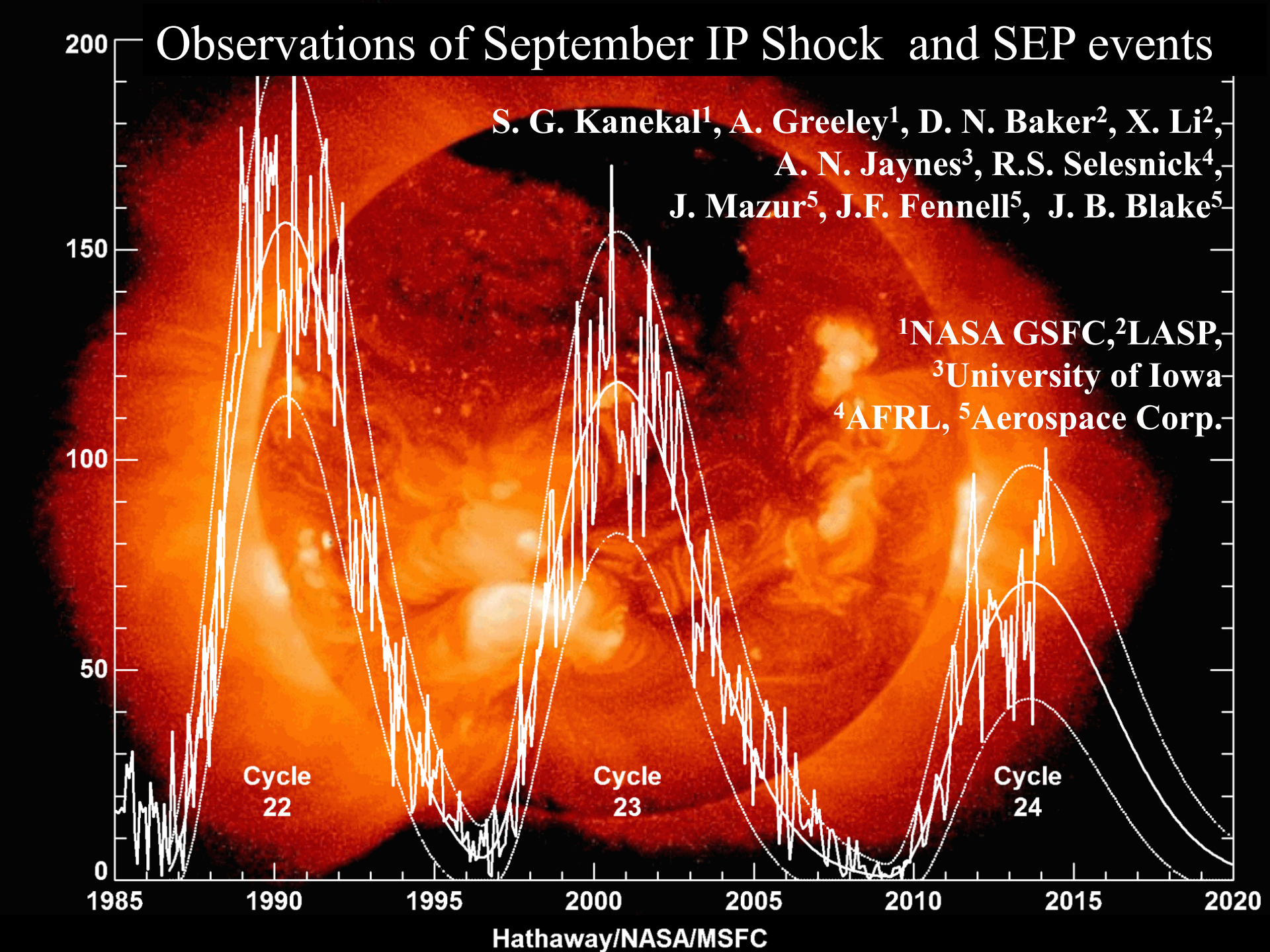
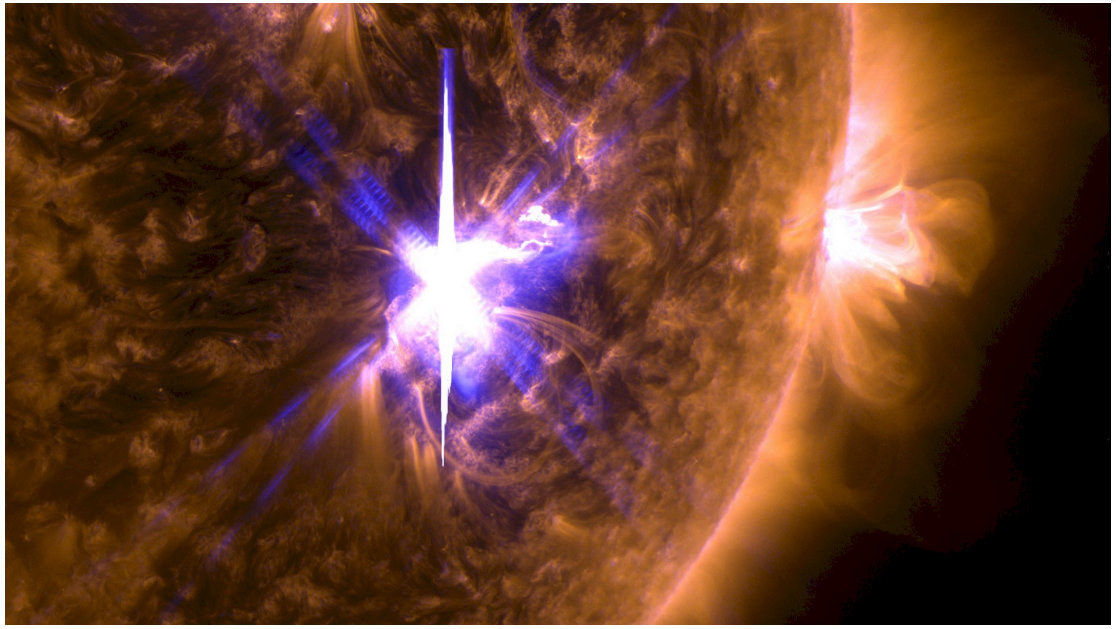
Observations of September IP Shock and SEP events

S. G. Kanekal[1], A. Greeley[1], D. N. Baker[2], X. Li[2],
A. N. Jaynes[3], R.S. Selesnick[4],
J. Mazur[5], J.F. Fennell[5], J. B. Blake[5]

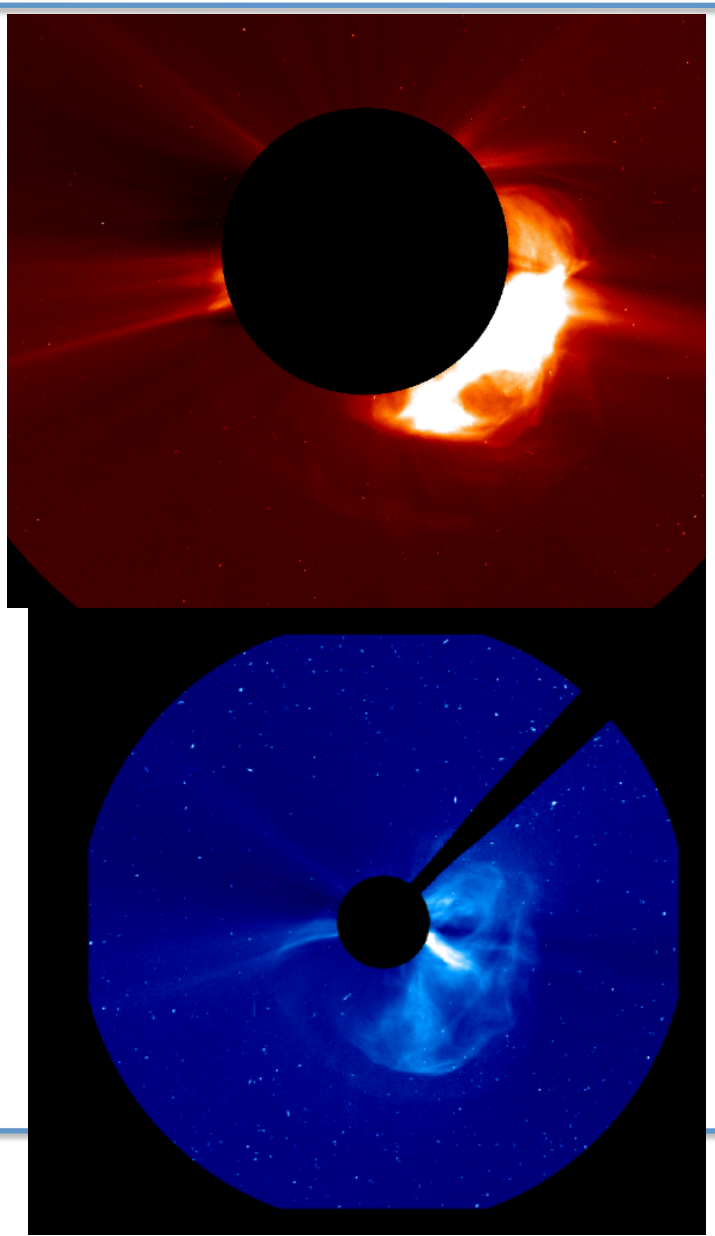
[1]NASA GSFC,[2]LASP,
[3]University of Iowa
[4]AFRL, [5]Aerospace Corp.

