Electron distributions in kinetic scale field line resonances: A comparison of simulations with Cluster and Van Allen Probes observations

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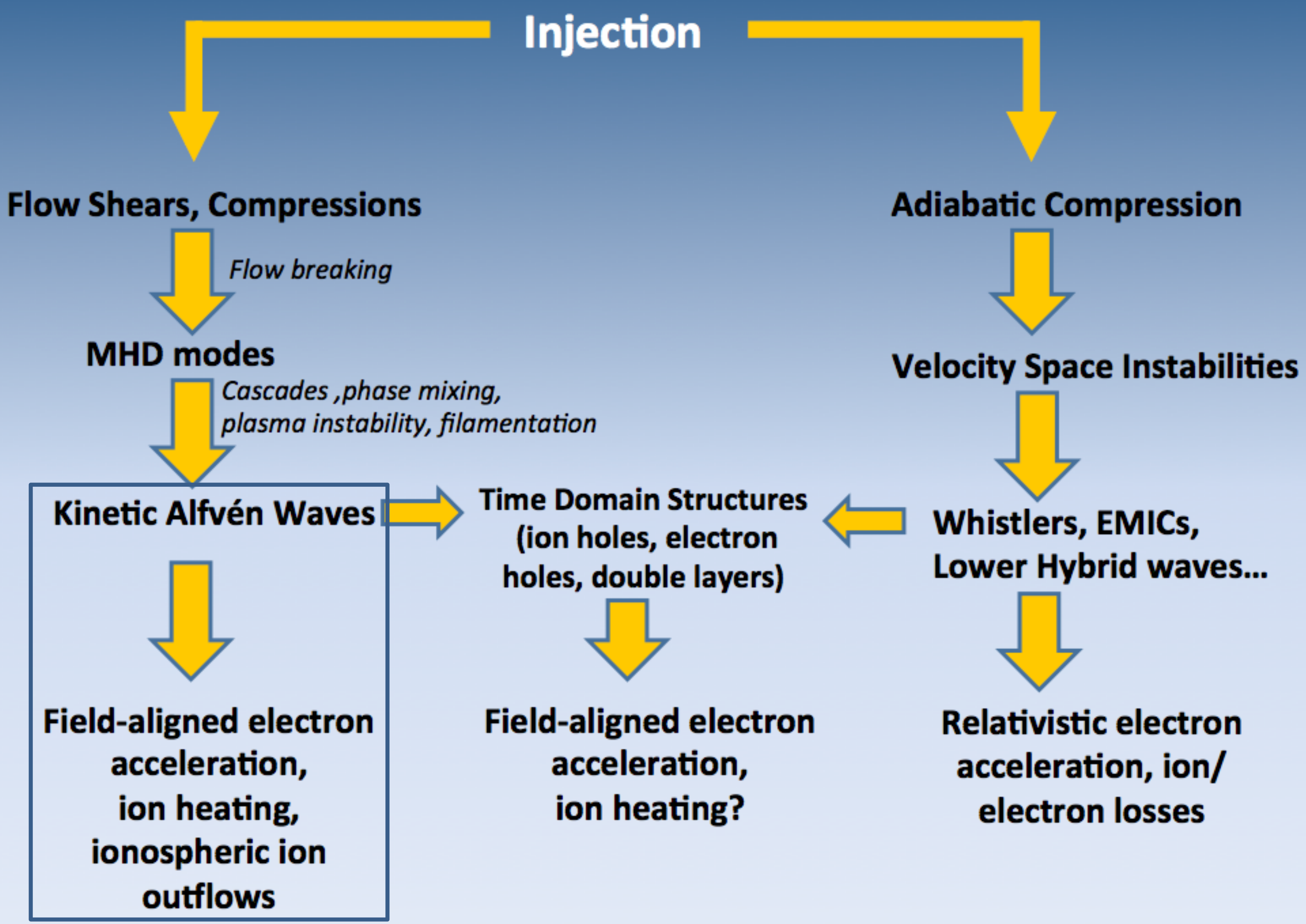
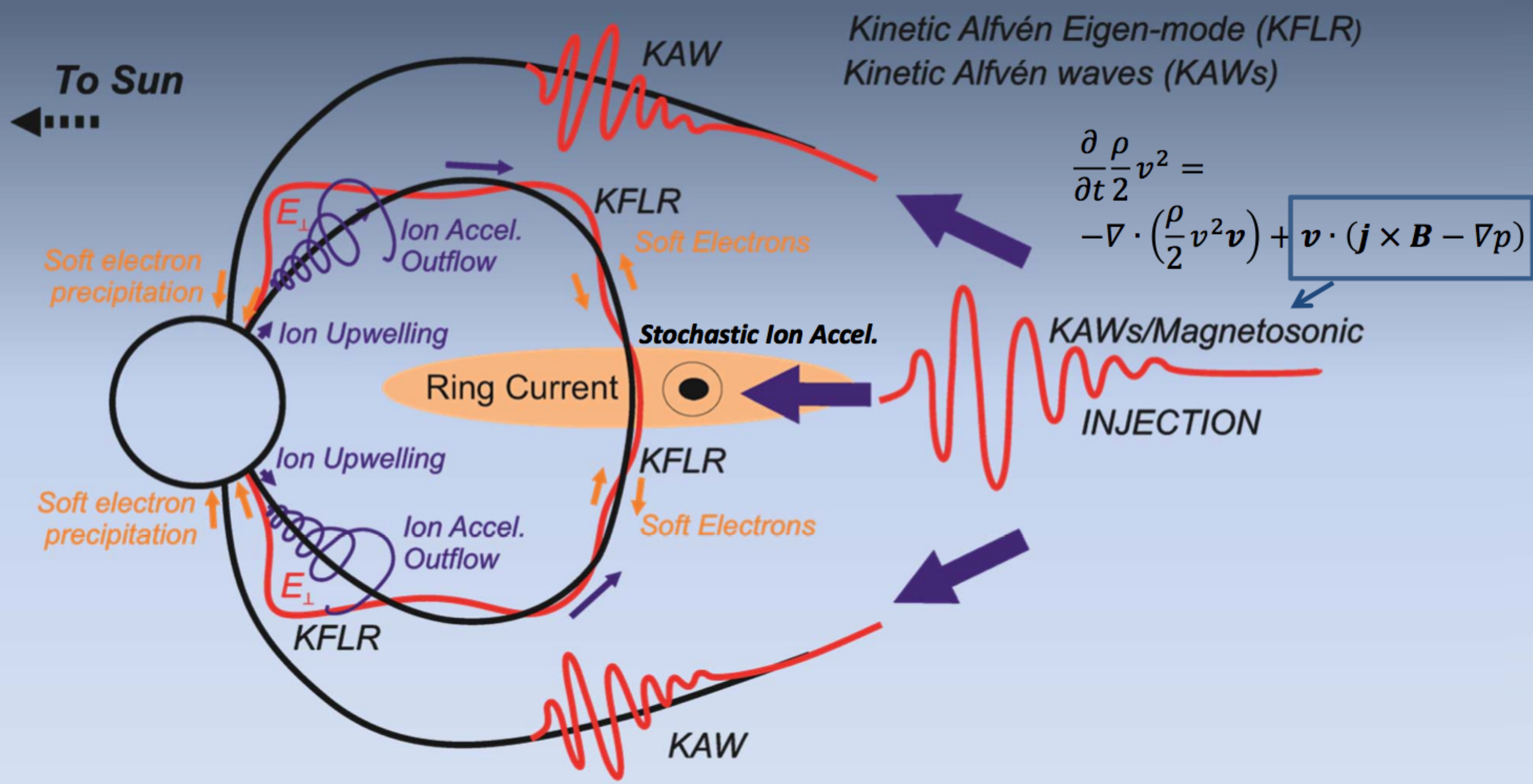


