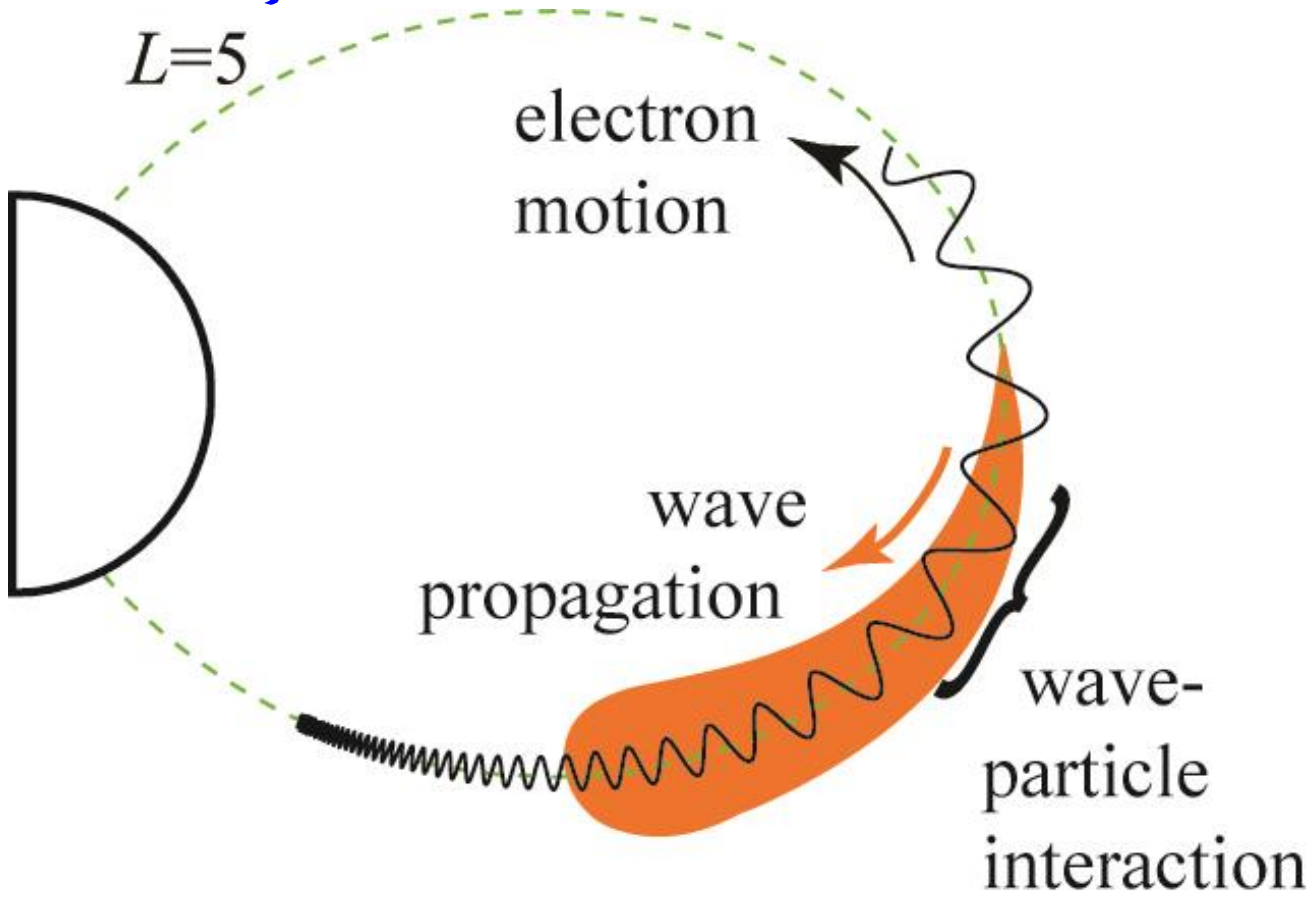
Space Physics Master's Course
Lecture 10
Wave-particle interactions