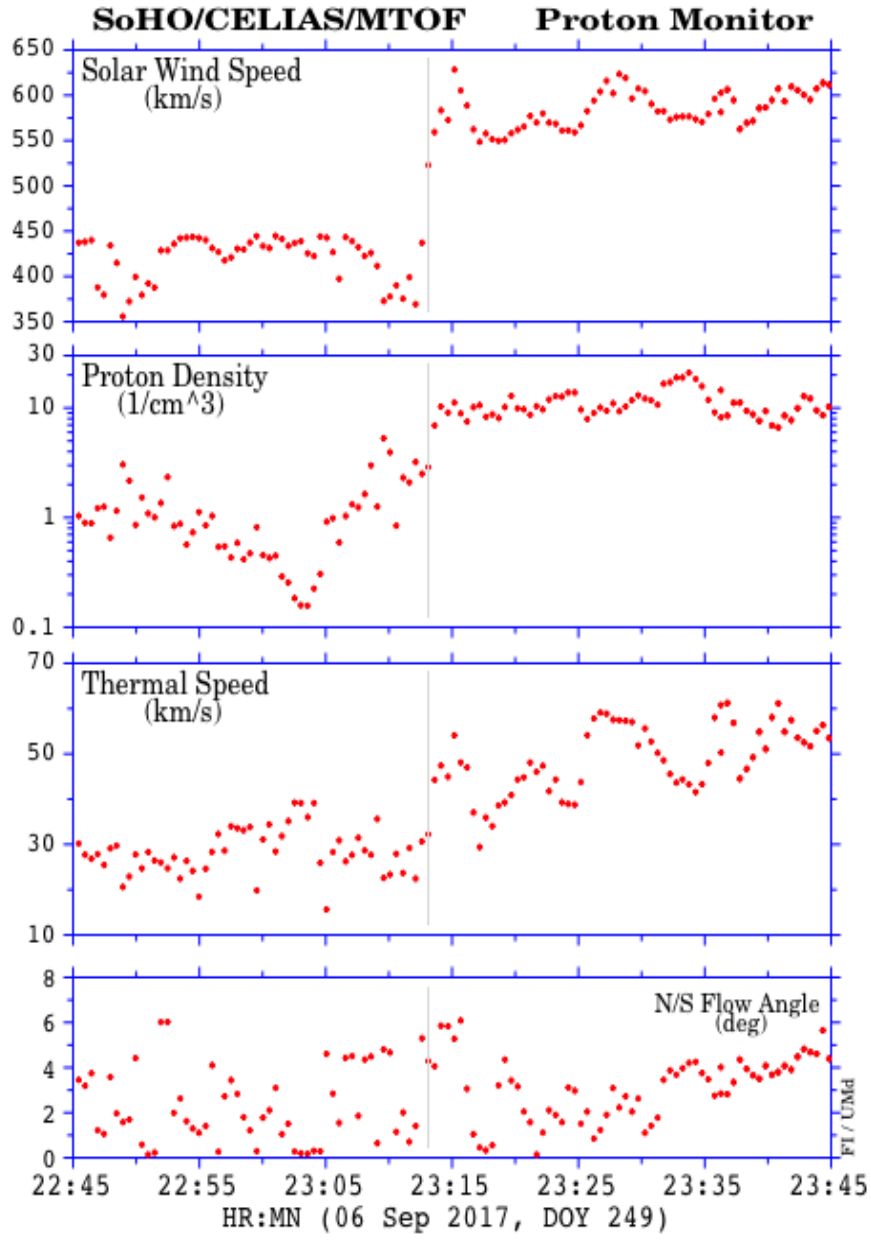


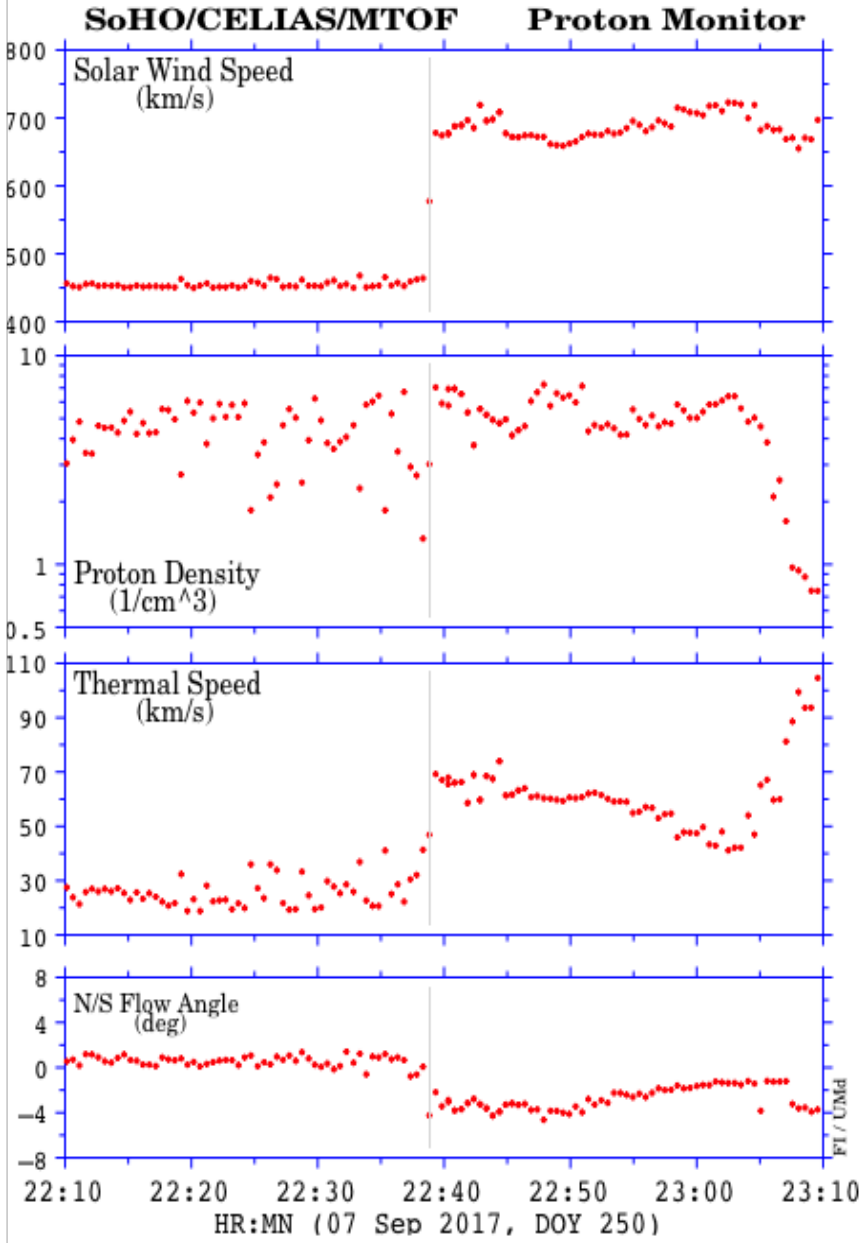
September Flare and CME



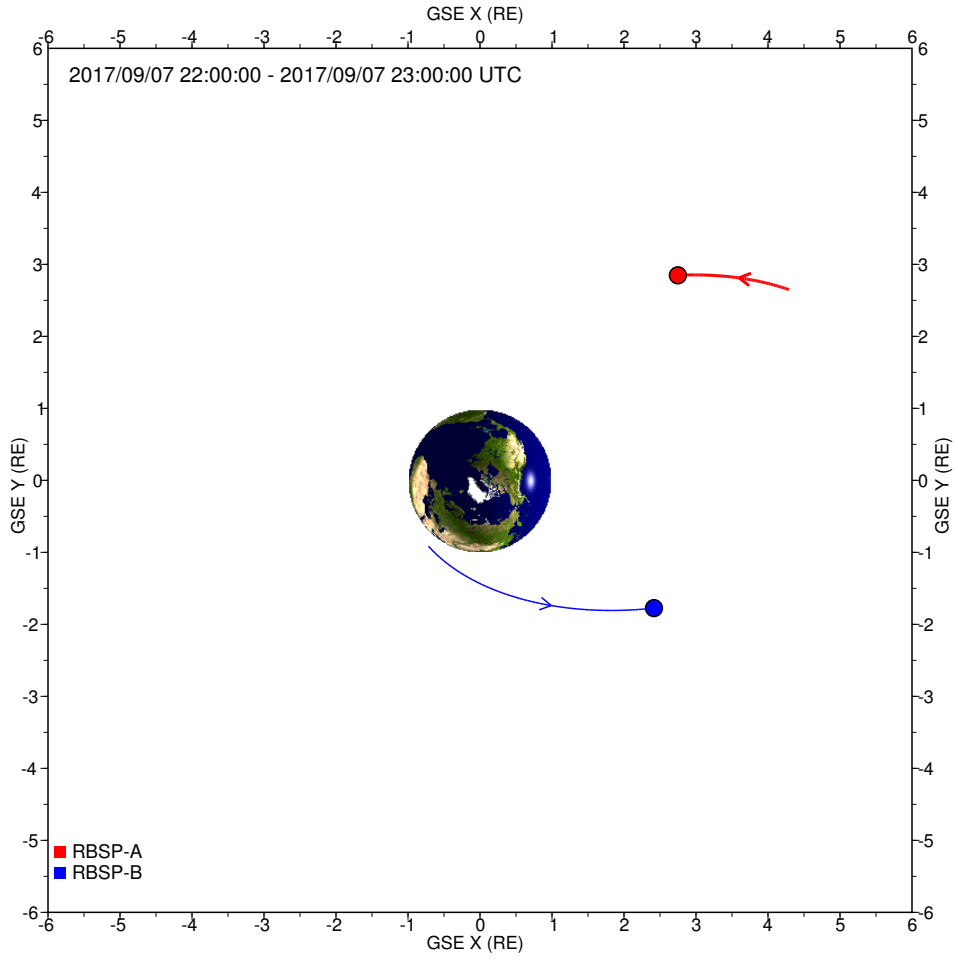
An X9.3 class solar flare flashes in the middle of the Sun on Sept. 6, 2017. This image was captured by NASA's Solar Dynamics Observatory and shows a blend of light from the 171 and 131 angstrom wavelengths.
https://svs.gsfc.nasa.gov/12706#X9.3

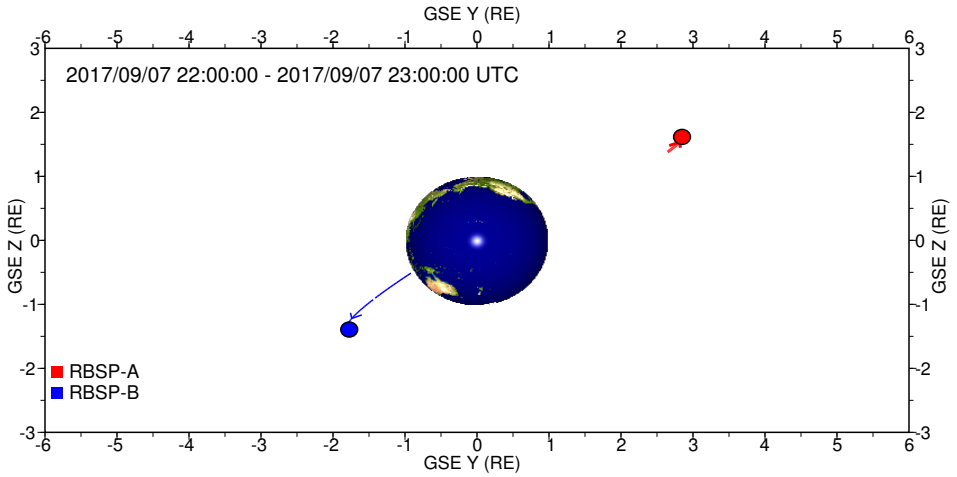


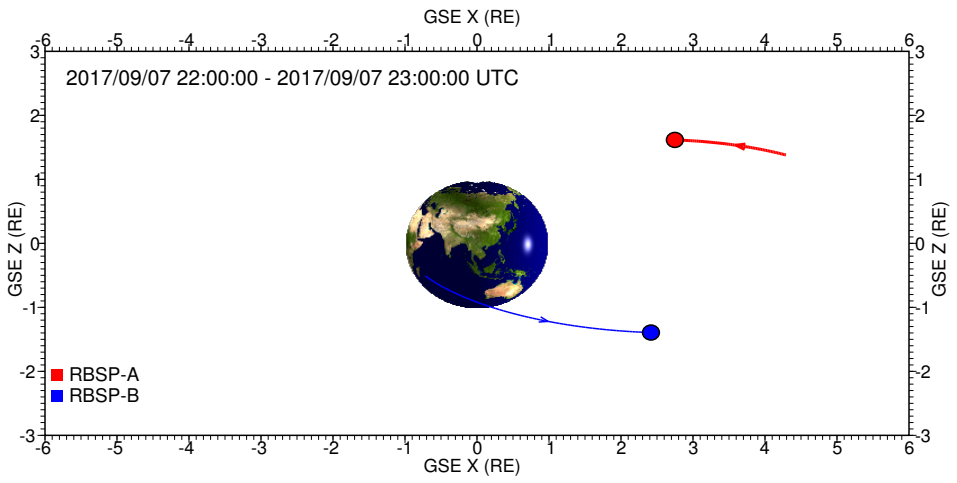

SoHO/CELIAS/MTOF
Proton Monitor
Solar Wind Speed
(km/s)
650
600
550
500
450
400
350
Proton Density
(1/cm^3)
30
10
1
0.1
Thermal Speed
(km/s)
70
50
30
10
N/S Flow Angle
(deg)
8
6
4
2
0
FI / UMd
22:45
22:55
23:05
23:15
23:25
23:35
23:45
HR:MN (06 Sep 2017, DOY 249)


SoHO/CELIAS/MTOF
Proton Monitor
Solar Wind Speed
(km/s)
800
700
600
500
400
Proton Density
(1/cm^3)
10
1
0.5
Thermal Speed
(km/s)
110
90
70
50
30
10
N/S Flow Angle
(deg)
8
4
0
−4
−8
FI / UMd
22:10
22:20
22:30
22:40
22:50
23:00
23:10
HR:MN (07 Sep 2017, DOY 250)

