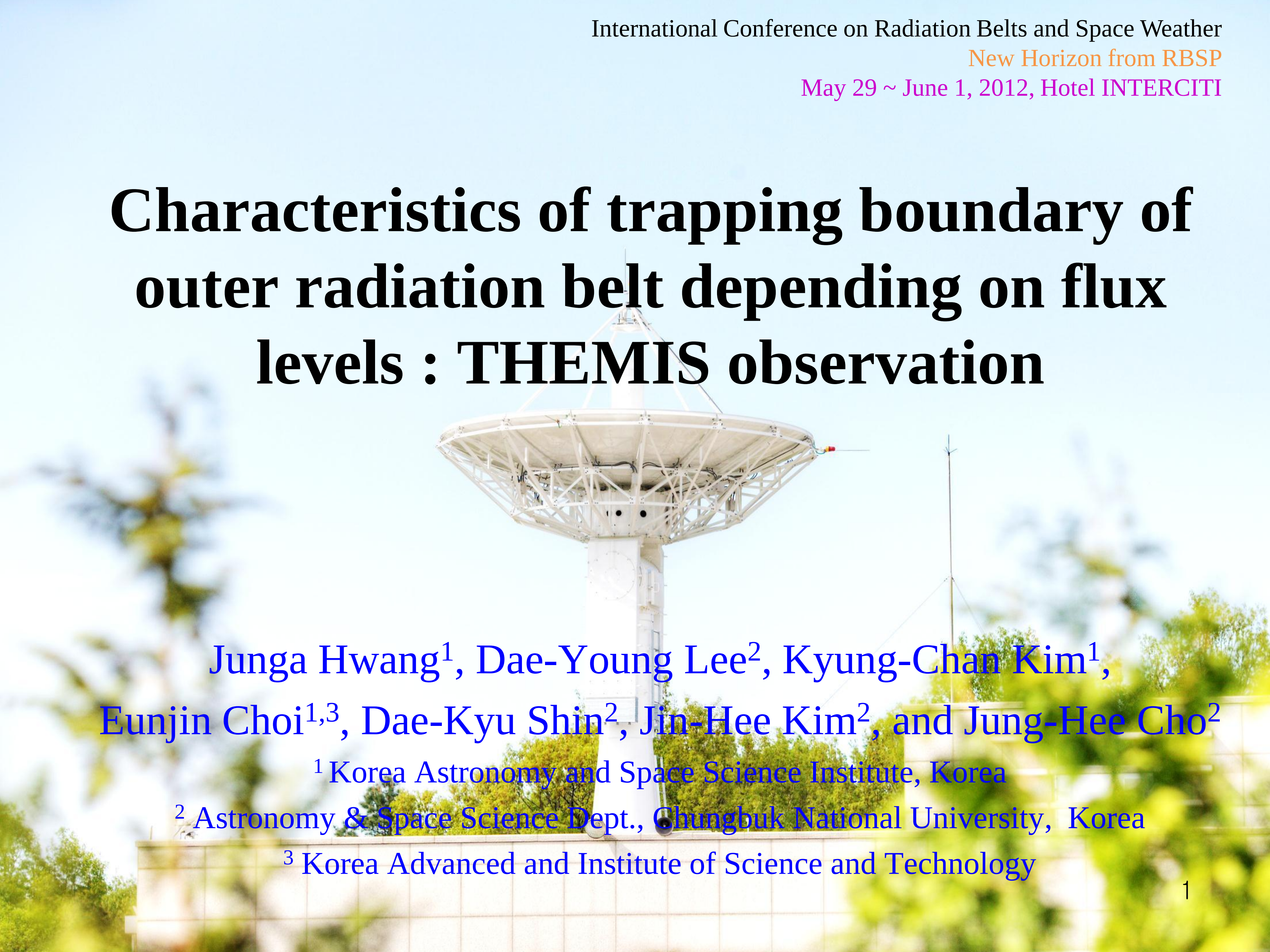


International Conference on Radiation Belts and Space Weather
New Horizon from RBSP
May 29 ~ June 1, 2012, Hotel INTERCITI

Characteristics of trapping boundary of outer radiation belt depending on flux levels : THEMIS observation

Junga Hwang[1], Dae-Young Lee[2], Kyung-Chan Kim[1],
Eunjin Choi[1,3], Dae-Kyu Shin[2], Jin-Hee Kim[2], and Jung-Hee Cho[2]
[1] Korea Astronomy and Space Science Institute, Korea
[2] Astronomy & Space Science Dept., Chungbuk National University, Korea
[3] Korea Advanced and Institute of Science and Technology

Outline

1. Introduction
2. Motivation
3. Dataset
4. Results
   - Statistical study of three dataset during 2008-2010: dropout, GREE, quiet
   - Case study of three dropout events
5. Summary

INTRODUCTION: Radiation Belt Electrons Drift loss

Proposed major mechanisms for relativistic electron loss or flux dropout

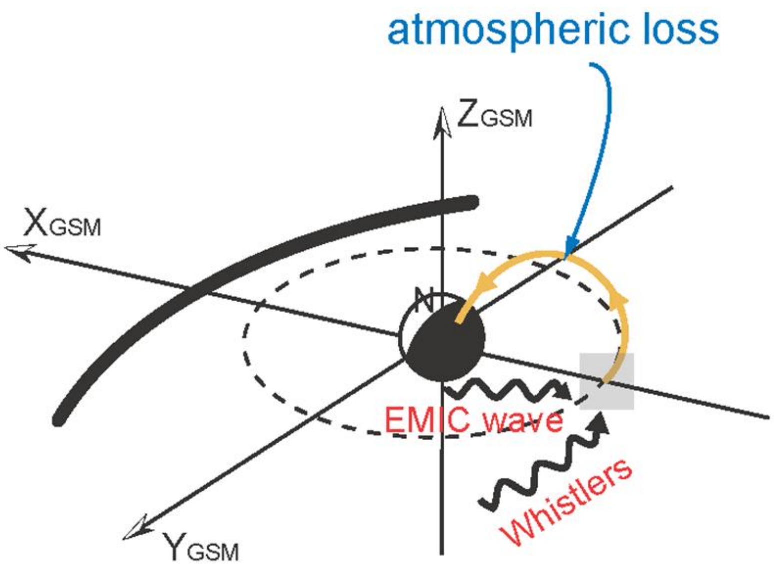
(1) Atmospheric Precipitation by Wave-Particle Interaction
[e.g., Horne and Thorne(2003), Green et al.(2004)]

(2) Drift loss to the Magnetopause (or Magnetopause shadowing)
[e.g., Li et al.(1997), Desorgher et al.(2000), Ukhorskiy et al.(2006), Shprits et al.(2006), Ohtani et al.(2009), Kim et al.(2005), Kim et al.(2008), Kim et al.(2010)]

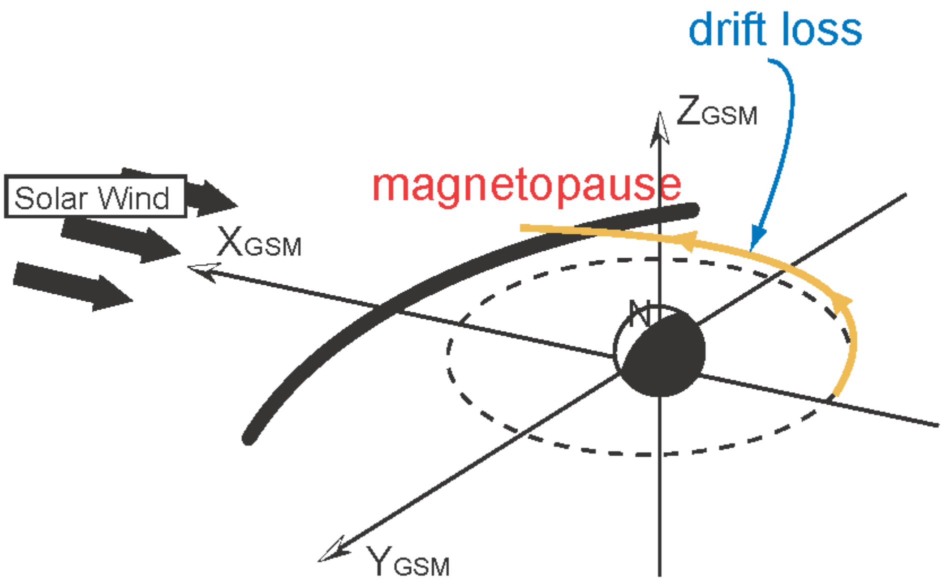
(3) Fully-Adiabatic Flux Changes (or Dst effect)
[e.g., Kim and Chan(1997),Li et al.(1997)]

(4) Outward radial diffusion
[e.g., Bortnik et al. 2006; Shprits et al. 2006]