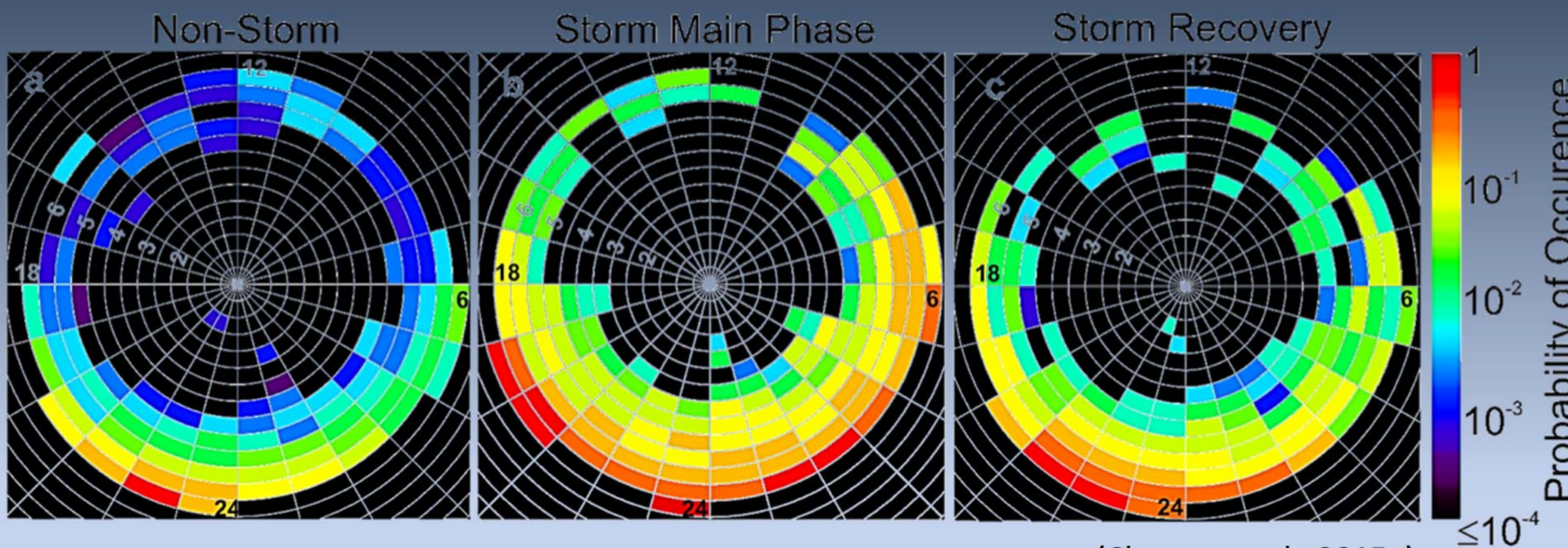
Courtesy C. Chaston

Alfvénic Interactions



Courtesy C. Chaston

How Common and Where ?

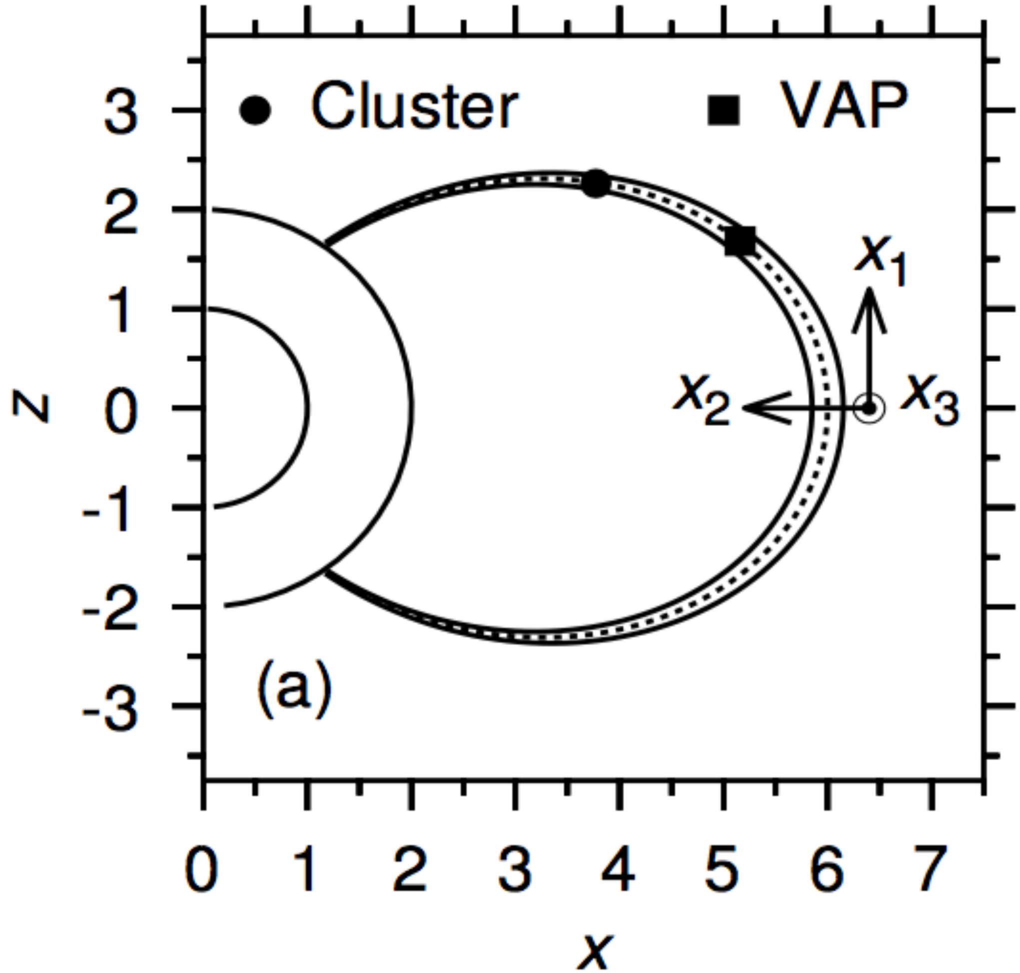


(Chaston et al., 2015a)

