ICPPA-2016

The big geomagnetic storm of 17 March 2015: Measurements from EPT / PROBA-V as well as their interpretation

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Energetic Particle Detector: EPT

- Design & development:
  Centre Space Radiation / *UCL / LLN*
  Belgian Institute Space Aeronomy */ Brussels*
  QinetiQ Space

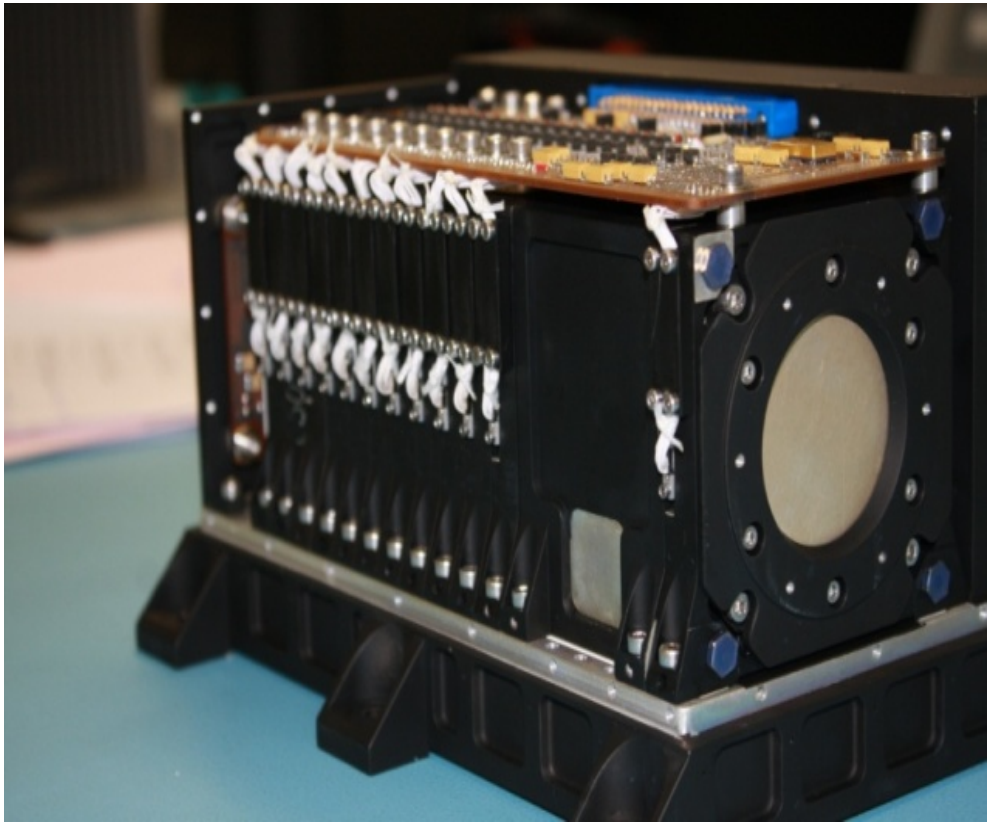
- Digital PIPS detector/spectrometer/ FOV : 52°
  LES : 3 sensors ΔE - E
  HES: stack of 10 absorber/detector

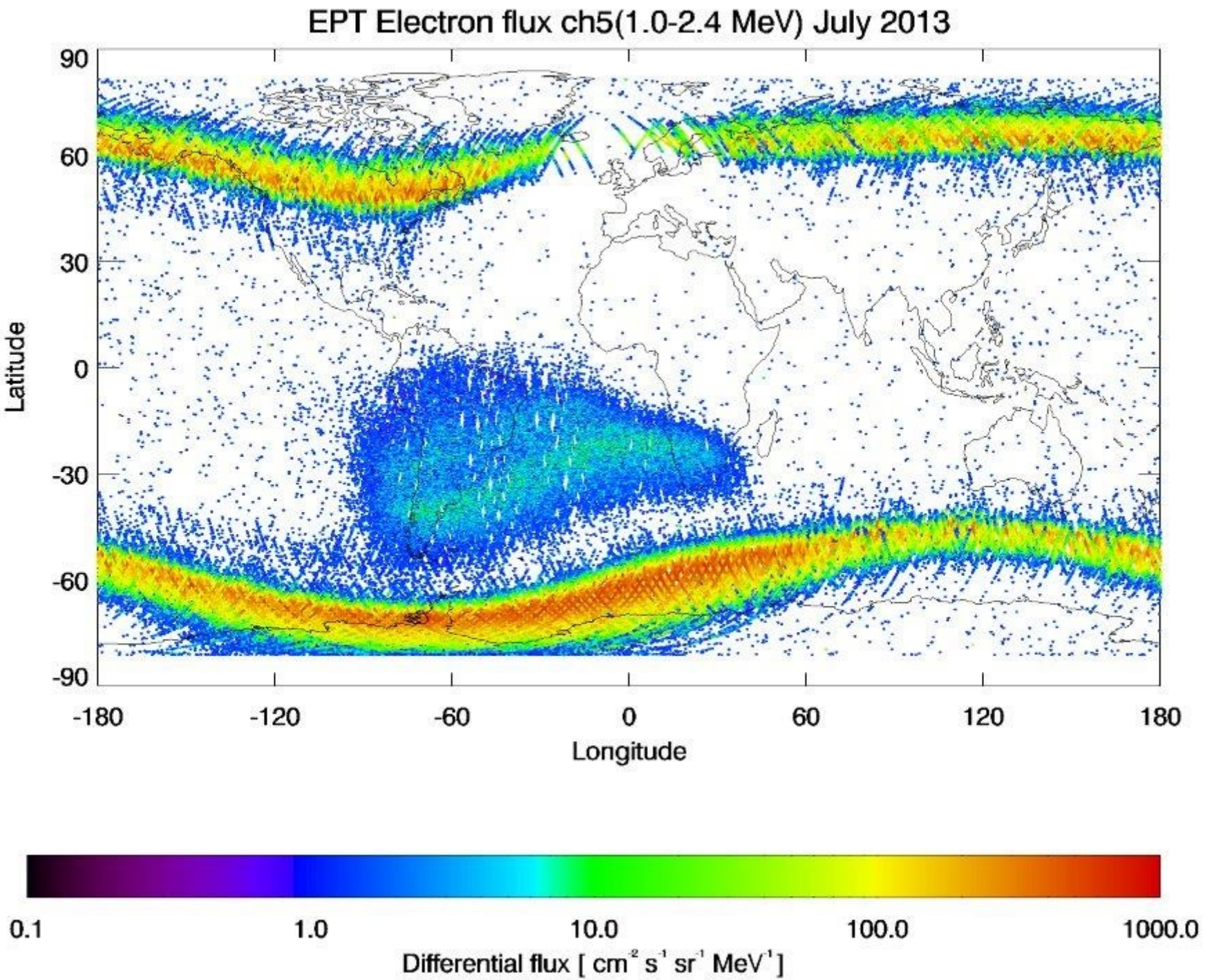
- Discrimination particle species :
  e^- (0.5 - 20 MeV ; 7 ch)
  p^+ (9.5 - 248 MeV ; 11 ch)
  Heavy ions

- Efficiency Calculation with GEANT4

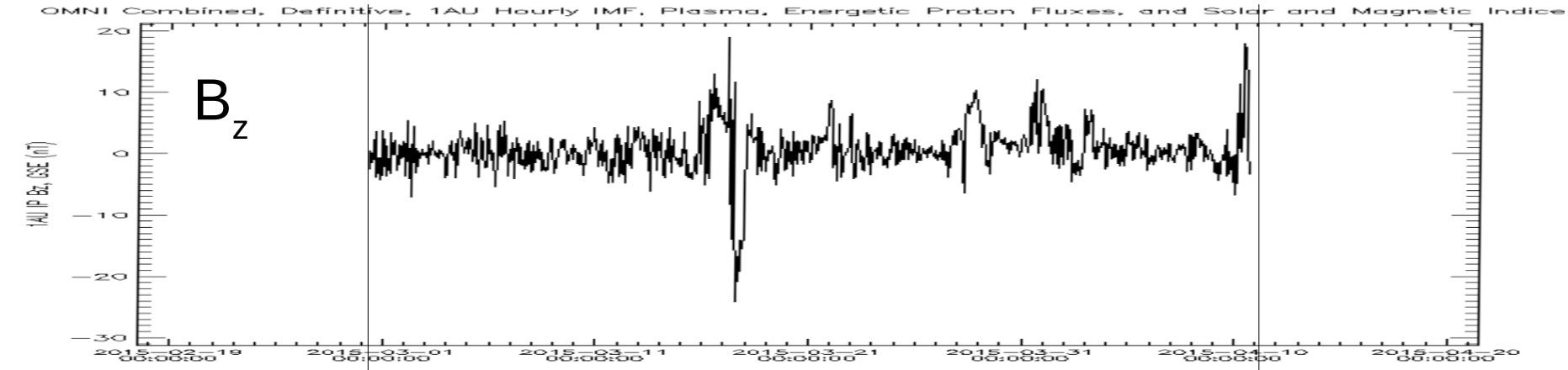
- *Cyamukungu et al., IEEE Trans. Nucl. Sci. 61, 3667, 2014,*

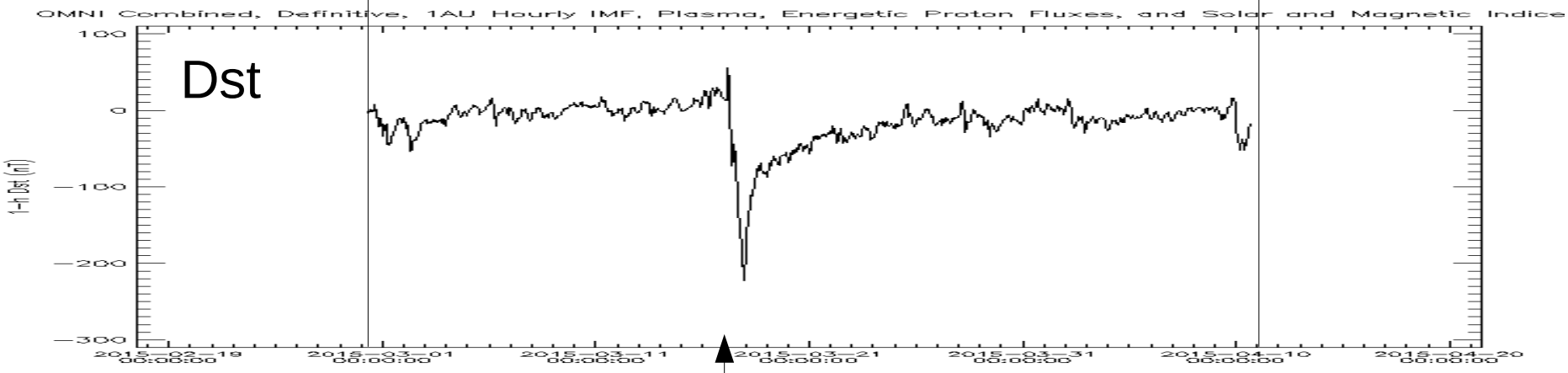
- *Pierrard et al., Space Sc. Rev, 184, 87, 2014*




EPT Electron flux ch5(1.0-2.4 MeV) July 2013
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude
0.1
1.0
10.0
100.0
1000.0
Differential flux [cm-2 s-1 sr-1 MeV-1]