INTRODUCTION: Radiation Belt Electrons Drift loss

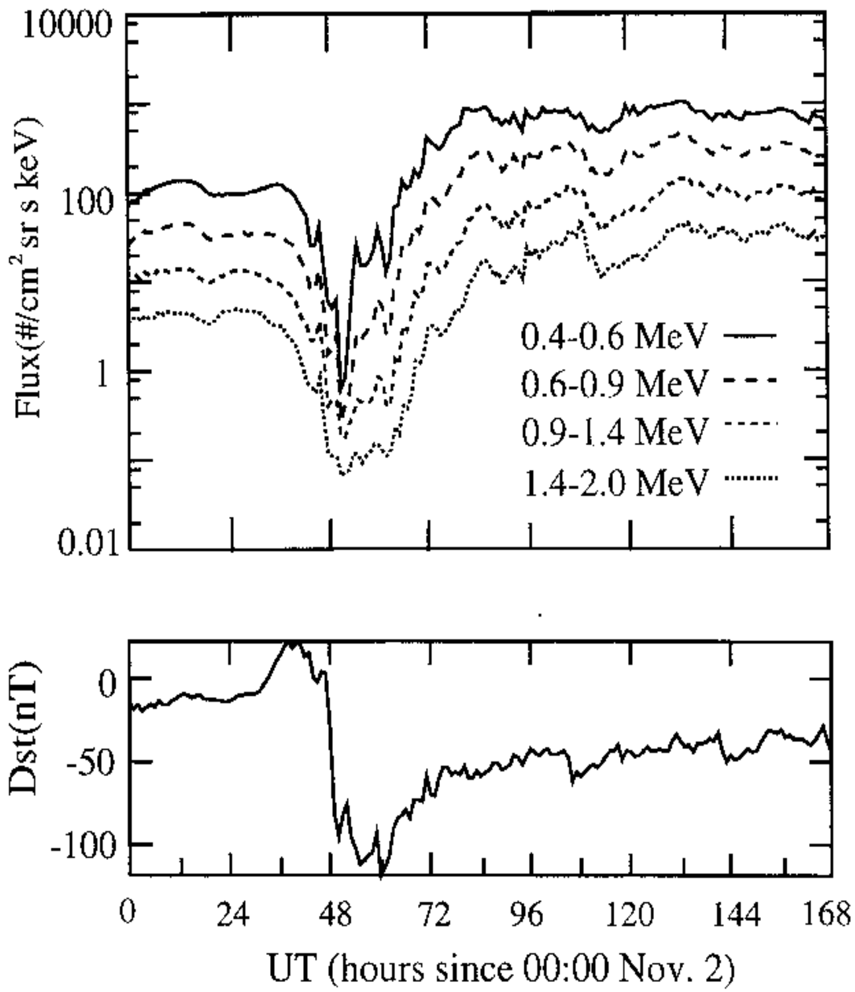


Atmospheric loss

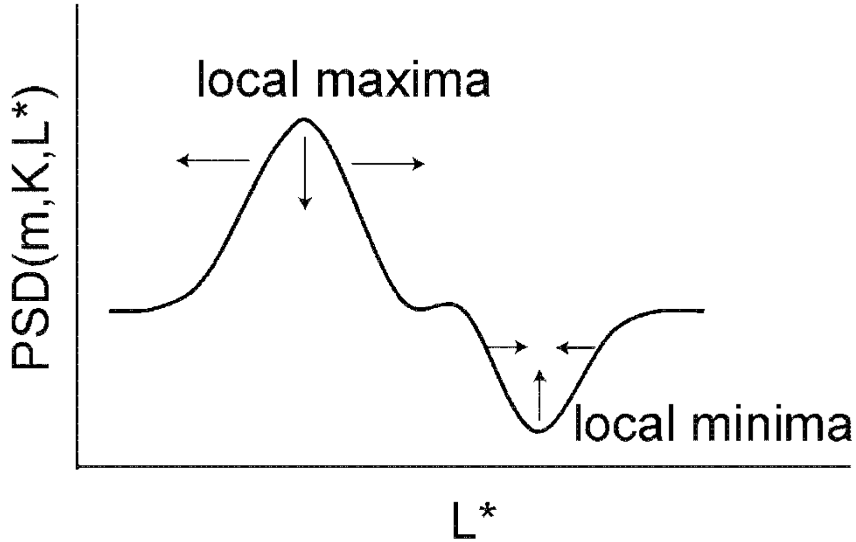


Drift loss to magnetopause or
Magnetopause shadowing

INTRODUCTION: Radiation Belt Electrons Drift loss



Fully adiabatic flux change or Dst effect



Outward radial diffusion

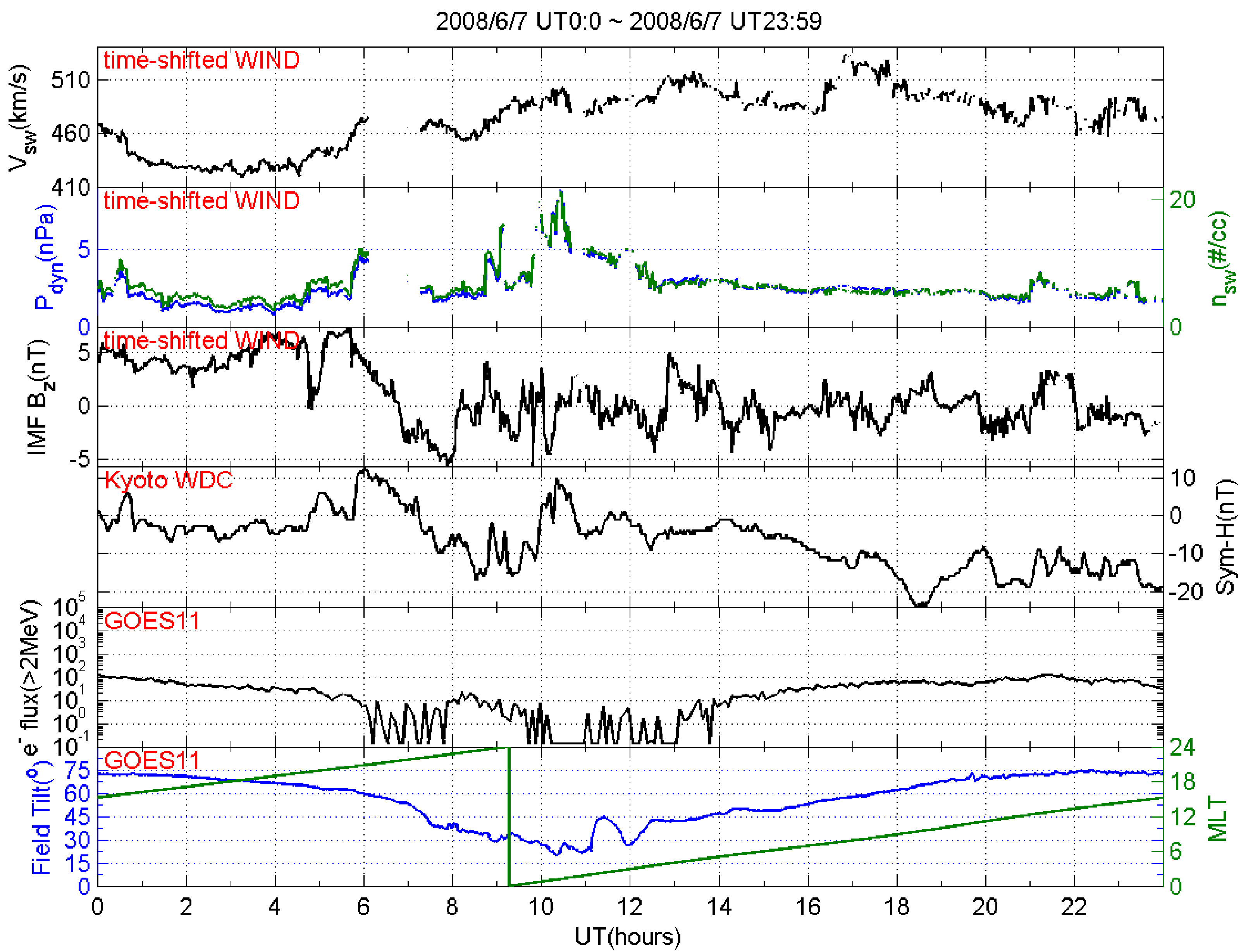
Motivations

- Geosynchronous electron flux "dropouts" are most likely due to fast drift loss of the particles to the magnetopause, or "magnetopause shadowing".
- Recent simulation by Kim et al.(2011) investigated radial diffusion process by solving the diffusion equation with a set of initial and boundary conditions set by the drift loss, which is not from observational data.
- For providing the inputs for those simulations, we find experimental fitting function of the energy spectrum and pitch angle distribution both inside and near boundary of the belts during the geosynchronous flux dropouts, geosynchronous flux enhancement and quiet periods.
- The only previous equatorial observation was by CRESS during 1990-1991, which is the solar maximum, **we have performed a comprehensive analysis of the belts using the THEMIS multi-satellites for the 2007-2010 period, corresponding to the solar ascending phase**.
- This work is valuable because THEMIS can provide the equatorial observations of the earth's radiation belts.

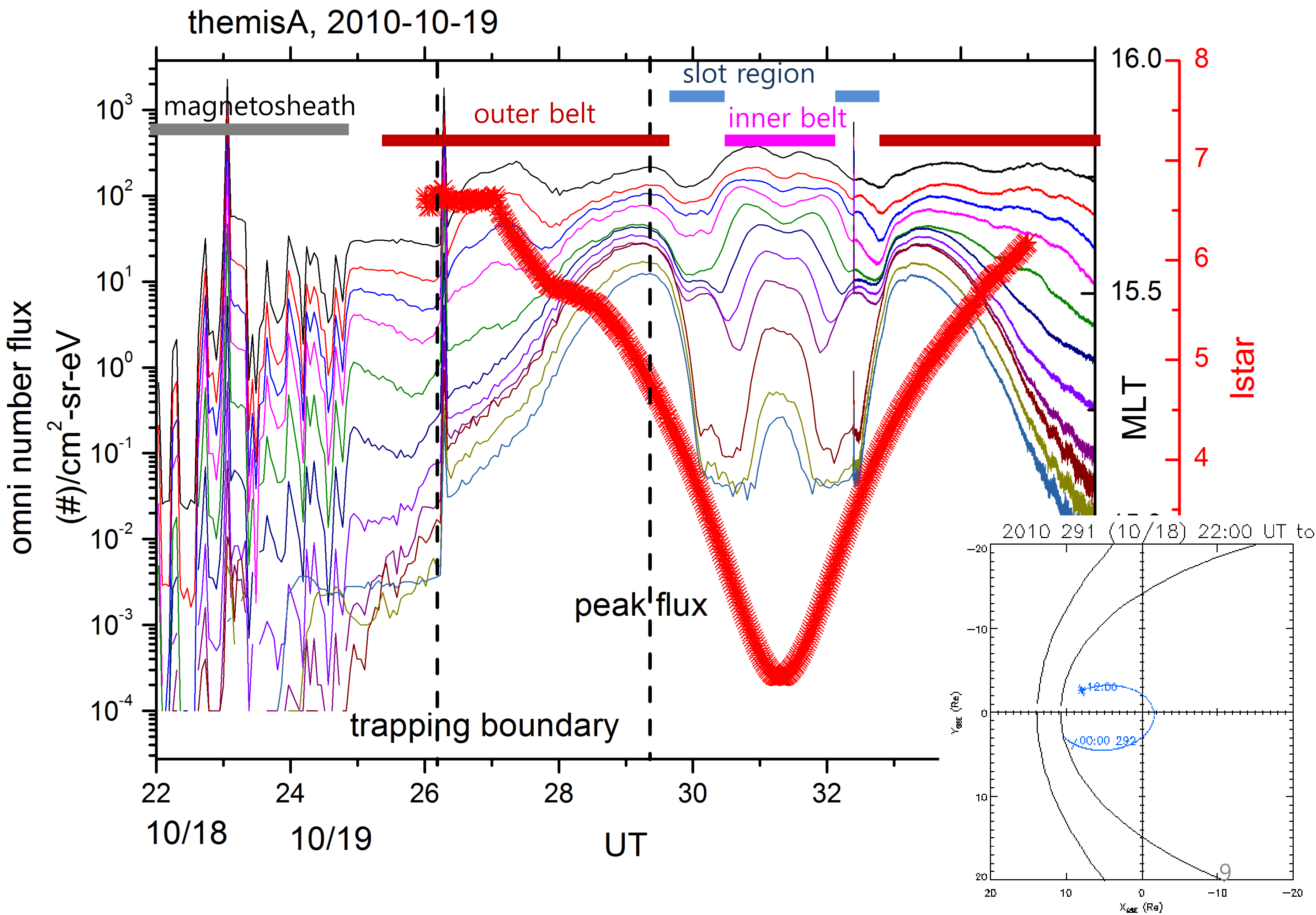
Event selection

- GEO dropout : 27 events (52 themis data)
  - 2007-2010, (GOES >2MeV channel) < 50
  - dropout observation by GOES
- GREE : 122 events (363 themis data)
  - 2008-2010, GOES 2MeV > 1000 /cm^2 sr s
  - V_{sw} > 500km/s , more than 3days
  - Not overlapped with GEO dropout, quiet time
- Quiet time : 117 events (382 themis data)
  - 2008-2010, Vsw < 400km/s
  - 50 < (GOES >2MeV channel) < 1000
- THEMIS SST
  - 1~10 Re , inner magnetosphere

Example of GEO dropout event



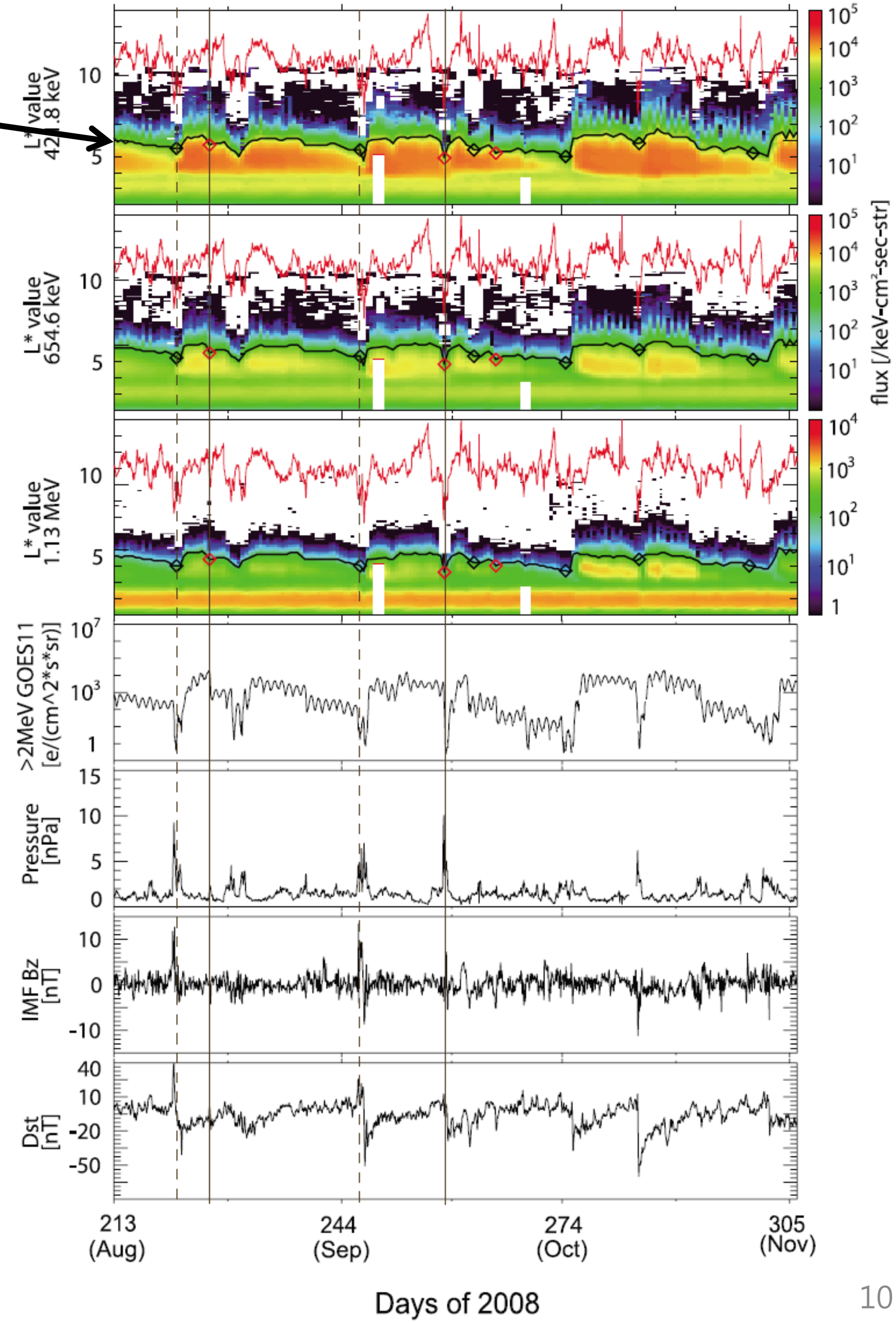
Pick out trapping boundary and peak flux position