- *These waves are always present in the inner magnetosphere during geomagnetic storms with peak amplitudes in and around storm-time injection fronts .*
- *These waves are observed at all local times but primarily from 18 to 6 MLT close to apogee and extend inside L=4.*

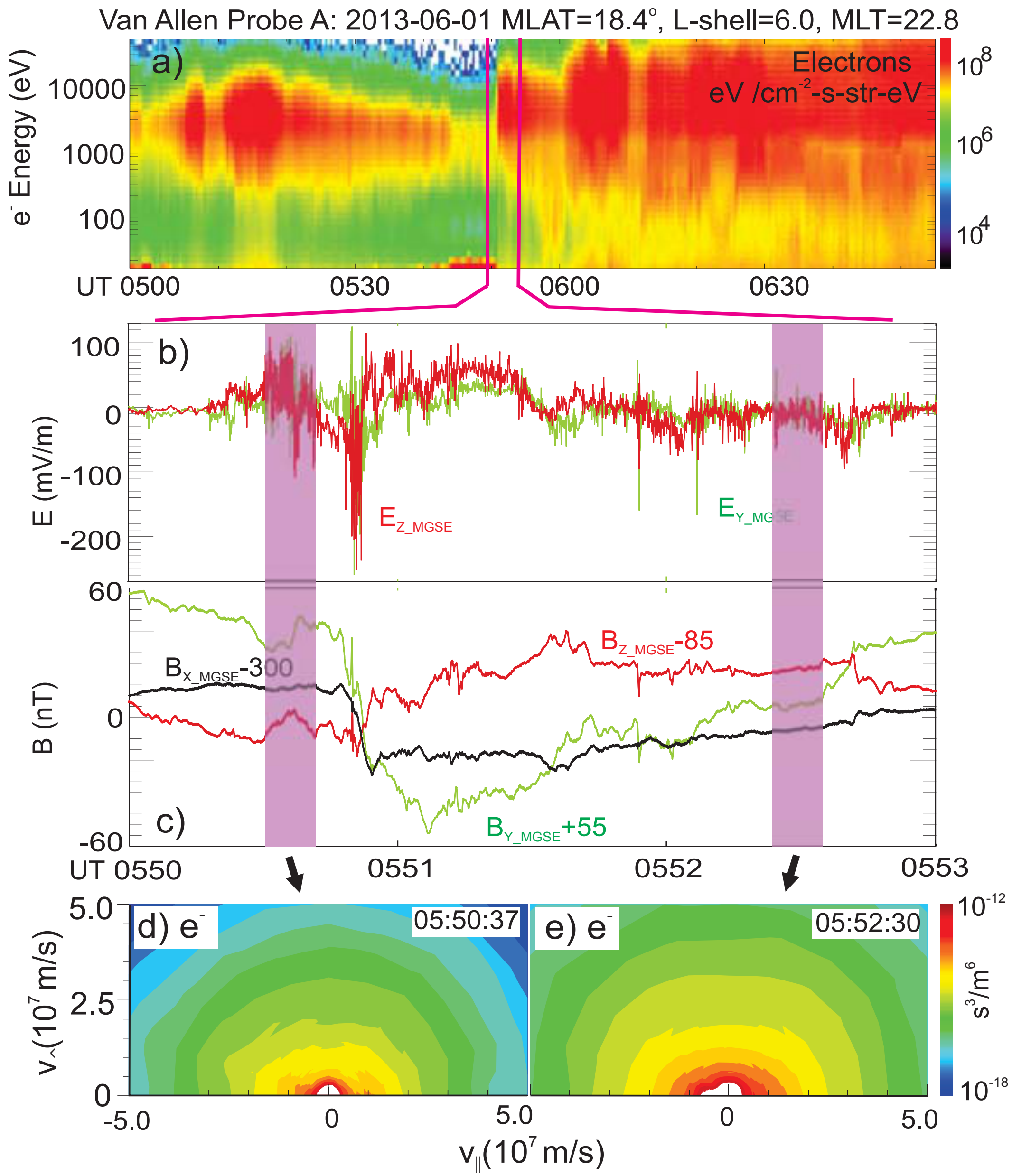
Courtesy C. Chaston

Relative spacecraft positions



Observations not conjunctive: Qualitative comparison.

Van Allen Probes observations



(Figure modified from *Chaston et al.*, 2015)

Mix of standing and travelling modes.

