

# Recent Progress in Space Plasma Physics

Yoshiharu Omura\* and Lou-Chuang Lee

\*RISH, Kyoto University

[omura@rish.Kyoto-u.ac.jp](mailto:omura@rish.Kyoto-u.ac.jp)

# New Challenges in Space

Modified from Nishida's Plenary Talk

## 1. Magnetic structure of coronal mass ejection (CME)

[S-O1:Tian] [S-I4:Huang]

## 2. Reconnection in the magnetotail

[S-I12:Fu] [S-I13:Zhu] [S-I17:Lu] [S-I18:Zenitani]  
[S-I19:Wang] [S-I9:Ebihara]

## 3. Acceleration by wave-particle interactions

[S-I8:Zong] [S-I23:Omura] [S-I24:Lee] [S-I26:Tao]

## 4. Turbulence in the magnetosheath and Solar Wind

[S-I5:He] [S-I6:Zhao] [S-I7:Kakad] [S-10:Shi] [S-I11:Yang]

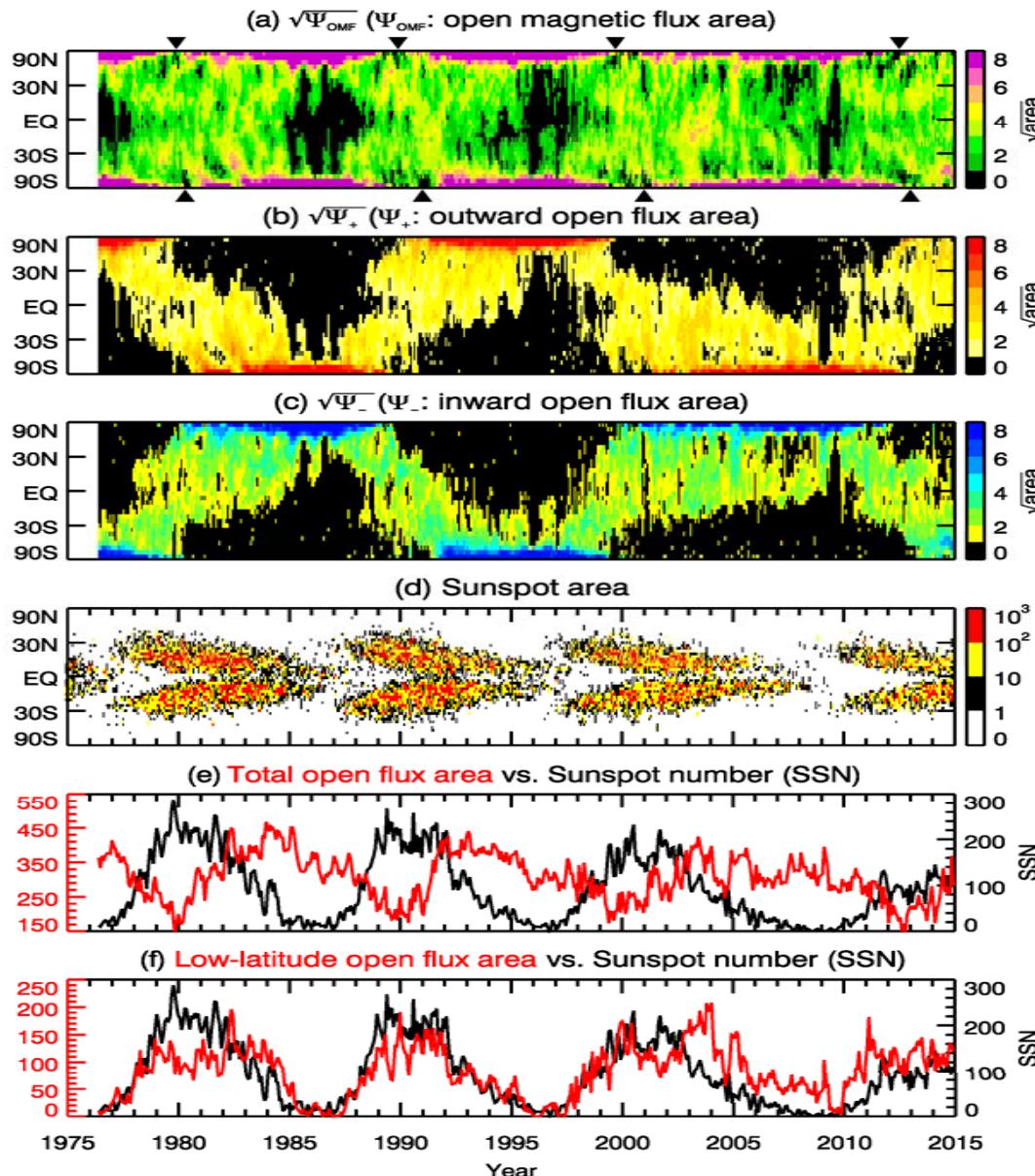
## 5. Planetary Period Oscillations in (Saturnian) magnetospheres

[S-I2: Mauel] [S-I3:Nishiura] [S-I14:Rong]

## 6. Others (Atmosphere, Ionosphere)

[S-I20: Chen] [S-O2:Rauf]

# Examining the Solar Cycle Variation of Coronal Holes



Open flux areas migrating across the equator

New pen flux areas generated in the low latitude and migrating poleward

New open flux areas locally generated in the polar region

During the sunspot rising phase, the outward and inward solar open fluxes perform pole-to-pole trans-equatorial migrations in opposite directions. The migration of the solar open fluxes consists of three parts.

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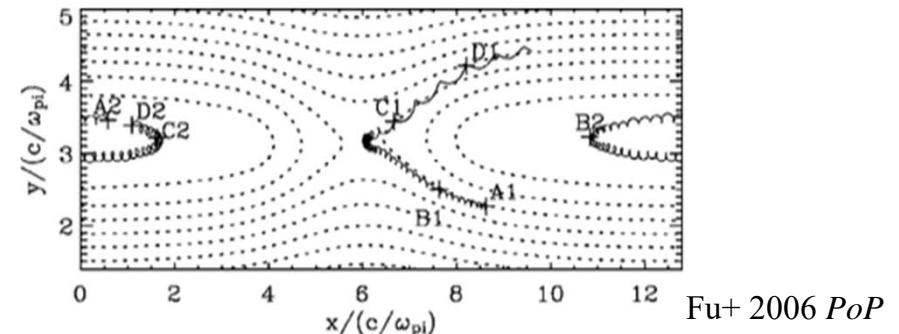
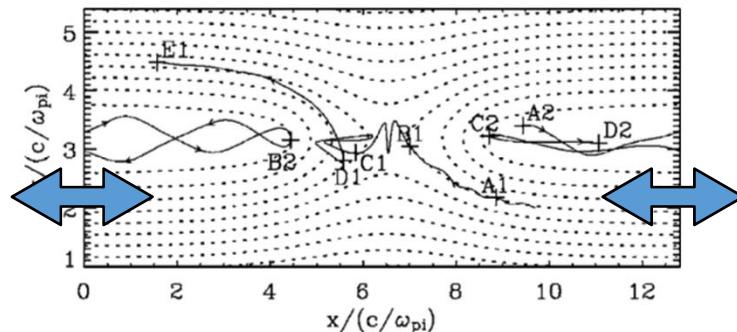
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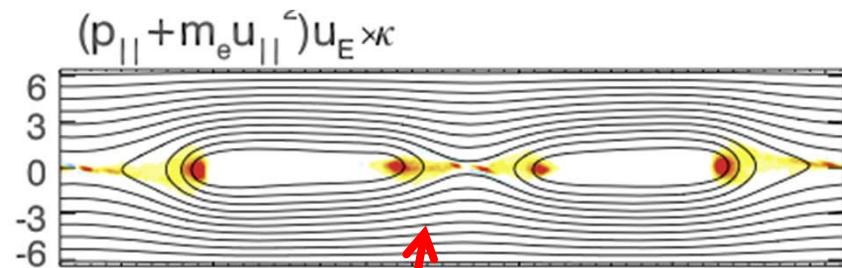
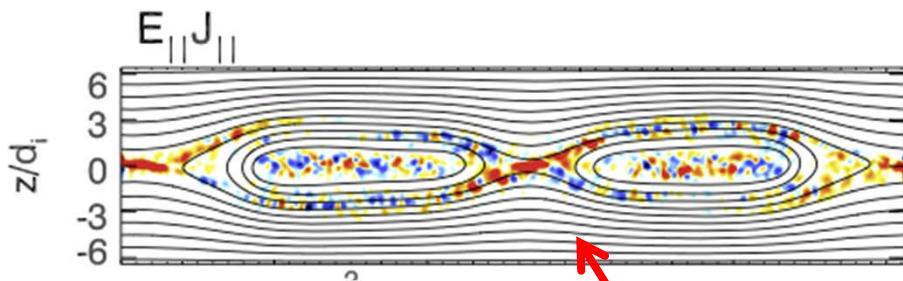
[S-I20: Chen] [S-O2:Rauf]

# Electron acceleration during magnetic reconnection: PIC simulations

- Individual orbits of acc. electrons



- Ensemble energy-gain (adiabatic theory)



$$\frac{dU}{dt} = E_{\parallel} J_{\parallel} - \frac{p_{\perp}}{B} \left( \frac{\partial B}{\partial t} + \mathbf{u}_E \cdot \nabla B \right) + (p_{\parallel} + m_e n u_{\parallel}^2) \mathbf{u}_E \cdot \boldsymbol{\kappa}$$

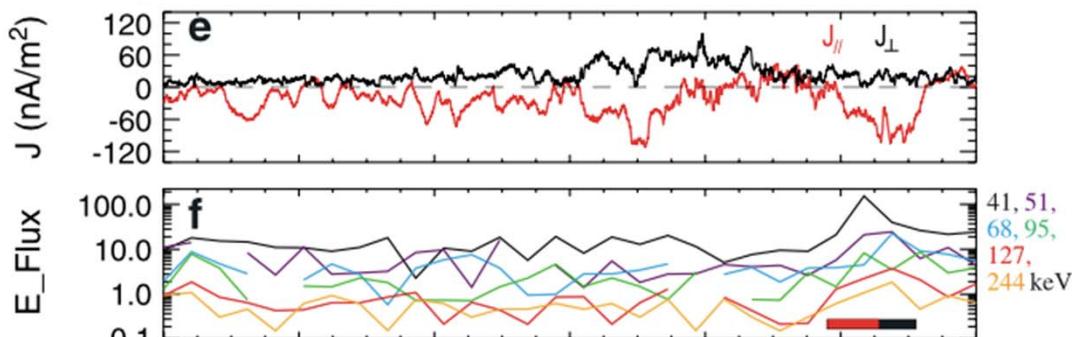
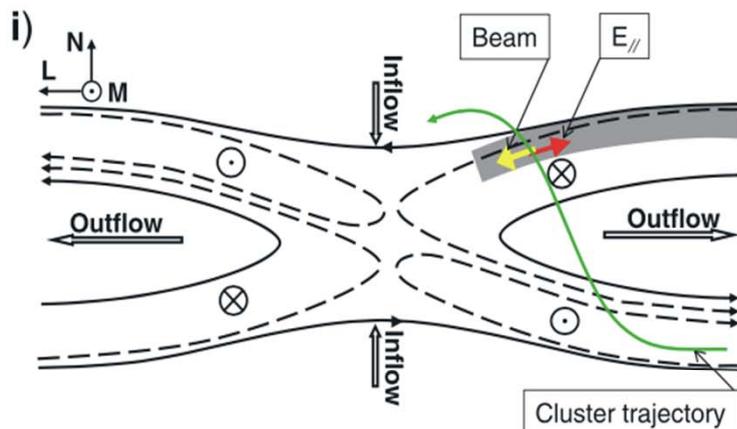
Wang+ 2016 ApJ

- Magnetic topology (guide field) changes dominant acc. process

[S-I17:Lu]