Trapping boundary

- outer edge of outer radiation belt
- 20% of peak flux

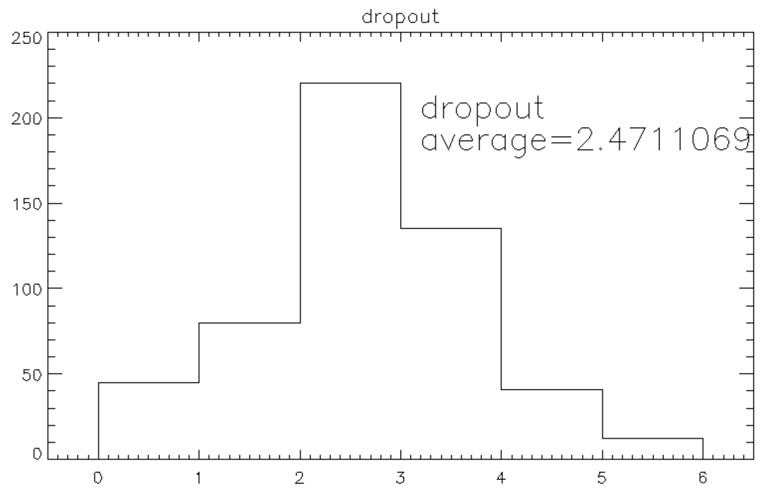
[Matsumura et al., 2011]

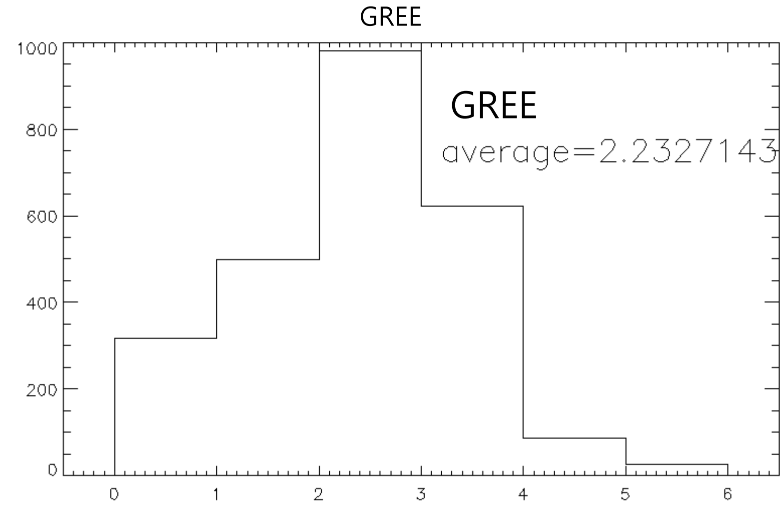


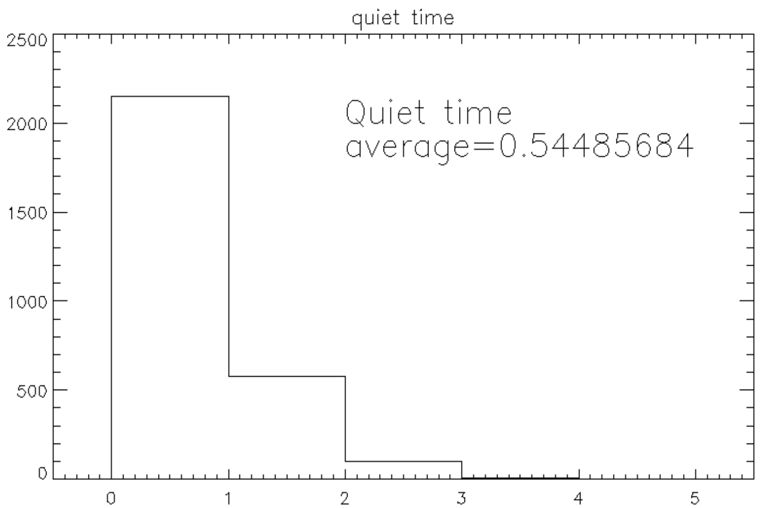
GEO dropout events list

event	year-month-day	doy	UT_start	UT_end	probe
1	2007-07-20	201	8	22	a,b,c,d,e
2	2007-07-27	208	0	13	a,b,c,d,e
3	2007-08-26	238	0	15	a,b,c,d,e
4	2007-09-28	271	1:30	7	a,c,d,e
5	2007-12-11	345	1:30	13	d,e
6	2008-03-09	69	2:30	15	a
7	2008-04-23	114	4:45	8	a
8	2008-08-18	231	7:40	9	a,c,d,e
9	2008-09-03	247	5	13	a,c,d,e
10	2008-09-26	270	3:30	13	a,d,e
11	2008-10-01	275	3:30	15	a,c,d,e
12	2008-10-02	276	3	15	a,d,e
13	2008-11-08	313	11-7, 23:30	11	a,c,d,e
14	2008-11-16	321	0:30	13	a,d,e
15	2008-12-04	339	0:00	24	a,d,e
16	2008-12-06	341	2:30	7	a,d,e
17	2008-12-23	358	2	15	a,c,d,e
18	2008-12-31	366	2	24	a,d,e
19	2009-07-20	201	9:30	24	d,e
20	2009-08-12	224	8	13	c,d,e
21	2009-09-01	244	7:30	16	a,d,e
22	2010-02-02	33	0	9	a,d,e
23	2010-08-23	235	6:00	12	a,d,e
24	2010-10-06	279	6	14	a,d,e
25	2010-10-09	282	6	12	a,d,e
26	2010-10-16	289	3:30	12	a,d,e
27	2010-10-19	292	3:30	11	a,d,e

Kp index



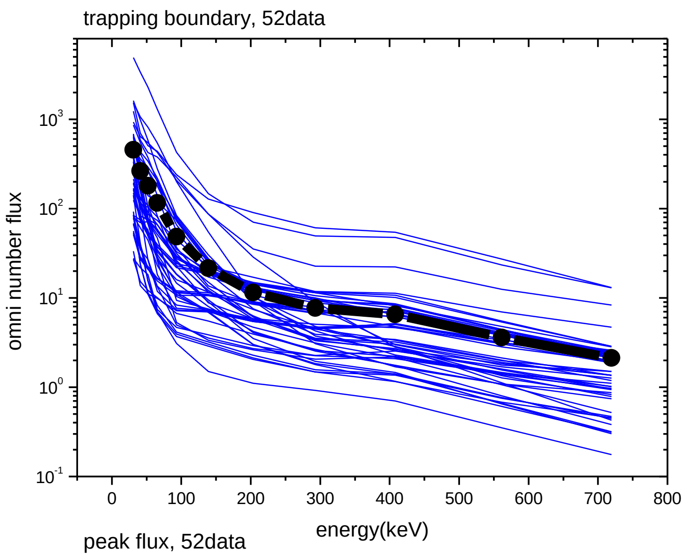


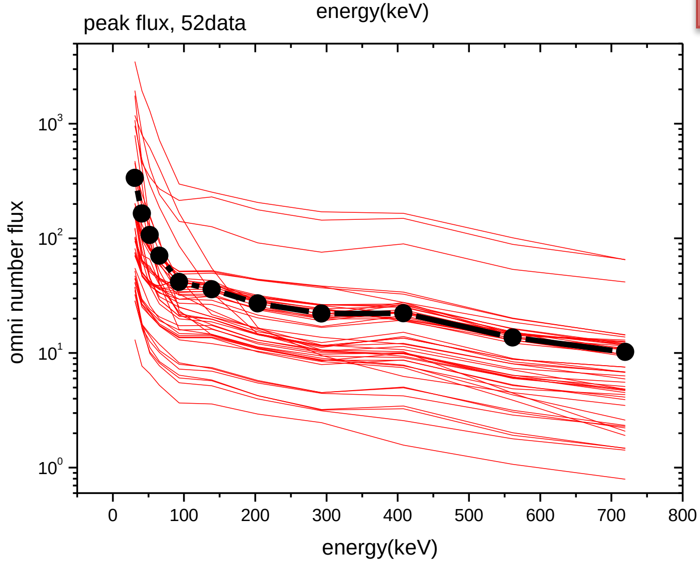


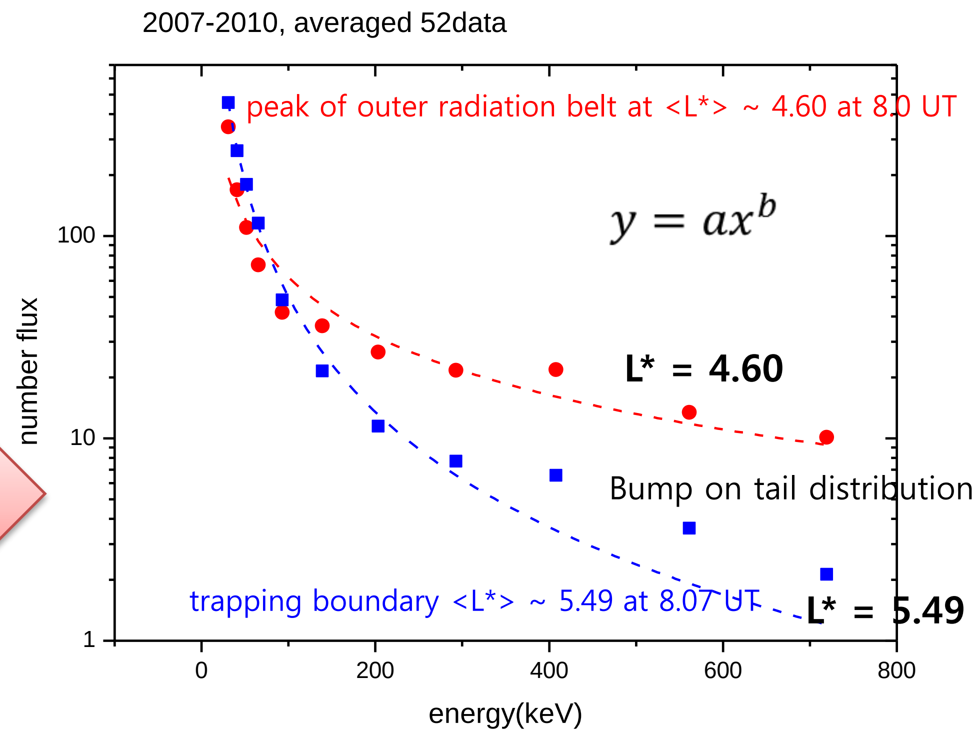
Dropout <Kp> = 2.47
GREE <Kp> = 2.23
Quiet time <Kp> = 0.54