Broad, symmetric plateau

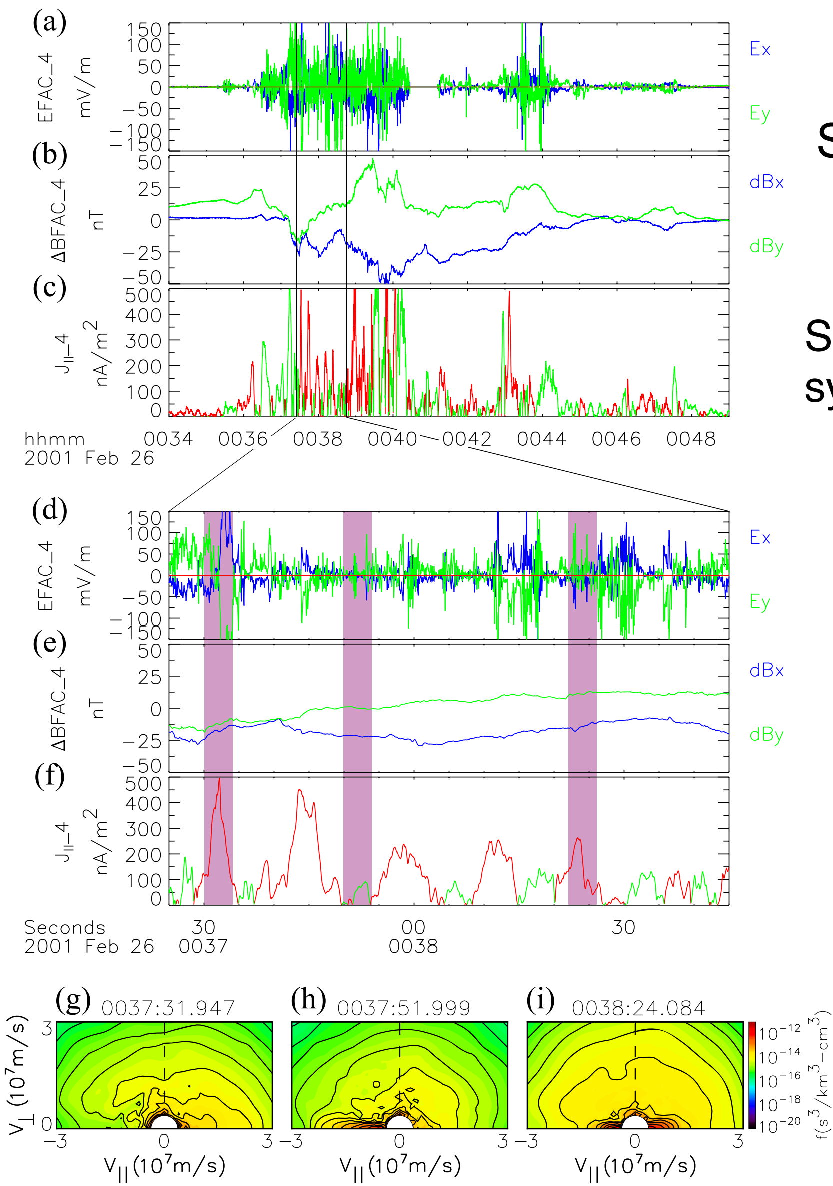
(e.g. *Chaston* et al., 1999; *Wygant*, 2002)

Temporal cadence ~ 11 s

Cluster observations

Upward current

Downward current



SC4

Standing nature of system evident in $J_{||}$

Temporal cadence ~ 4 s

Asymmetric features that vary in concert with the sense of $J_{||}$

Hybrid Gyrofluid-Kinetic-Electron (GKE) model

(*Damiano et al.*, 2007; *Damiano et al.*, 2015, 2016; *Cheng and Johnson*, 1999)

Fluid equations (not solved as shown)

Momentum equation

$$\rho\frac{\partial \tilde{\mathbf{V}}_\perp}{\partial t} = (\mathbf{B}_0 \cdot \nabla)\mathbf{B}_\perp$$

where $\tilde{\mathbf{V}}_\perp = (1 - 1.25\rho_i^2\nabla_\perp^2)\mathbf{V}_\perp$

Faraday's Law

$$\frac{\partial \mathbf{B}_\perp}{\partial t} = -\nabla \times \mathbf{E}$$

Perpendicular Ohm's law

$$\mathbf{E}_\perp = \mathbf{B_0} \times (\mathbf{1} - \rho_\mathbf{i}^\mathbf{2}\nabla_\perp^\mathbf{2})\tilde{\mathbf{V}}_\perp$$

Parallel Ohm's law

$$E_{||} = \boxed{\frac{m_e}{ne^2}\frac{\partial j_{||}}{\partial t}} - \boxed{\frac{1}{ne}\nabla_{||}P_{e_{||}}} - \boxed{\frac{1}{ne}\frac{P_{e_{||}} - P_{e_\perp}}{B_o}\nabla_{||}B_o}$$