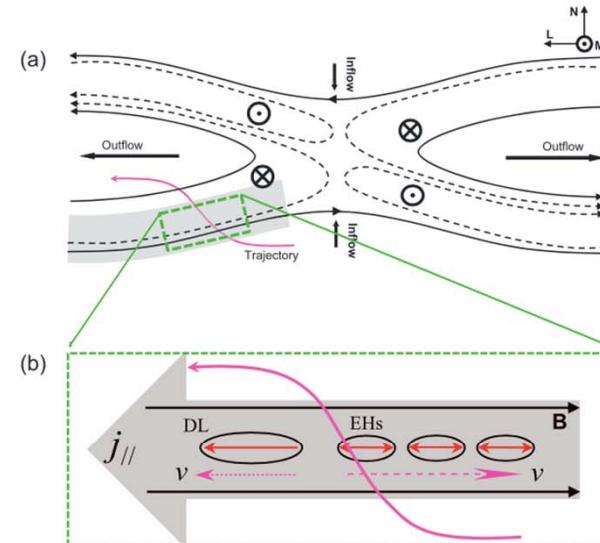
# Electron acceleration in the separatrix region: Cluster observation

- Energetic electrons travel in the parallel, inflowing direction
- $E_{\parallel}$  is detected



Wang+ 2013 GRL

- Double layers (DLs) and electron holes (EHs)



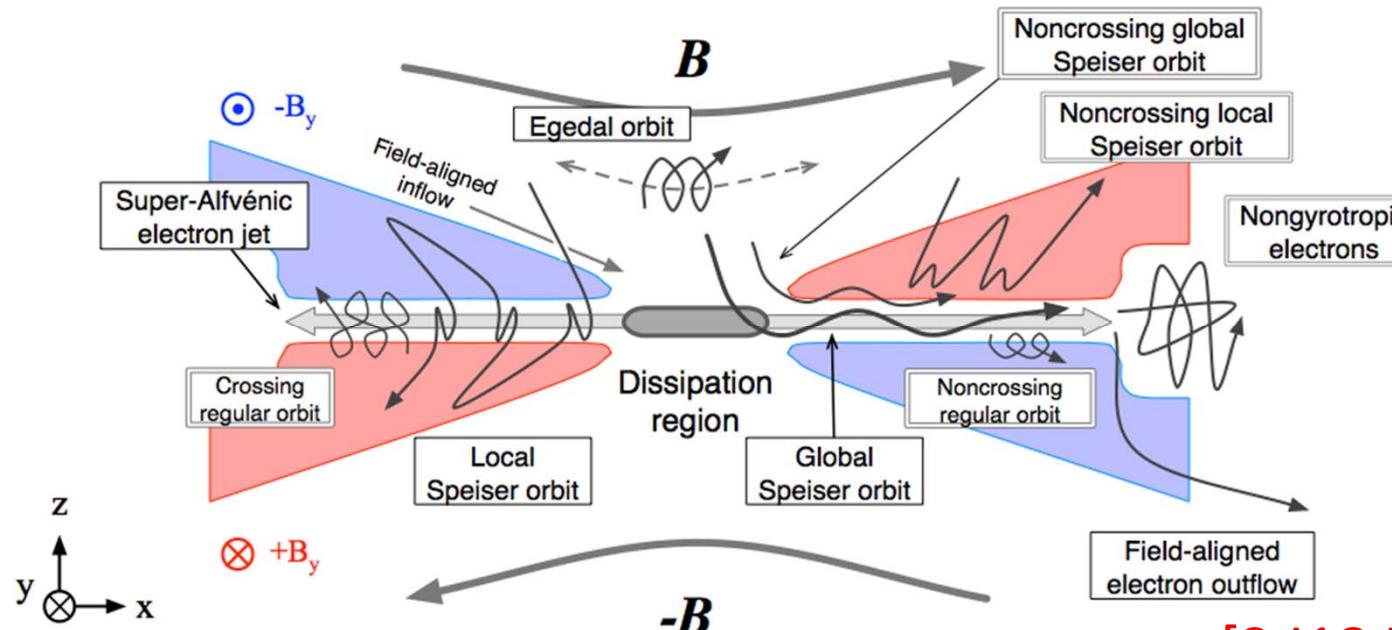
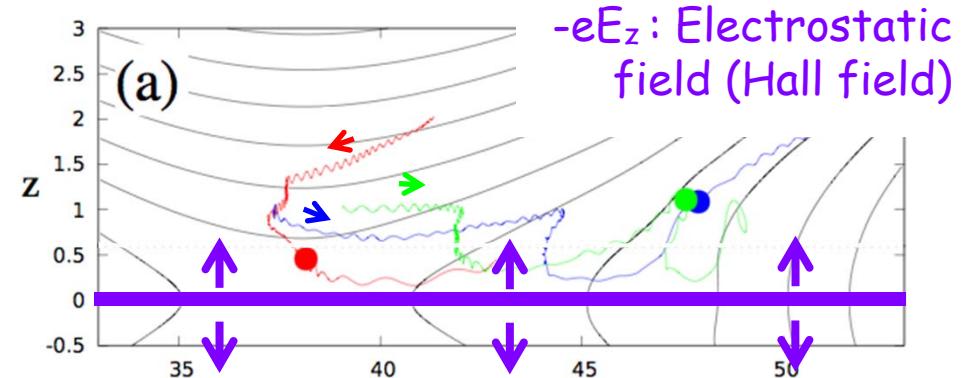
Wang+ 2014 GRL

- Rich variety of electrostatic processes [for electron acc.]

[S-I19:Wang]

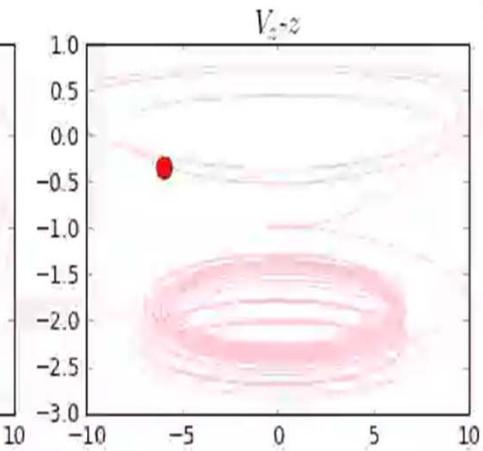
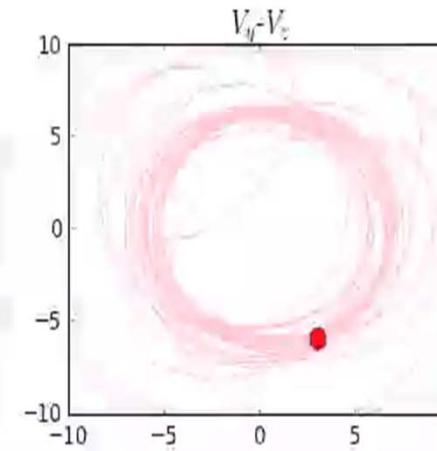
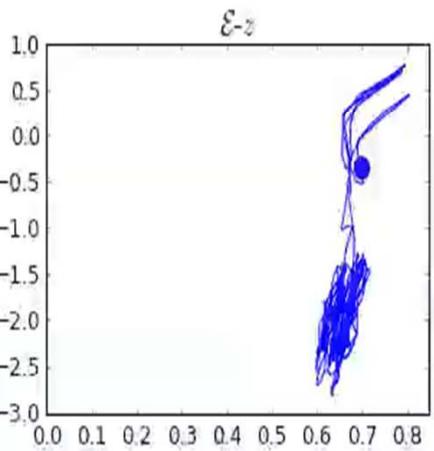
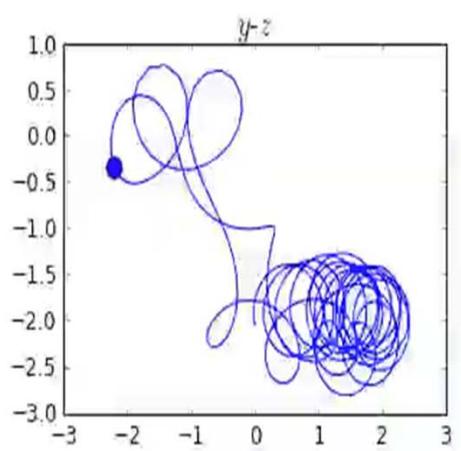
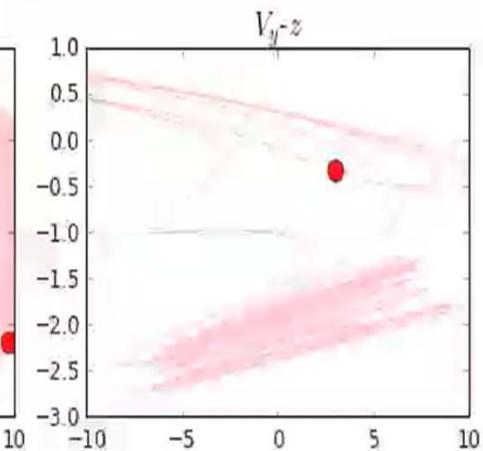
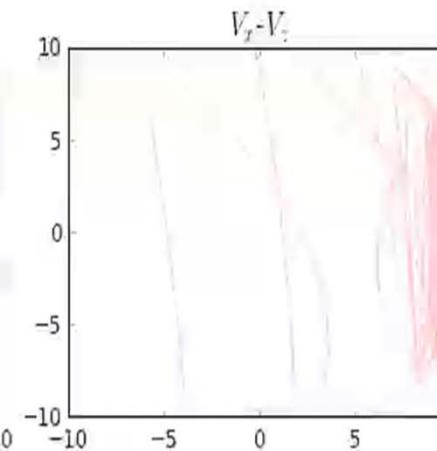
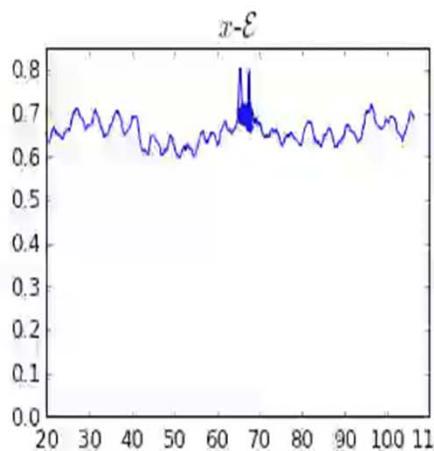
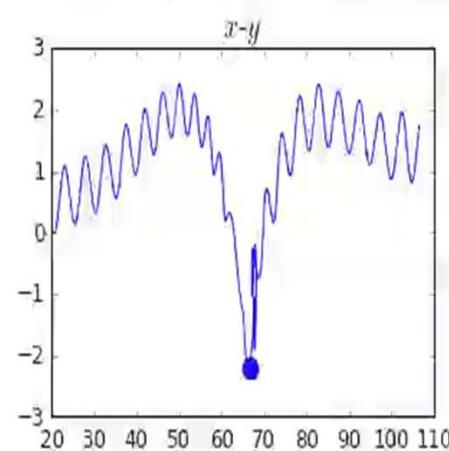
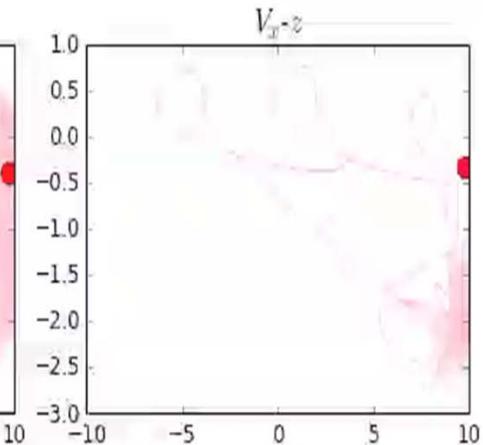
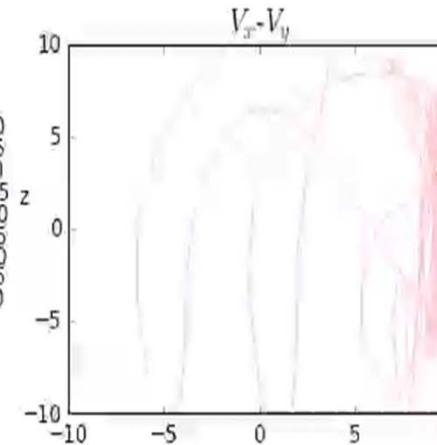
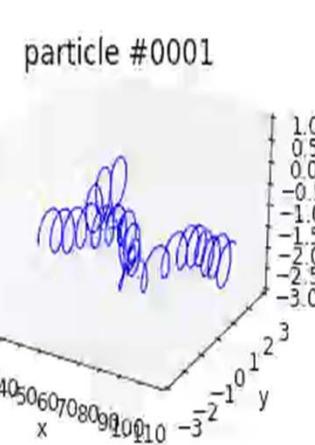
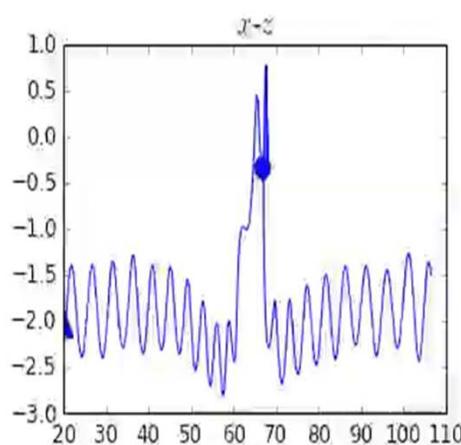
# Comprehensive survey of electron orbits: PIC simulations