* CRESS' full observation period :
<Kp> = 6

Superposed analysis and fitting function

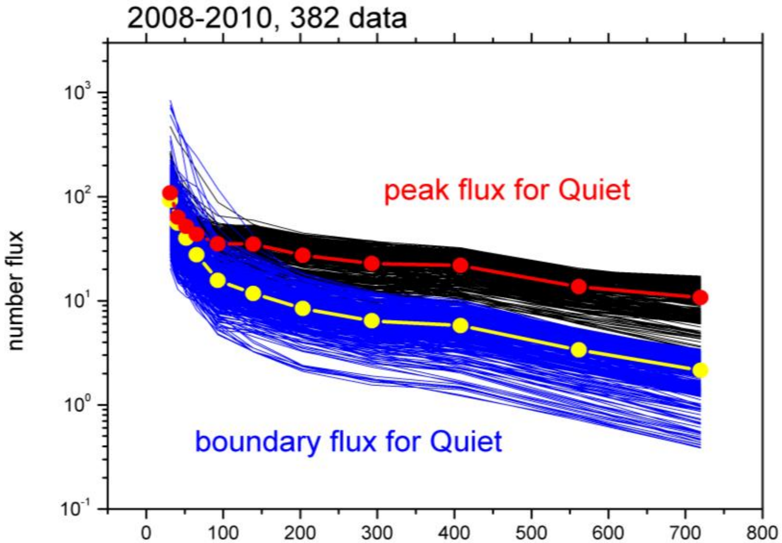


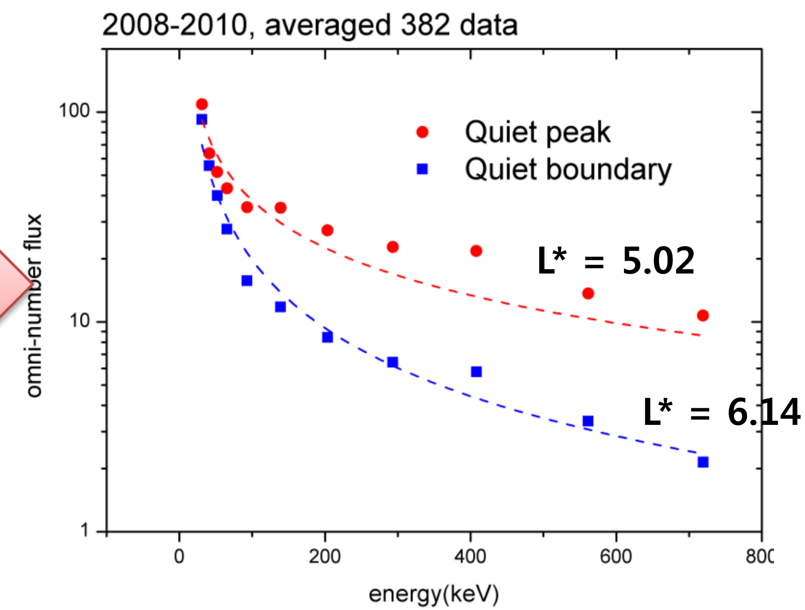


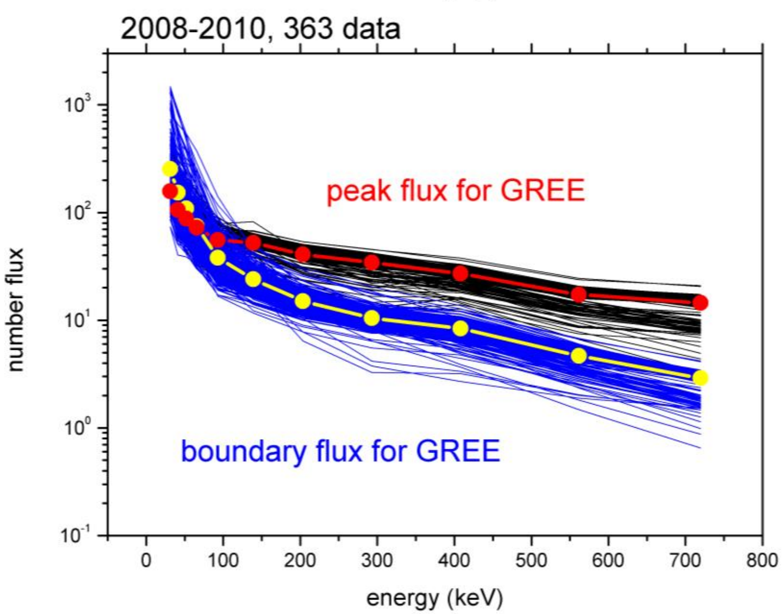


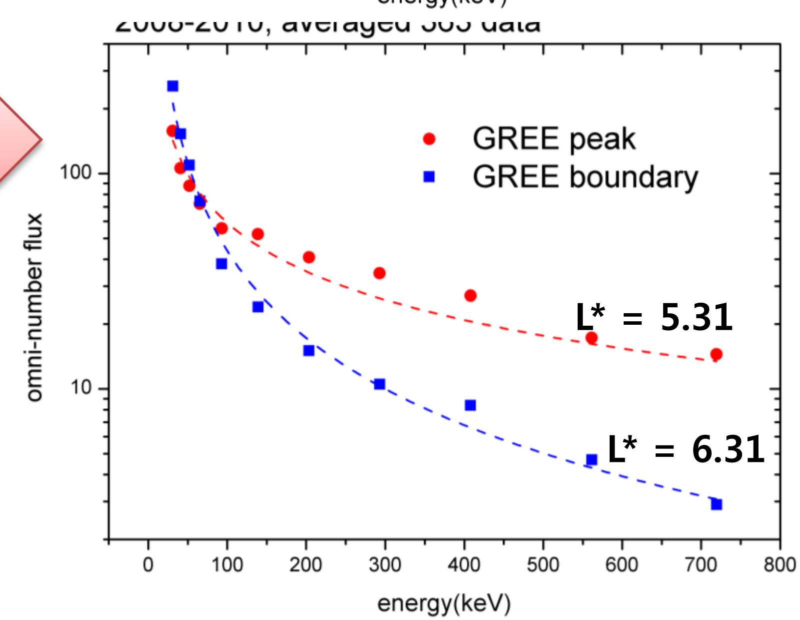
	a	b
Trapping boundary	2.9×10^5	-1.88
Peak flux	5.3×10^3	-0.96

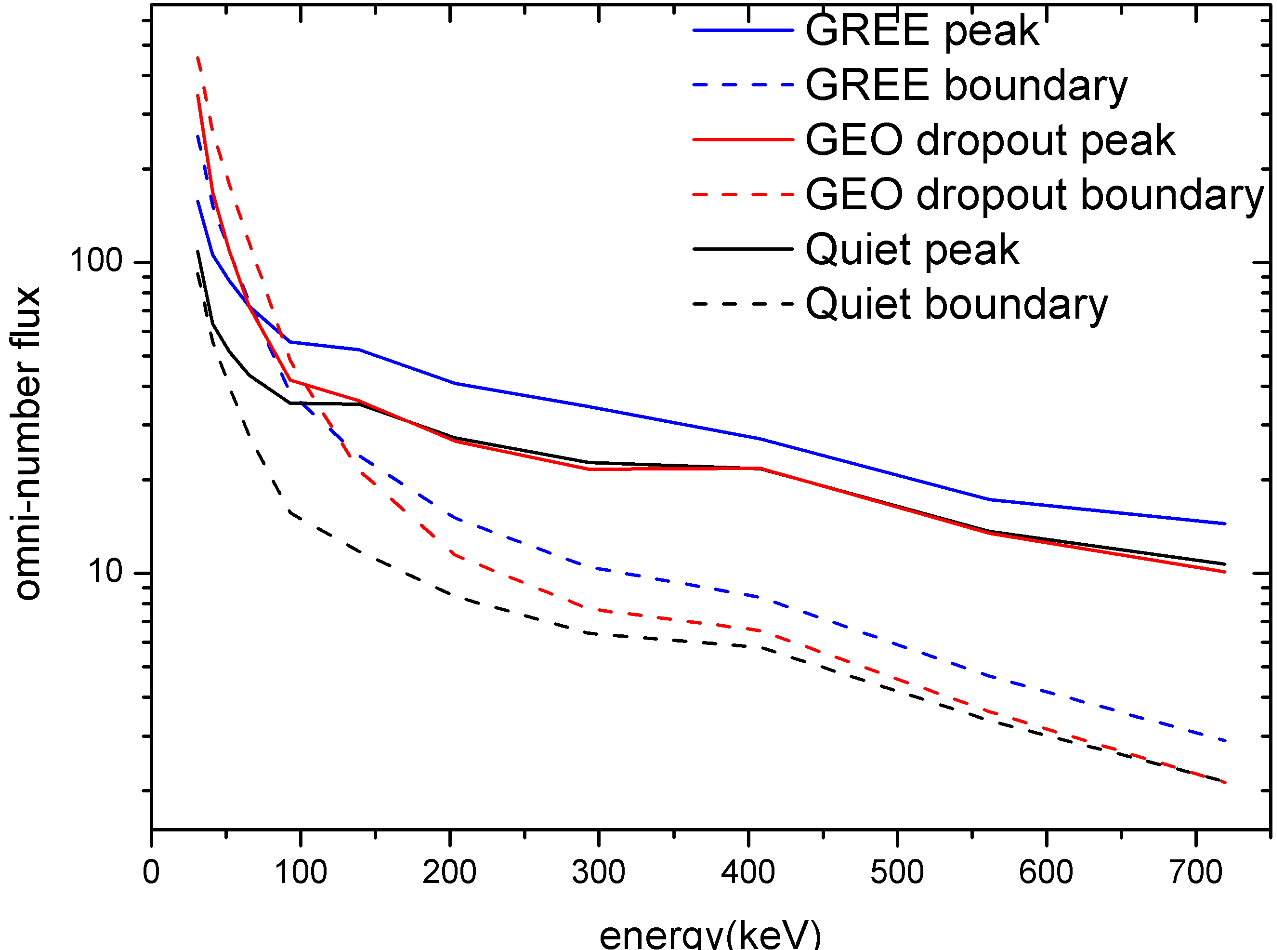
Expansion to GREE and quiet time











Fitting function

$$y = ax^b$$

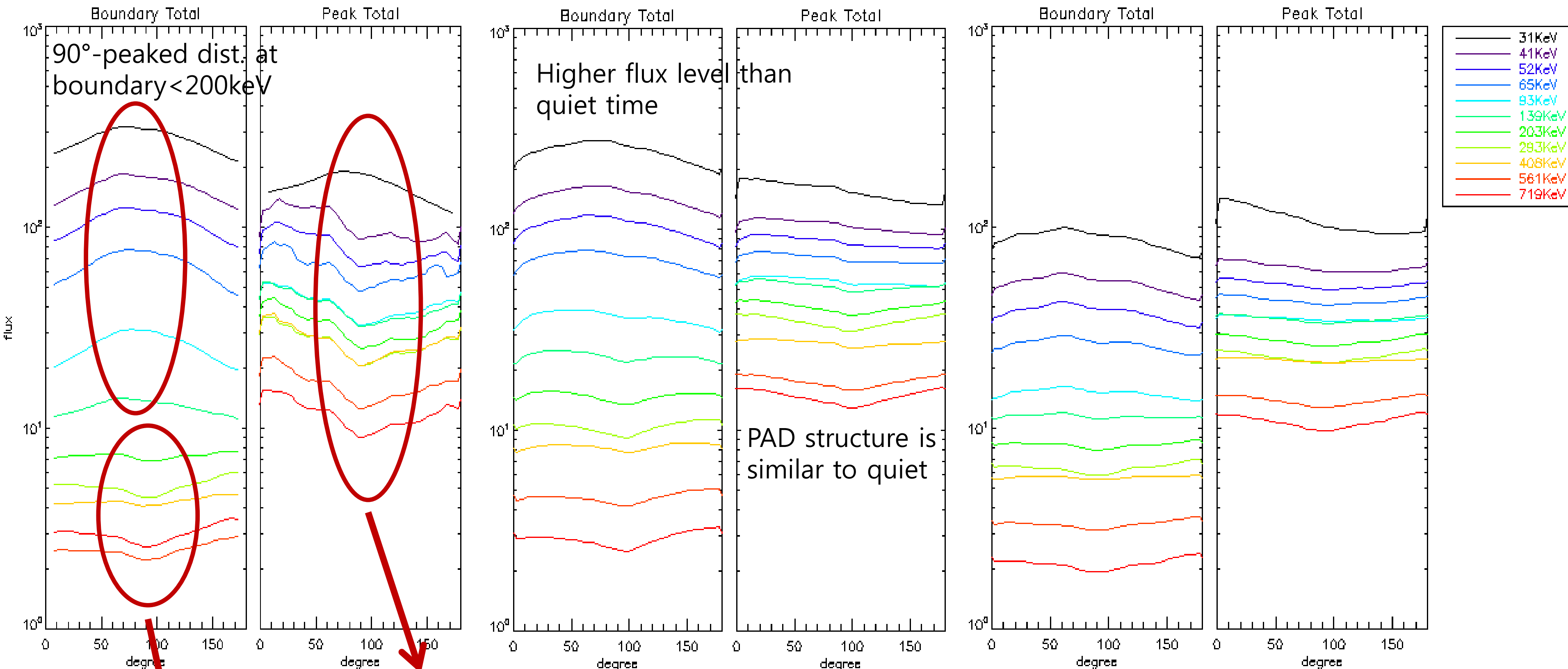
		a	b	L*
GEO dropout	TR	2.9×10^5	-1.88	5.49
	Peak	5.3×10^3	-0.96	4.60
GREE	TR	2.1×10^4	-1.34	6.31
	Peak	1.8×10^3	-0.75	5.31
Quiet time	TR	2.5×10^3	-1.07	6.14
	Peak	1.2×10^3	-0.75	5.02