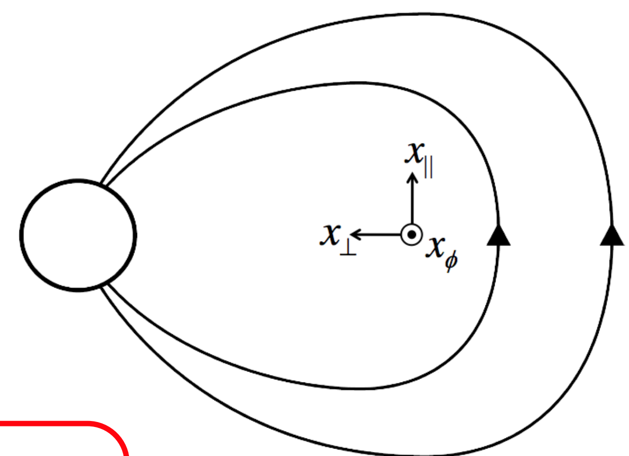
IAW KAW Mirror force

Moments of electron distribution function calculated via PIC techniques

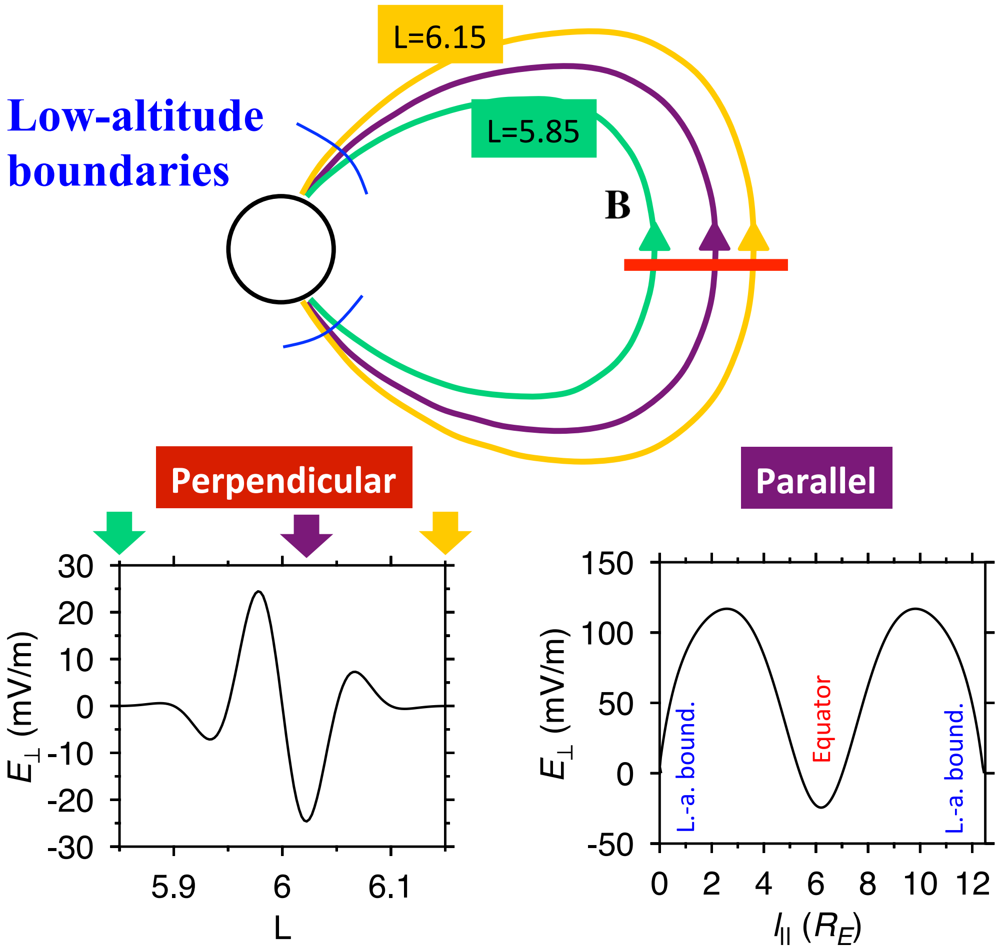
Guiding center equations

$$m_e\frac{dv_{||}}{dt} = -eE_{||} - \boxed{\mu_m\nabla_{||}B_o}$$

$$h_{||}\frac{dx_{||}}{dt} = v_{||}$$



KFLR – Initialization (n=5 mode)



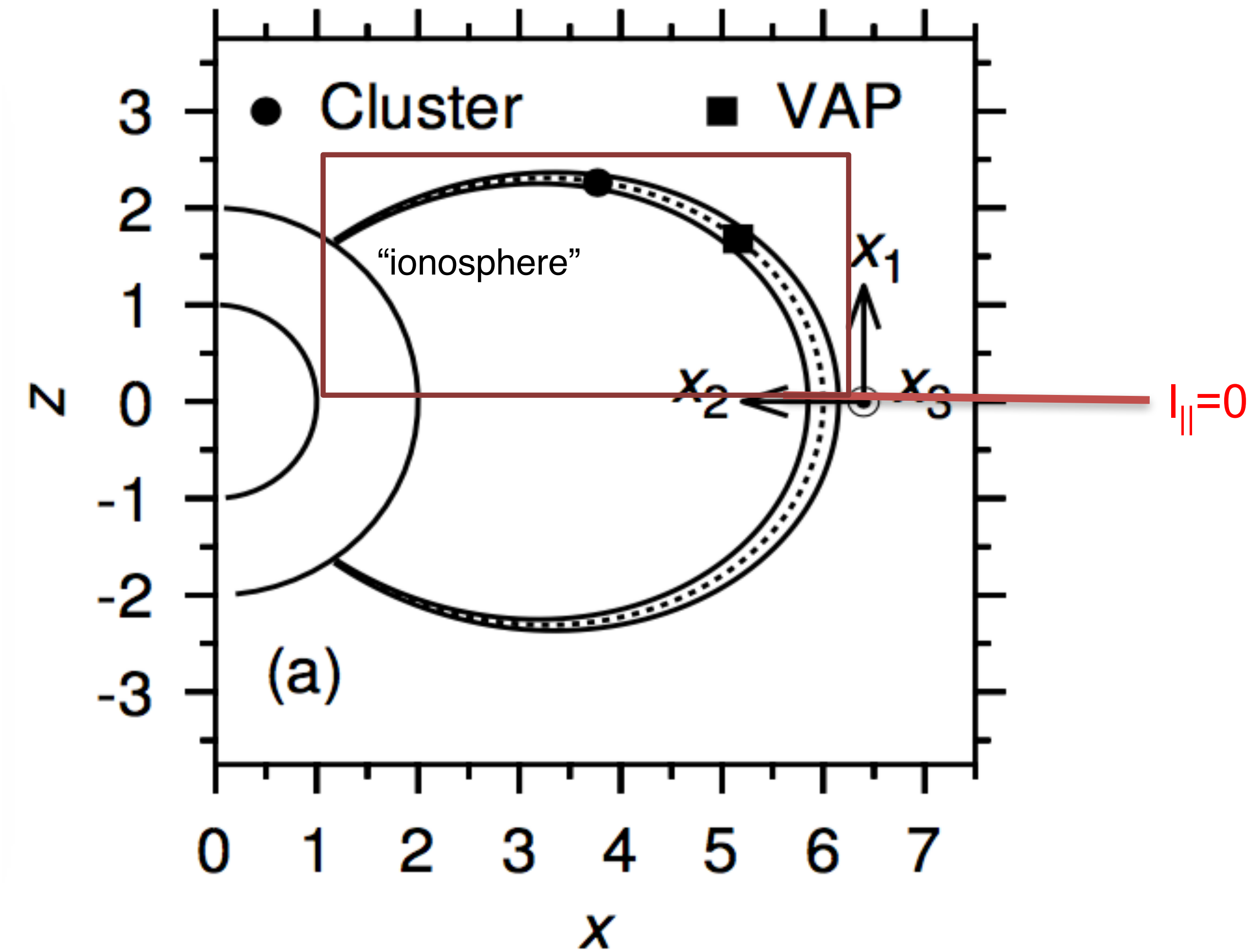
$$k_\perp \rho_i \sim 1$$

Harmonic composition unknown.

(n=n_e=1 cm^{-3}, T_e=1 keV, T_i=10 keV, Period=5.5 s)

Previous studies: **Two fluid -** *Streltsov et al.*, (1998). **Vlasov** - *Rankin et al*,. (2007). **Two fluid/test particle** - *Chaston et al., (2016, 2017, 2018).*