Geomagnetic Storm of 17 March 2015 (Dst_min = -223 nT)

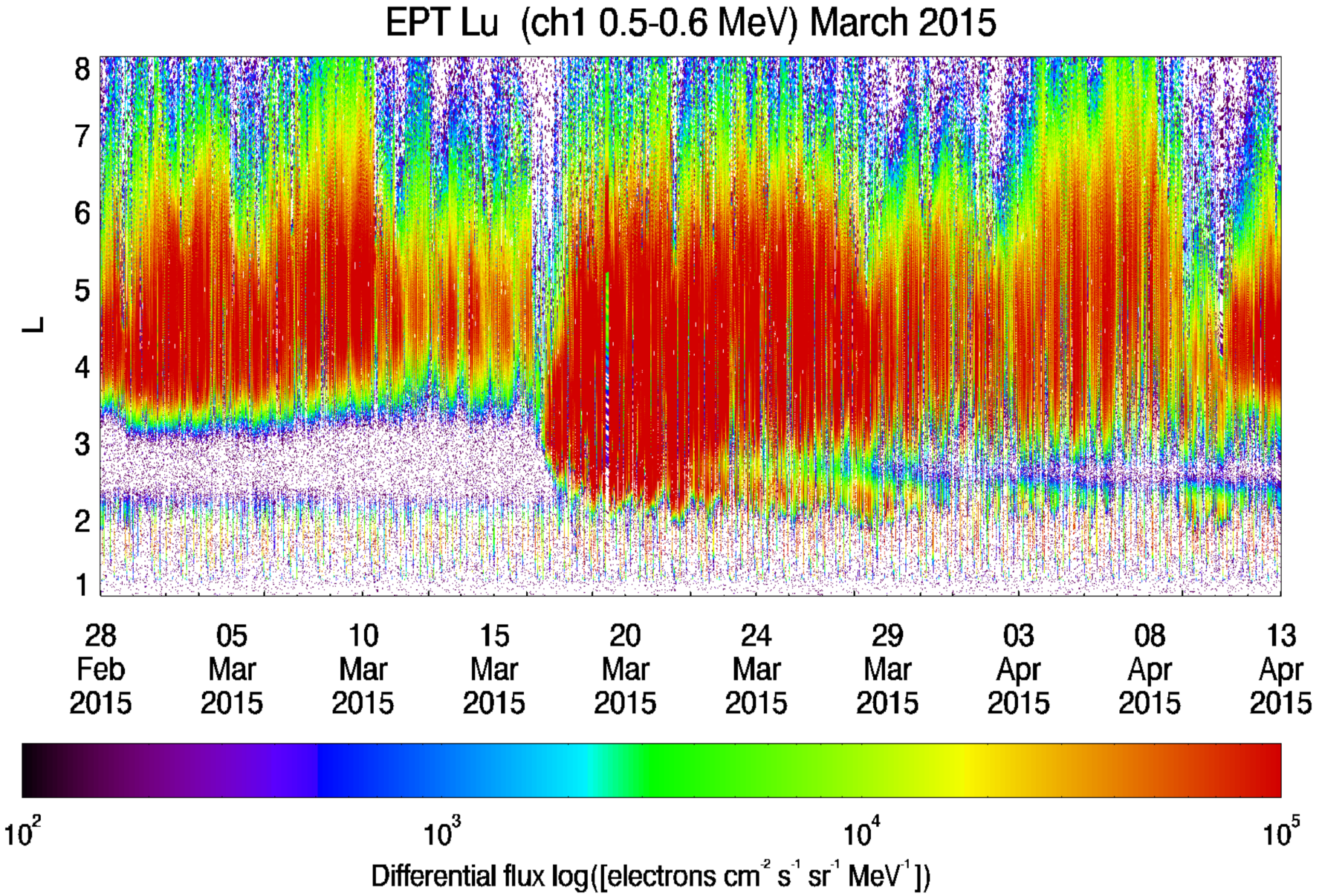


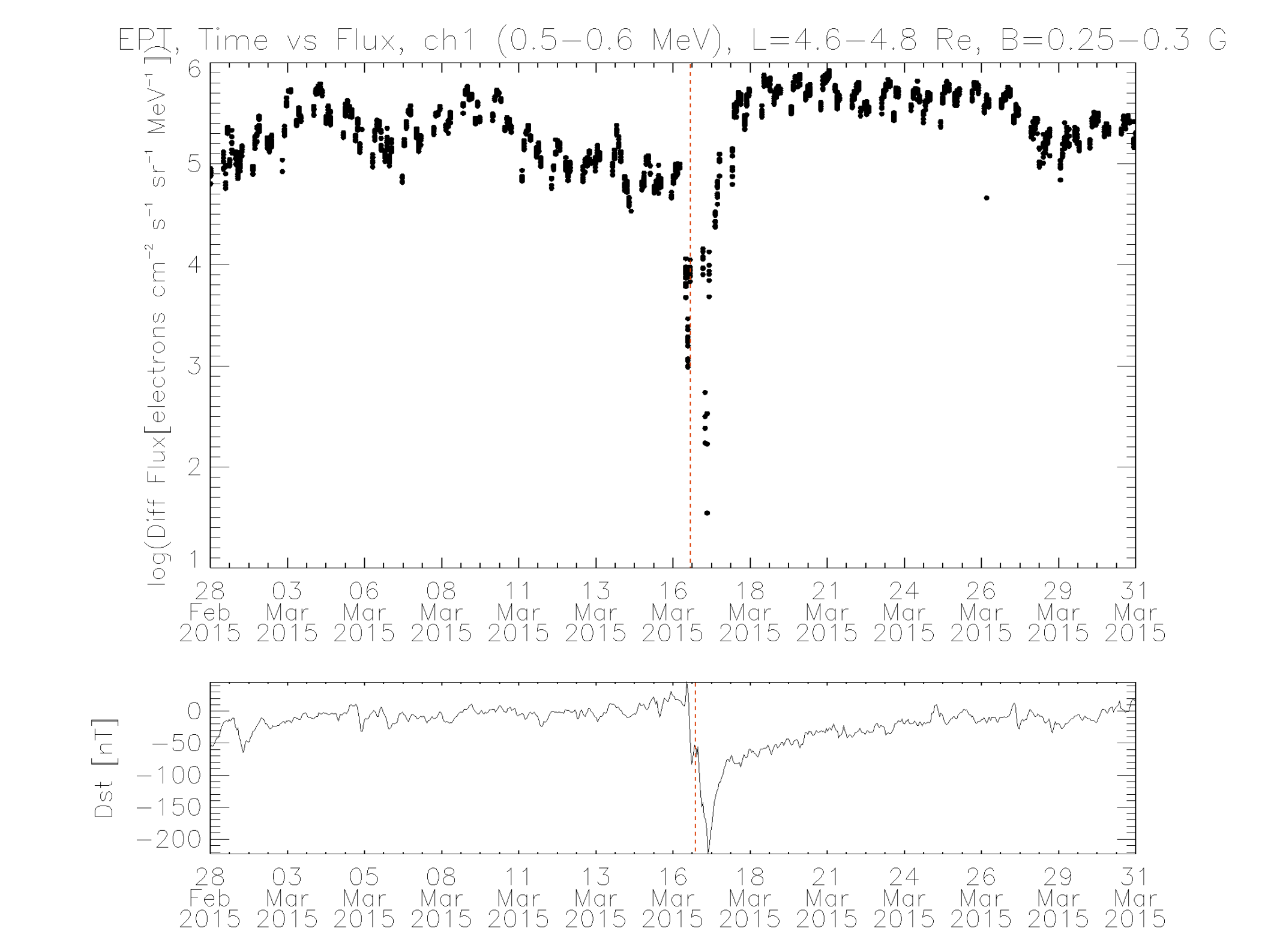


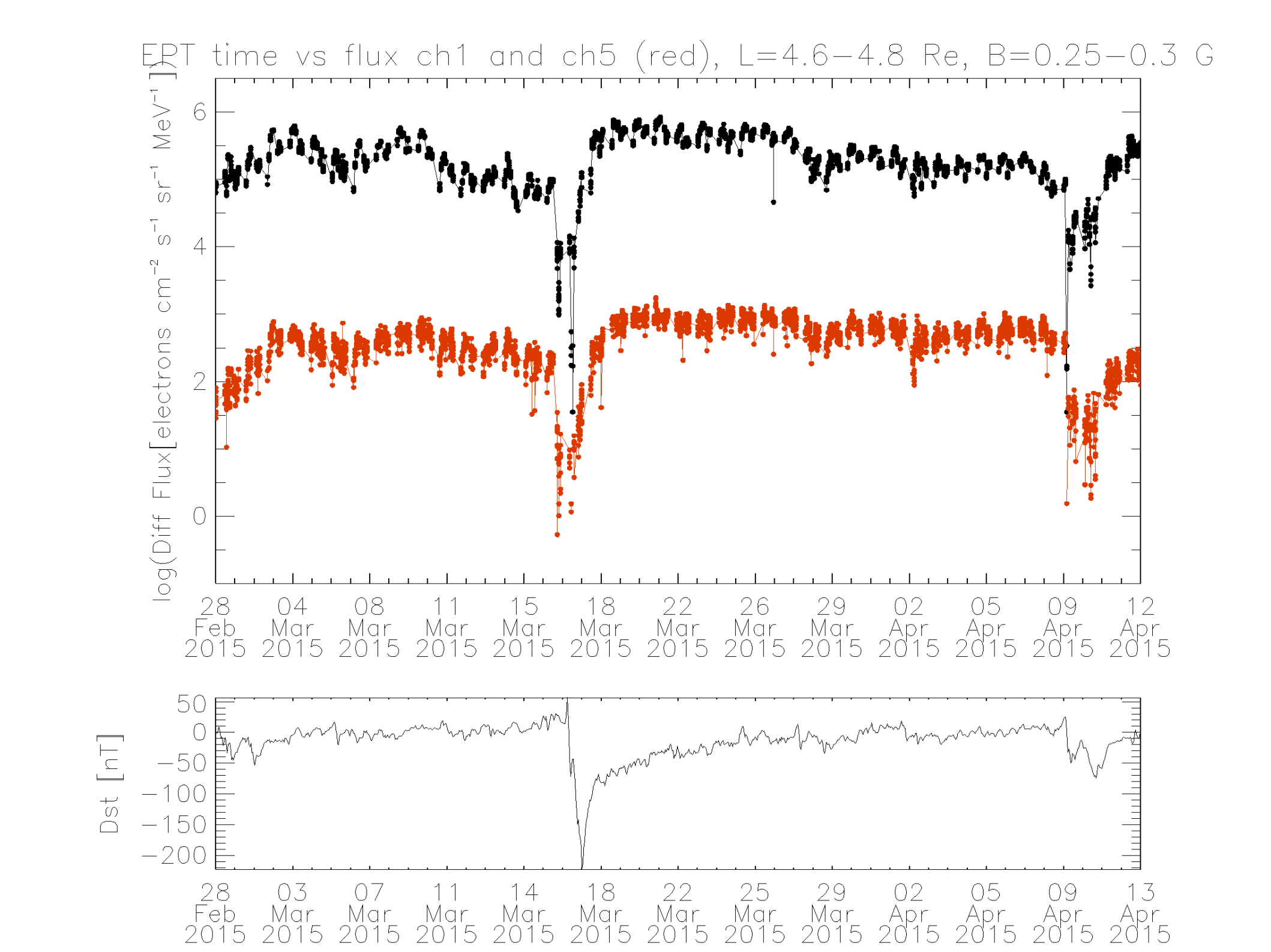
28 Feb 15

17 March

11 Apr 15

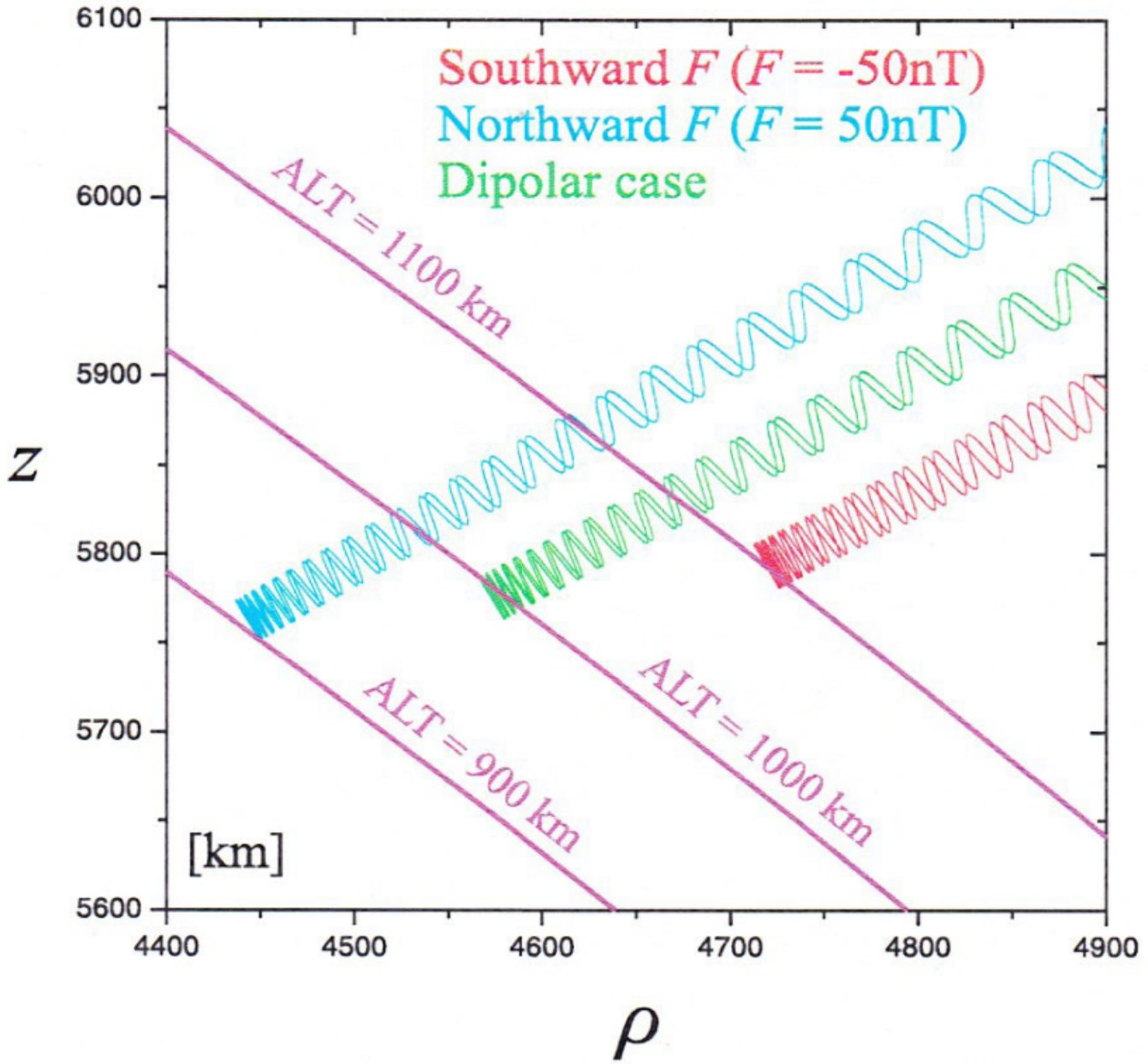

EPT Lu (ch1 0.5-0.6 MeV) March 2015
L
8
7
6
5
4
3
2
1
28 Feb 2015
05 Mar 2015
10 Mar 2015
15 Mar 2015
20 Mar 2015
24 Mar 2015
29 Mar 2015
03 Apr 2015
08 Apr 2015
13 Apr 2015
10^2
10^3
10^4
10^5
Differential flux log([electrons cm^-2 s^-1 sr^-1 MeV^-1])