Pitch angle distribution

GEO dropout

GREE

Quiet time

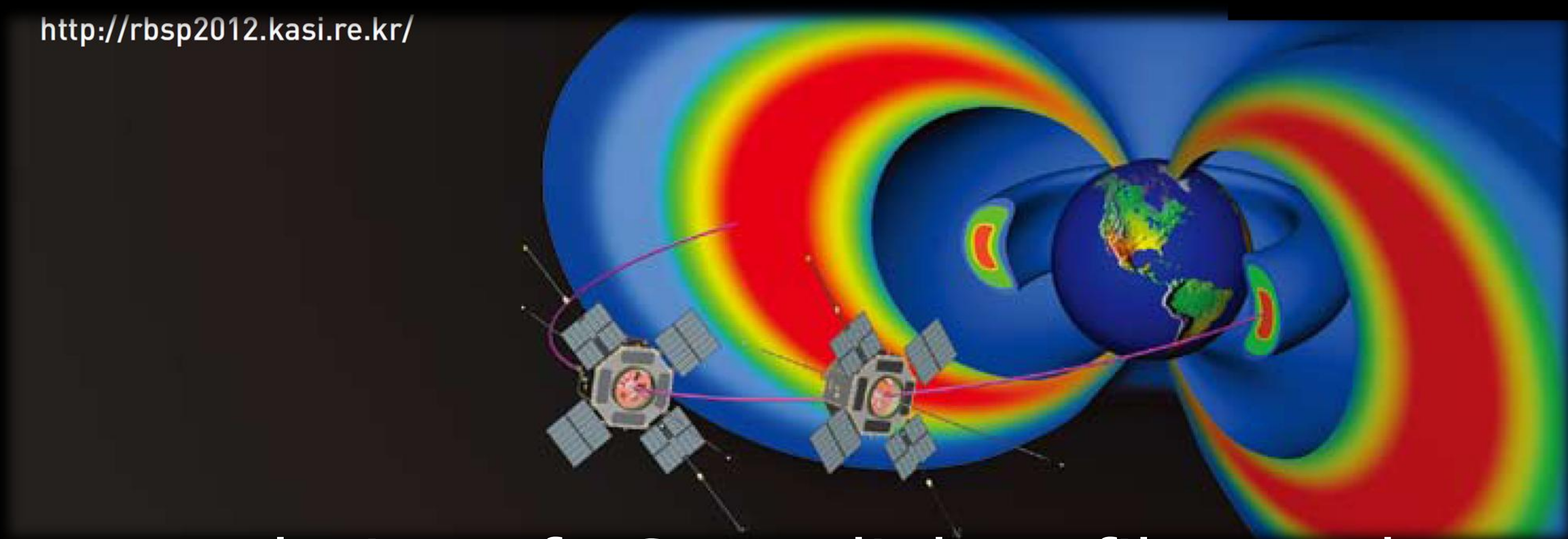


Butterfly dist. at peak

Weak butterfly dist. at boundary>200keV

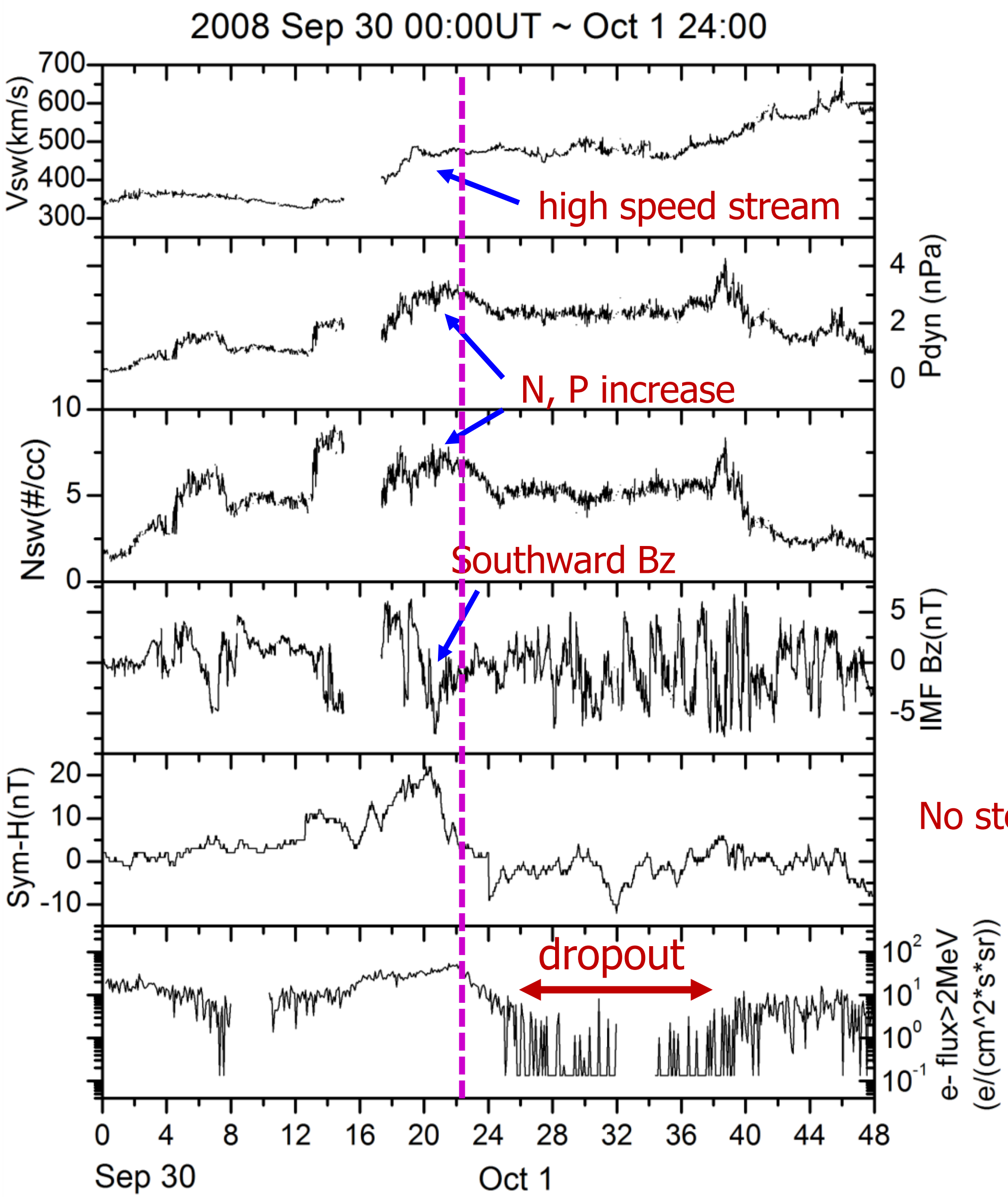
Summary

- We find fitting function of energy spectrum at trapping boundary and peak of outer radiation belt depending on geosynchronous electron flux levels in the equatorial plane.
- The fitting function is power-law like $y = ax^b$
- During GEO dropout, L* is 4.6/5.5 at peak/boundary, that is compressed into the inner shell keeping the thickness between peak and boundary, while GREE, L* is 5.3/6.3.
- During GEO dropout, (1) butterfly distribution at peak is shown and (2) there are energy dependent PAD, i.e. 90°-peaked distribution <200keV and butterfly distribution >200keV.
- During GREE, higher flux level than quiet time at both peak and boundary.
- During quiet interval, very similar PAD to GREE appears.



Evolution of PSD radial profiles at the outer radiation belt associated with geosynchronous flux dropouts: THEMIS observations