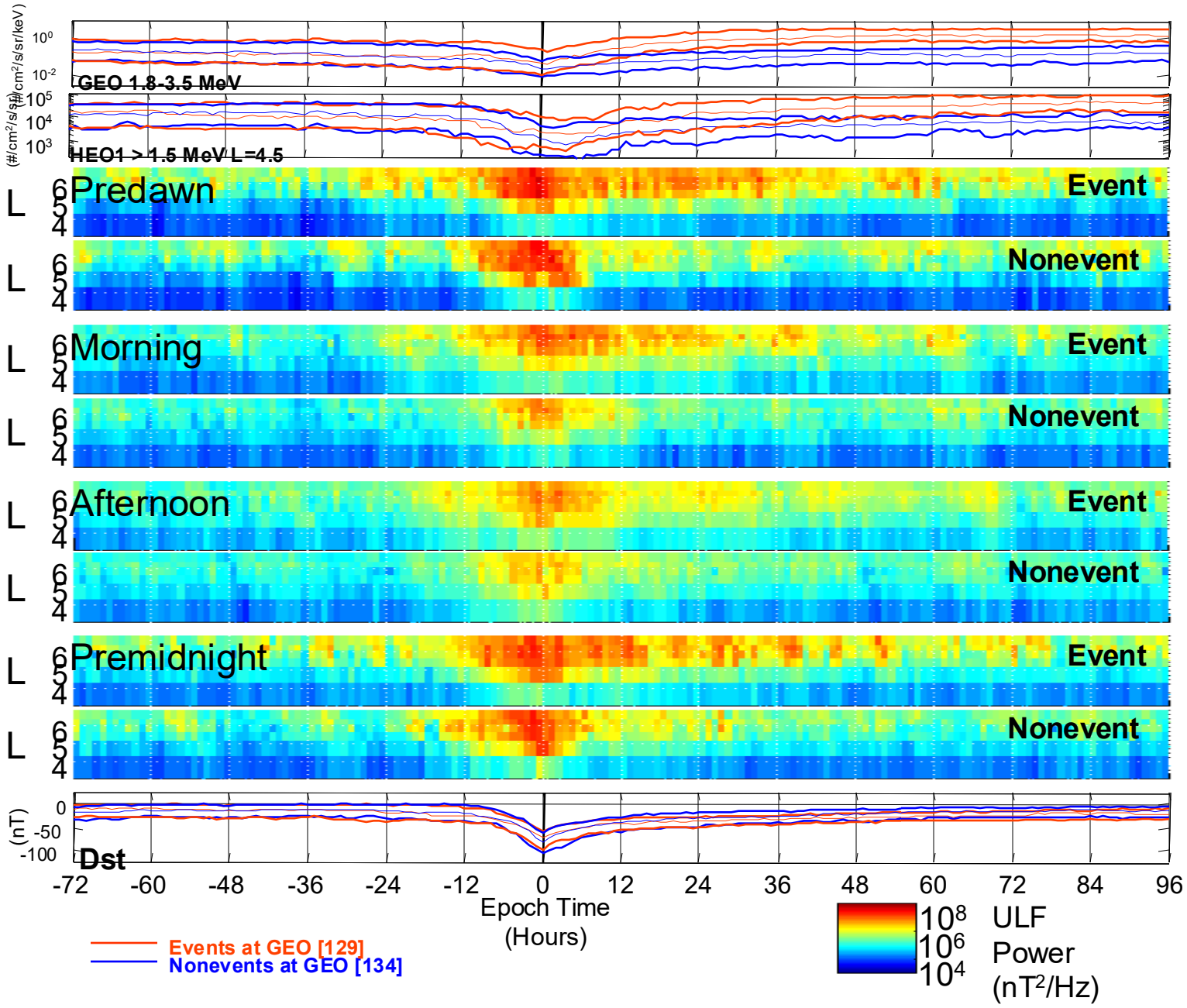


ULF Pc5 waves result from:

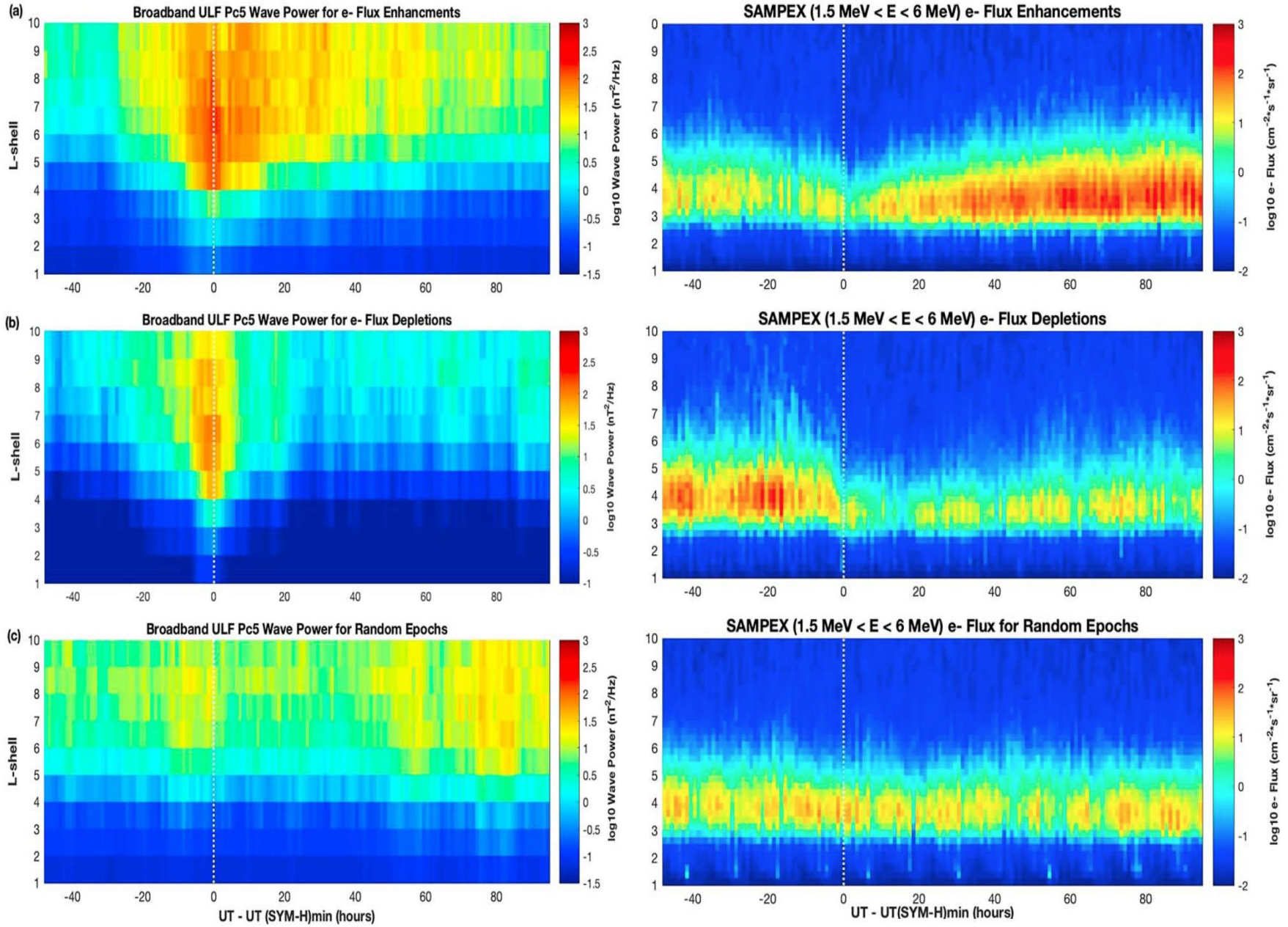
- *solar wind pressure*
- *magnetopause shear flow instabilities (K-H)*
- *mirror/drift-bounce instabilities*
- *anisotropies in the ring current*