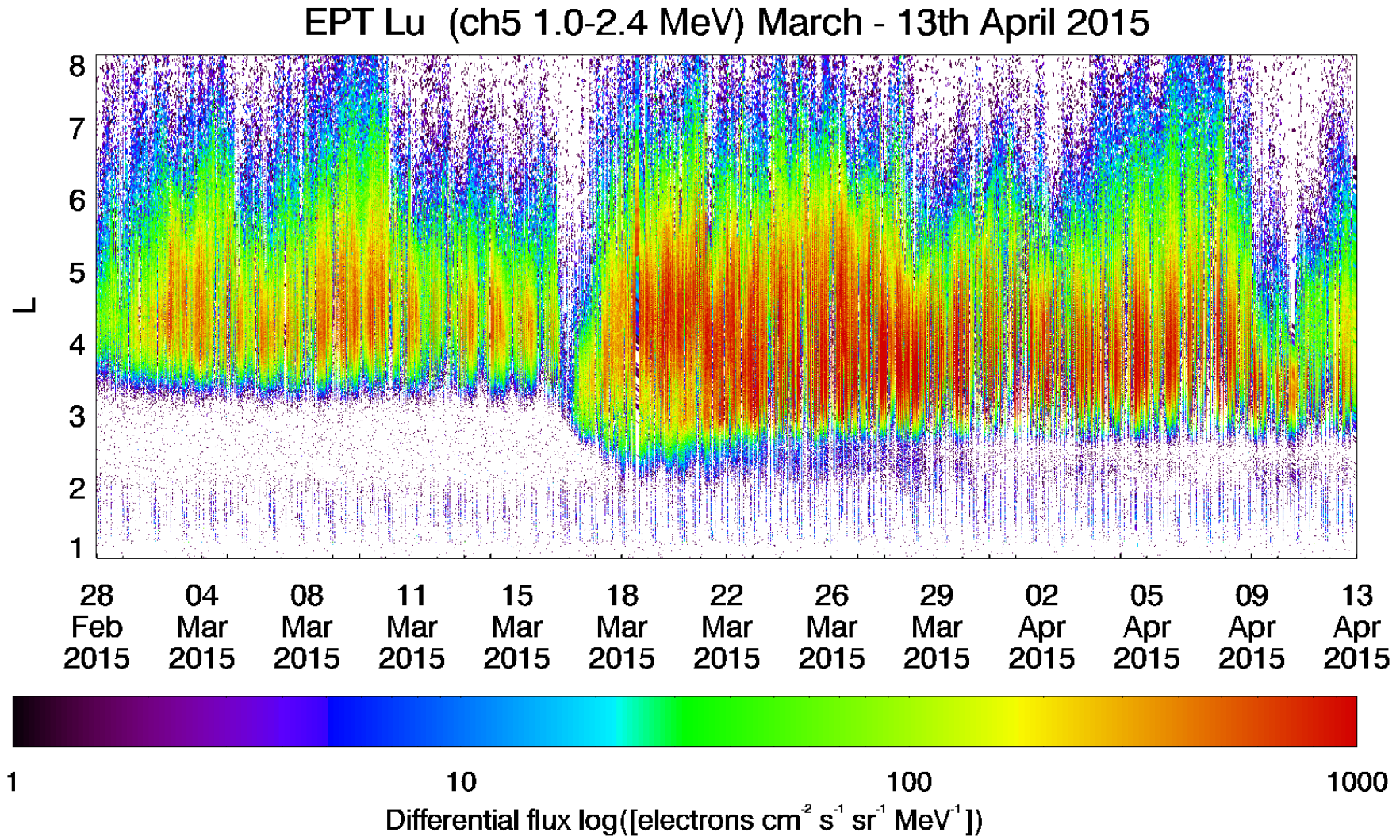

EPI, Time vs Flux, ch1 (0.5–0.6 MeV), L=4.6–4.8 Re, B=0.25–0.3 G
log(Diff Flux[electrons cm^{-2} s^{-1} sr^{-1} MeV^{-1}])
6
5
4
3
2
1
28 Feb 2015
03 Mar 2015
06 Mar 2015
08 Mar 2015
11 Mar 2015
13 Mar 2015
16 Mar 2015
18 Mar 2015
21 Mar 2015
24 Mar 2015
26 Mar 2015
29 Mar 2015
31 Mar 2015
Dst [nT]
0
−50
−100
−150
−200
28 Feb 2015
03 Mar 2015
05 Mar 2015
08 Mar 2015
11 Mar 2015
13 Mar 2015
16 Mar 2015
18 Mar 2015
21 Mar 2015
24 Mar 2015
26 Mar 2015
29 Mar 2015
31 Mar 2015