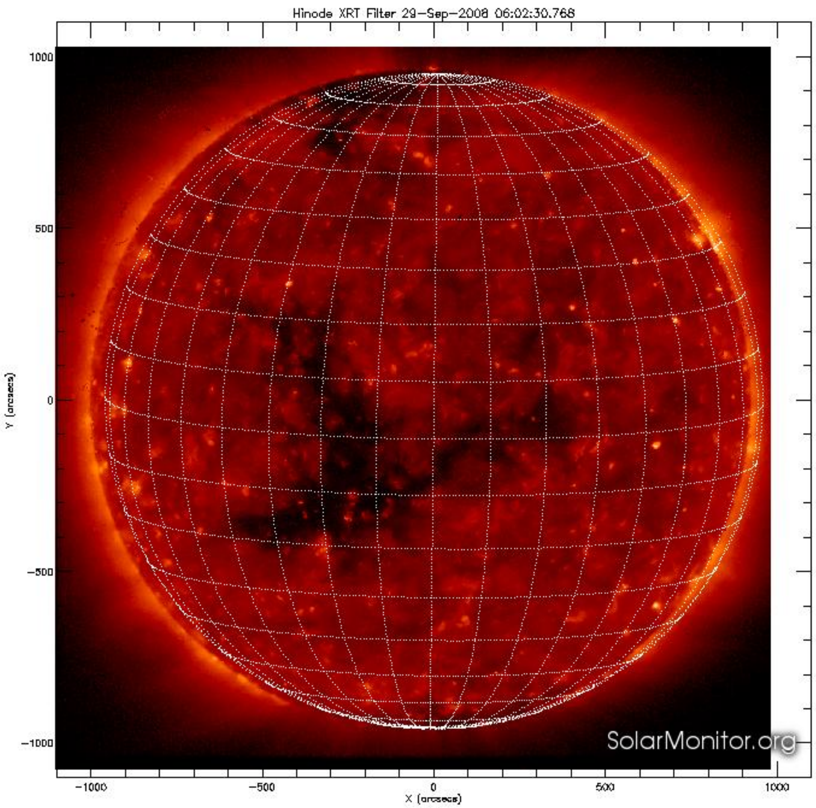
Geosynchronous flux dropout : Case 1

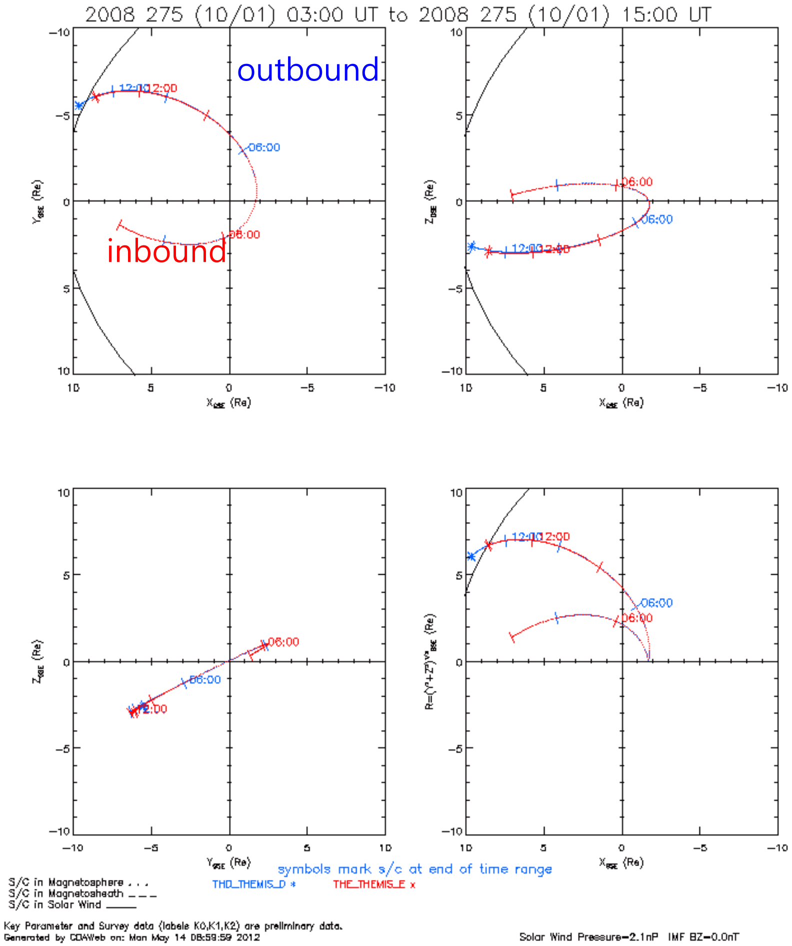


No storm

Oct 1 03:00 – 15:00

THEMIS D&E orbits

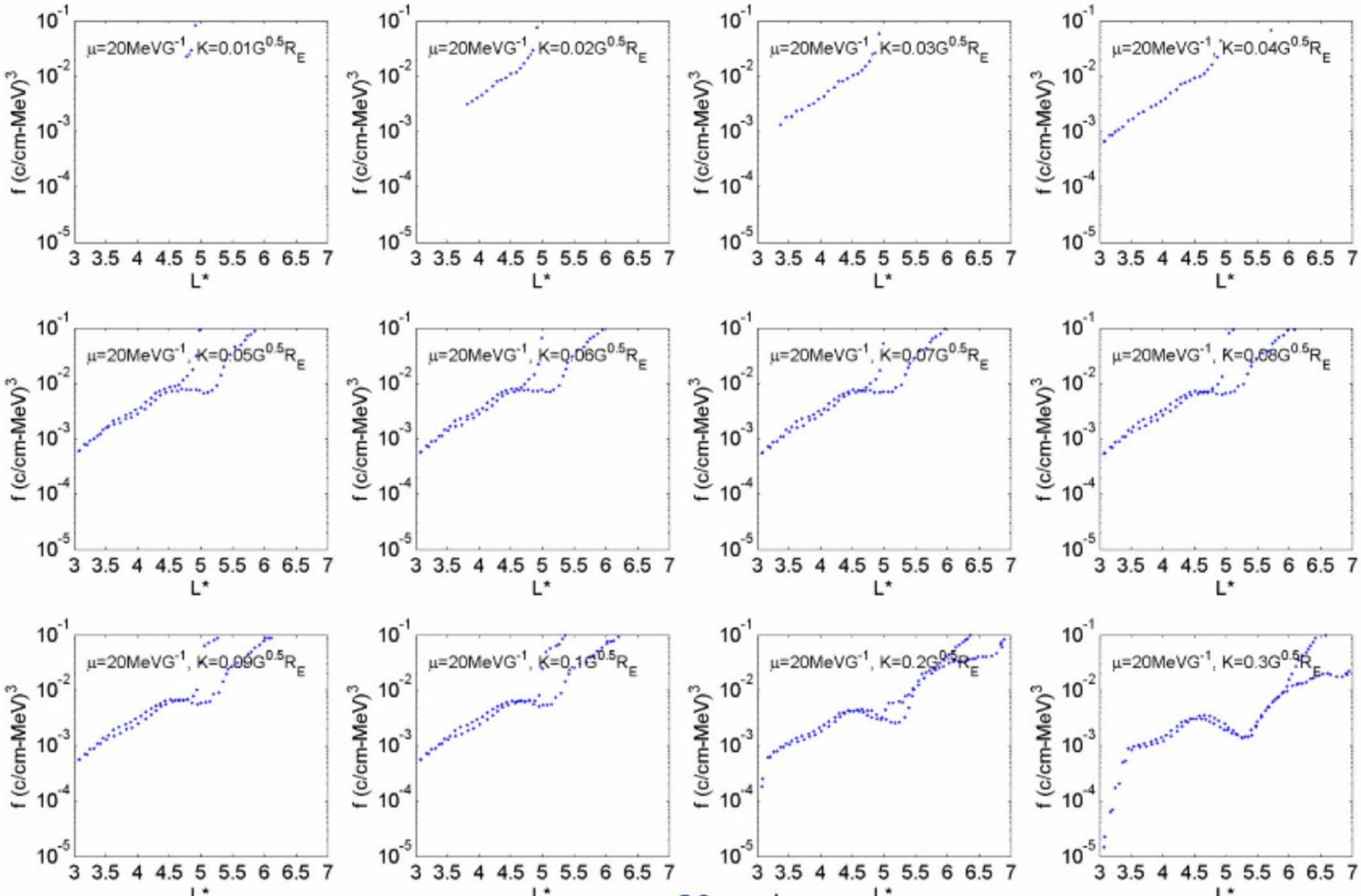




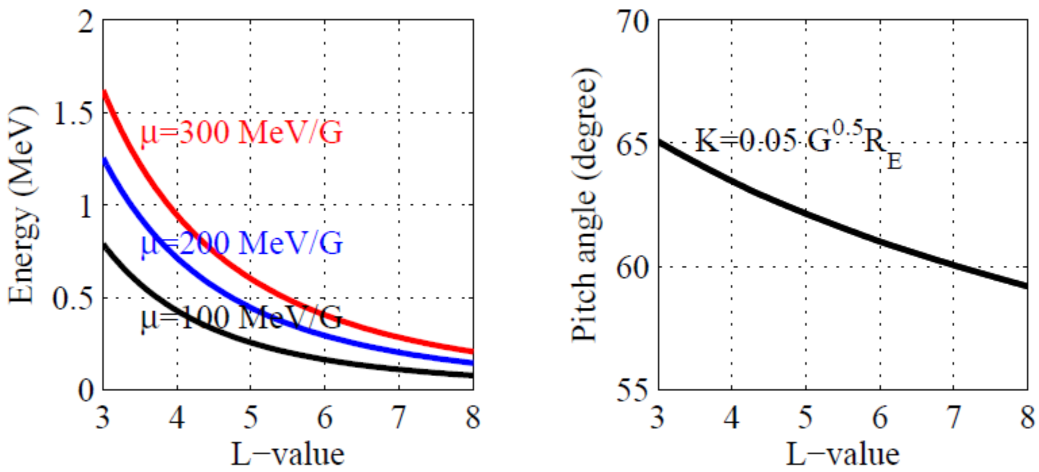
Coronal hole on Sep 29

PSD(Phase Space Density) radial profile: case1

Mu = 20MeV/G ~ 700MeV/G, K = 0.01 ~ 0.3$G^{0.5}R_E$

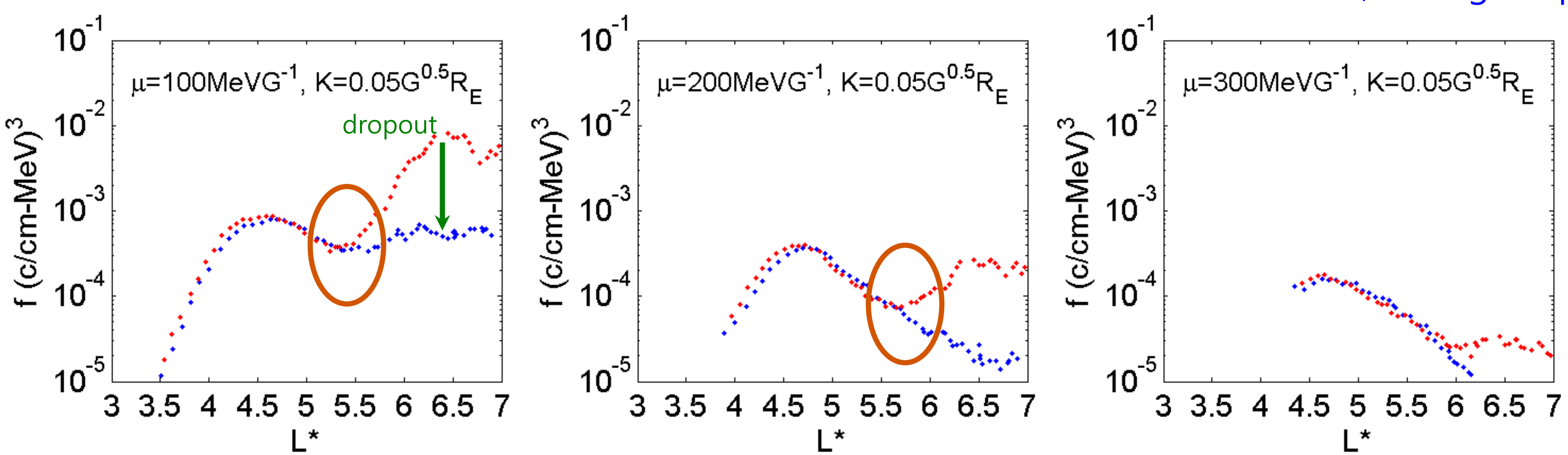


mu_20_psd



- Energy range of 0.5~1.5 MeV in the outer radiation belt
- pitch angle coverage of 60-65 degree

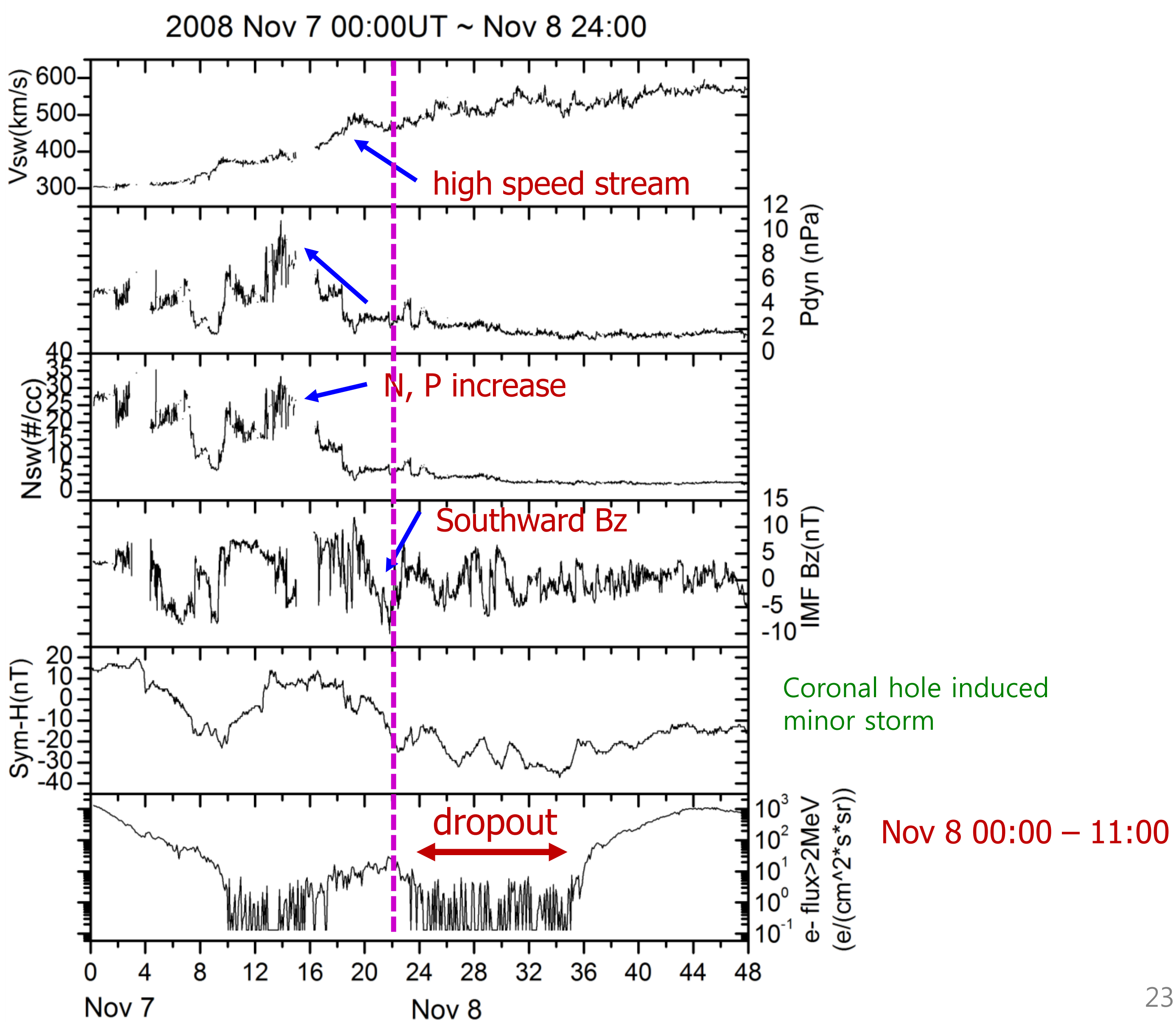
Red: inbound, before dropout
blue: outbound, during dropout



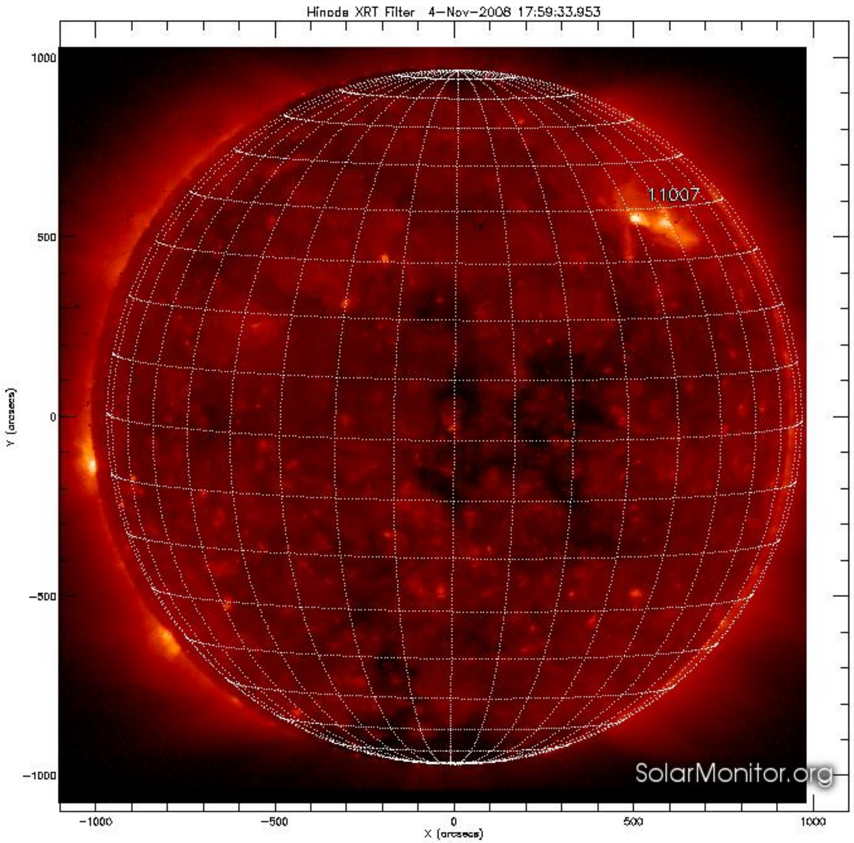
Positive radial PSD gradient in both inbound and outbound motions outside of 5.5RE