- “Noncrossing” family of electron orbits are discovered
- This will lead to the revision of orbit theory and reconnection models

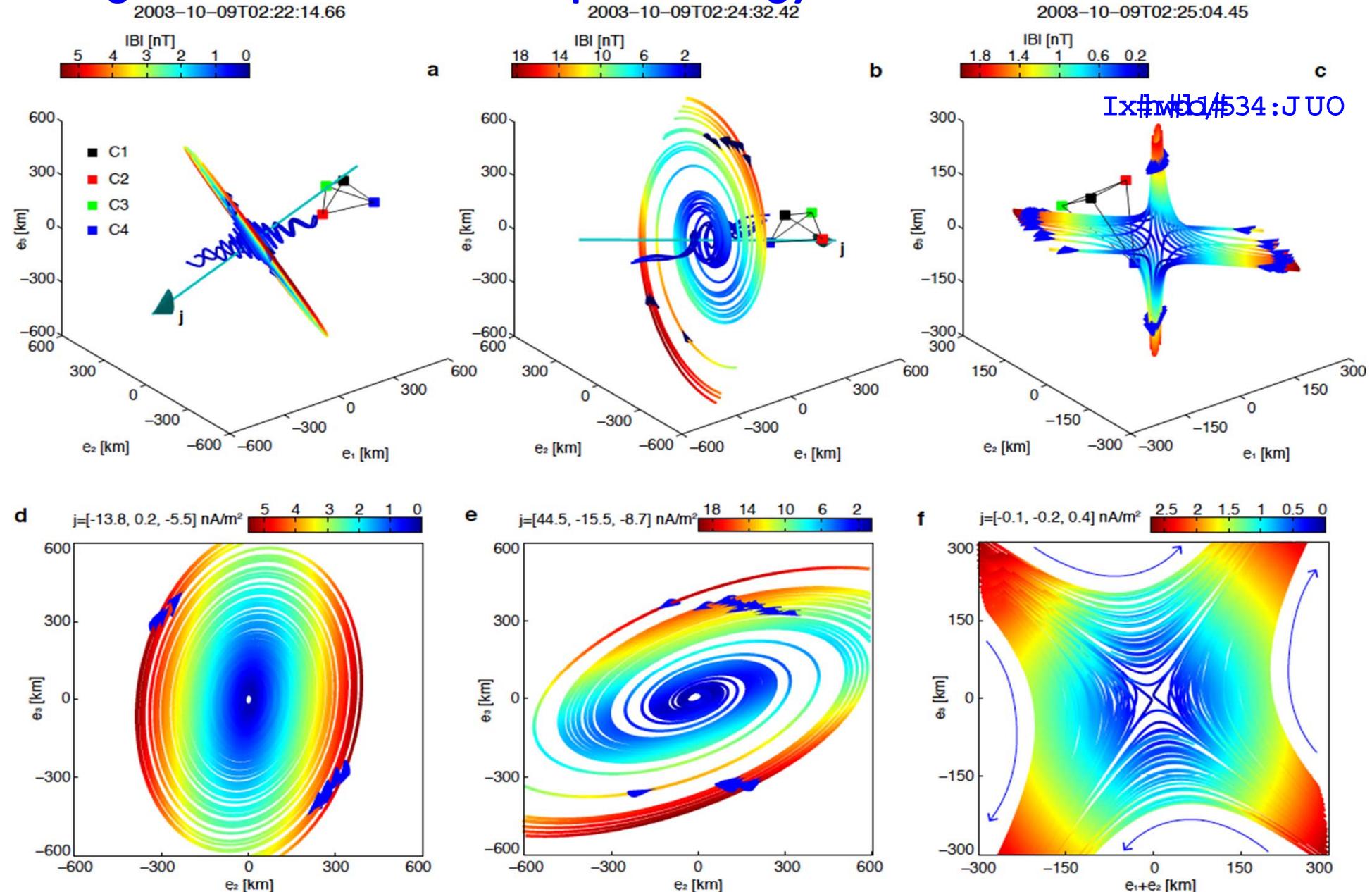


Zenitani & Nagai 2016 PoP

[S-I18:Zenitani]



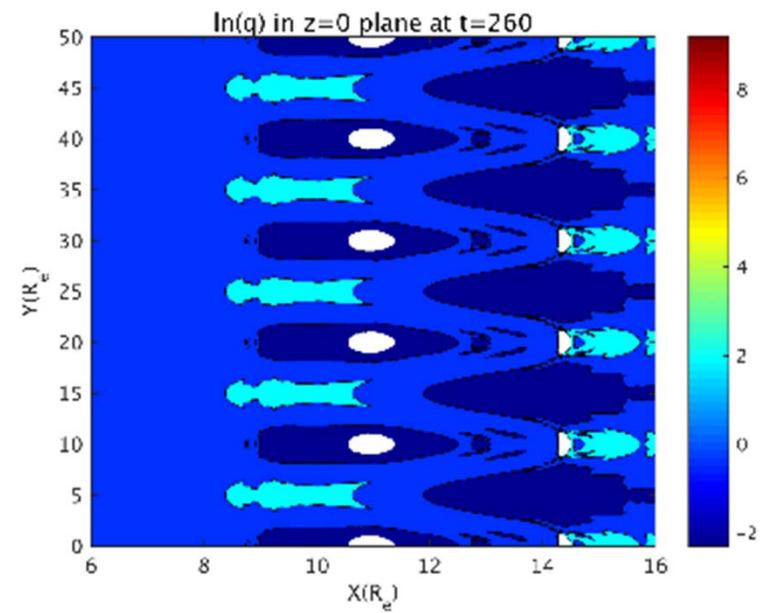
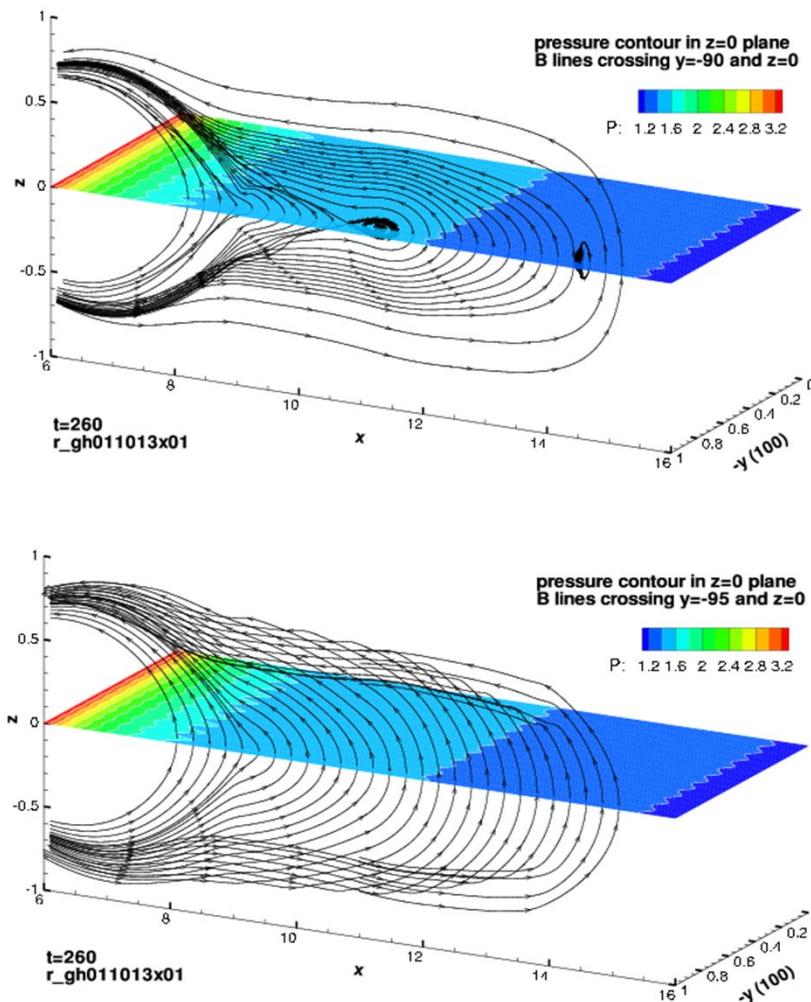
# Magnetic reconnection dissipates energy at O-lines but not X-lines



First-order Taylor expansion (FOTE)

[S-I12:Fu]

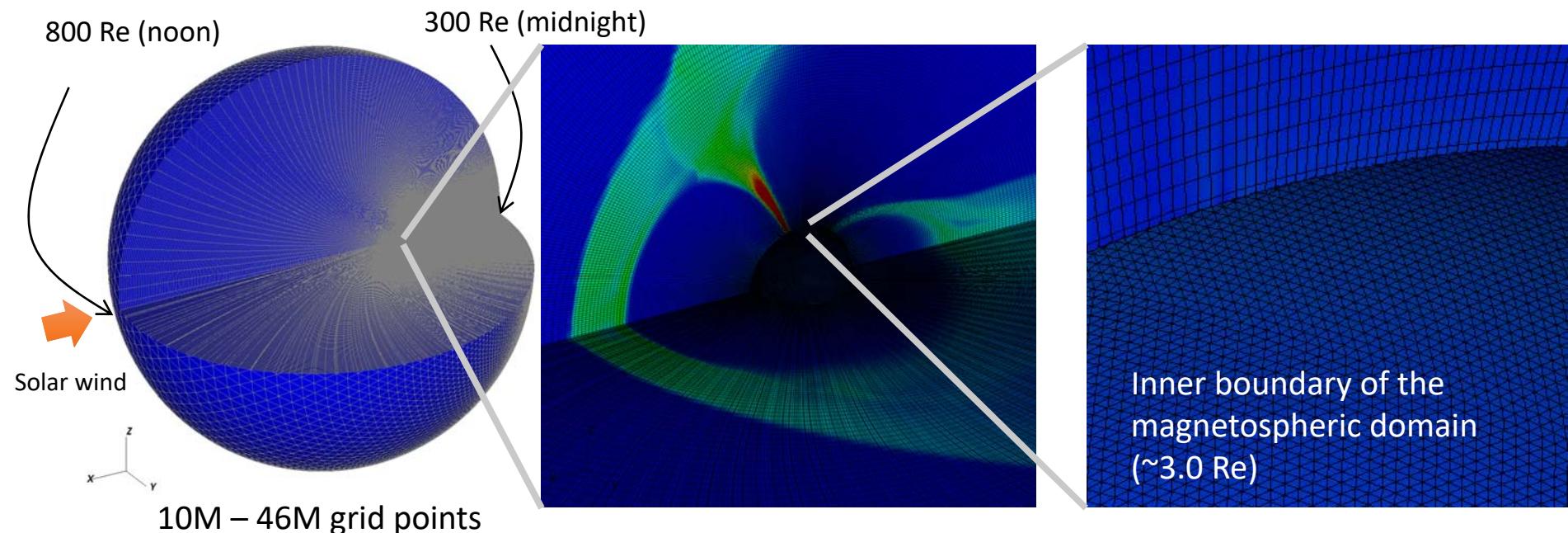
# Quasi separatrix layers (QSLs) provide more global and complete views on 3D plasmoid and reconnection structure



- Above: QSL in  $z=0$  plane.
- Upper: ballooning finger plane ( $dp > 0$ )  $y = -90$ .
- Lower: ballooning bubble plane ( $dp < 0$ )  $y = -95$ .