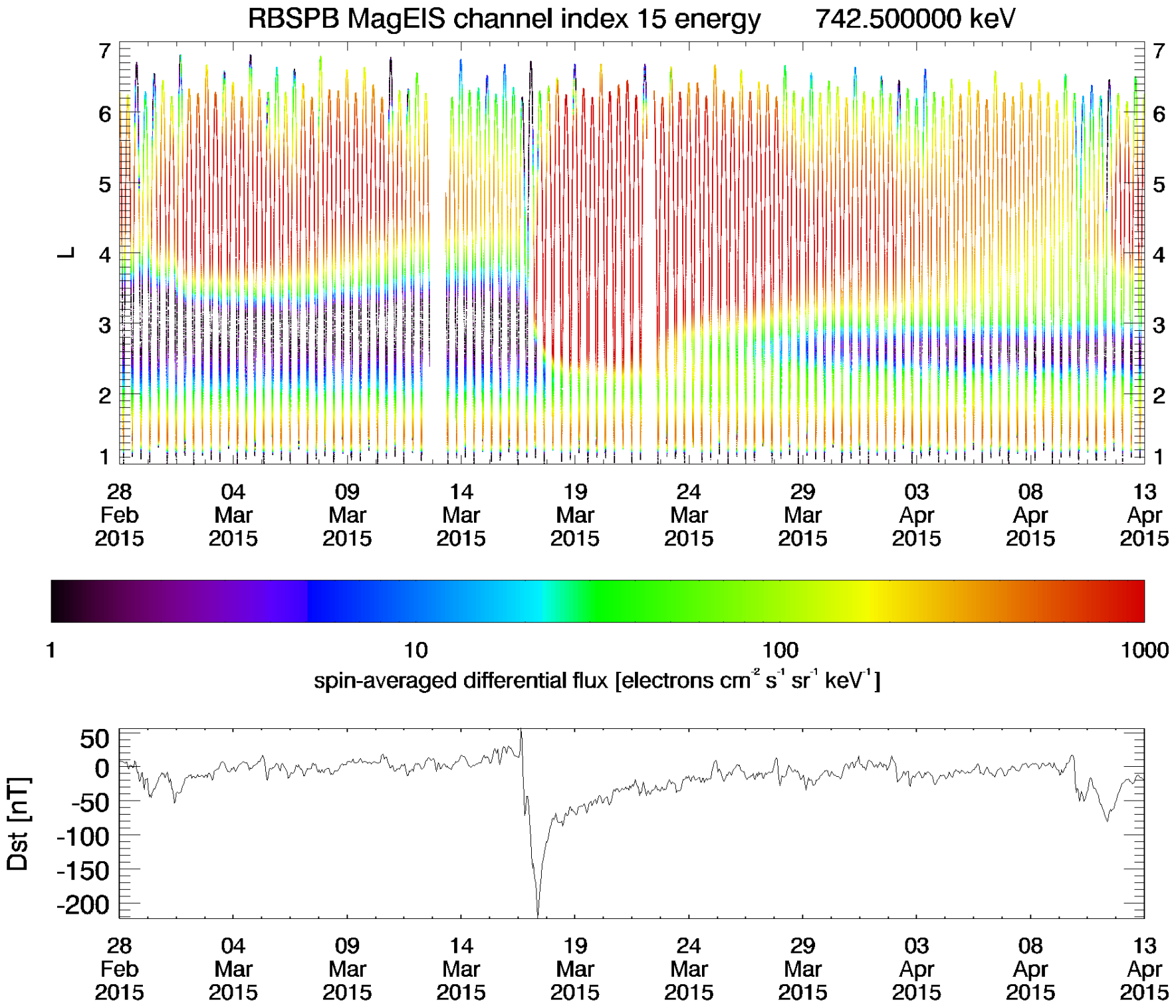

EPT time vs flux ch1 and ch5 (red), L=4.6–4.8 Re, B=0.25–0.3 G
log(Diff Flux[electrons cm^{-2} s^{-1} sr^{-1} MeV^{-1}])
6
4
2
0
28 Feb 2015
04 Mar 2015
08 Mar 2015
11 Mar 2015
15 Mar 2015
18 Mar 2015
22 Mar 2015
26 Mar 2015
29 Mar 2015
02 Apr 2015
05 Apr 2015
09 Apr 2015
12 Apr 2015
Dst [nT]
50
0
−50
−100
−150
−200
28 Feb 2015
03 Mar 2015
07 Mar 2015
11 Mar 2015
14 Mar 2015
18 Mar 2015
22 Mar 2015
25 Mar 2015
29 Mar 2015
02 Apr 2015
05 Apr 2015
09 Apr 2015
13 Apr 2015

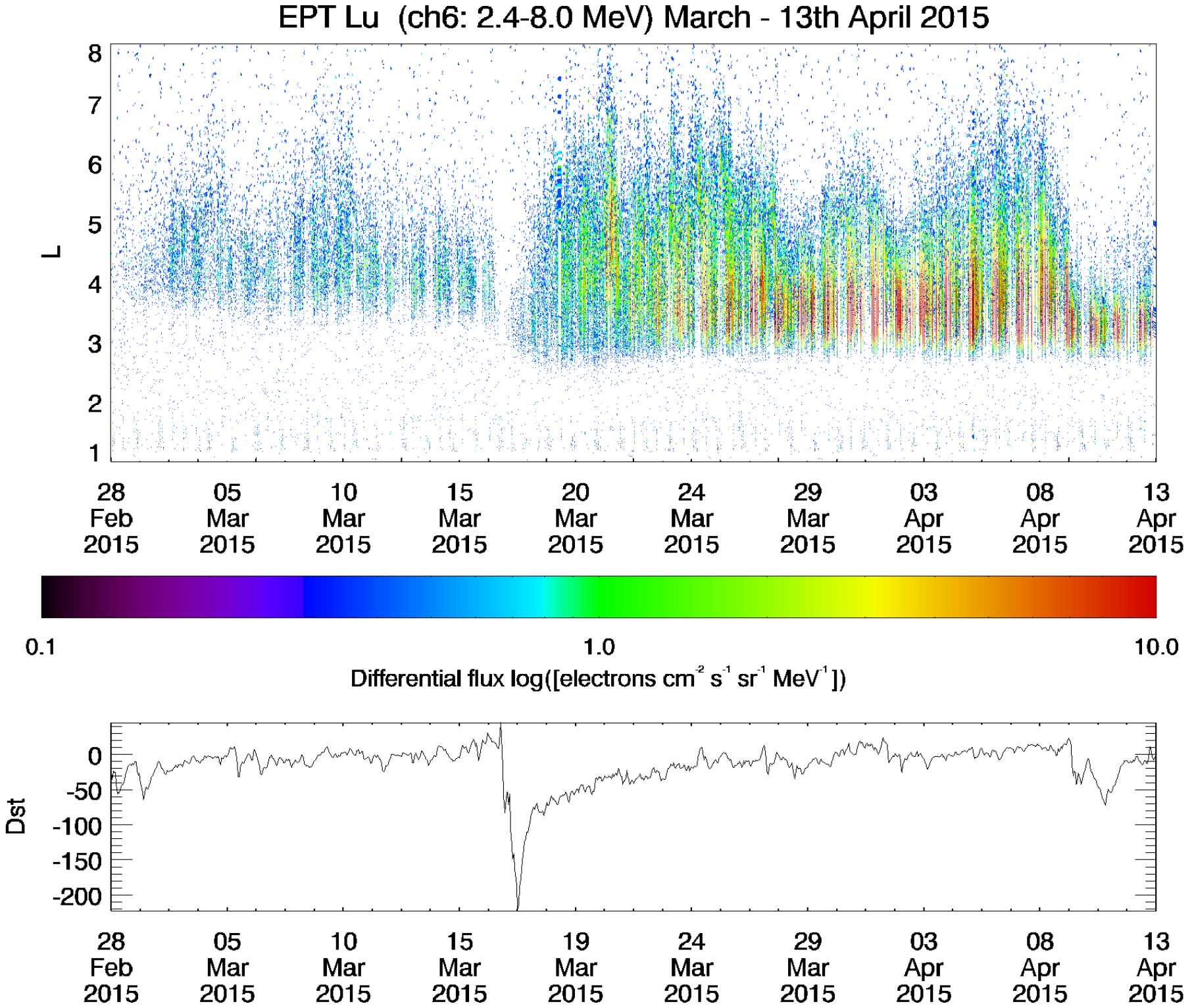
Lemaire, Batteux & Slypen , 2005, JASTP, 89, 719.

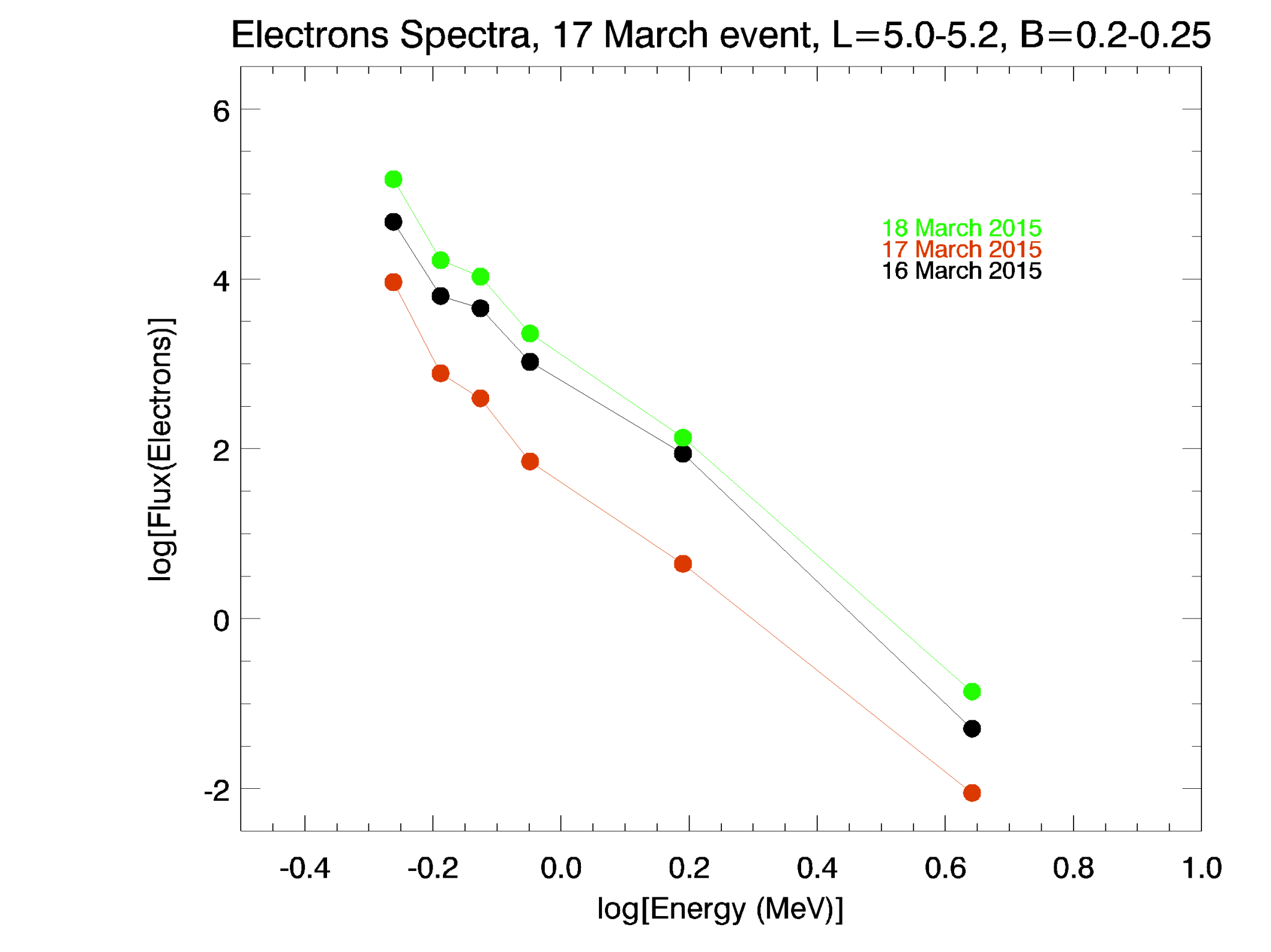
Effect of a Bz-field (Dst) on trajectoty of charged particle