Simulation grid and relative spacecraft positions

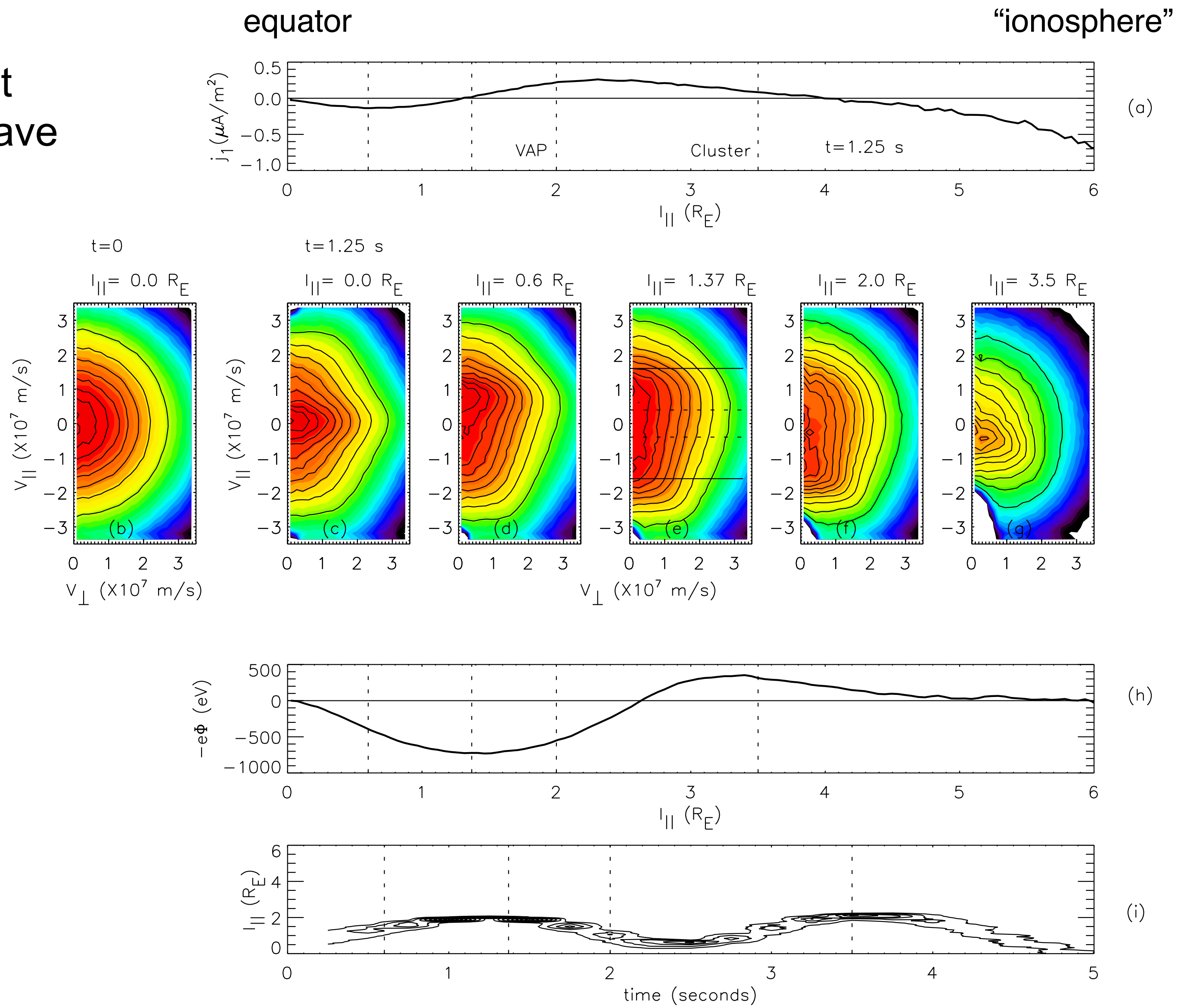


Let us consider features along L=6 field line in the northern hemisphere – field line of maximum $j_{||}$ (dotted line).

Parallel current and distribution function evolution (n=5)