Ref: [Zhu and Raeder PRL 2013, JGR 2014, Zhu et al. POP 2017]

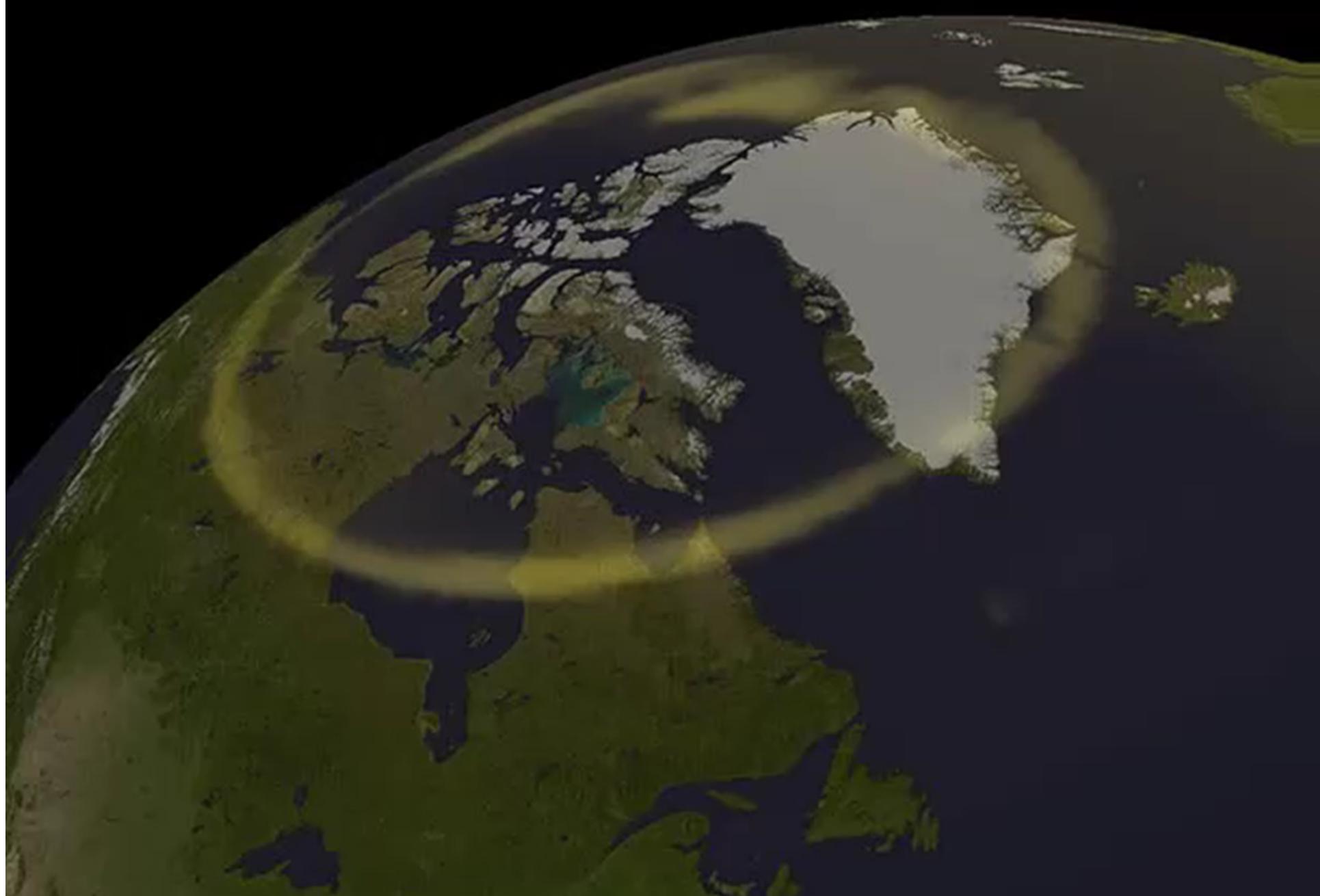
[S-I13:Zhu]



- Global MHD simulation (REPPU) developed by Tanaka (2015) was used.
- Grid system has no singular point.
- The magnetosphere is coupled with the ionosphere.

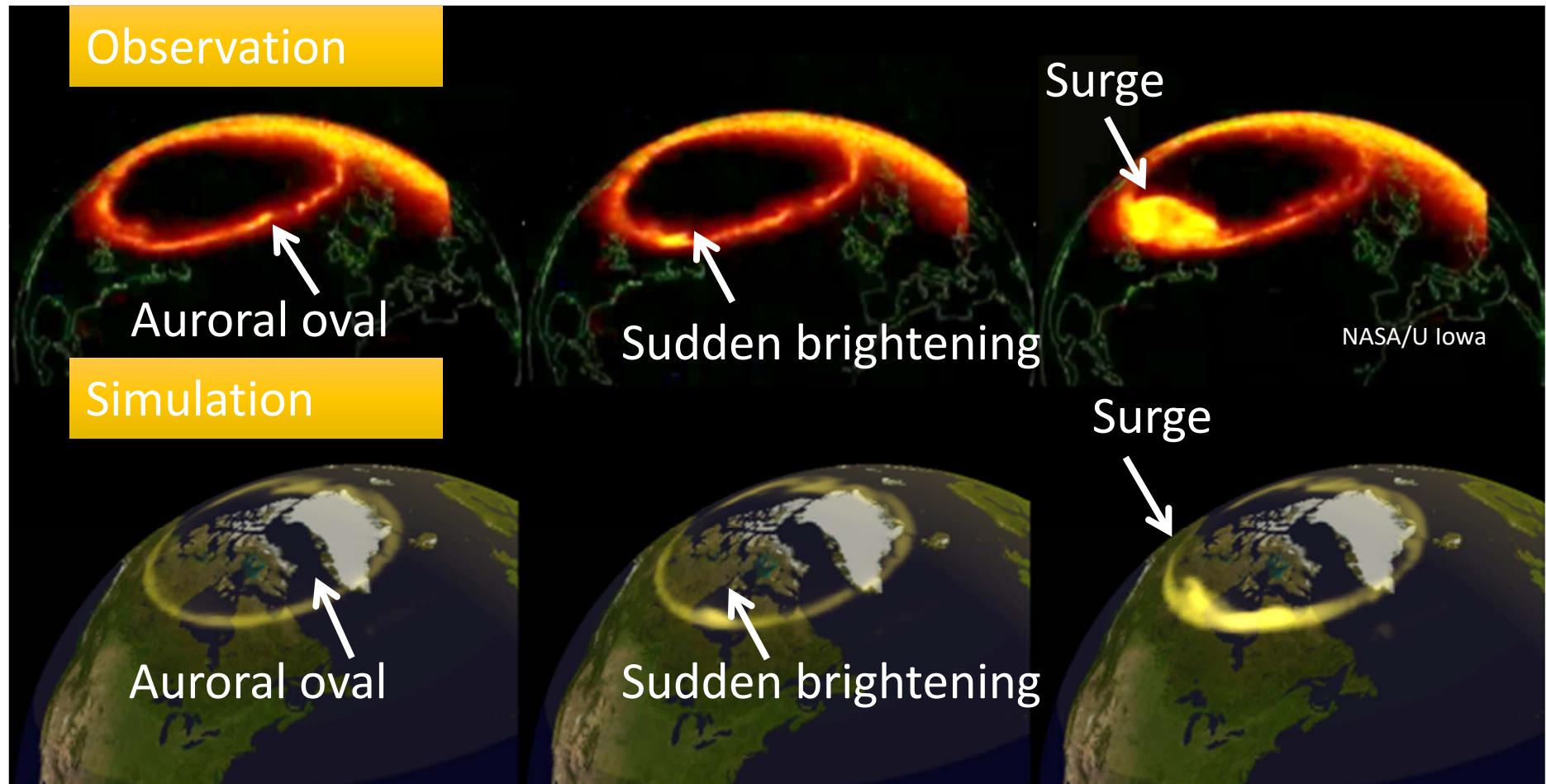
# Simulated auroral breakup

12



# Evolution of aurora (comparison with observation)

13



[SI-9:Ebihara]