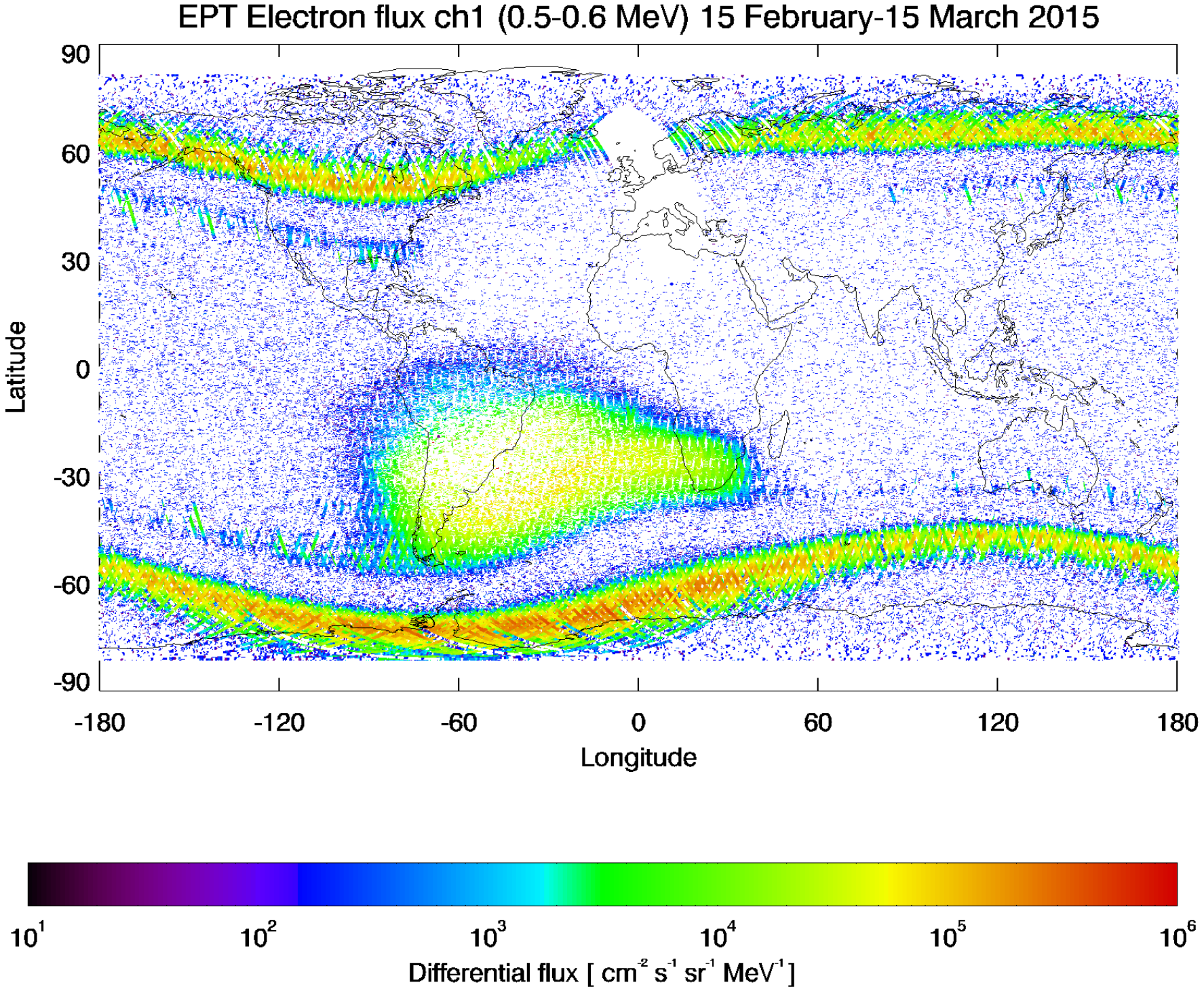


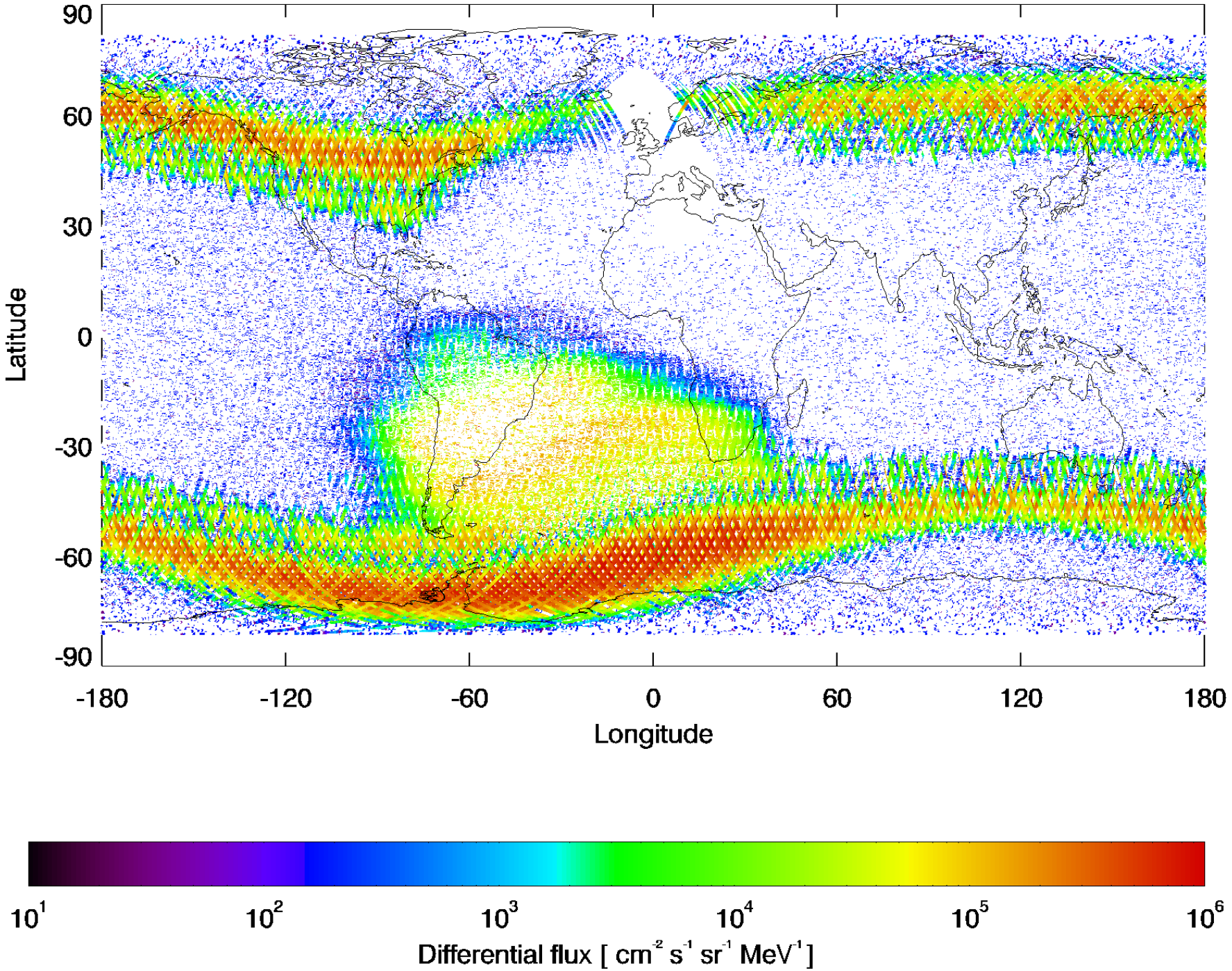

EPT Lu (ch5 1.0-2.4 MeV) March - 13th April 2015
L
8
7
6
5
4
3
2
1
28 Feb 2015
04 Mar 2015
08 Mar 2015
11 Mar 2015
15 Mar 2015
18 Mar 2015
22 Mar 2015
26 Mar 2015
29 Mar 2015
02 Apr 2015
05 Apr 2015
09 Apr 2015
13 Apr 2015
1
10
100
1000
Differential flux log([electrons cm-2 s-1 sr-1 MeV-1])

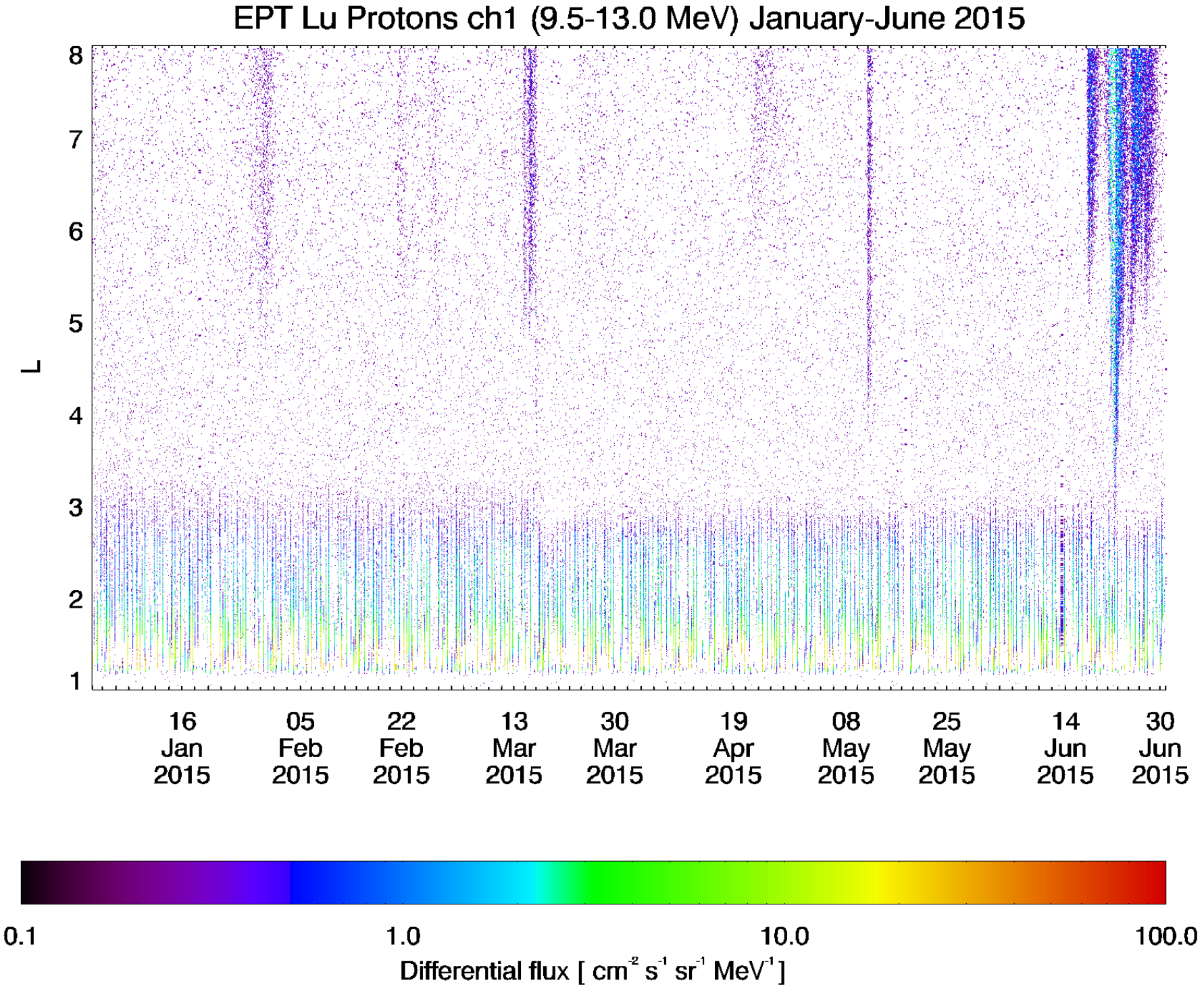

RBSPB MagEIS channel index 15 energy 742.500000 keV
L
7
6
5
4
3
2
1
28 Feb 2015
04 Mar 2015
09 Mar 2015
14 Mar 2015
19 Mar 2015
24 Mar 2015
29 Mar 2015
03 Apr 2015
08 Apr 2015
13 Apr 2015
1
10
100
1000
spin-averaged differential flux [electrons cm-2 s-1 sr-1 keV-1]
Dst [nT]
50
0
-50
-100
-150
-200