RC O^+ ions, in particular, provide a source of free energy to **drive Pc5 waves**

Geospace Storms and Radiation Belts



O'Brien et al., JGR2003



SEA. SuperMAG, SAMPEX. 40 isolated storms

Georgiou+, JGR2018

ULF waves

Irregular pulsations		
Κατηγορία	Κάτω όριο συχνότητας	Άνω όριο συχνότητας
Pi2	2 mHz	25 mHz
Pi1	0.025 Hz	1 Hz

Continuous pulsations		
Κατηγορία	Κάτω όριο συχνότητας	Άνω όριο συχνότητας
Pc5	2 mHz	7 mHz
Pc4	7 mHz	22 mHz
Pc3	22 mHz	100 mHz
Pc2	0.1 Hz	0.2 Hz
Pc1	0.2 Hz	0.5 Hz

Από 1 mHz μέχρι 1 Hz:

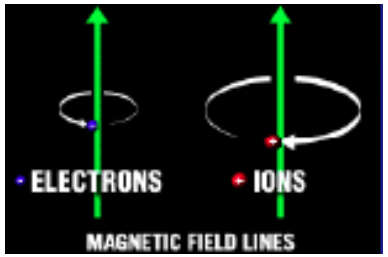
Από τη χαμηλότερη συχνότητα που υποστηρίζει η μαγνητοσφαιρική κοιλότητα μέχρι τη συχνότητα περιστροφής των διαφόρων φορτισμένων σωματιδίων γύρω από τις δυναμικές γραμμές του πεδίου (γυροσυχνότητα)

Αλληλεπίδραση σωματιδίων-κυμάτων

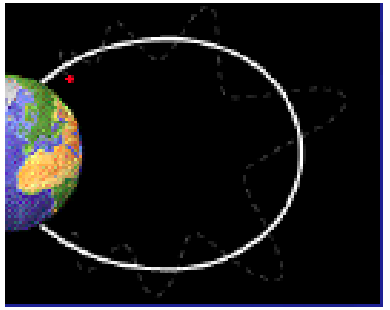
Περίοδος κυμάτων από 0.2 s μέχρι 10 min

Continuous pulsations		
Κατηγορία	Κάτω όριο περιόδου	Άνω όριο περιόδου
Pc5	150 s	600 s
Pc4	45 s	150 s
Pc3	10 s	45 s
Pc2	5 s	10 s
Pc1	0.2 s	5 s