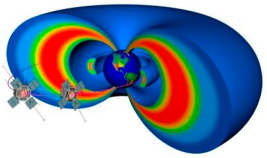
Van Allen Probes 7 September 2017

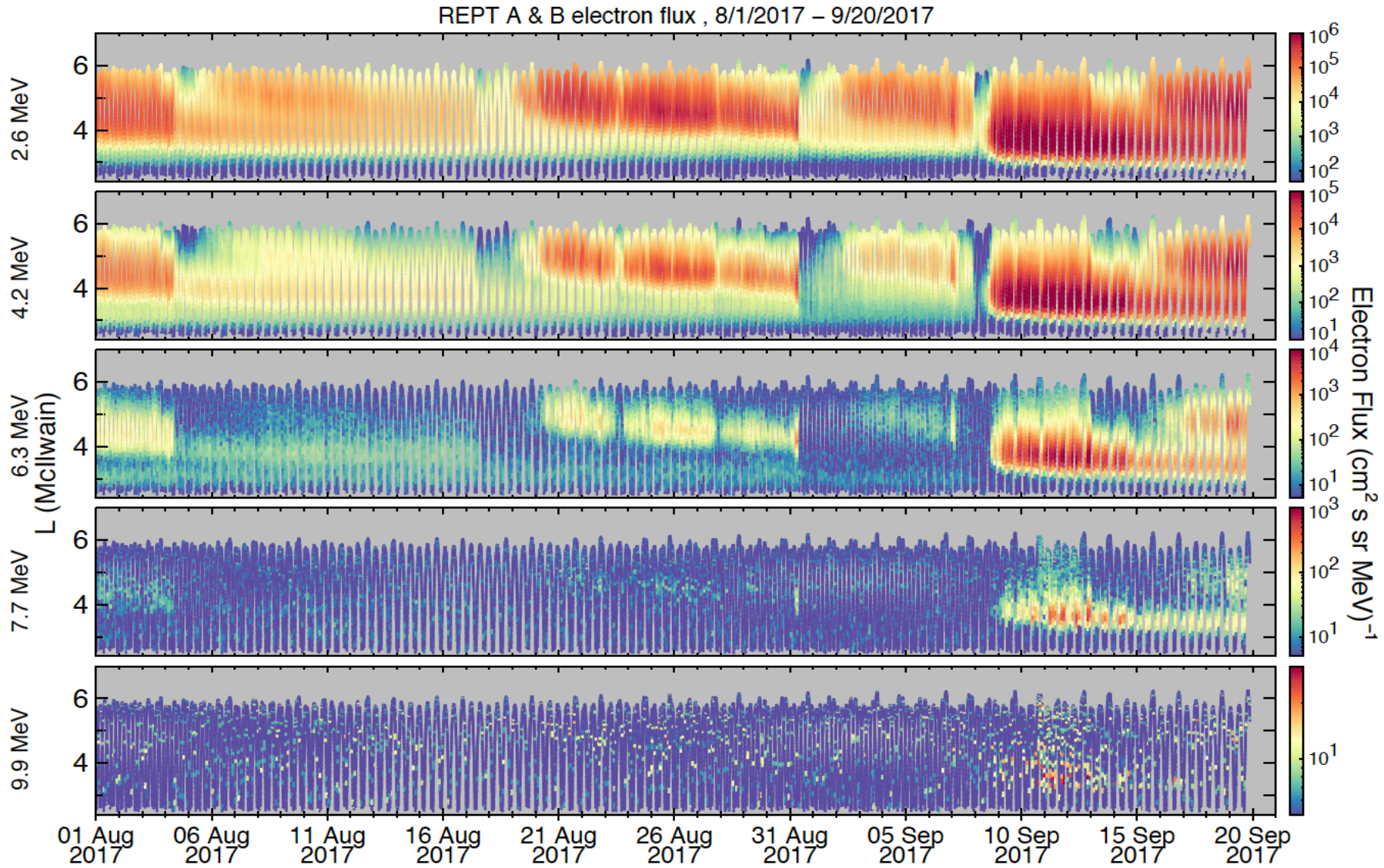






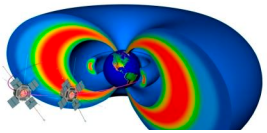
Overview REPT Observations

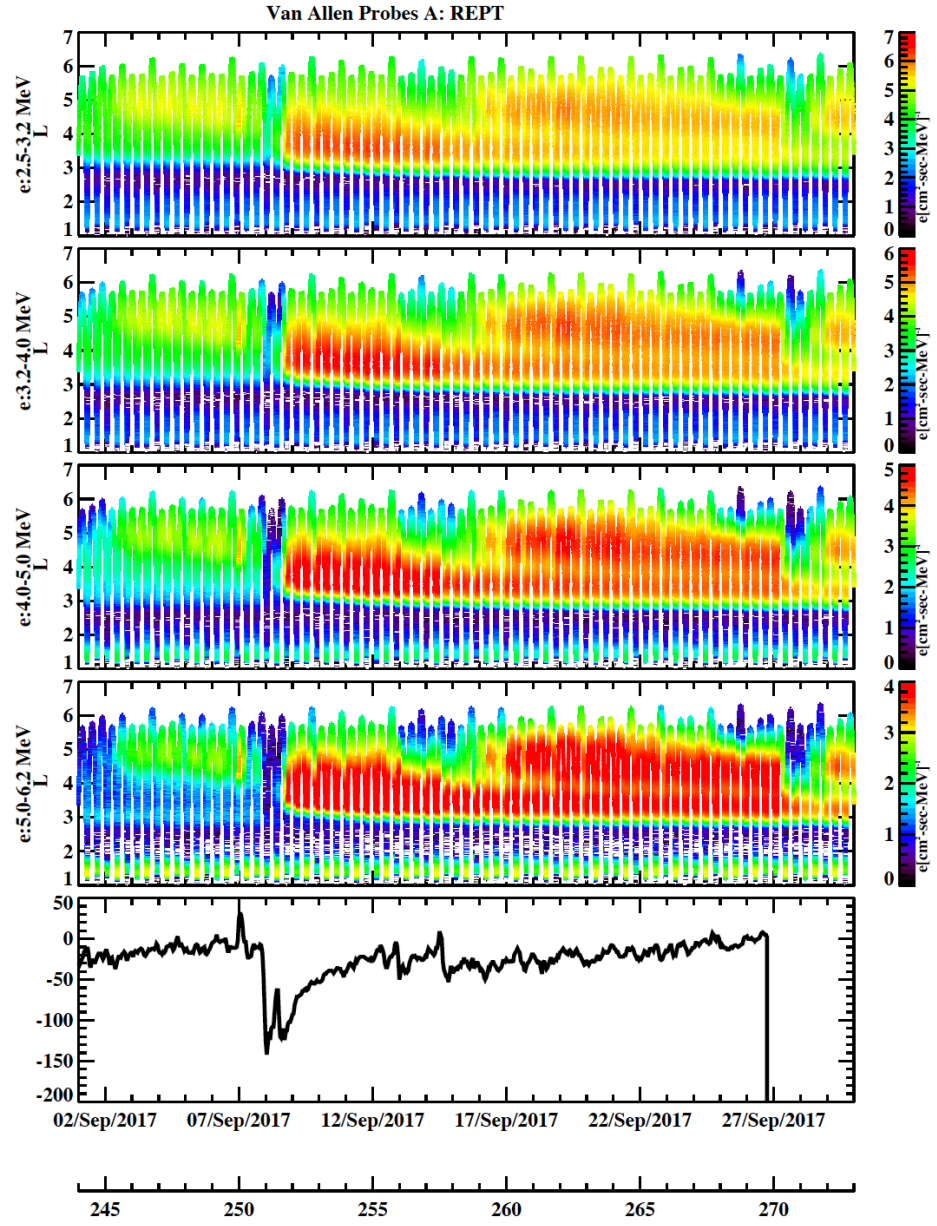


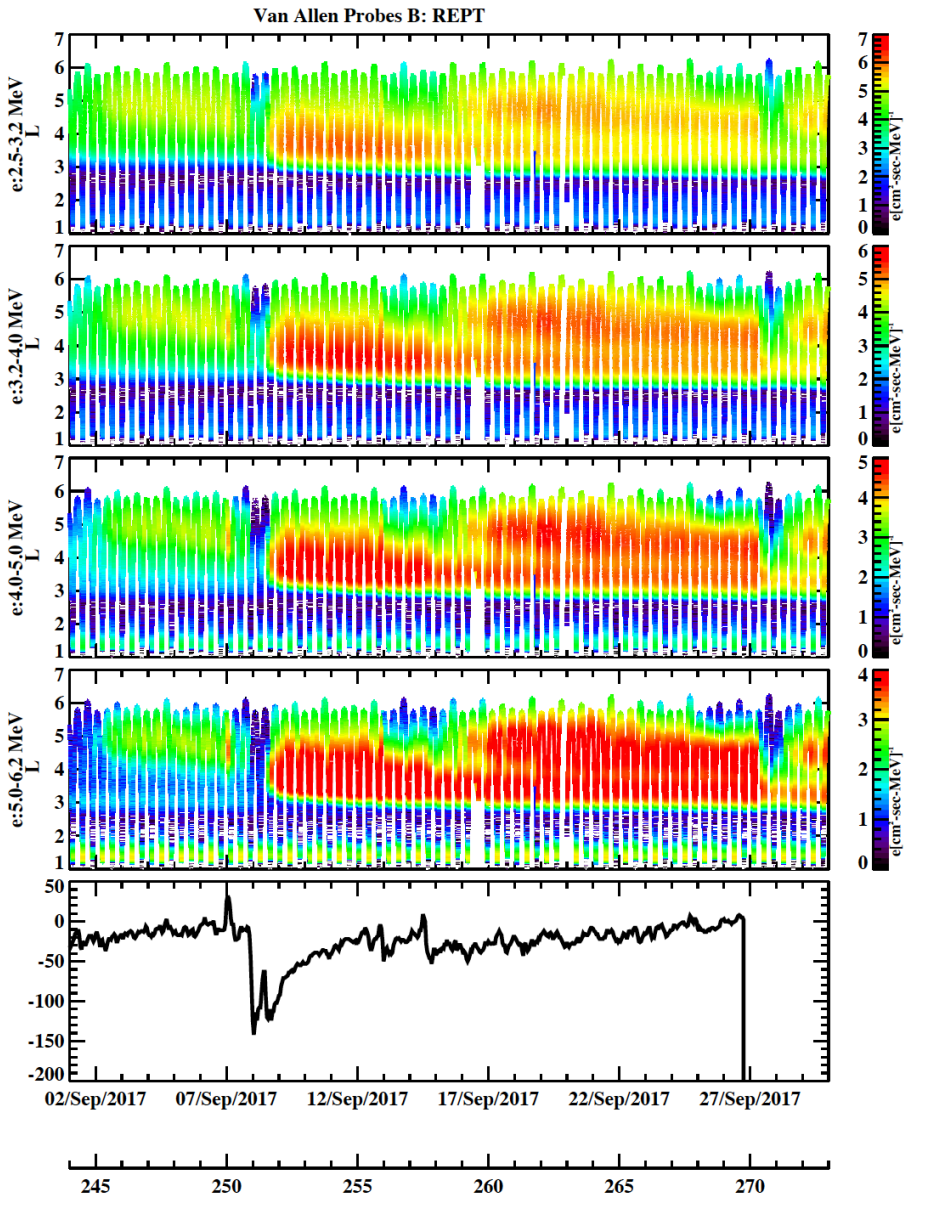


Allison Jaynes

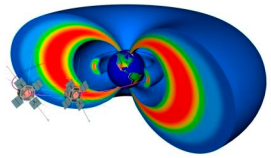
September events

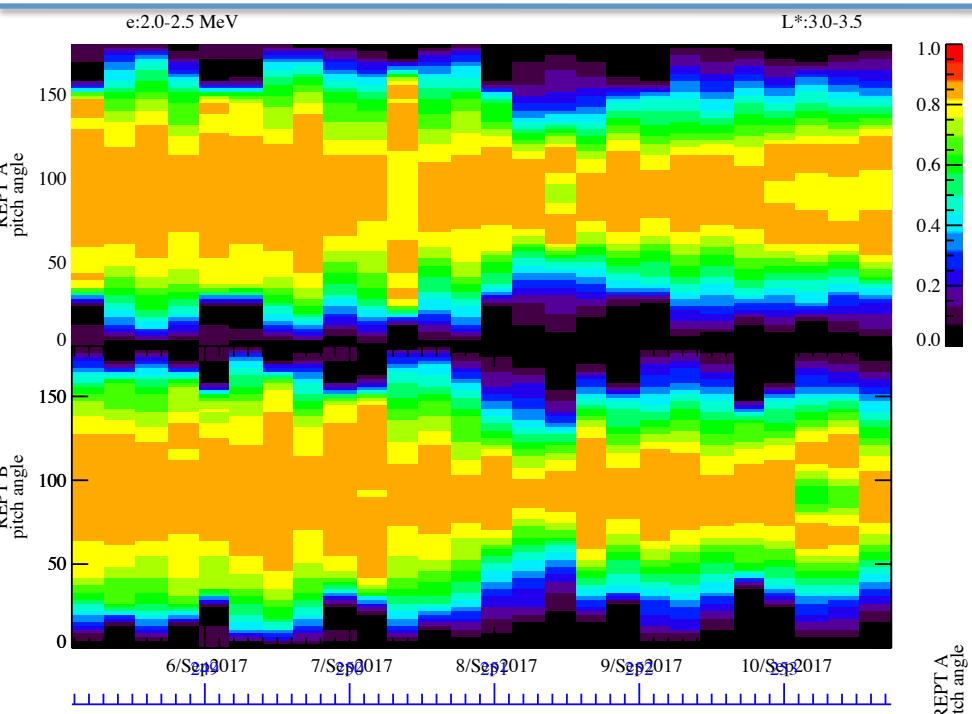