EPT Lu (ch6: 2.4-8.0 MeV) March - 13th April 2015
L
8
7
6
5
4
3
2
1
28 Feb 2015
05 Mar 2015
10 Mar 2015
15 Mar 2015
20 Mar 2015
24 Mar 2015
29 Mar 2015
03 Apr 2015
08 Apr 2015
13 Apr 2015
0.1
1.0
10.0
Differential flux log([electrons cm-2 s-1 sr-1 MeV-1])
Dst
0
-50
-100
-150
-200
28 Feb 2015
05 Mar 2015
10 Mar 2015
15 Mar 2015
19 Mar 2015
24 Mar 2015
29 Mar 2015
03 Apr 2015
08 Apr 2015
13 Apr 2015


Electrons Spectra, 17 March event, L=5.0-5.2, B=0.2-0.25
18 March 2015
17 March 2015
16 March 2015
log[Flux(Electrons)]
log[Energy (MeV)]
6
4
2
0
-2
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0


EPT Electron flux ch1 (0.5-0.6 MeV) 15 February-15 March 2015
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude
10^1
10^2
10^3
10^4
10^5
10^6
Differential flux [cm^-2 s^-1 sr^-1 MeV^-1]


EPT Electron flux ch1 (0.5-0.6 MeV) 16 March-13 April 2015
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude
10^1
10^2
10^3
10^4
10^5
10^6
Differential flux [cm^-2 s^-1 sr^-1 MeV^-1]


EPT Lu Protons ch1 (9.5-13.0 MeV) January-June 2015
L
8
7
6
5
4
3
2
1
16 Jan 2015
05 Feb 2015
22 Feb 2015
13 Mar 2015
30 Mar 2015
19 Apr 2015
08 May 2015
25 May 2015
14 Jun 2015
30 Jun 2015
0.1
1.0
10.0
100.0
Differential flux [cm-2 s-1 sr-1 MeV-1]

Conclusions

The Energetic Particle Detector developped at CSR and BISA
is Science-Instrument to study the RB

Uncontaninated spectra of Electrons, Protons, Alphas, ...
High spectral time resolution flux measurements
with < 5W and < 5 kg

It is till operating nominally on polar LEO at 820 km alt.

Data are available from CSR, UCL, Louvain-La-neuve
and BISA, Brussels

EPT data have been used for cross-calibration other RB instruments
in orbit : e.g. VAP/MAGEIS

Conclusions

In this presentation we have shown
how the fluxes and spectras of trapped electrons of different energies varies during a large Geomagnetic Storm (17 March 2015) (World Maps, L-vs-t flux variations, Energy spectras, ...).

To study Betatron effects on RB particles
as well as the uplift of mirror points,
acceleration/deceleration of charged particle during GS
Field-aligned distributions of charged particles of all energies.

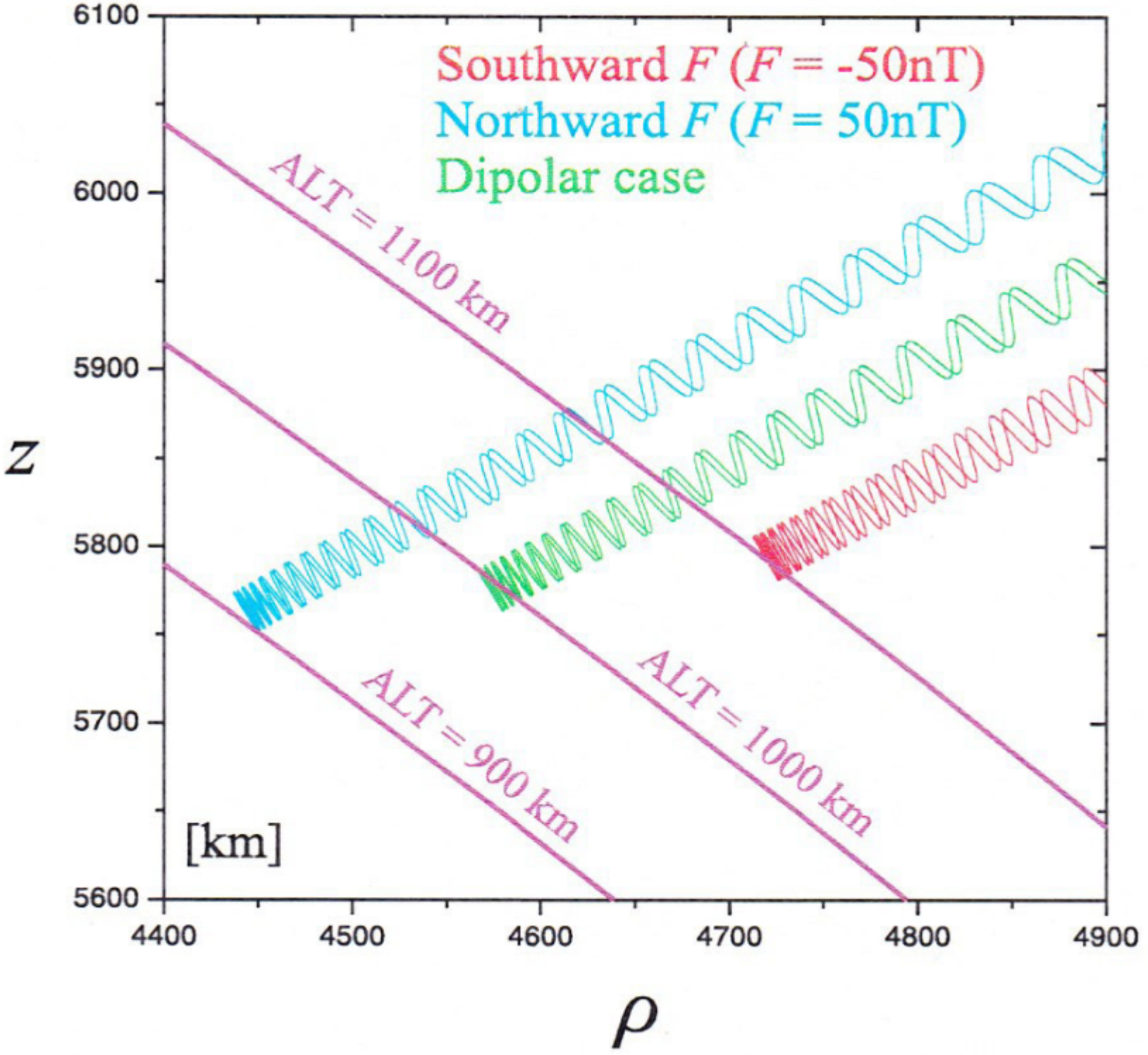
To study the new inhomogeneity discovered in SAA particle fluxes

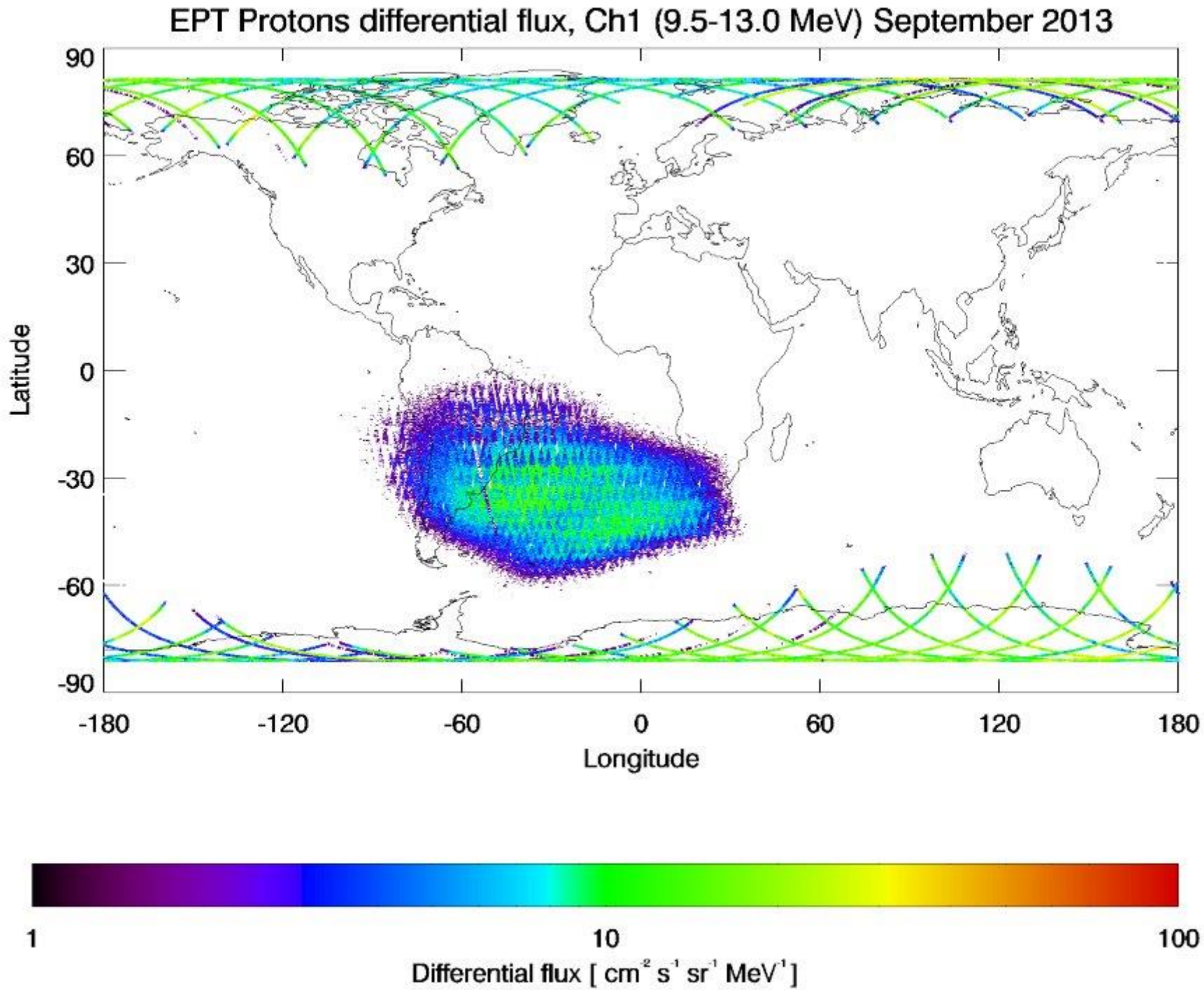
Drop out of RB fluxes during the main phase of storms