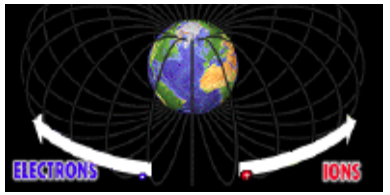
Χαρακτηριστικές κινήσεις e-



~ 0.001 s



~ 0.1 s



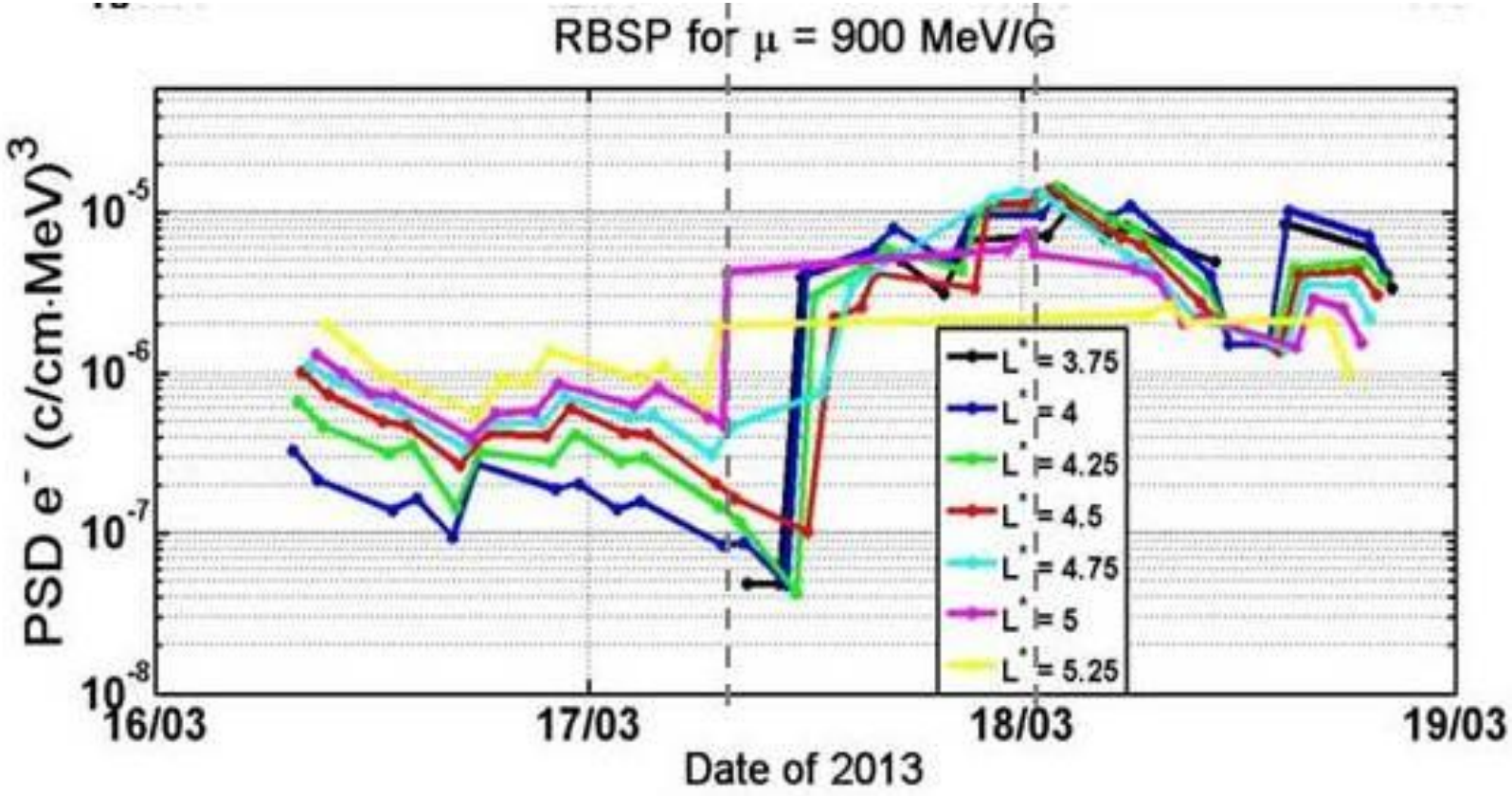
~10 min

Ultralow Frequency Waves as an Intermediary for Solar Wind Energy Input Into the Radiation Belts

Marina Georgiou
& I.A. Daglis, I.J. Rae, E. Zesta, D.G. Sibeck, I.R. Mann, G. Balasis, K. Tsinganos