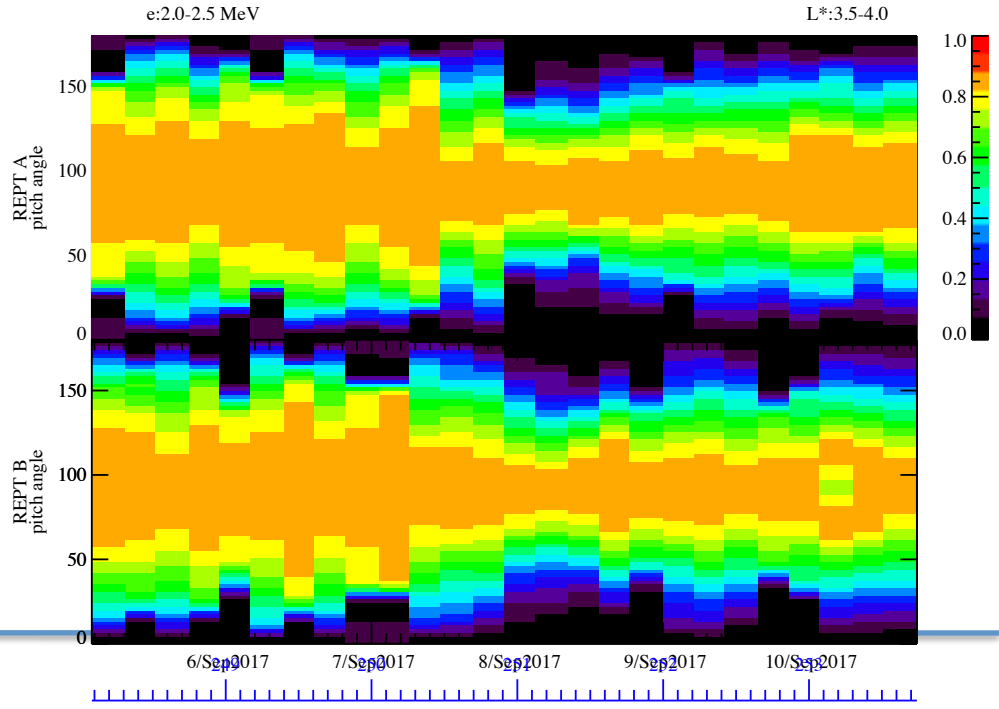


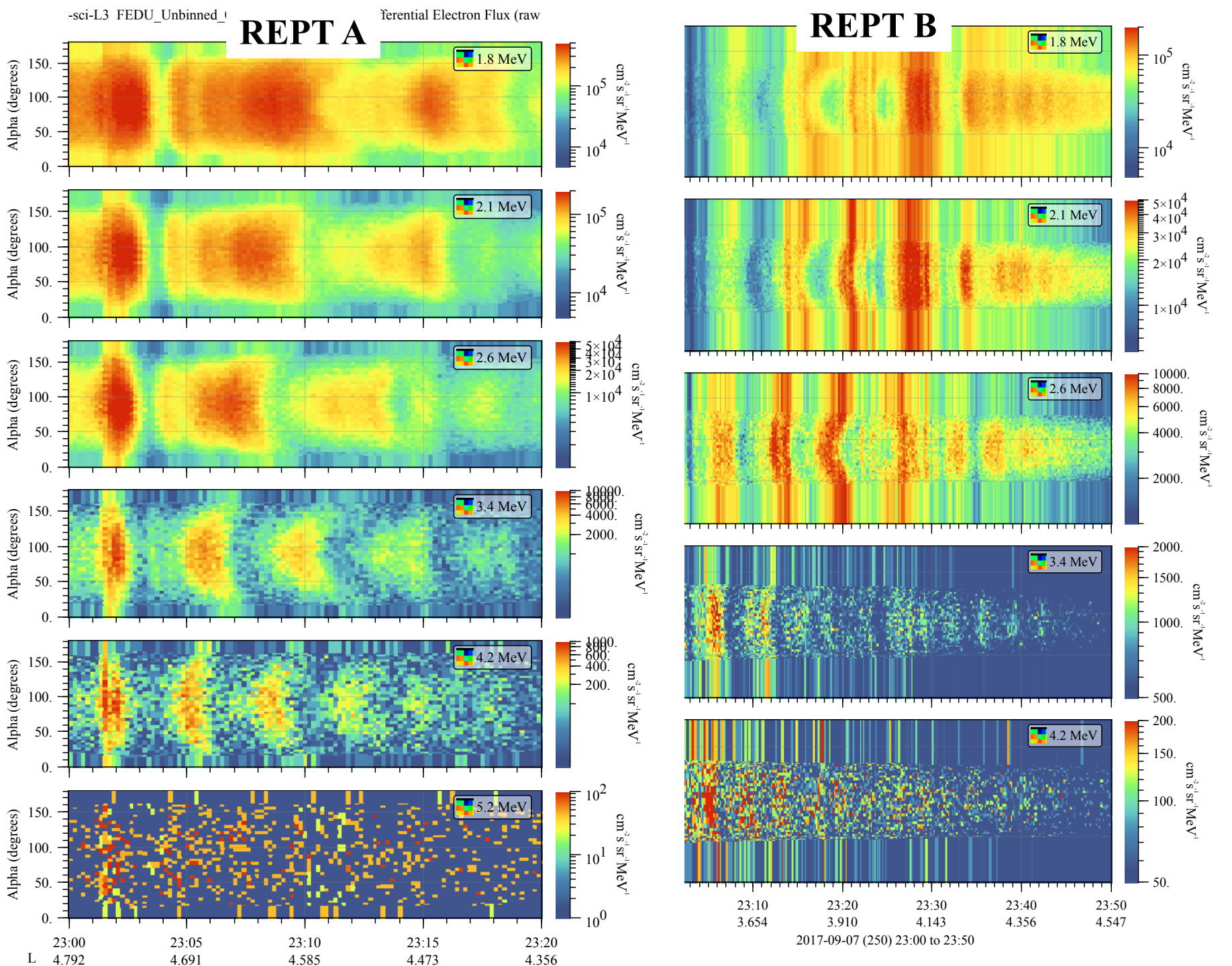


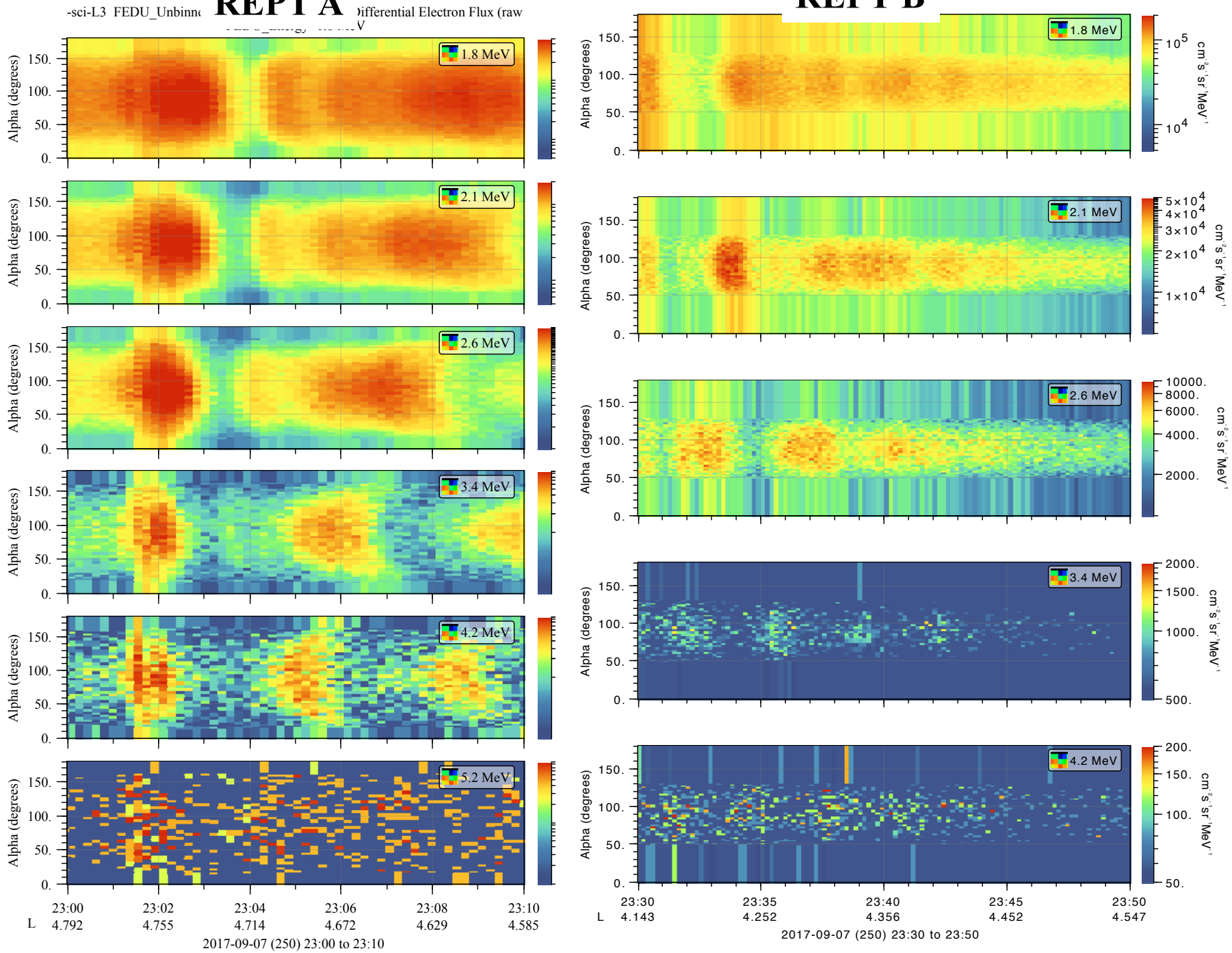
September events: PAD evolution



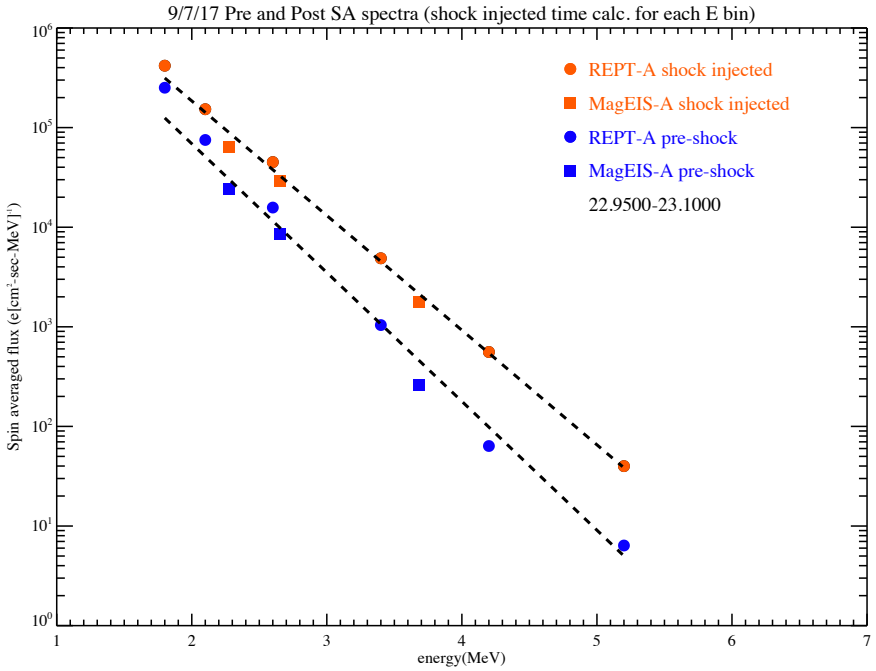


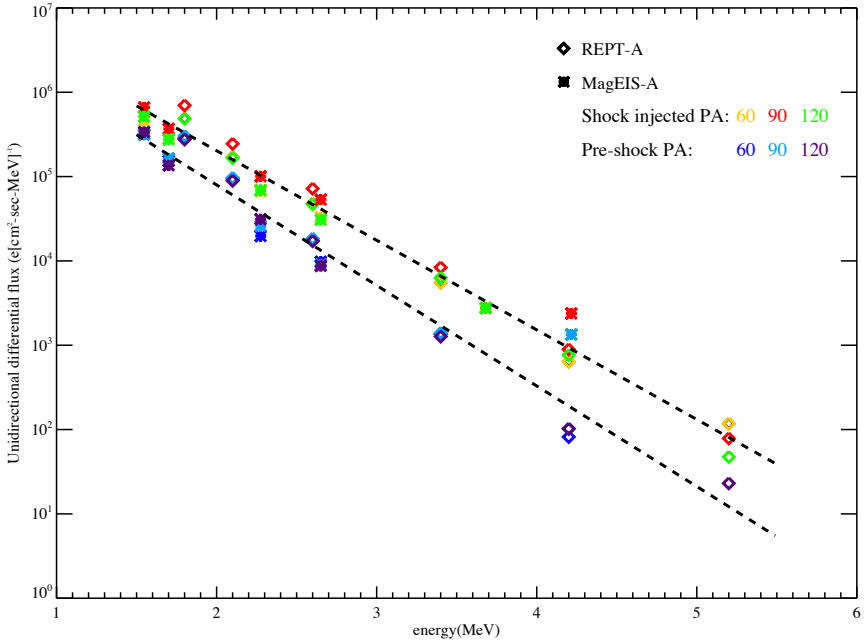



-sci-L3 FEDU_Unbinned_
ferential Electron Flux (raw
REPT A
REPT B
1.8 MeV
2.1 MeV
2.6 MeV
3.4 MeV
4.2 MeV
