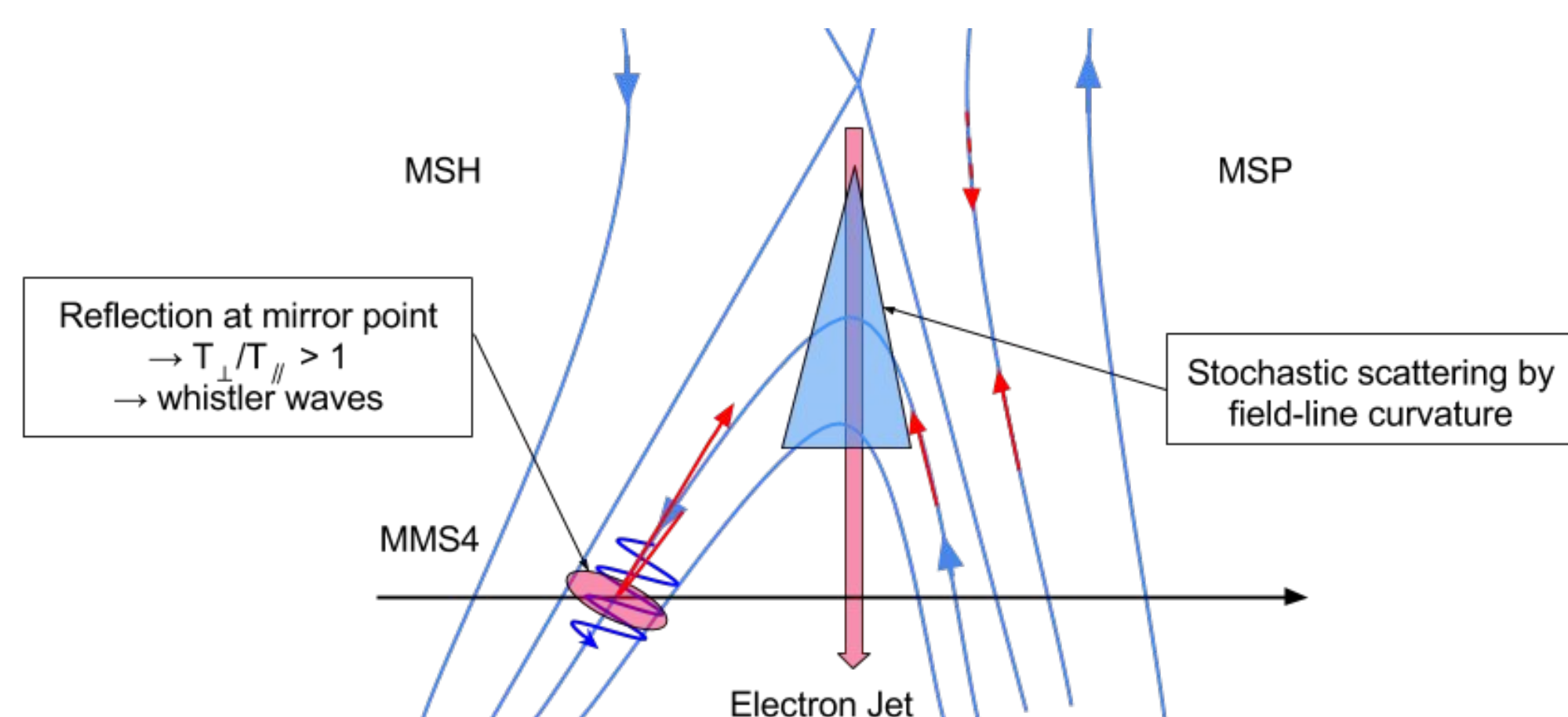
- Magnetic and electric fields show wave power from 100-400Hz
- EDI fluxes modulated from 70-200Hz
 - $\sim 160^\circ$ PA resonate strongest, in agreement with θ_k

Wave Electric Field



- Parallel-component of whistler waves modulates field-aligned electron fluxes
- Louville mapping of 500eV fluxes provides wave potential and $E_{||}$
 - $\phi_W \sim 20$ 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

- [1] Fu, et al. (2006) *Phys. Plasmas*, 13, 1
- [2] Khotyaintsev, et al. (2016) *GRL*, 43, 11
- [3] Matsui, et al. (2008) *JGR*, 113, 8
- [4] Torbert, et al. (2015) *Space Sci. Rev.*, 199, 1
- [5] Wang, et al. (2010) *JGR*, 115, A1