https://doi.org/10.1029/2018JA025355

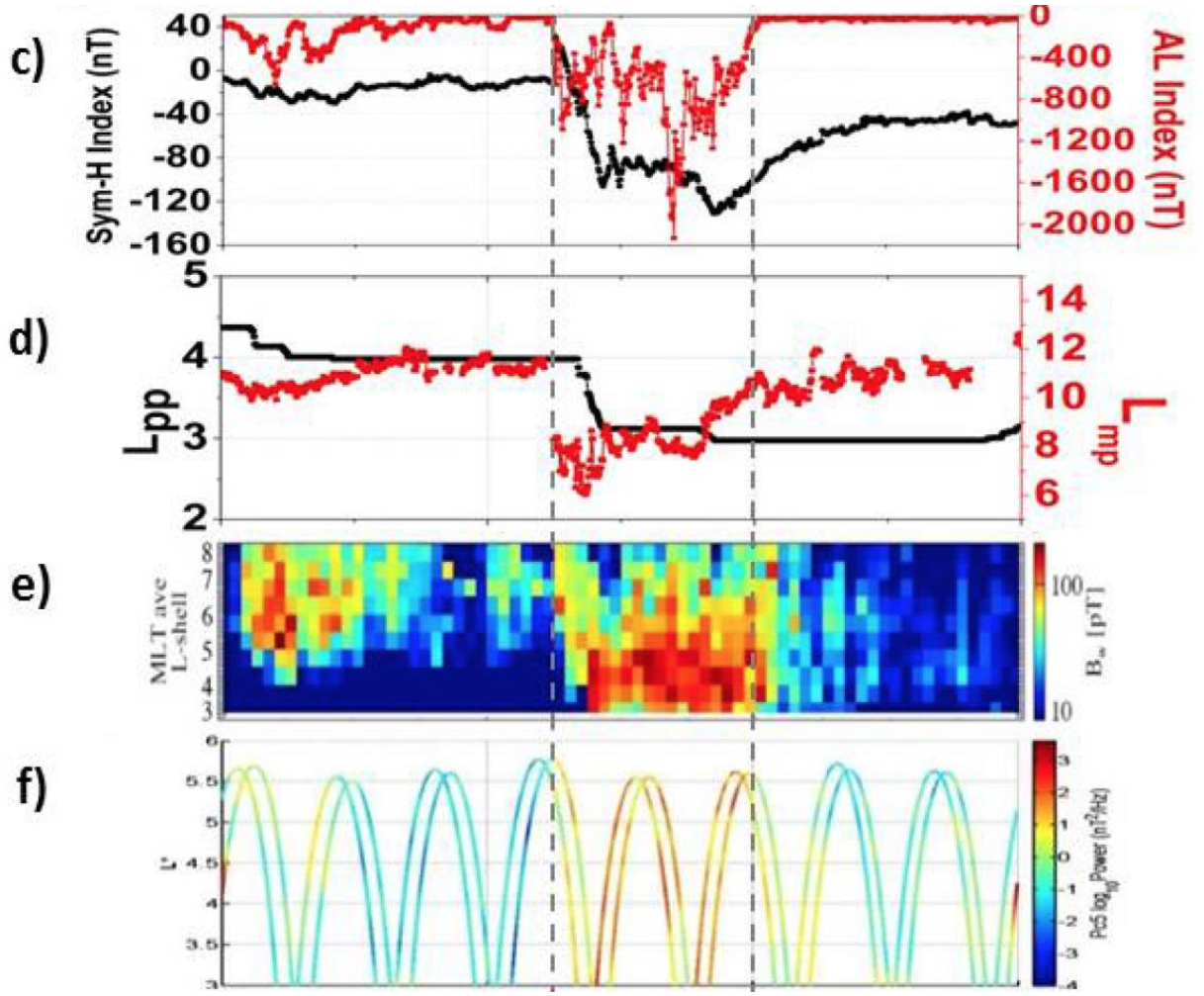
Waves synergy and RB acceleration



Pc5 and Chorus synergy in March 2013 storm

Enhancement of relativistic electrons, Katsavrias+, ANGEO2015

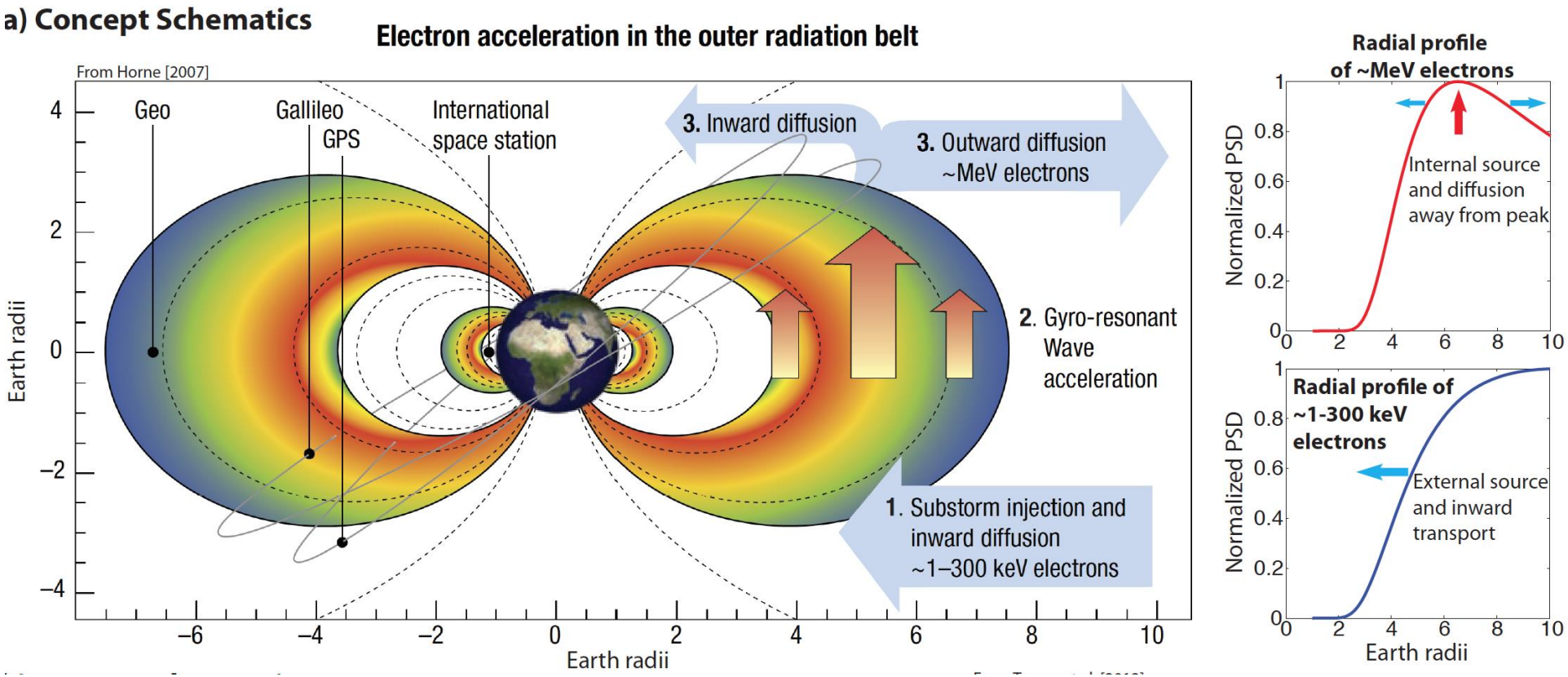
Waves synergy and RB acceleration

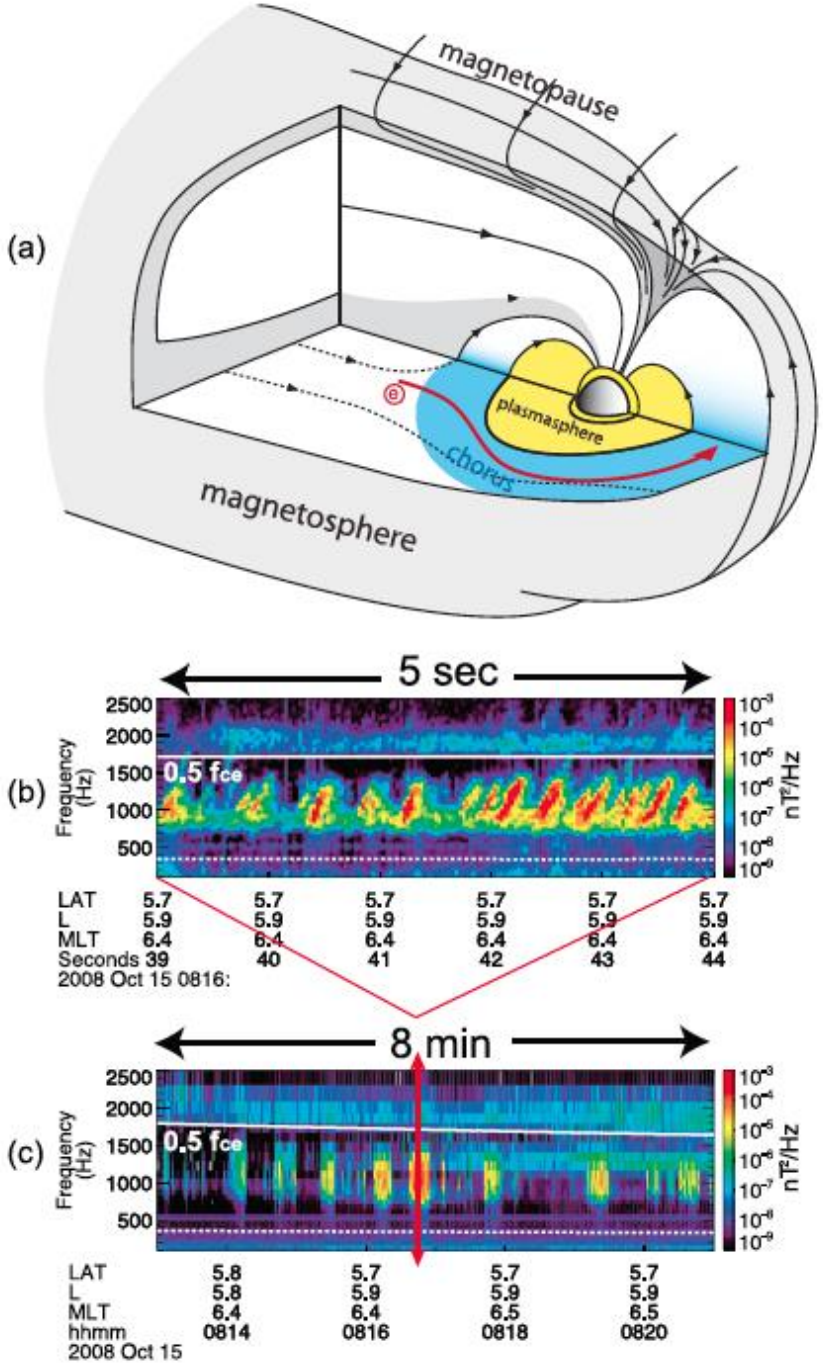