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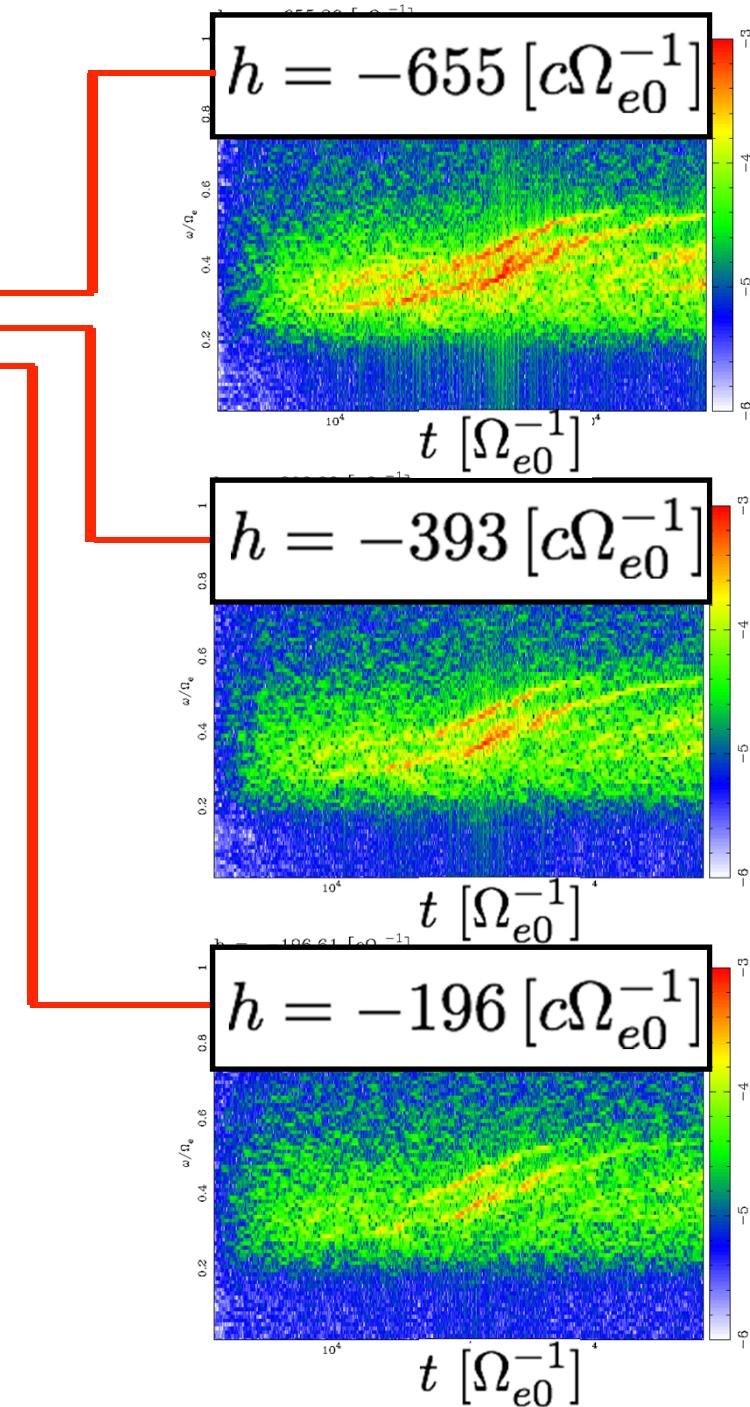
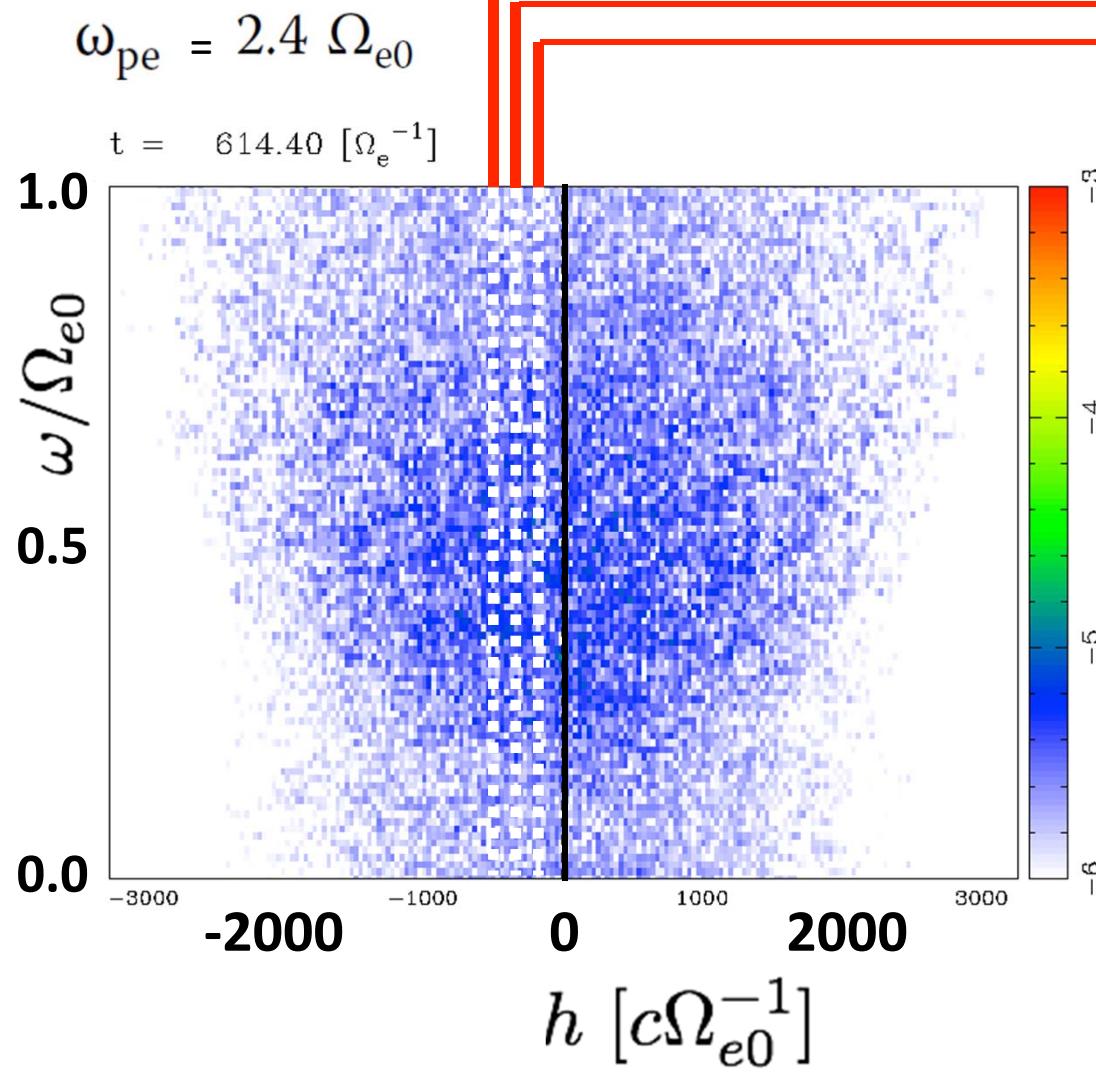
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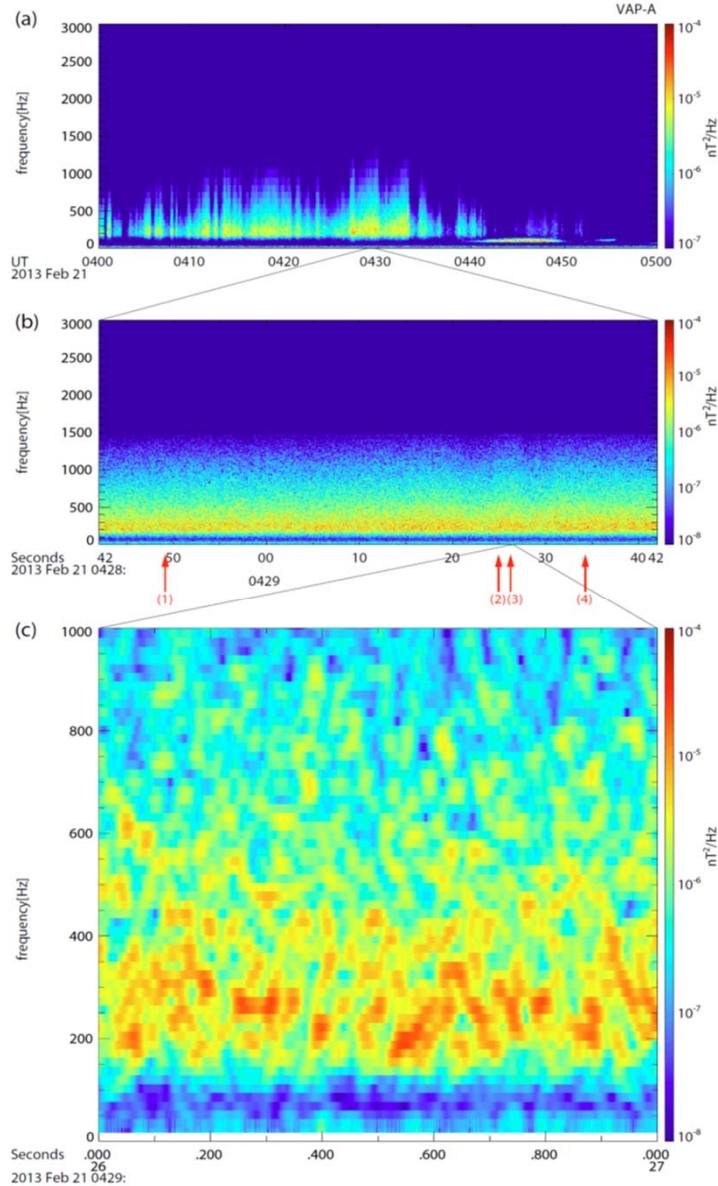
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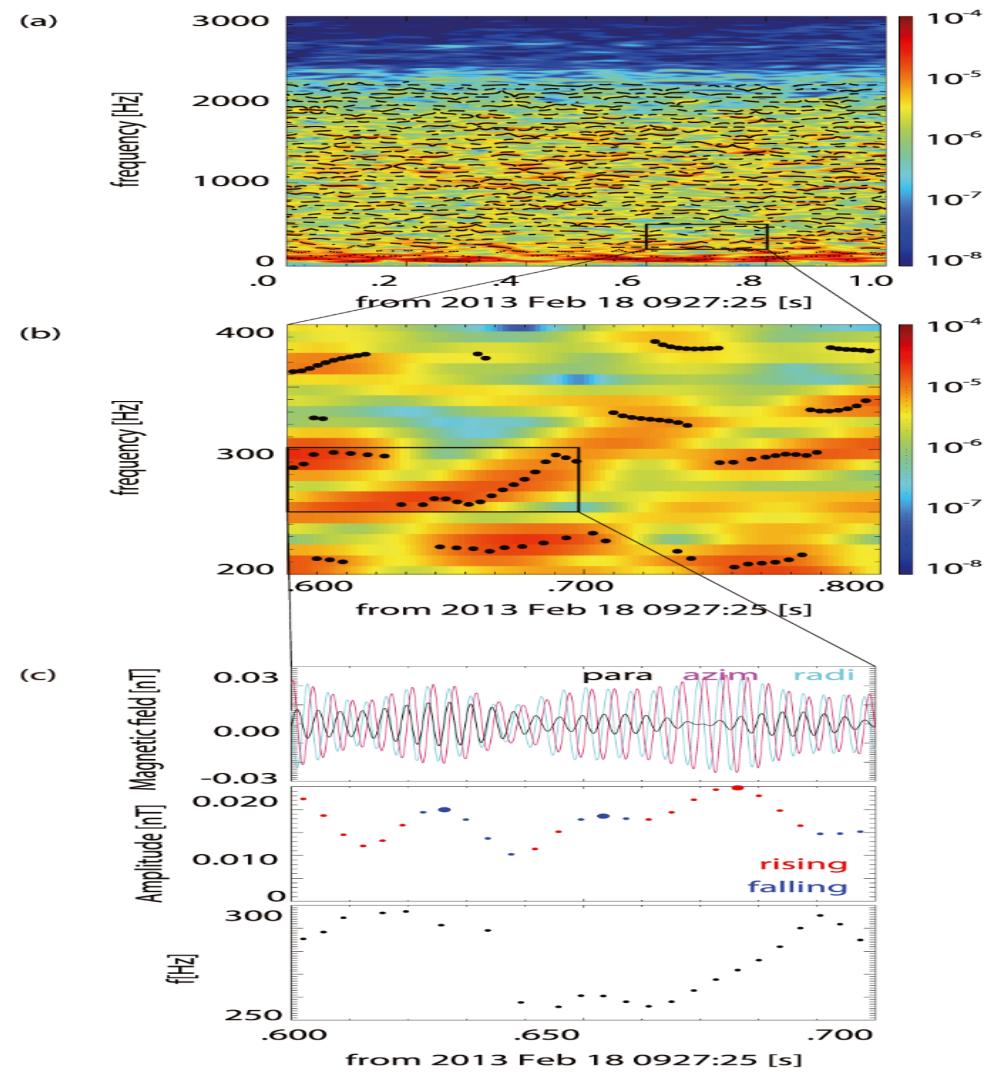
Chorus generation reproduced by electron hybrid simulation  
with real parameters  
[Kato and Omura, EPS, 2016]