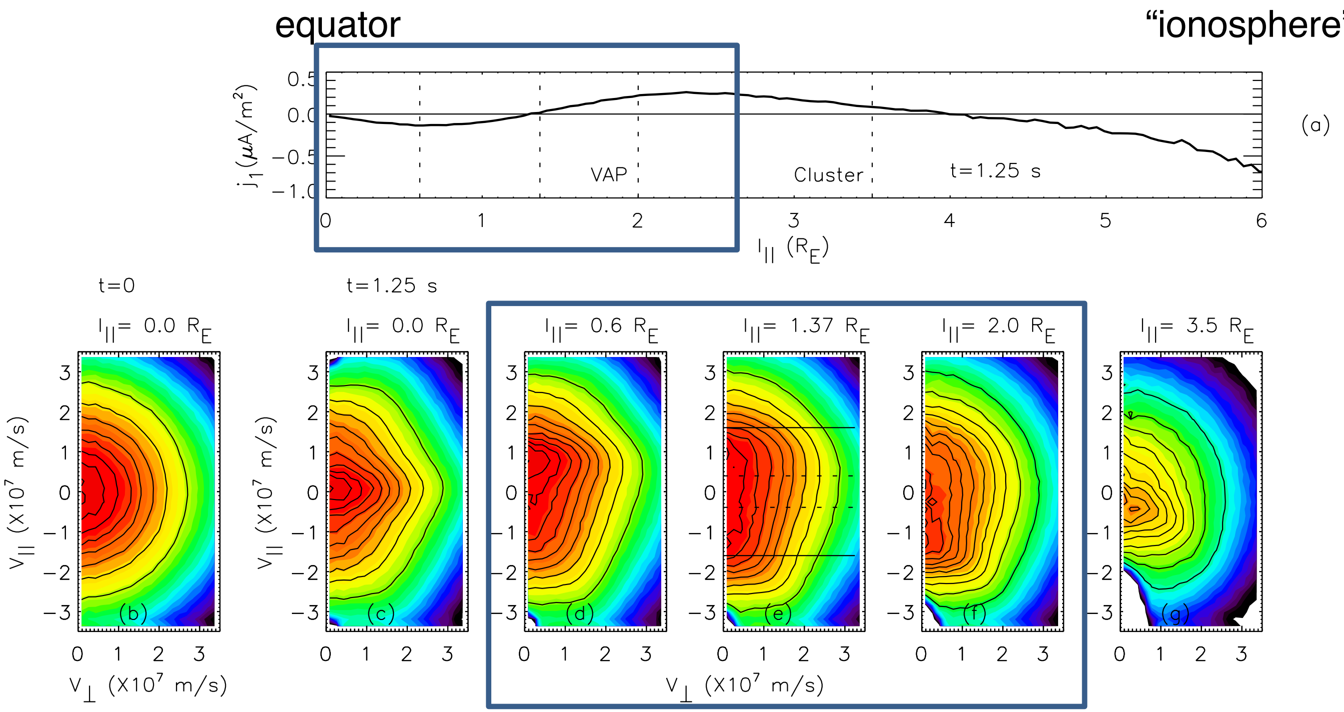
Parallel current signature of wave

Electron distributions at different points along field line

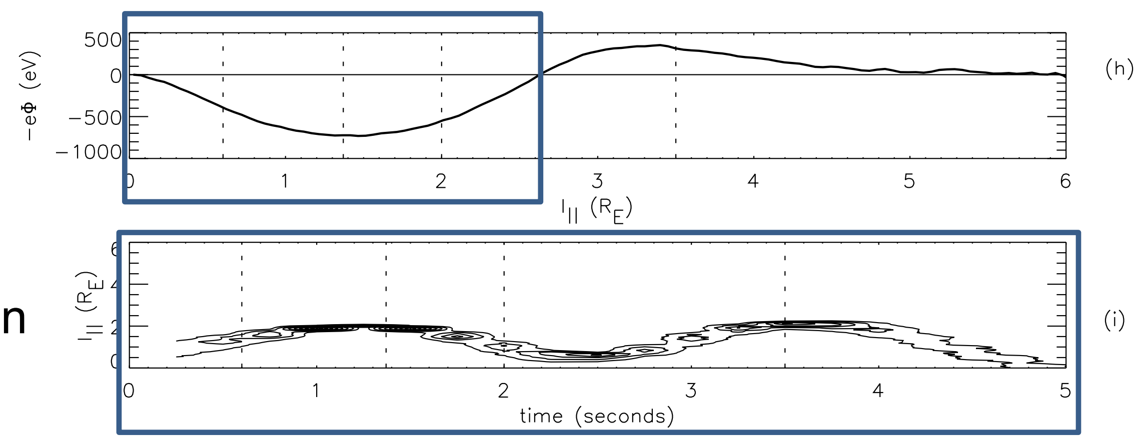


Wave trapped electrons

$$v_{tr} = \sqrt{\frac{2e\Phi}{m_e}}$$



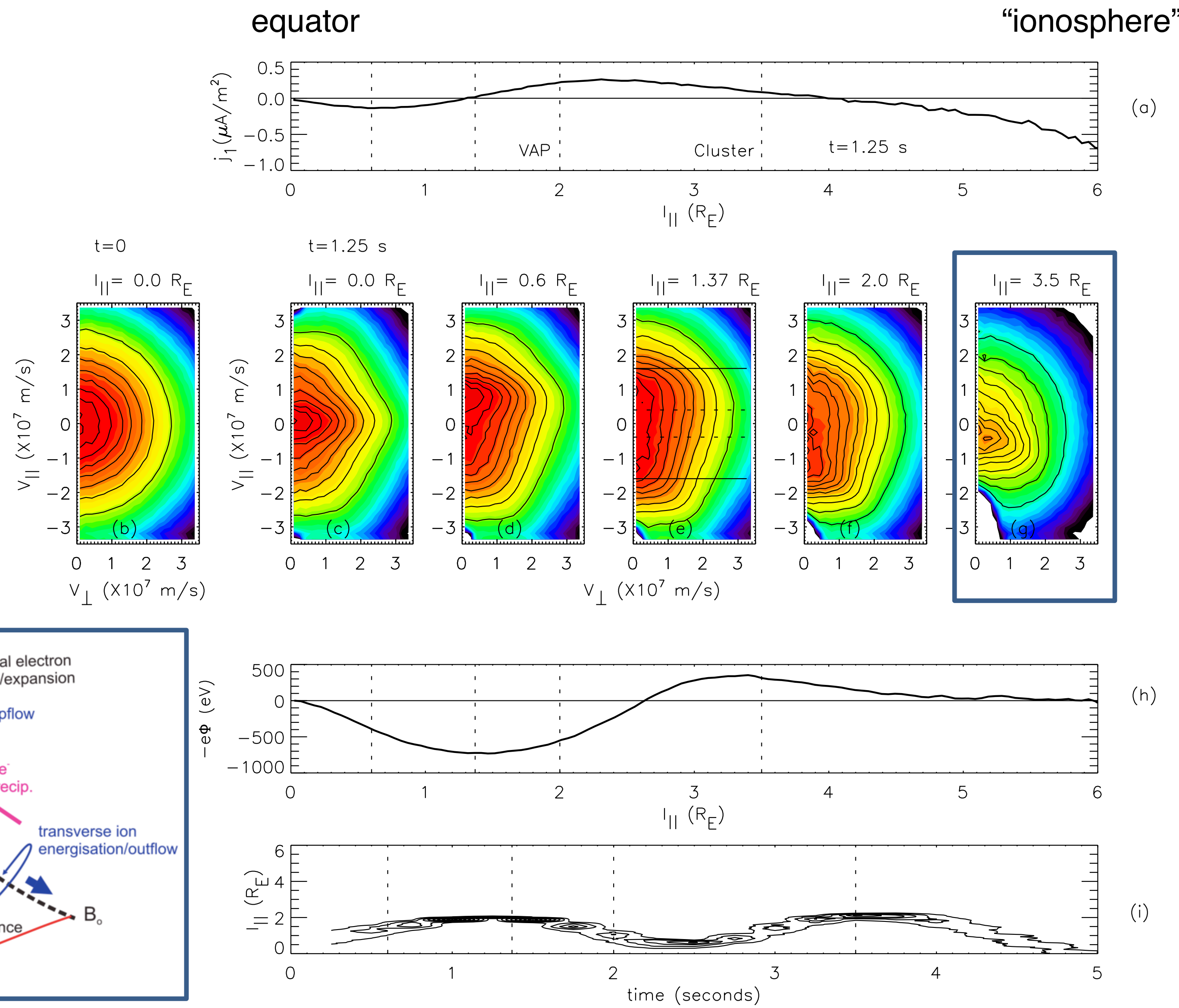
$$\Phi = -\int E_{||} dl_{||}$$



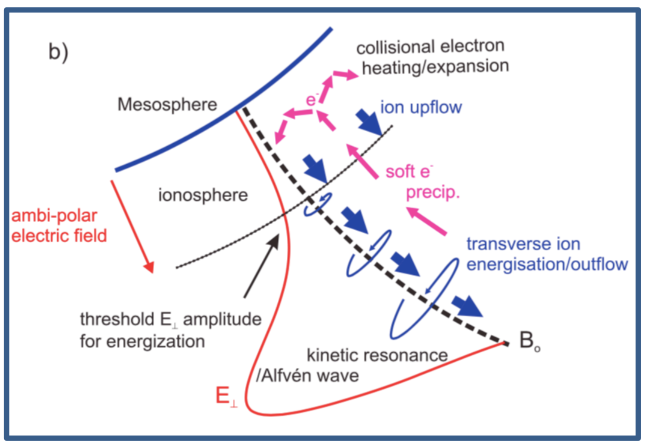
Trapped electron evolution

(*O'Neal*, 1965; **KAWs**: *Wygant*, 2002; *Watt and Rankin*, 2009; *Damiano et al.*, 2015, 2016, *Artemyev et al.*, 2015)