Negative radial PSD gradient in outbound during flux dropout outside of 5.5RE

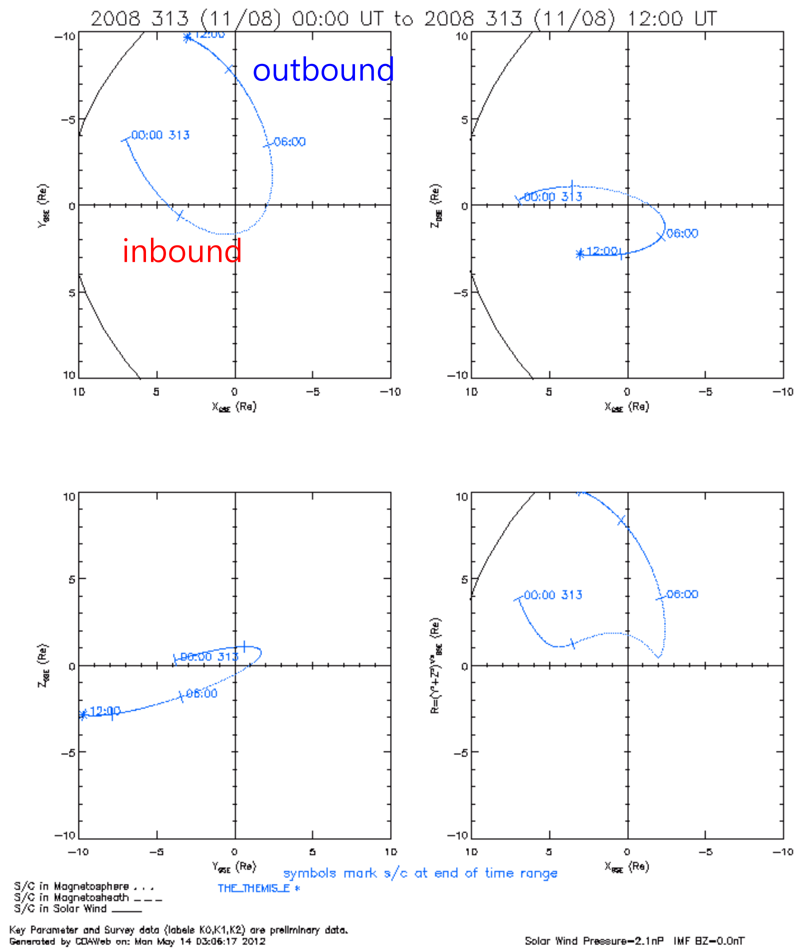
Geosynchronous flux dropout : Case 2



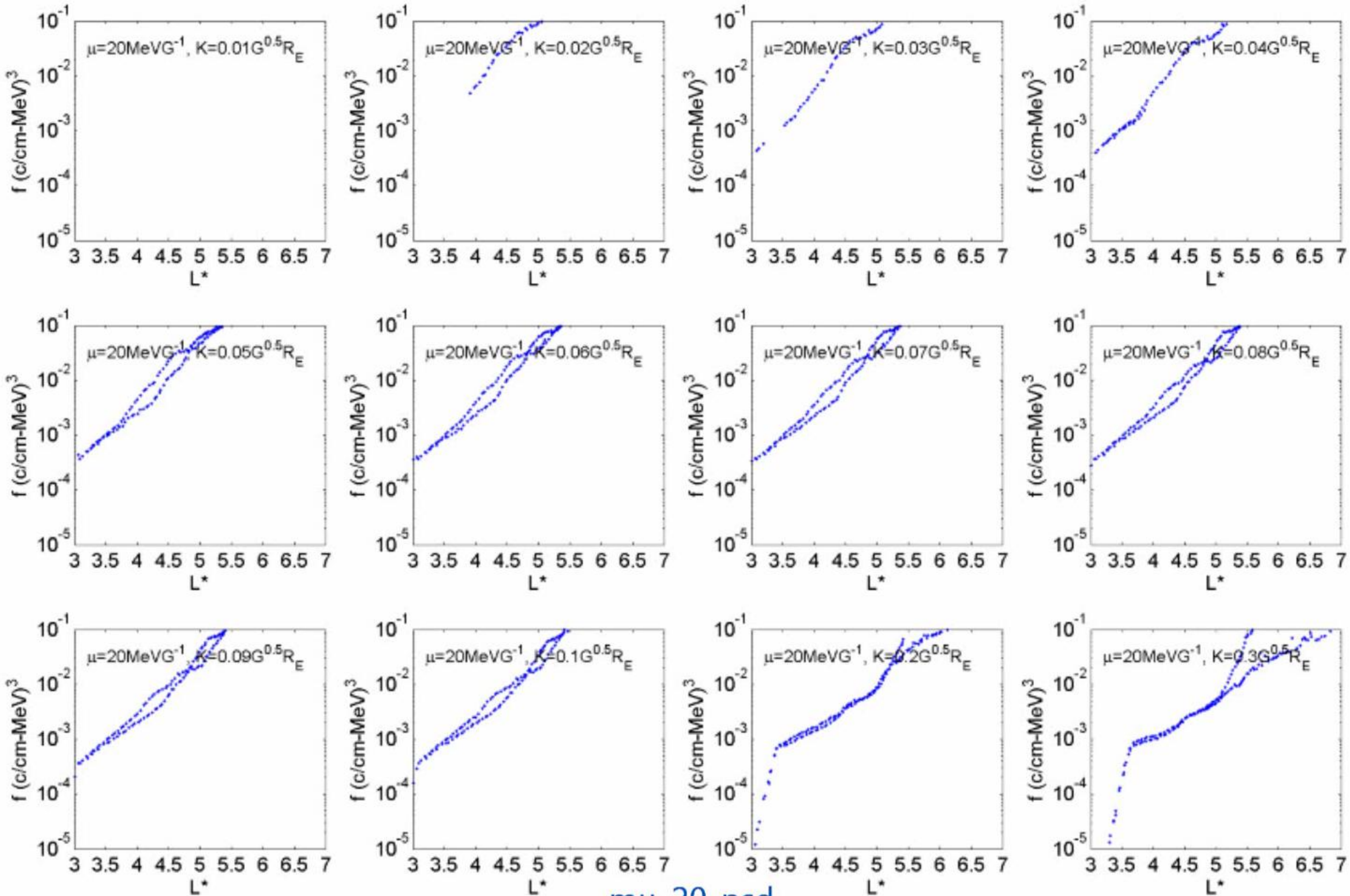
THEMIS E orbit



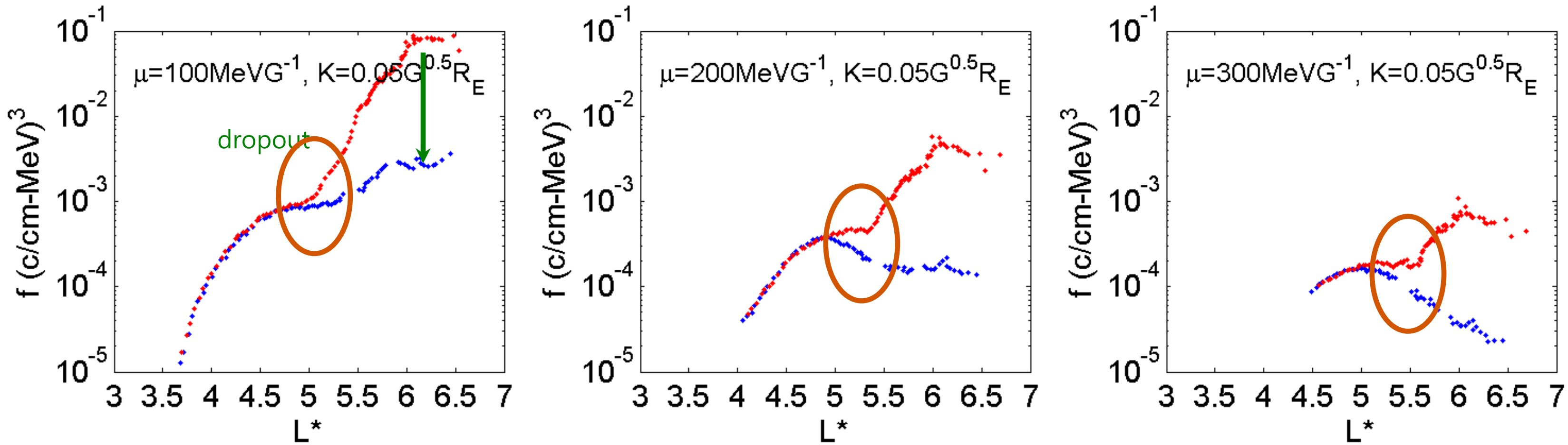
Coronal hole on Nov 4



PSD(Phase Space Density) radial profile: case2



mu_20_psd

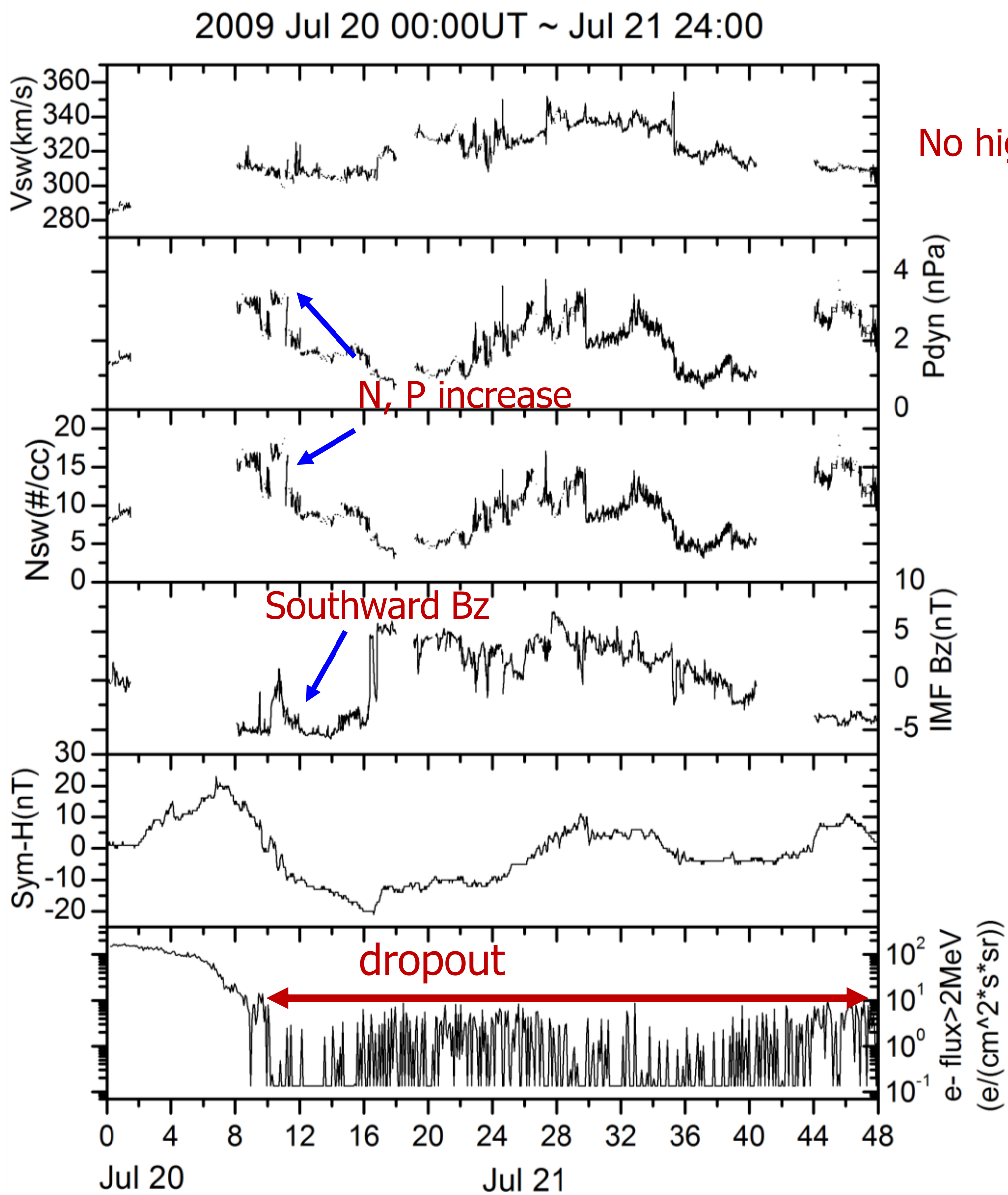


Positive radial PSD gradient in both inbound and outbound motions outside of 5.5RE

Negative radial PSD gradient in outbound during flux dropout outside of 5.5RE

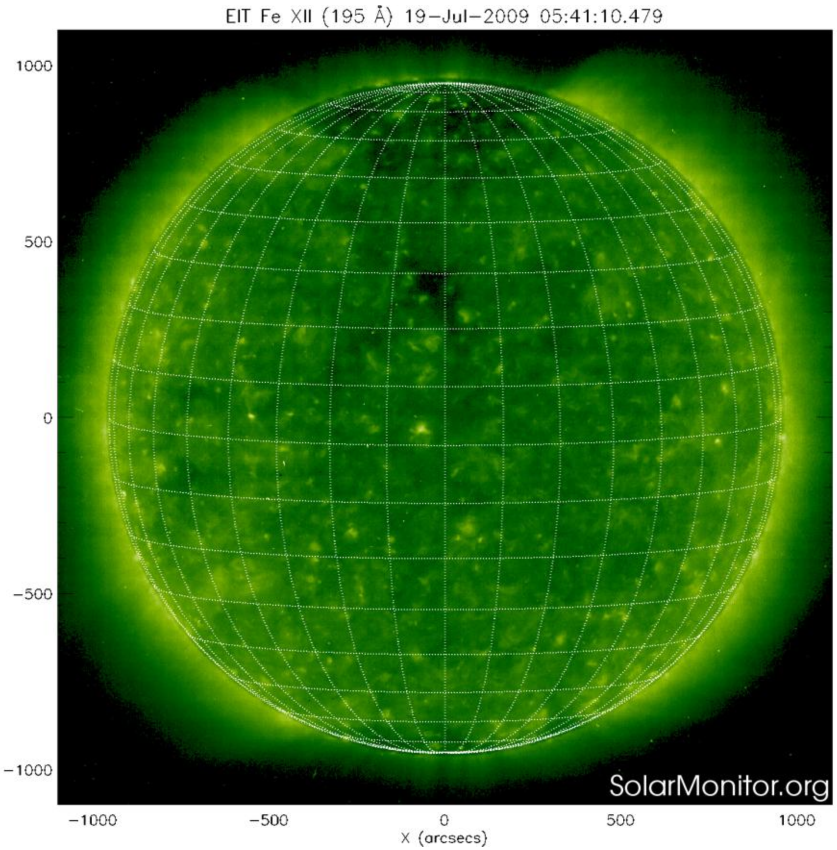
More negative radial PSD gradient in mu = 300 $MeVG^{-1}$