5.2 MeV
Alpha (degrees)
cm-2 s-1 sr-1 MeV-1
23:00
23:05
23:10
23:15
23:20
L
4.792
4.691
4.585
4.473
4.356
23:10
23:20
23:30
23:40
23:50
3.654
3.910
4.143
4.356
4.547
2017-09-07 (250) 23:00 to 23:50


REPT A
REPT B
-sci-L3 FEDU_Unbinn
ifferential Electron Flux (raw
1.8 MeV
2.1 MeV
2.6 MeV
3.4 MeV
4.2 MeV
5.2 MeV
Alpha (degrees)
0.
50.
100.
150.
cm⁻²s⁻¹sr⁻¹MeV⁻¹
10⁵
10⁴
5×10⁴
4×10⁴
3×10⁴
2×10⁴
1×10⁴
10000.
8000.
6000.
4000.
2000.
1500.
1000.
500.
200.
150.
100.
50.
23:00
23:02
23:04
23:06
23:08
23:10
L
4.792
4.755
4.714
4.672
4.629
4.585
2017-09-07 (250) 23:00 to 23:10
23:30
23:35
23:40
23:45
23:50
4.143
4.252
4.356
4.452
4.547
2017-09-07 (250) 23:30 to 23:50

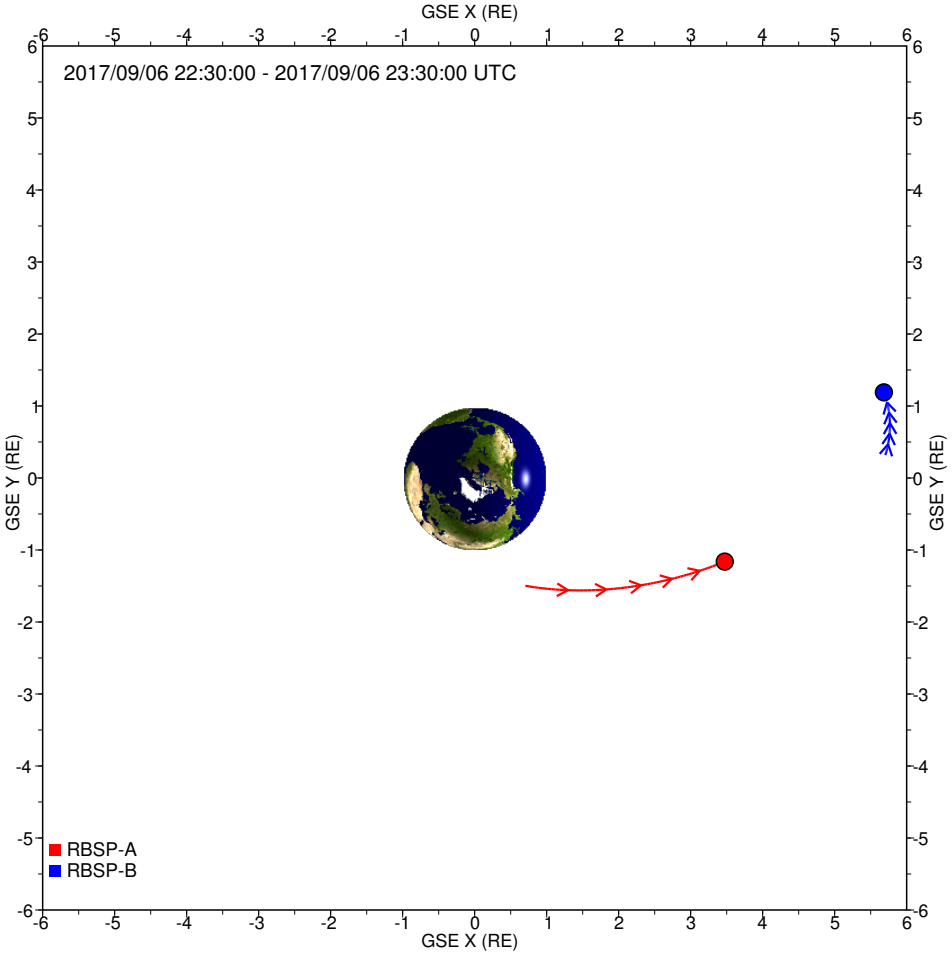
Spectra: Pre- and Post-injection 7 September