Precipitating electrons



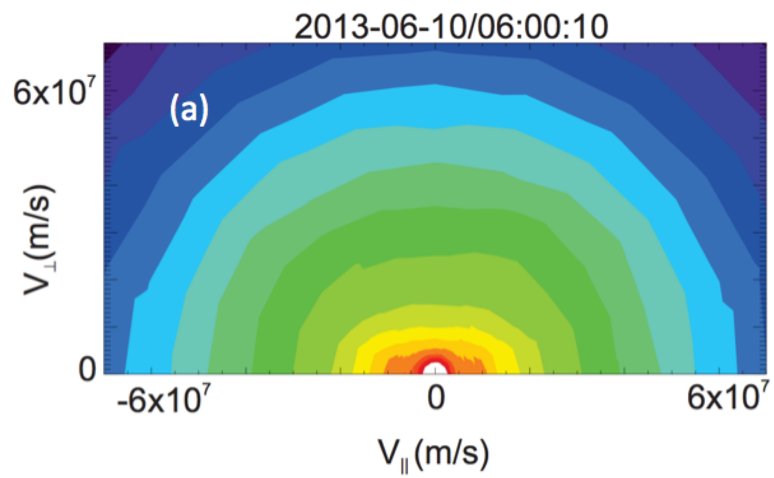
(*Chaston et al.*, 2015)

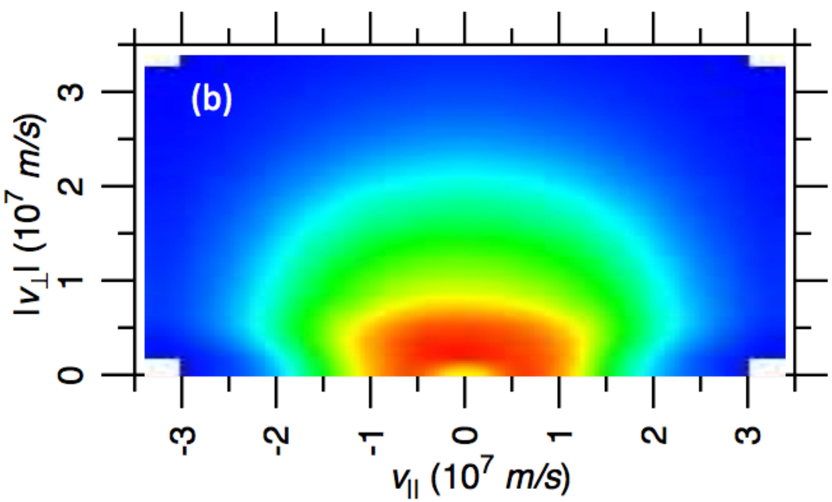


KFLRs facilitate soft electron precipitation that can drive outflow.

Time averaging of simulation data

Best temporal resolution of Van Allen probes for electrons and ions is ~ 11 seconds (1 spin period).





Time averaged simulation data (n=3 mode)

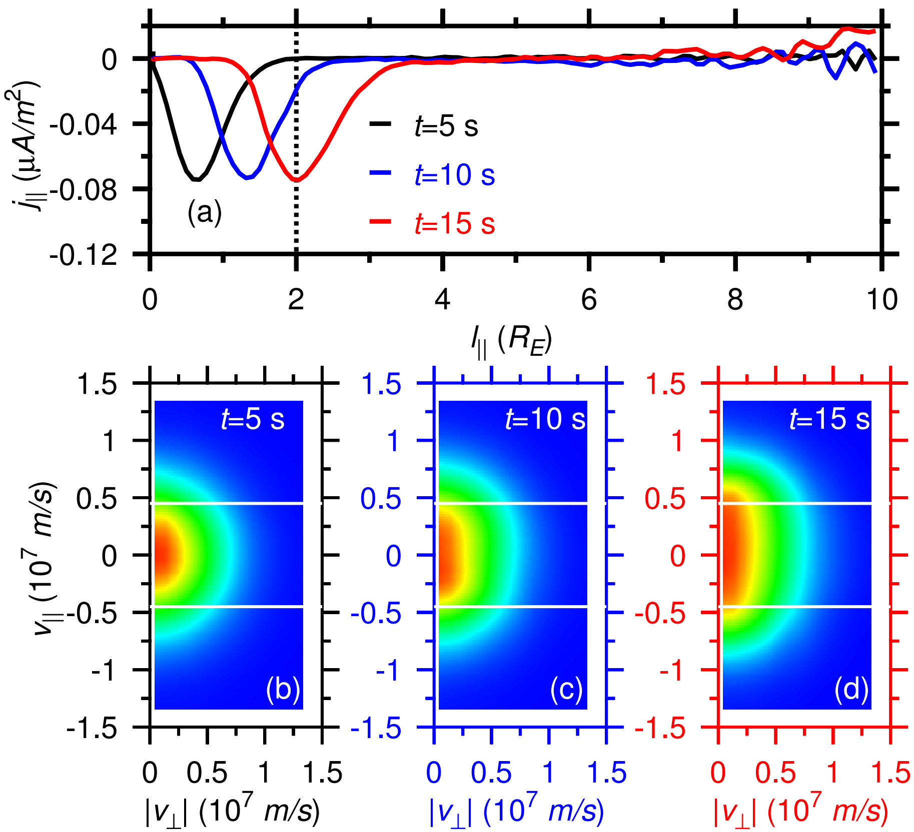
Good qualitative agreement for choice of representative parameters

Summary

- Electron distributions in kinetic field line resonances exhibit highly field-aligned cores due to electron trapping.
- Loss cone features result from the precipitation of higher energy un-trapped electrons.
  - This soft electron precipitation can facilitate outflow.
- These electron distribution features are evident in both simulations and observations.
- This qualitative comparison is limited by the presence of cold electron population, the unknown harmonic composition of fields and the temporal aliasing of the Van Allen probes electron measurements.

Damiano et al. Electron distributions in kinetic scale field line resonances: A comparison of simulations and observations (2018, submitted).

Distribution function evolution with passage of wave (T_i=0)



Parallel elongation defined by nonlinear trapping width (Wygant, 2002):

$$v_{tr} = \sqrt{\frac{2e\phi}{m_e}}$$

In the context of reconnection potentials - e.g. *Le et al.,* 2009.

Active injection experiments in ionosphere (Porcupine) - *Haeusler et al., 1986; Bohm et al., 1992.*

(*Damiano et al.*, JGR, 2016)

(First simulated in auroral context by *Watt and Rankin* 2009)

Initial trapping of electrons