17 March 2013 Storm, Pc5 and Chorus synergy

Katsavrias+ ANGEO2015

Waves synergy and RB acceleration

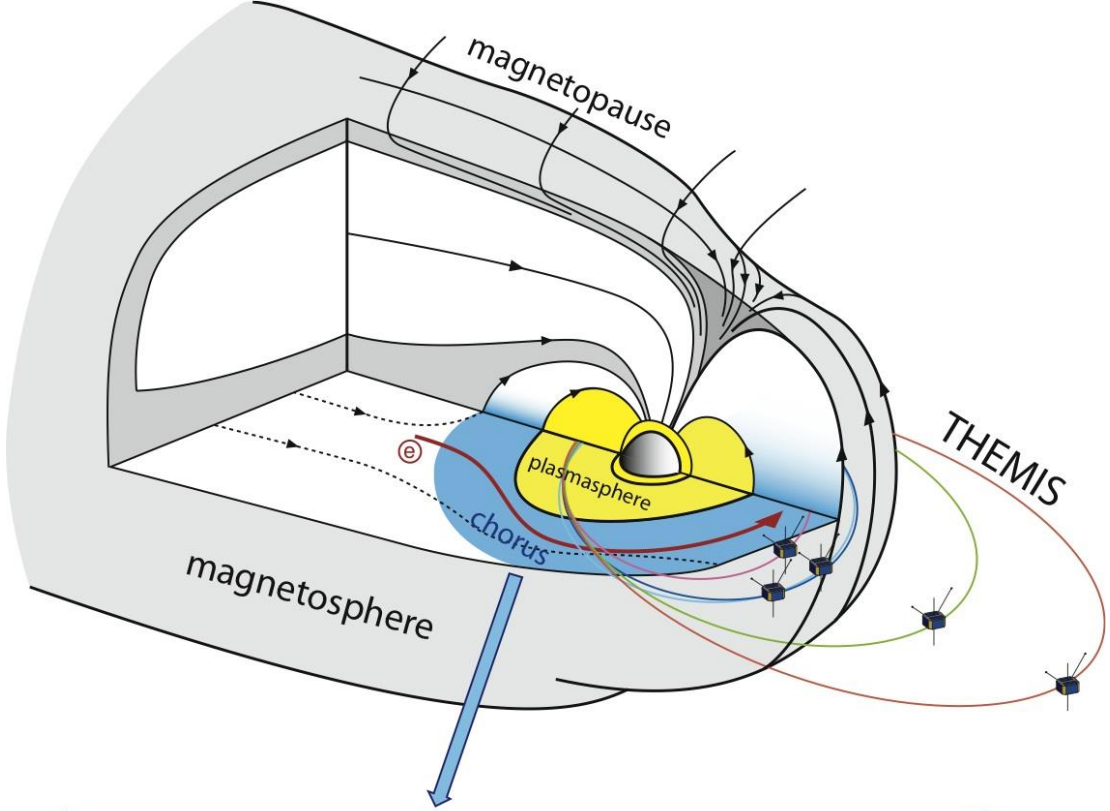


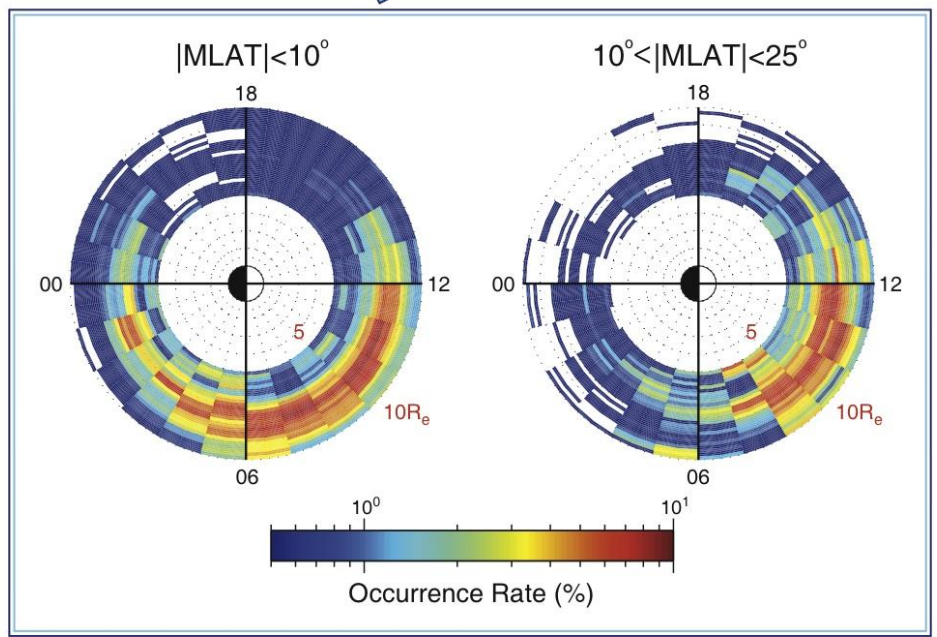


Li et al. [2012], Fig. 1

Chorus characteristics

- Found outside plasmasphere on **dawn-side**
- Due to unstable, drifting plasmasheet electrons
- Multi-scale structure in space and time