# Generation Mechanism of Plasmaspheric Hiss



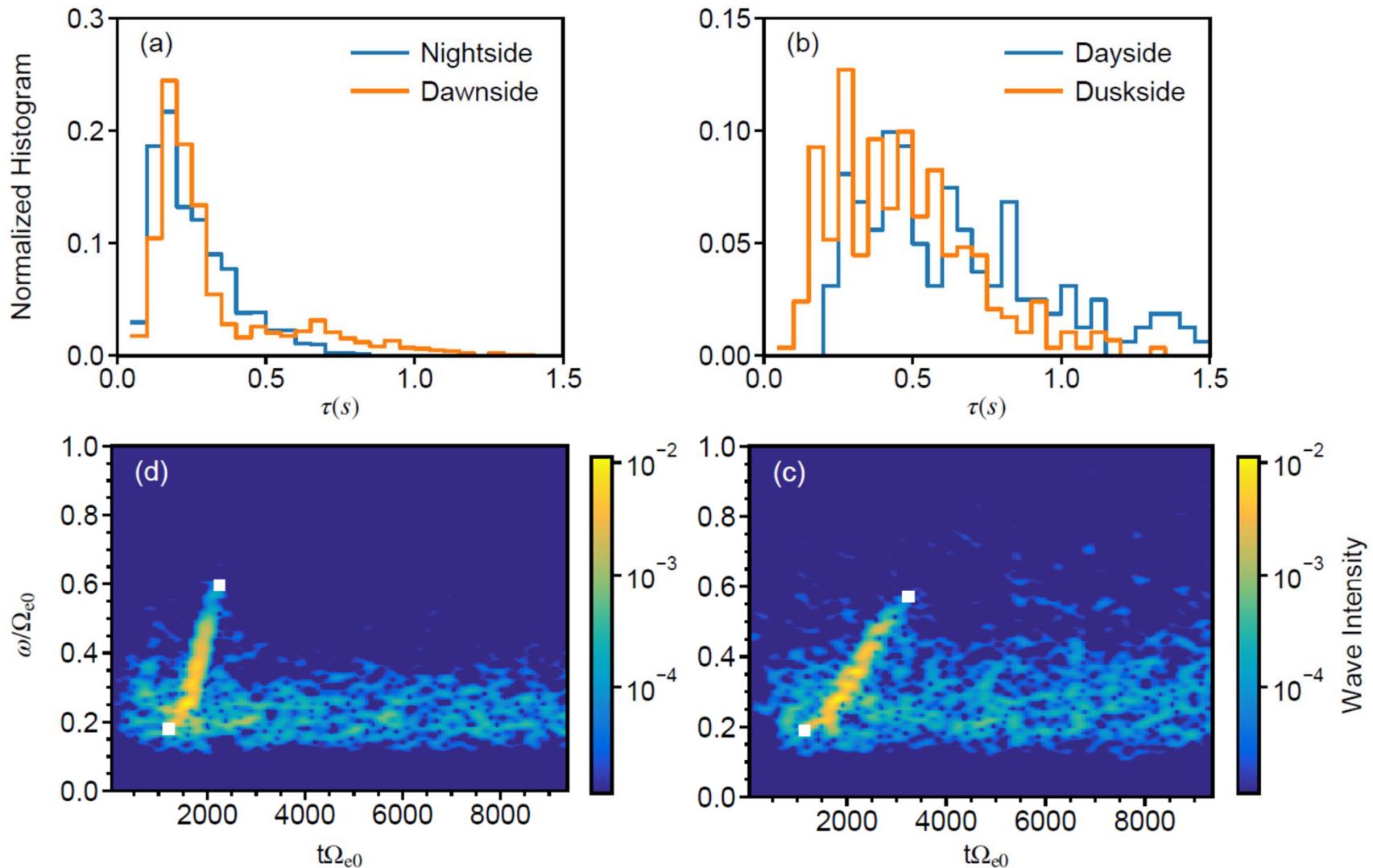
[Summers et al., JGR, 2014]



[Nakamura et al., JGR, 2016]

[S-I23:Omura]

We analyzed the dependence of duration on MLT and the AE index using Van Allen Probes data and DAWN code simulation. Our data analysis shows that the duration is larger at dayside (smaller AE) and smaller at nightside (larger AE).



[S-I26:Tao]

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# Nonlinear Instability of Alfvén wave in the interplanetary plasma

## 3 Transition from 2D- to 3D-decay: results (*Zhao+2017 submitted*)

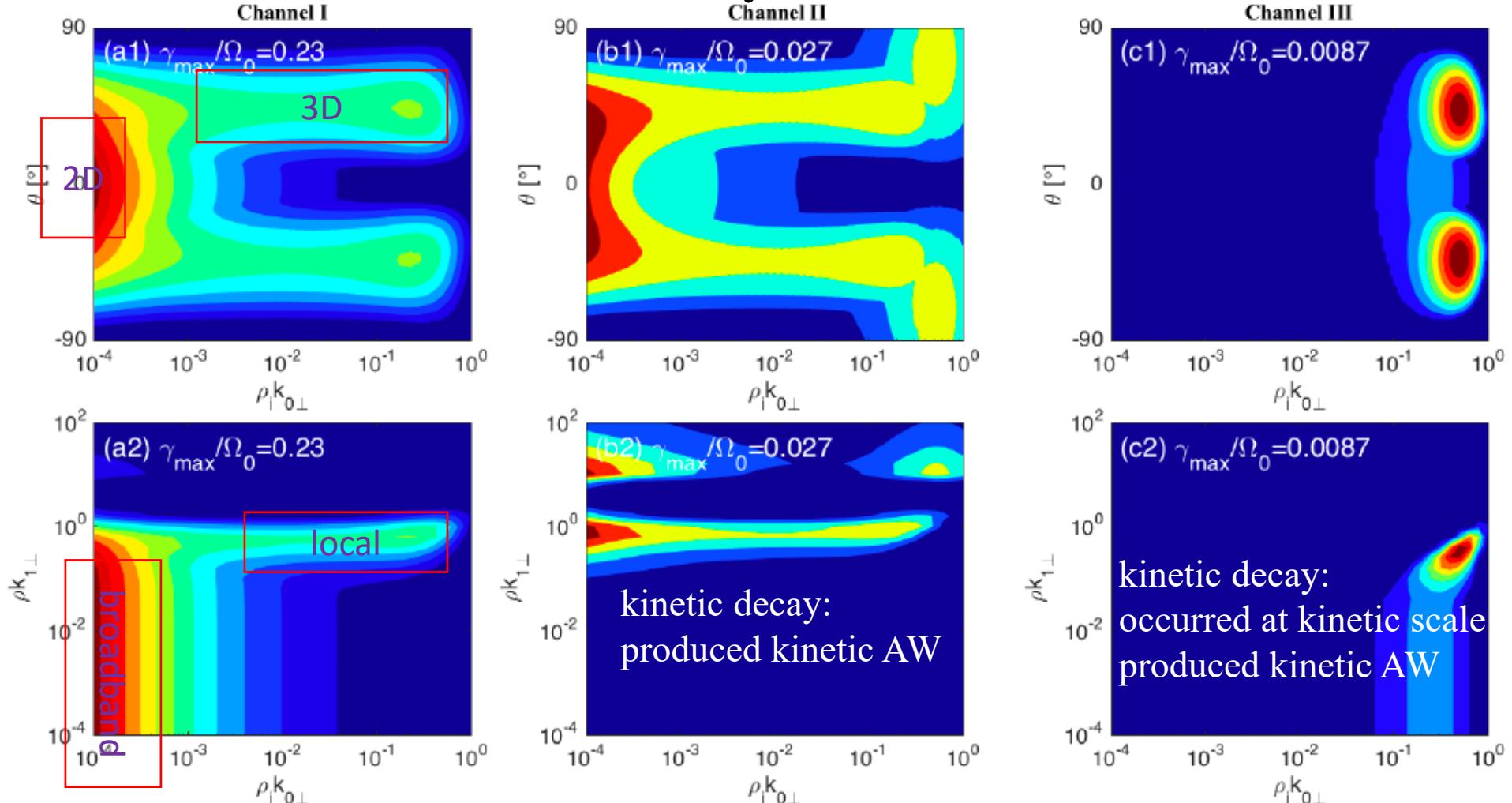
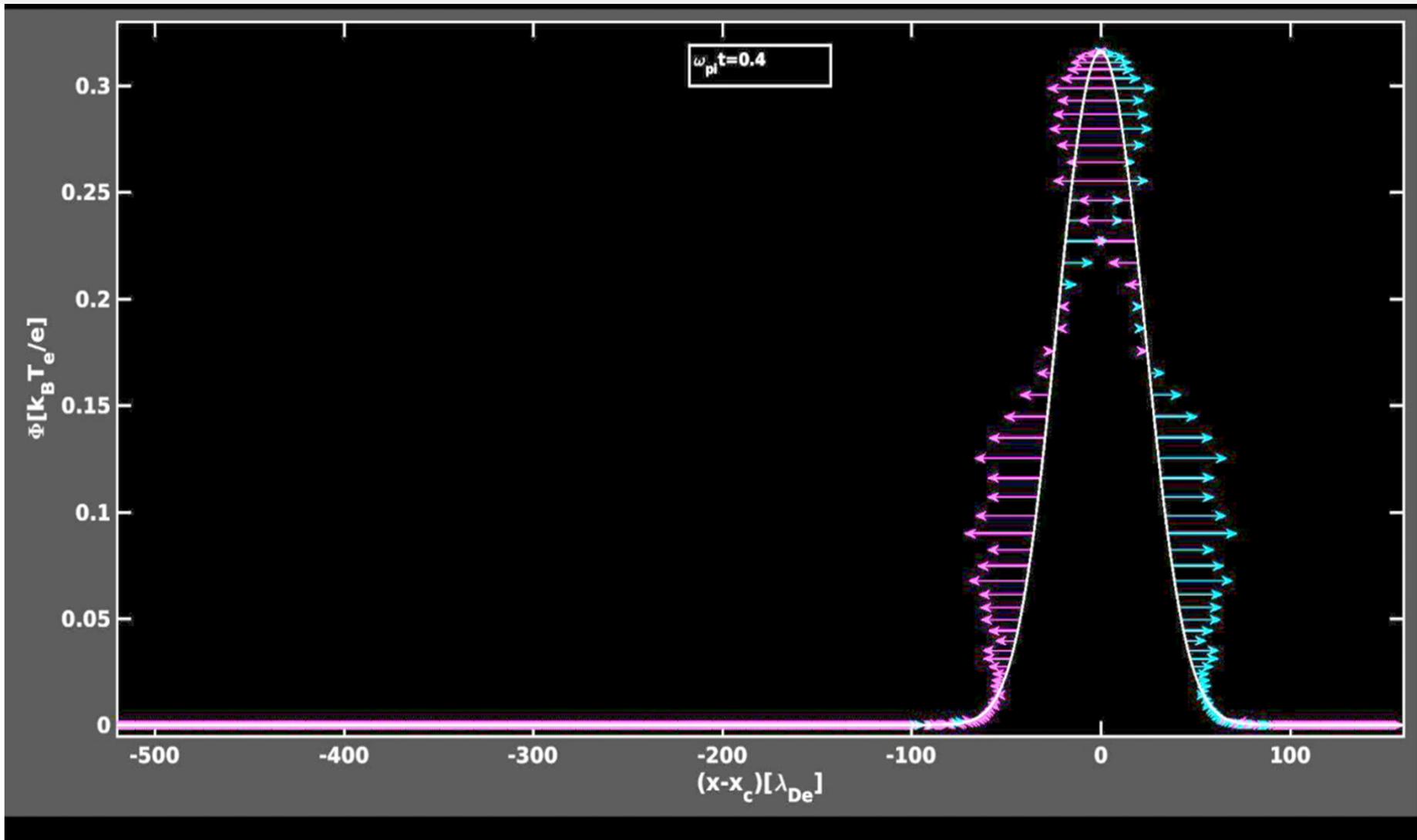


FIG. 1.— Panels (a1)–(c1) present the nonlinear growth rate  $\gamma/\Omega_0$  as a function of  $\rho_i k_{0\perp}$  and angle  $\theta$  between perpendicular wavevectors of two Alfvén waves: (a1) Channel I; (b1) Channel II; and (c1) Channel III. Panels (a2)–(c2) present  $\gamma/\Omega_0$  as a function of  $\rho_i k_{0\perp}$  and  $\rho_i k_{1\perp}$  for Channel I (a2), Channel II (b2), and Channel III (c2).