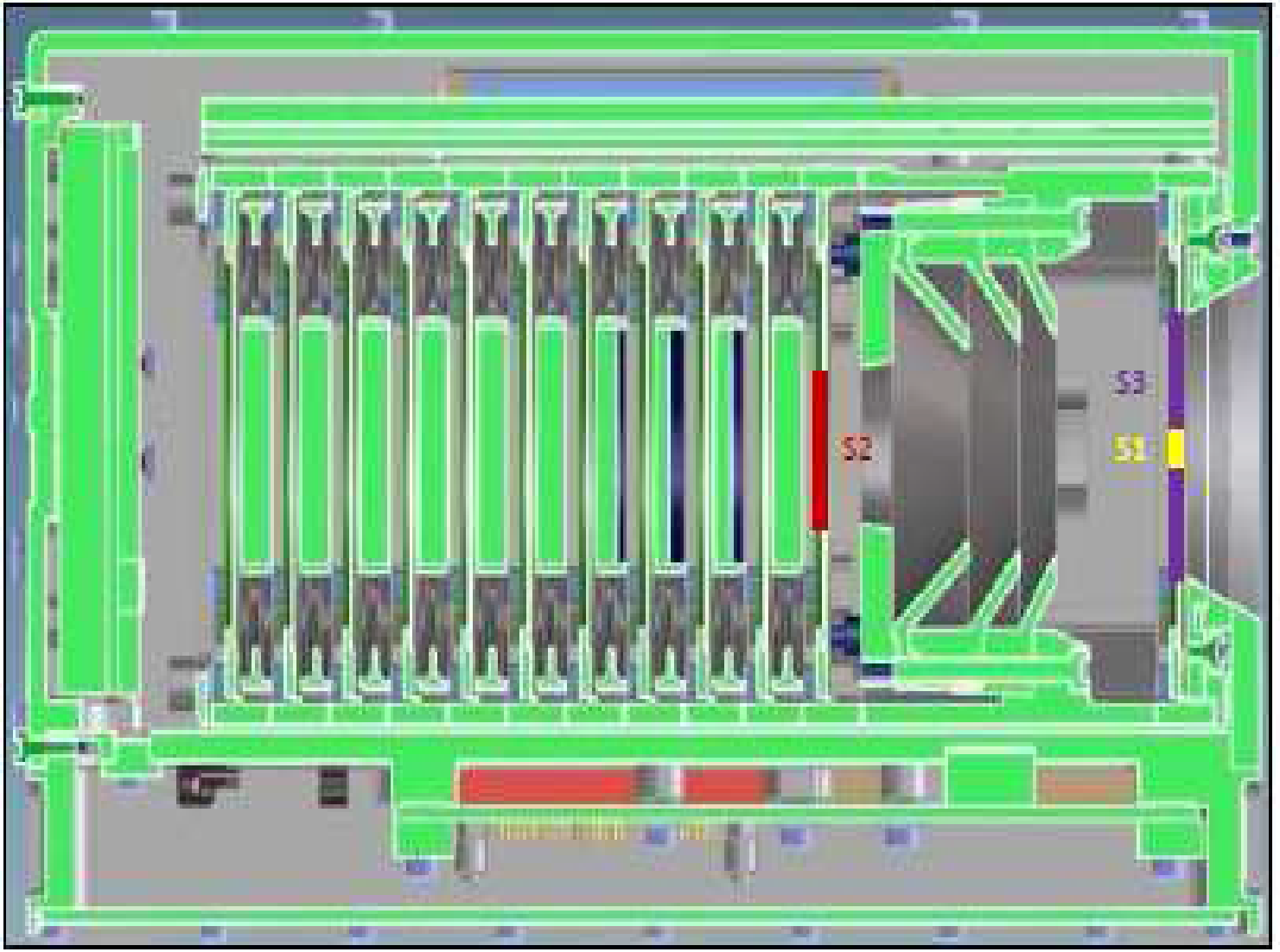
Penetration of SEP into magnetosphere.

To study the flux enhancement during the Recovery Phases

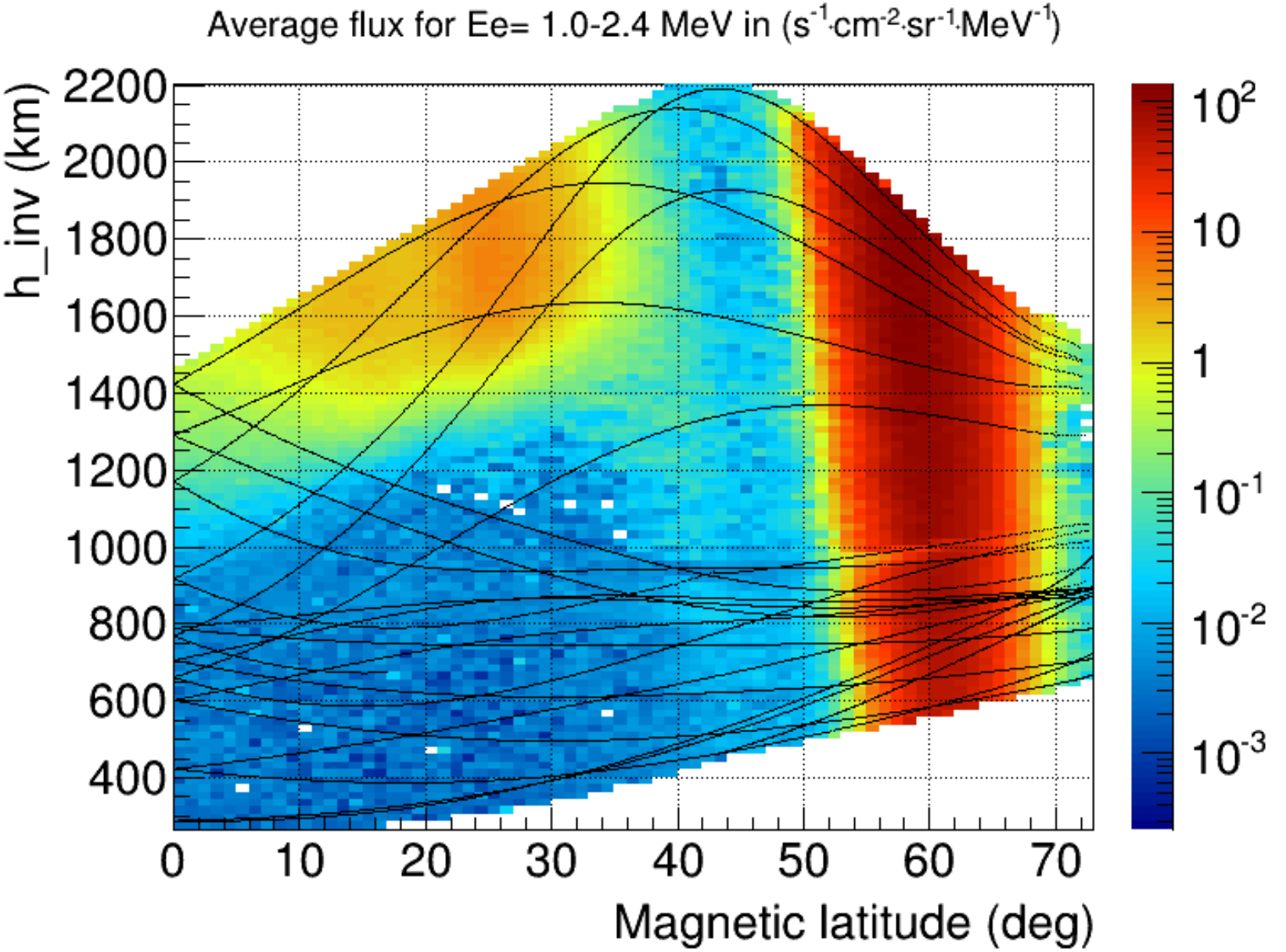
The post-storm enhancement of the electron fluxes in the outer belt
that may be explained by the combined effect of
non-resonnant pitch angle scattering and betatron acceleration
during the main phase and recovery phase og storms

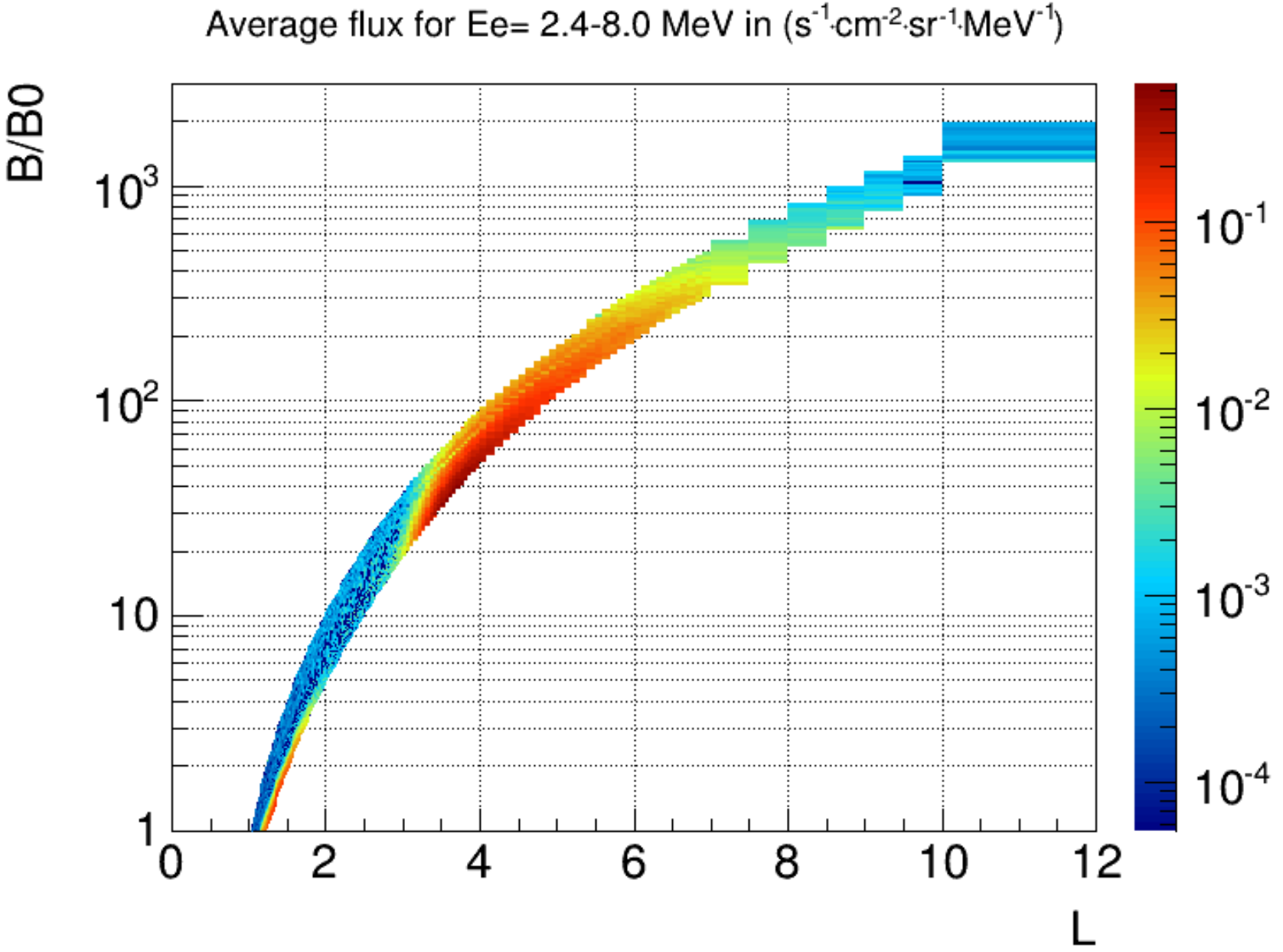

Southward F (F = -50nT)
Northward F (F = 50nT)
Dipolar case
ALT = 1100 km
ALT = 1000 km
ALT = 900 km
[km]
6100
6000
5900
5800
5700
5600
4400
4500
4600
4700
4800
4900
z
ρ