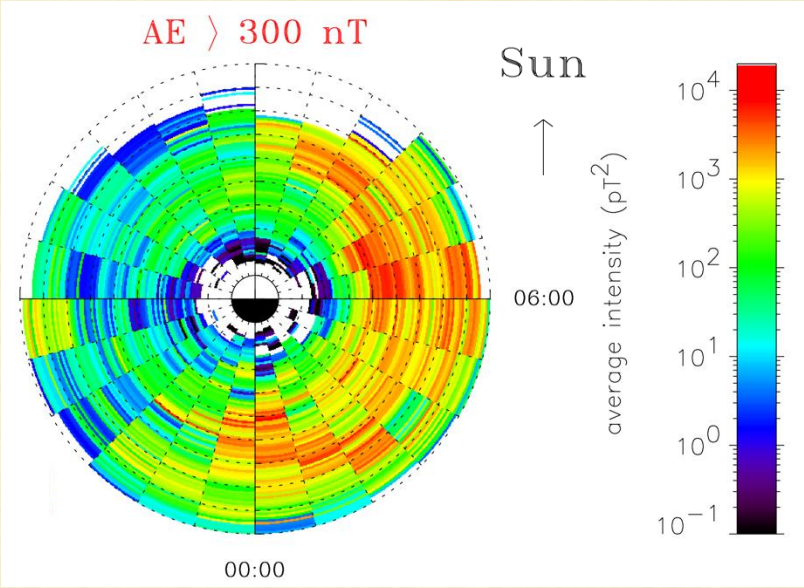

magnetopause
THEMIS
plasmasphere
chorus
magnetosphere


|MLAT|<10°
10°<|MLAT|<25°
18
00
12
06
5
10R_e
10^0
10^1
Occurrence Rate (%)

Chorus and Magnetic Storms

- Chorus emissions are enhanced during geomagnetic storms, because they are driven by ring current electrons

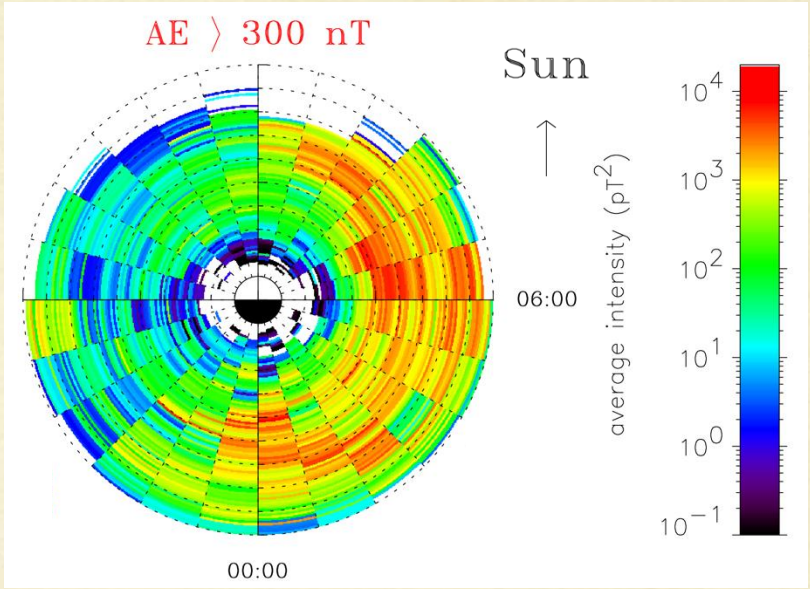
- The waves are strongest on the **dawn-side** at 4-9 Earth radii, as can be seen from this statistical survey using data from 7 satellites



Meredith *et al.*, 2012

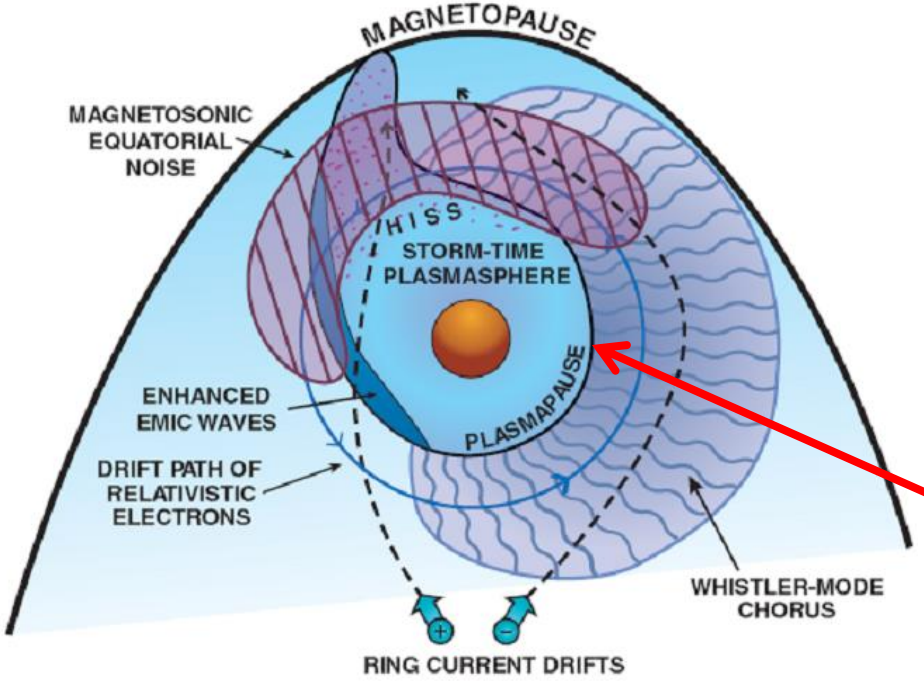
Chorus and Magnetic Storms

- Chorus waves accelerate electrons to relativistic energies
- We use global maps such as these in computer models to produce space weather forecasts