[S-I6:Zhao]

# Role of Ponderomotive Force in Formation of Coherent Wave Structures Through Wave Breaking in Plasma

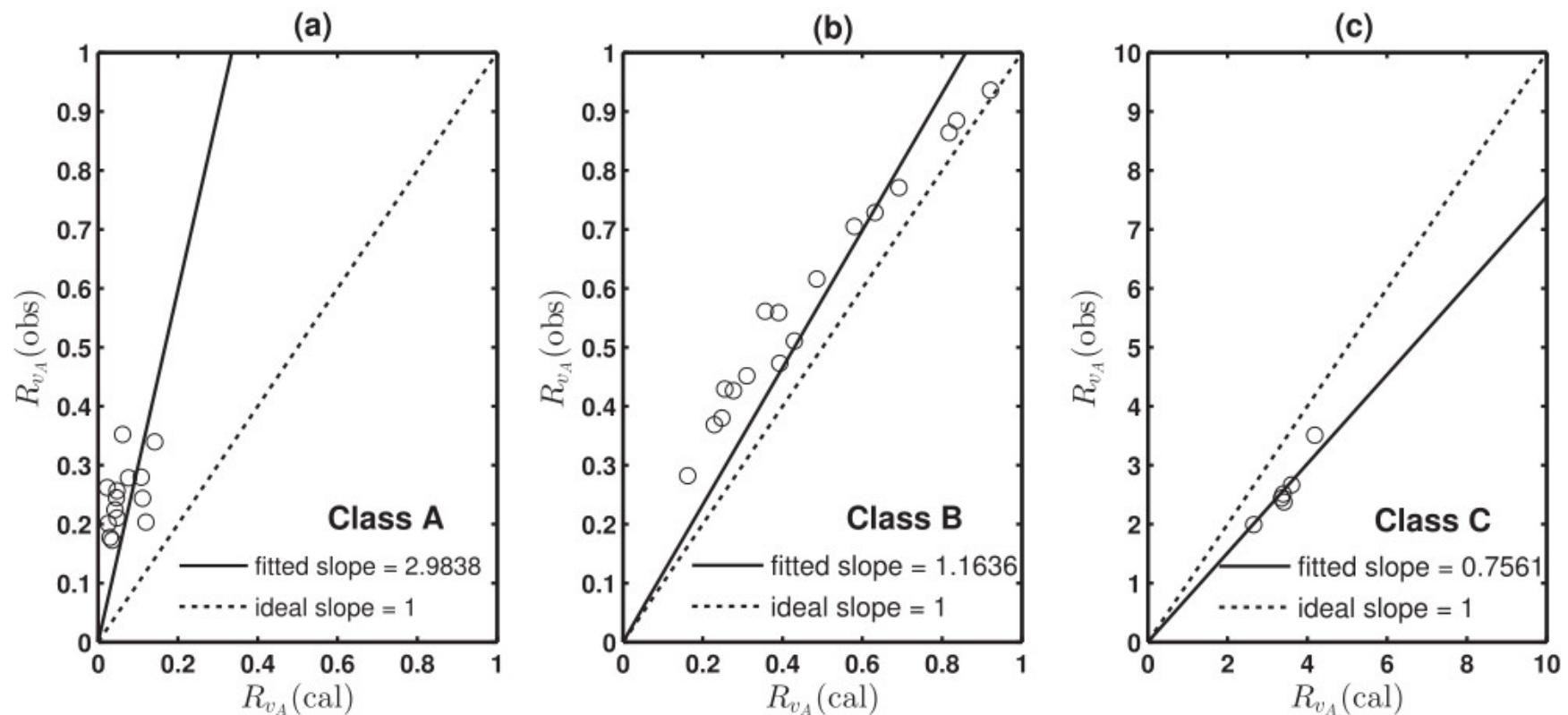


Magnitude & direction of spatially varying PF  
acting at different locations on the evolving wave

Lotekar+Kakad+Kakad,  
*Phys Plasmas* 2017

[S-I7:  
Kakad]

# A model for the Walen slope of Alfvénic fluctuations in the solar wind



Walen Relation

$$v = \pm A \frac{\mathbf{B}}{\sqrt{\mu_0 \rho}}$$

Walen Slope

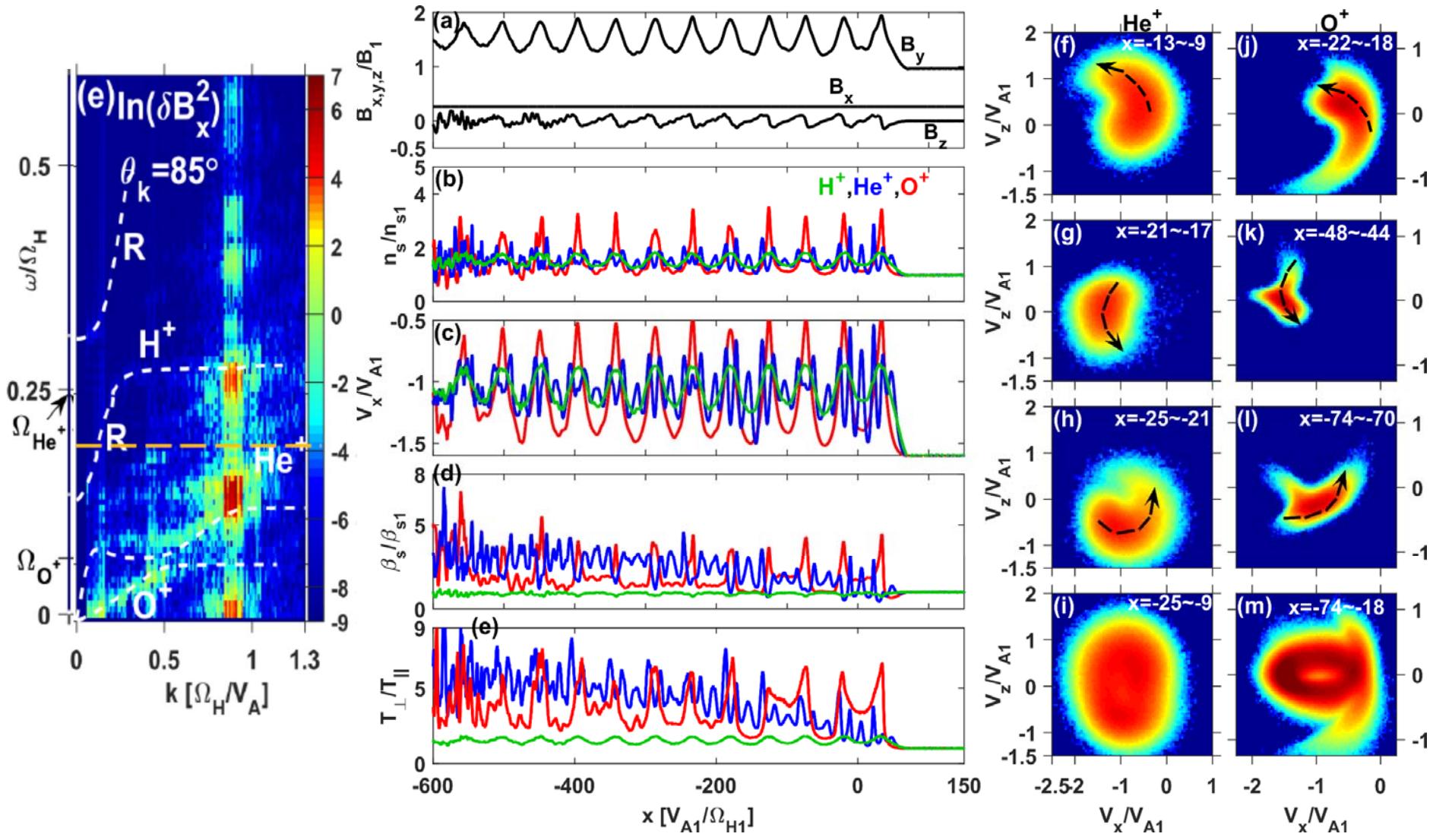
$$\Delta v = R_W \Delta v_A$$

[Yang et al., ApJ, 2016]

[S-I11:Yang]

# Generation of hydrogen, helium and oxygen cyclotron waves and harmonics by fast magnetosonic shocks

## Formation of Oxygen bunch distribution



[S-I24:Lee]

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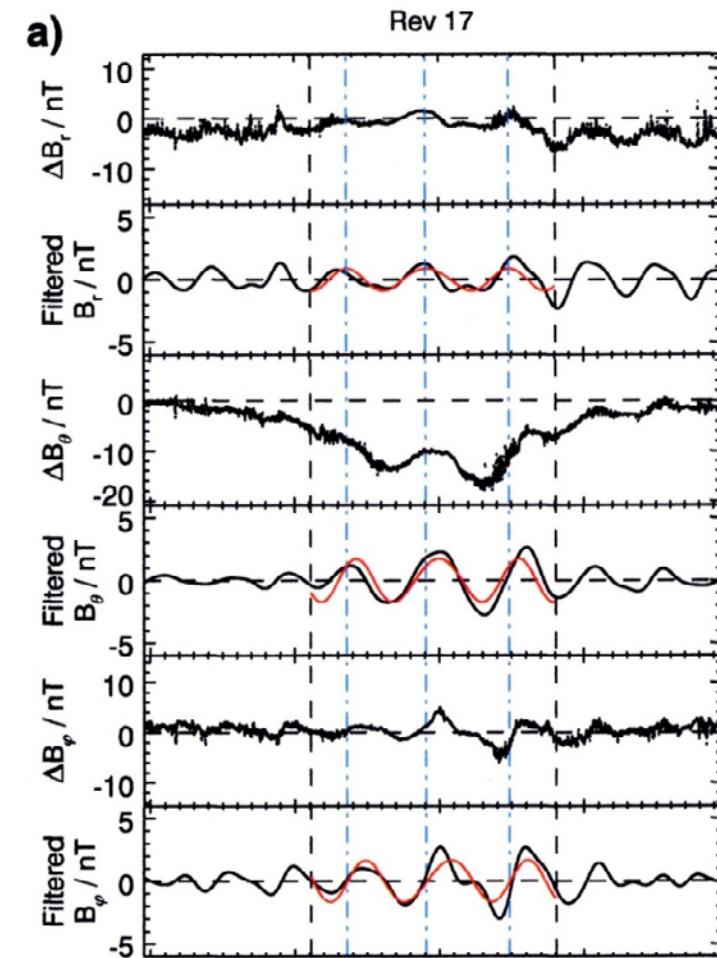
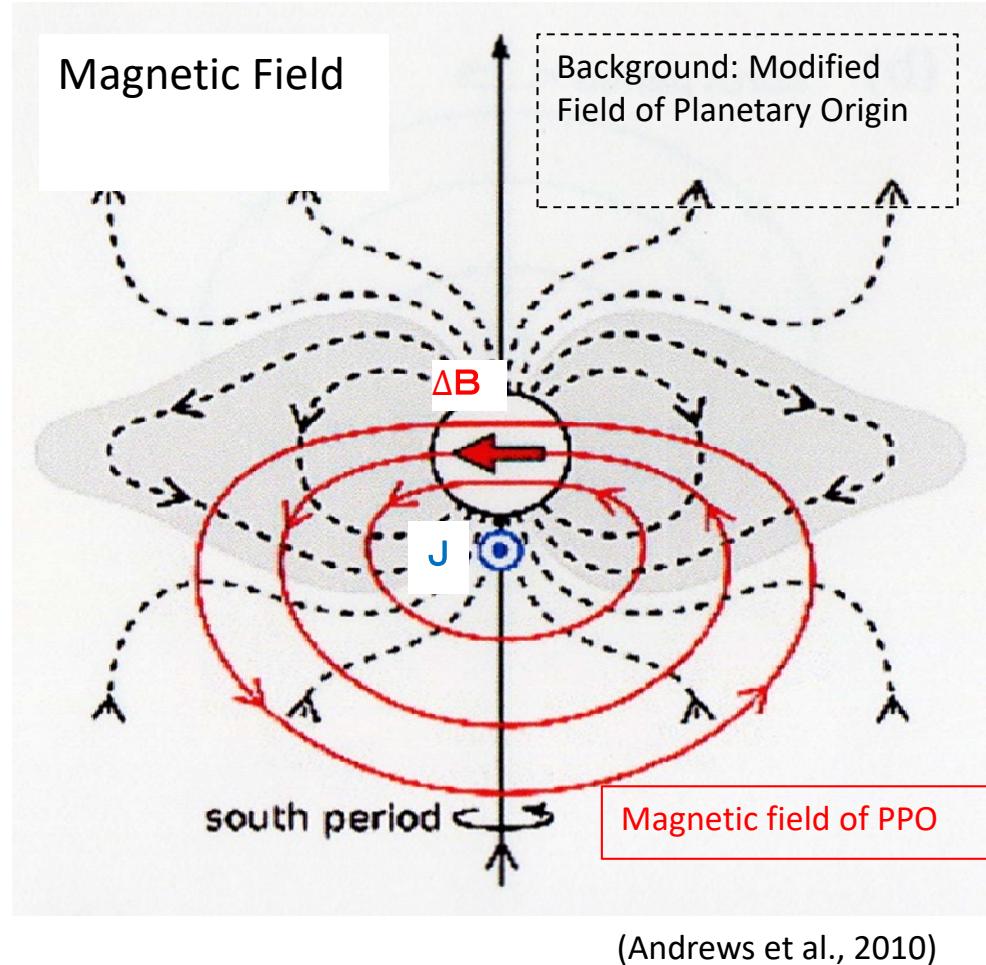
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# Planetary Period Oscillation (PPO) in Saturn's magnetosphere-ionosphere