EPT Protons differential flux, Ch1 (9.5-13.0 MeV) September 2013
90
60
30
0
-30
-60
-90
Latitude
-180
-120
-60
0
60
120
180
Longitude
1
10
100
Differential flux [cm-2 s-1 sr-1 MeV-1]


S3
S2
S1

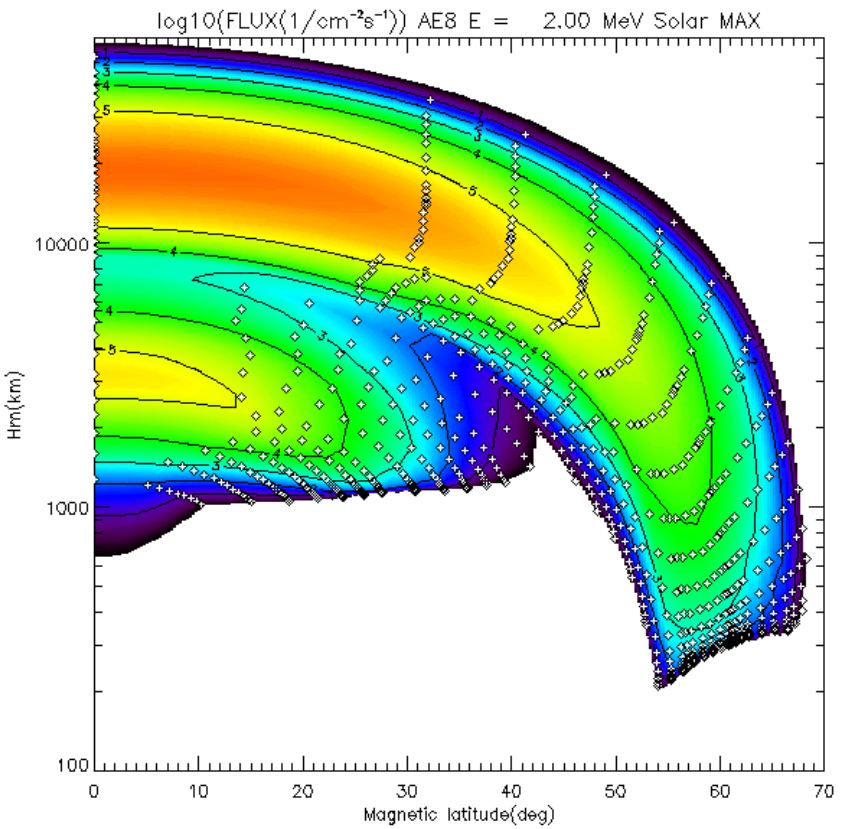
	Channel	Energy (MeV)	Channel	Energy (MeV)	Channel	Energy (MeV)	Channel	Energy (MeV)
LES	1	0.5 – 0.6	20	8.8 – **	39	35.5 – **	58	
	2	0.6 – 0.7	21		40		59	
	3	0.7 – 0.8	22		41		60	
	4	0.8 – 1.0	23	** – 9.5	42		61	
	5		24	9.5 - 13	43	** – 38	62	
	6		25		44	38 – 51	63	
	7		26		45		64	
	8		27		46		65	
	9		28		47		66	
HES	10	1.0 – 3.0	29	13 – 29	48	51 – 118	67	
	11	3.0 - .	30	29 – 61	49	118 – 245	68	
	12	4.0 _.	31	61 – 92	50	245 – 365	69	
	13		32	92 – 126	51	365 – 500	70	
	14		33	126 – 155	52	500 – 615	71	
	15		34	155 – 182	53	615 – 720	72	
	16		35	182 – 205	54	720 – 815	73	
	17		36	205 – 227	55	815 – 900	74	
	18		37	227 – 248	56	900 – 980	75	
	19		38	>248	57	>980	76	

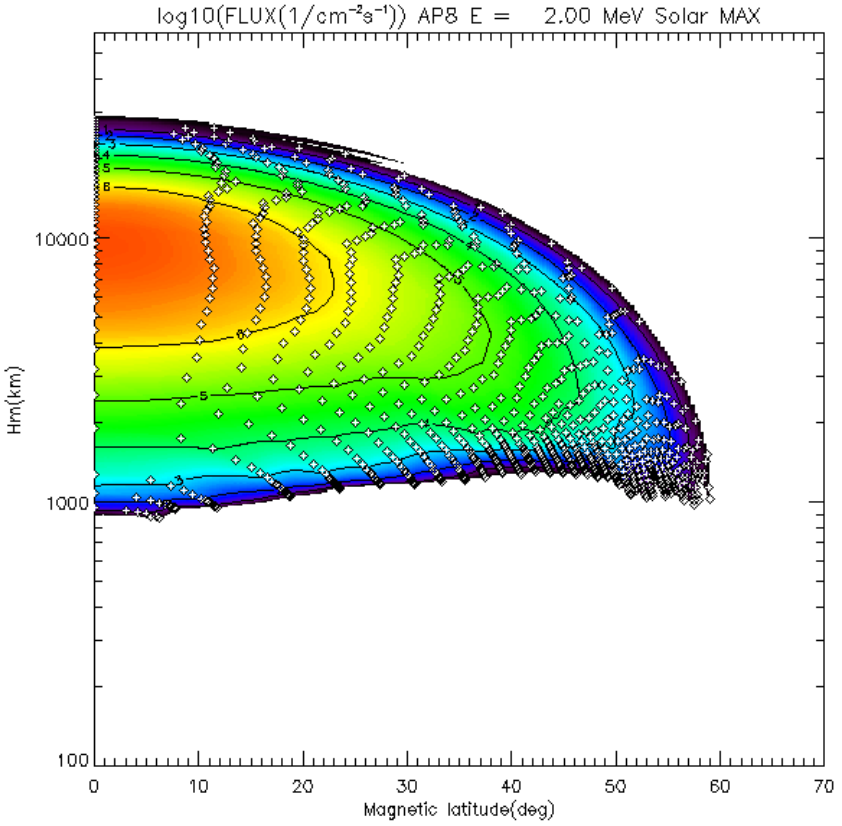

Average flux for Ee= 1.0-2.4 MeV in (s^{-1}·cm^{-2}·sr^{-1}·MeV^{-1})
h_inv (km)
2200
2000
1800
1600
1400
1200
1000
800
600
400
0
10
20
30
40
50
60
70
Magnetic latitude (deg)
10^{2}
10
1
10^{-1}
10^{-2}
10^{-3}

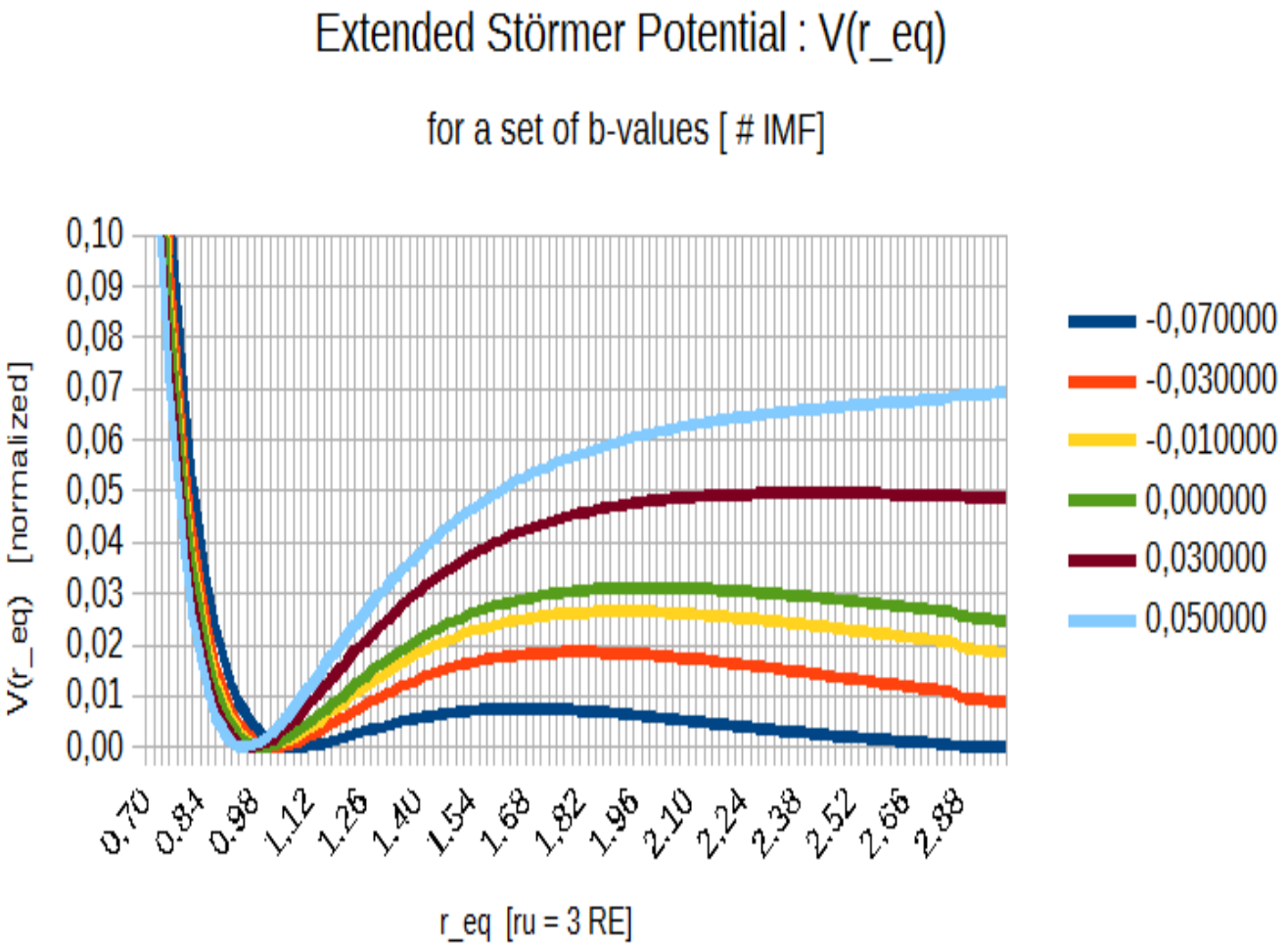

Average flux for Ee= 2.4-8.0 MeV in (s^{-1}·cm^{-2}·sr^{-1}·MeV^{-1})
B/B0
10^3
10^2
10
1
0
2
4
6
8
10
12
L
10^{-1}
10^{-2}
10^{-3}
10^{-4}

Log(Invariant Altitude) vs Magnetic Latitude

MAX & E = 2 MeV






Extended Störmer Potential : V(r_eq)
for a set of b-values [# IMF]
V(r_eq) [normalized]
0,10
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,70
0,84
0,98
1,12
1,26
1,40
1,54
1,68
1,82
1,96
2,10
2,24
2,38
2,52
2,66
2,80
r_eq [ru = 3 RE]
-0,070000
-0,030000
-0,010000
0,000000
0,030000
0,050000