Geosynchronous flux dropout : Case 3



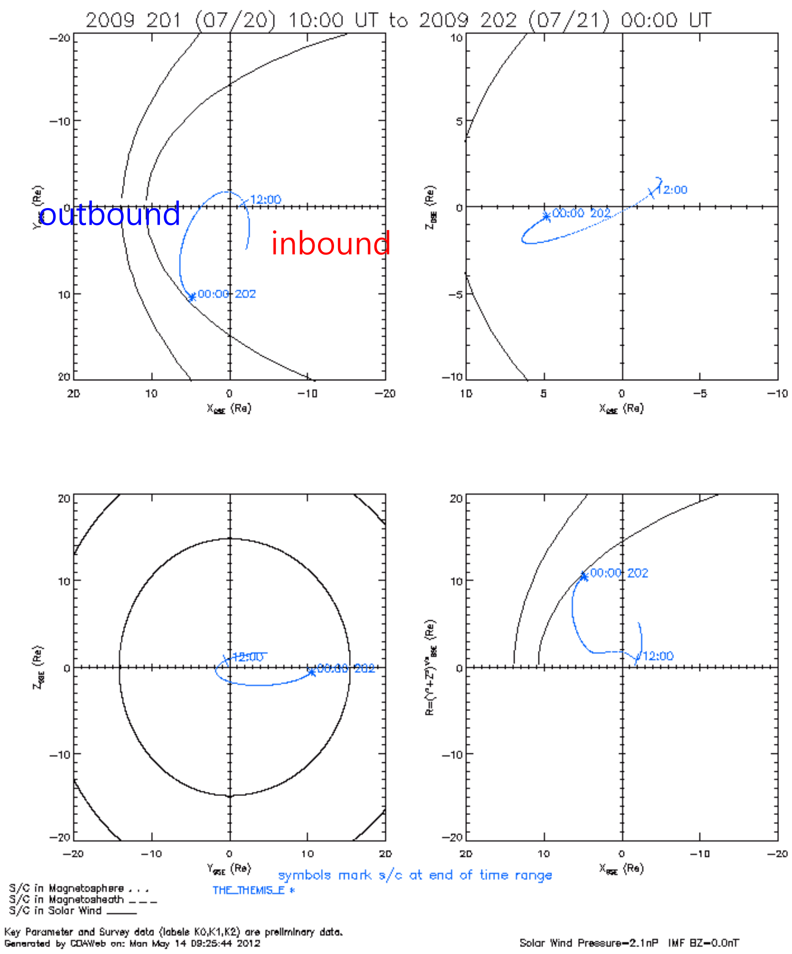
No high speed stream

Jul 20 10:00 – 24:00

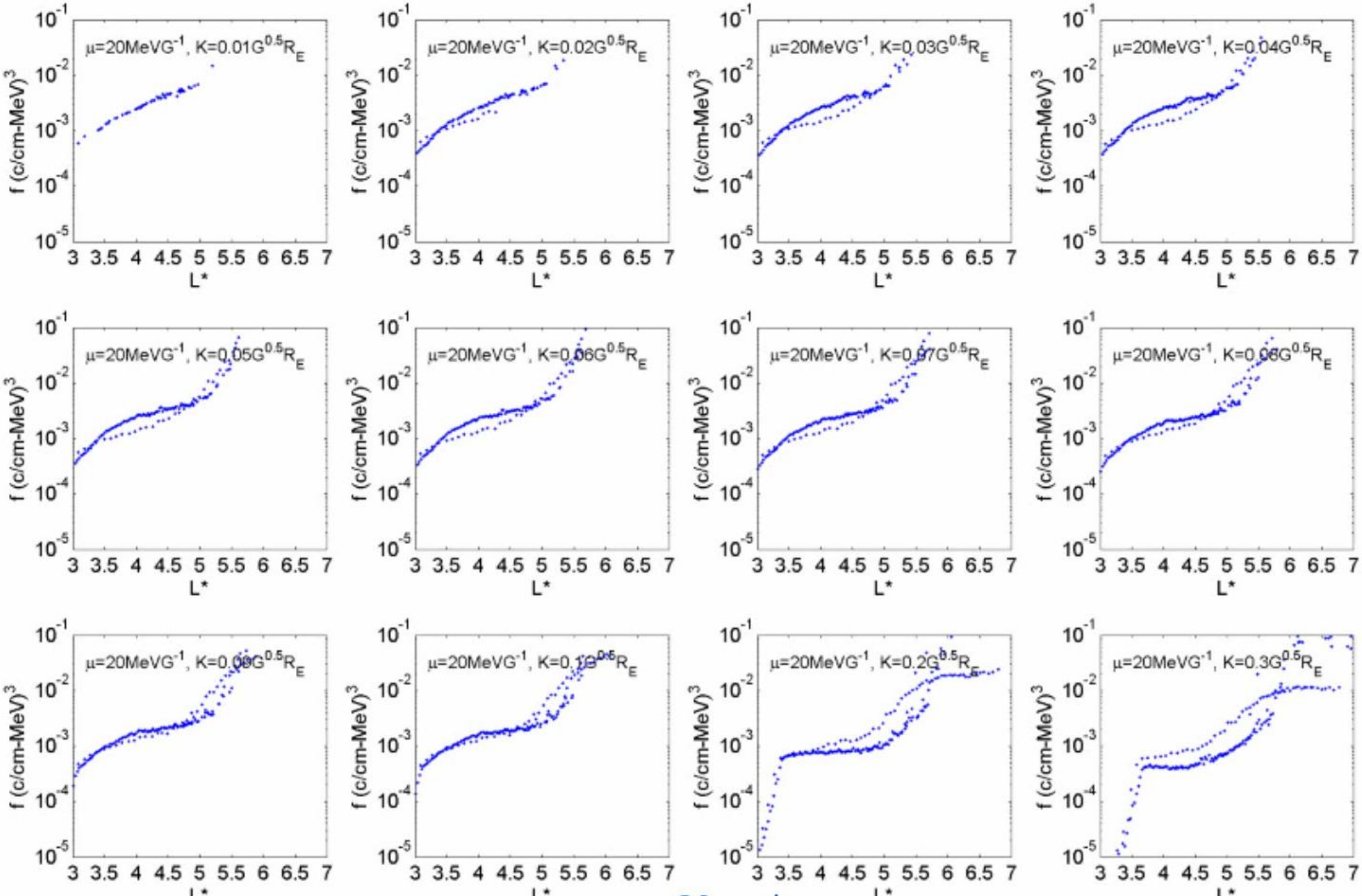


No coronal hole

THEMIS E orbits

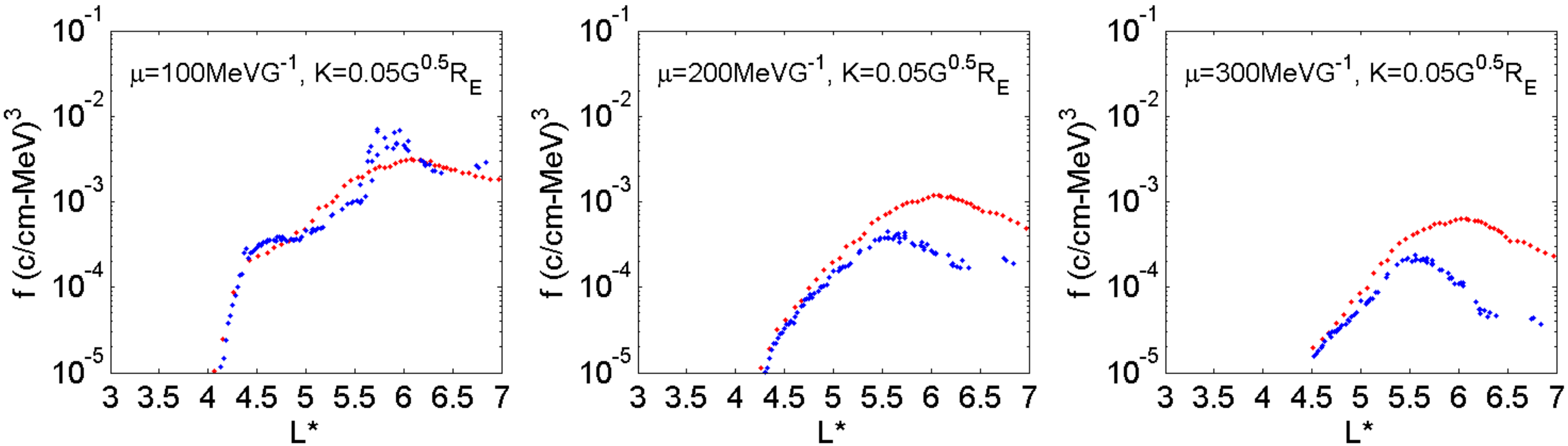


PSD(Phase Space Density) radial profile: case3



mu_20_psd

Red: inbound, before dropout
blue: outbound, during dropout



Positive radial PSD gradient in both inbound and outbound motions outside of 5.5RE

Negative radial PSD gradient in both inbound and outbound during flux dropout outside of 5.5RE

More steepened negative radial PSD gradient in outbound during flux dropout outside of 5.5RE

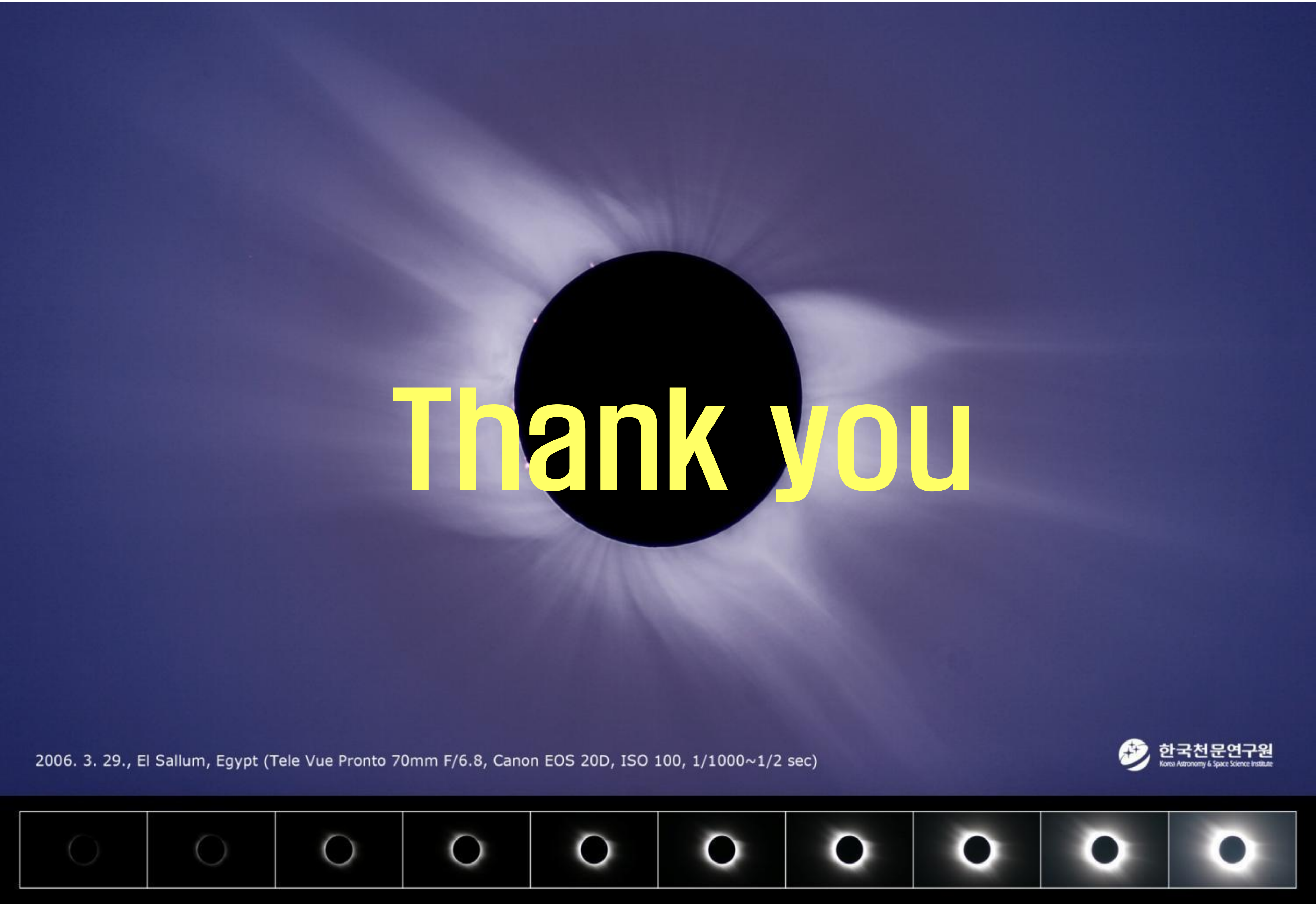
Summary & Conclusion

We have investigated geosynchronous flux dropouts during 2008-2010 using GOES.

We estimated the PSD radial profiles for various mu (20~700MeV/G) and K ($0.01 \sim 0.3 G^{0.5} R_E$) values in the outer radiation belt during flux dropouts using THEMIS.

We find the PSD radial profile changes abruptly between 100MeV/G and 200MeV/G of 0.05 $G^{0.5}R_E$ of K in most dropout cases outside of 5.5R_E. During the flux dropout, there is a negative PSD radial gradient in sub-relativistic and relativistic electrons inside the geosynchronous orbit. It makes local peak (~4.5R_E) more clear.

Such a PSD radial gradient change is not associated with the storm existence, just associated with the increase of dynamic pressure/ solarwind density's sudden increase and southward IMF Bz.


Thank you
2006. 3. 29., El Sallum, Egypt (Tele Vue Pronto 70mm F/6.8, Canon EOS 20D, ISO 100, 1/1000~1/2 sec)
한국천문연구원
Korea Astronomy & Space Science Institute