Year/DOY	2005/302	303	304
$r/R_s$	13.0	4.7	13.9
$\lambda/\text{deg}$	-0.4	0.2	0.3
LT/h	10.6	19.0	2.0

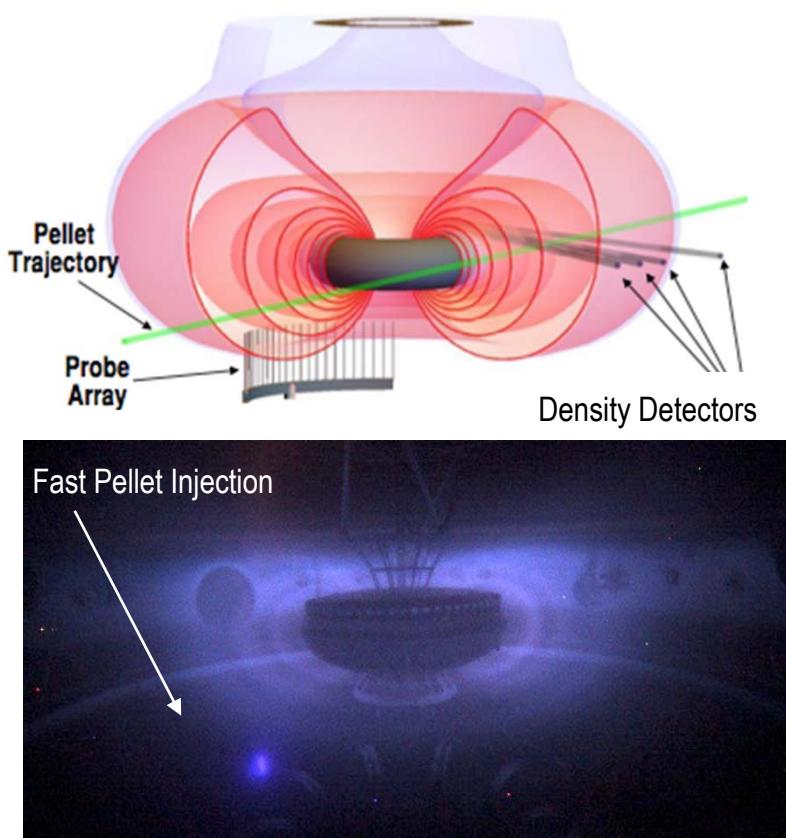
(Andrews et al., 20012)

[P3: Nishida]

# Laboratory Magnetosphere Reveals Fundamental Plasma Phenomena

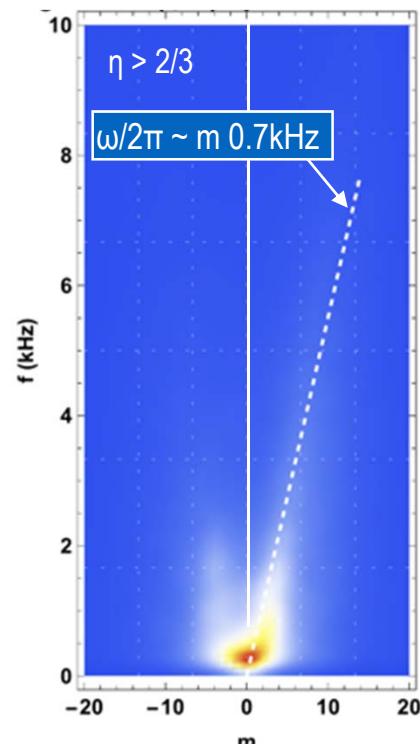
High-resolution detection of power spectrum with and without “Artificial Moon”  
Shows consequence of Inward Curvature Pinch of magnetospheric diffusion

“Artificial Moon” creates Inner Particle Source  
in Laboratory Magnetosphere

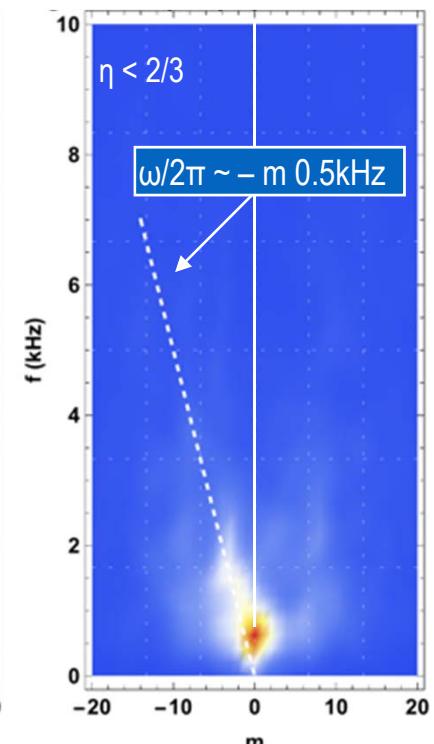


Turbulence Reversal:

Without “Moon”



With “Moon”



Forward  
Propagation



Reversed  
Propagation



[S-I2: Mauel]

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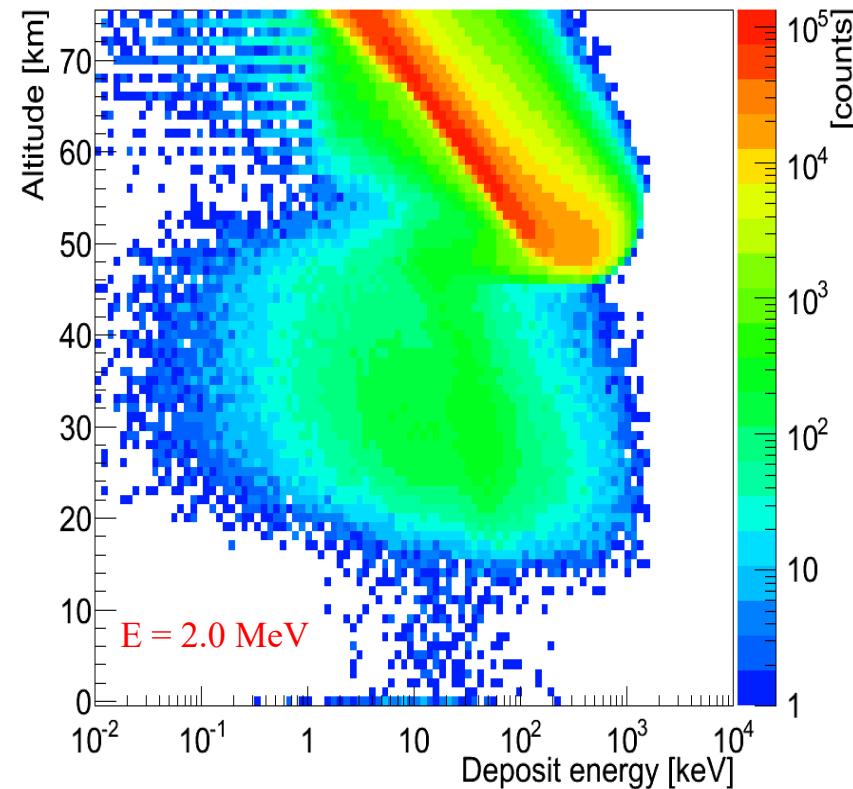
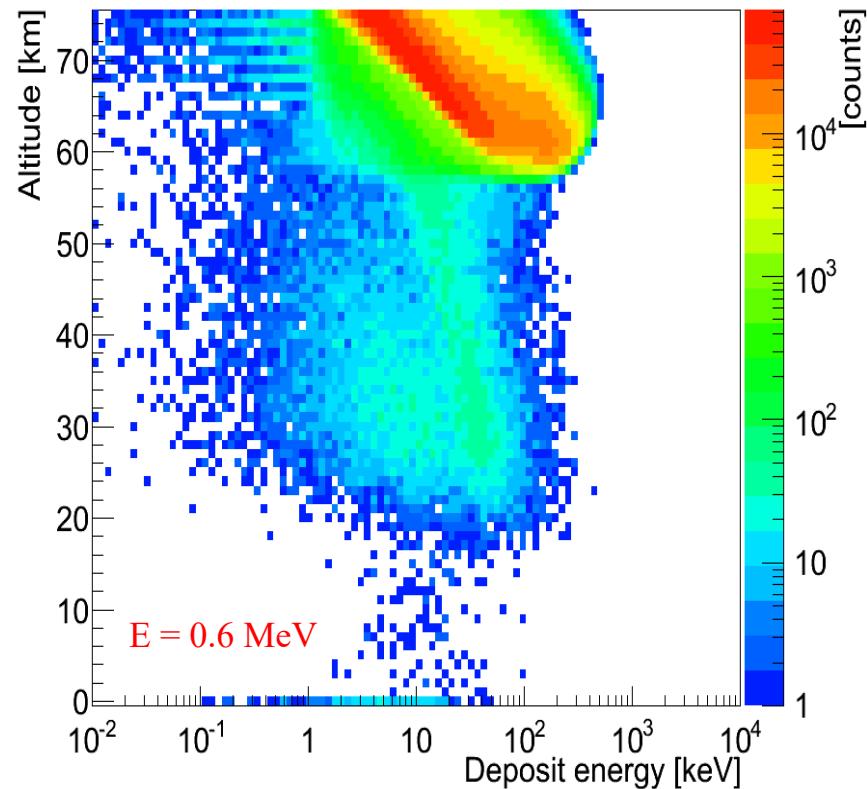
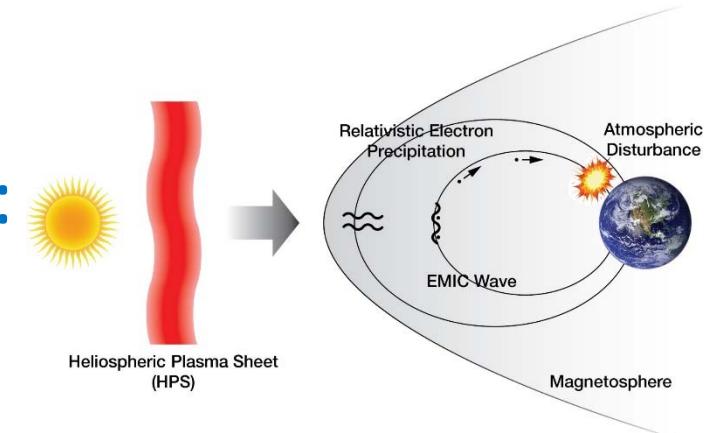
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# Space Plasma Physics Applied: Global Climate Change



The GEANT4 Monte Carlo Code Developed by CERN  
Vertical magnetic fields assumed in simulations

[P20: Tsurutani]