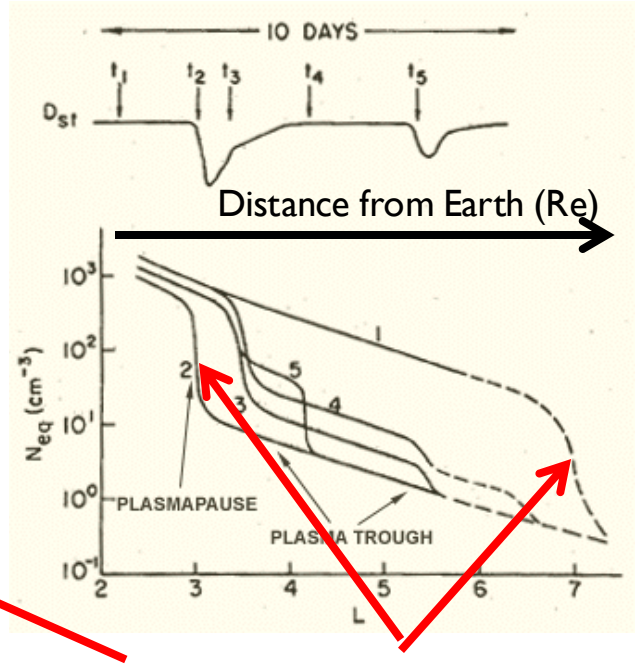


Meredith *et al.*, 2012

What drives strong and weak diffusion?



There are many different waves, which drive weak and strong diffusion depending on storm levels



Wave penetration is dependent on the **position of the plasmapause**

Storm influence on RB dynamics

Plasmapause location changes dramatically during magnetic storms.

In this way, storms influence indirectly, yet decisively, the earthward penetration of waves and therefore their effectiveness in the heart of the outer belt.

Synergy of waves in acceleration

(i) inward radial diffusion by Pc5 waves

plus subsequent

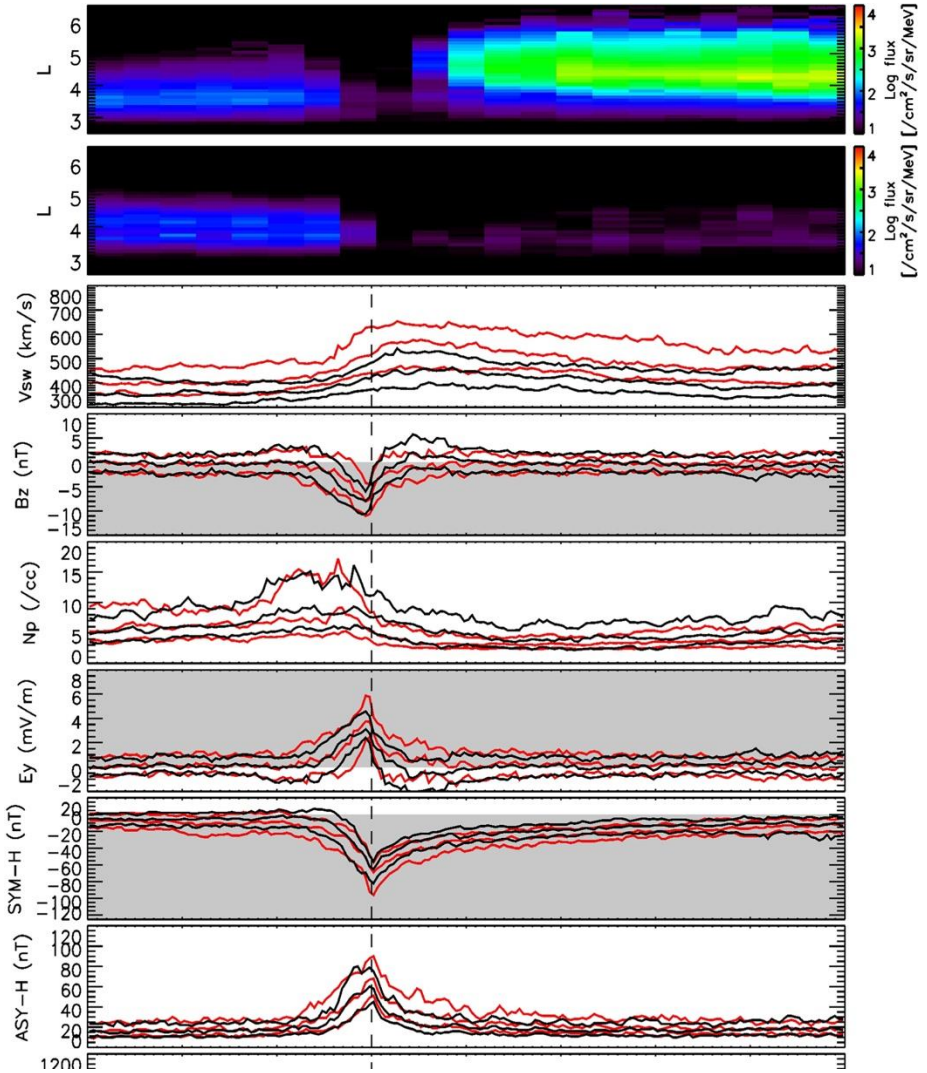
(ii) local acceleration by lower band chorus

Zhao, H., Baker, D. N., Li, X., Jaynes, A. N., & Kanekal, S.
*The effects of geomagnetic storms and solar wind conditions on the **ultrarelativistic** electron flux enhancements. JGR 2019*

SEA of 87 storms
Sept. 2012 – Apr. 2018
49 (38) enhancement (no)
of 5.2 MeV e^-

Storms with Enhancement

- ◇ High solar wind speed (ULF wave generation)
- ◇ Sustained IMF Bs (storms)
- ◇ Higher AE (substorms - chorus, seed electrons)
- ◇ Higher ASY-H (ULF wave generation)



Synergy of waves in acceleration

(i) inward radial diffusion by Pc5 waves

driven by solar wind speed/pressure and/or ring current

(ii) local acceleration by lower band chorus

driven by substorm-injected electrons