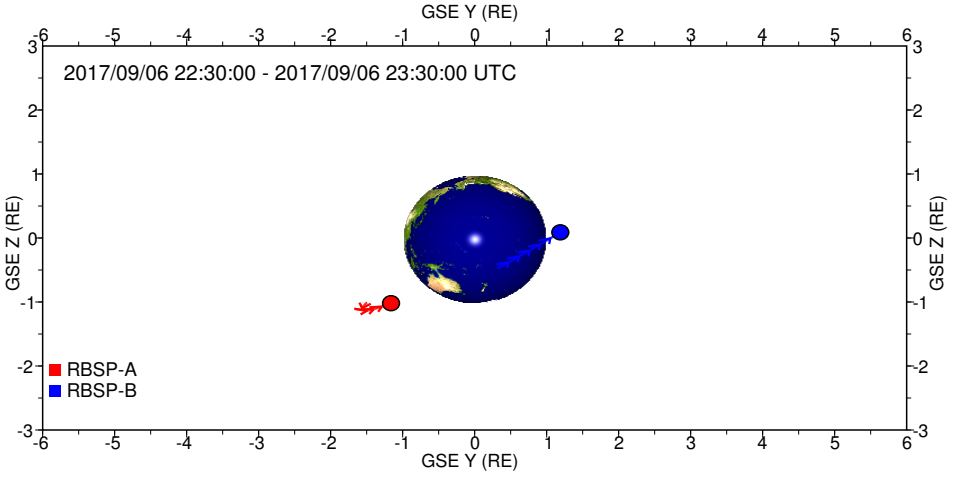


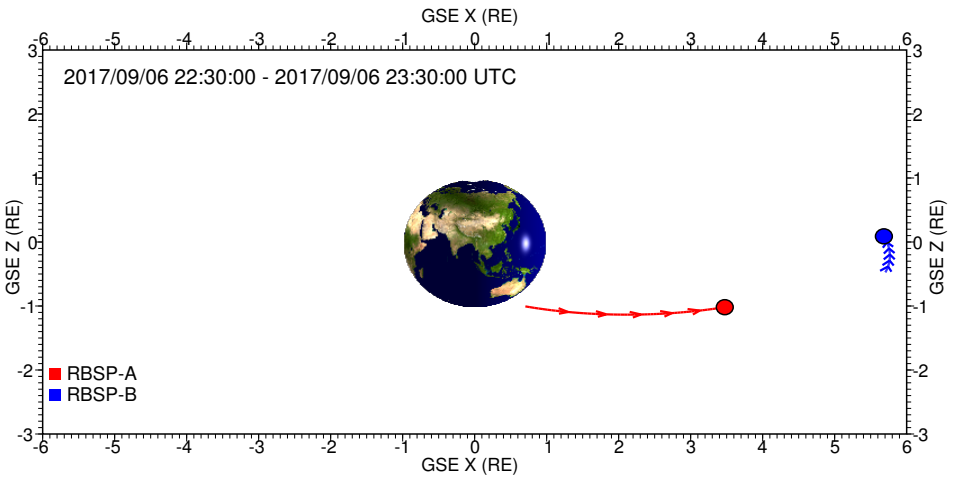


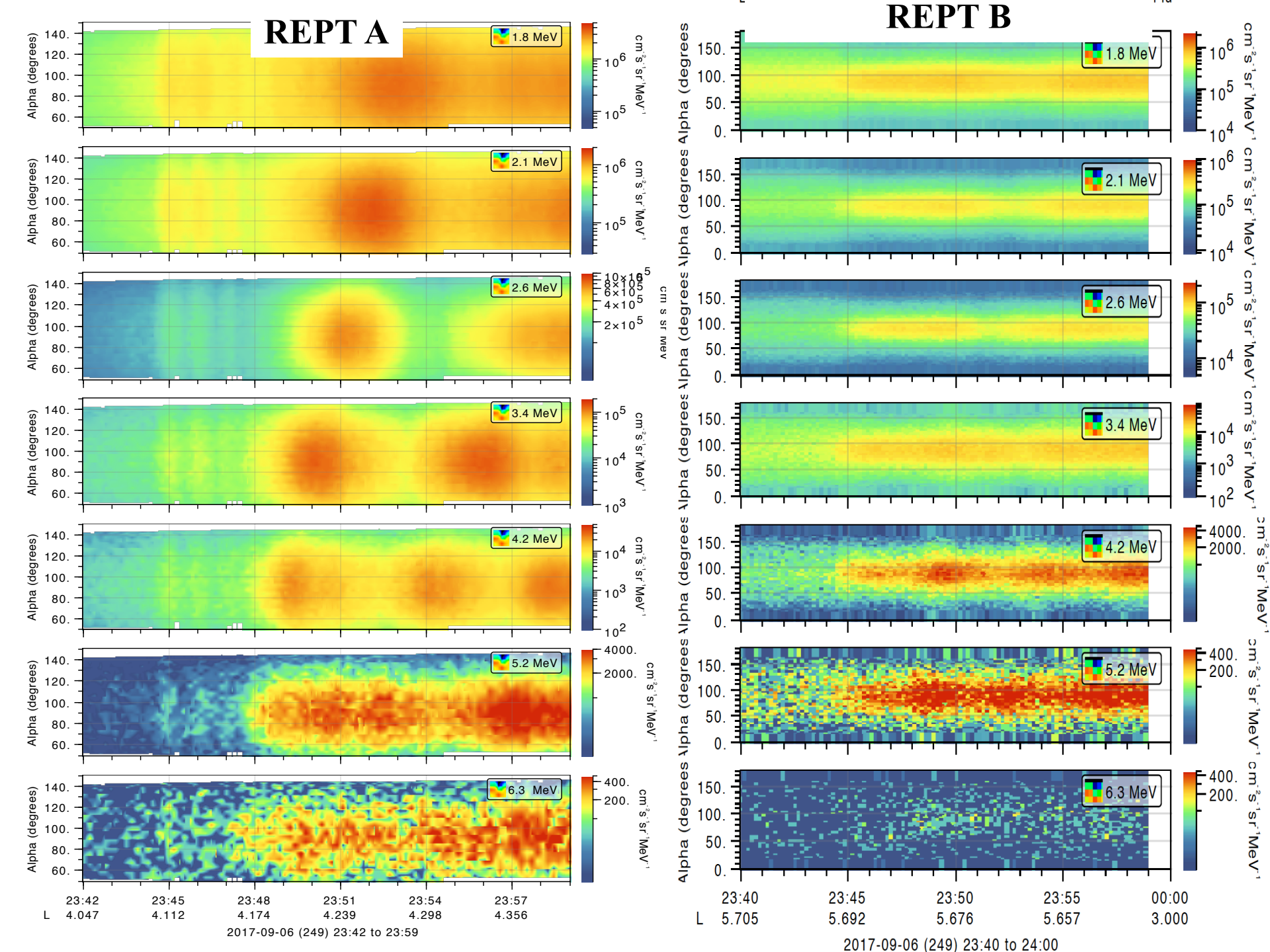
Ashley Greeley

Van Allen Probes 6 September 2017

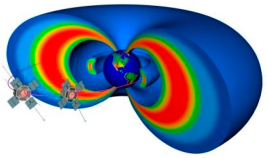


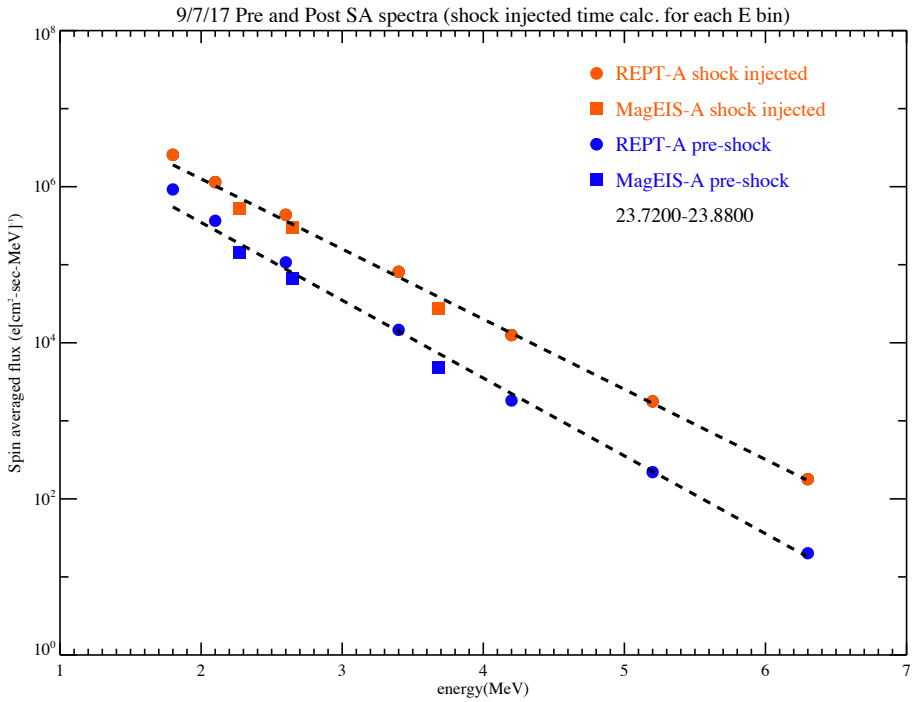


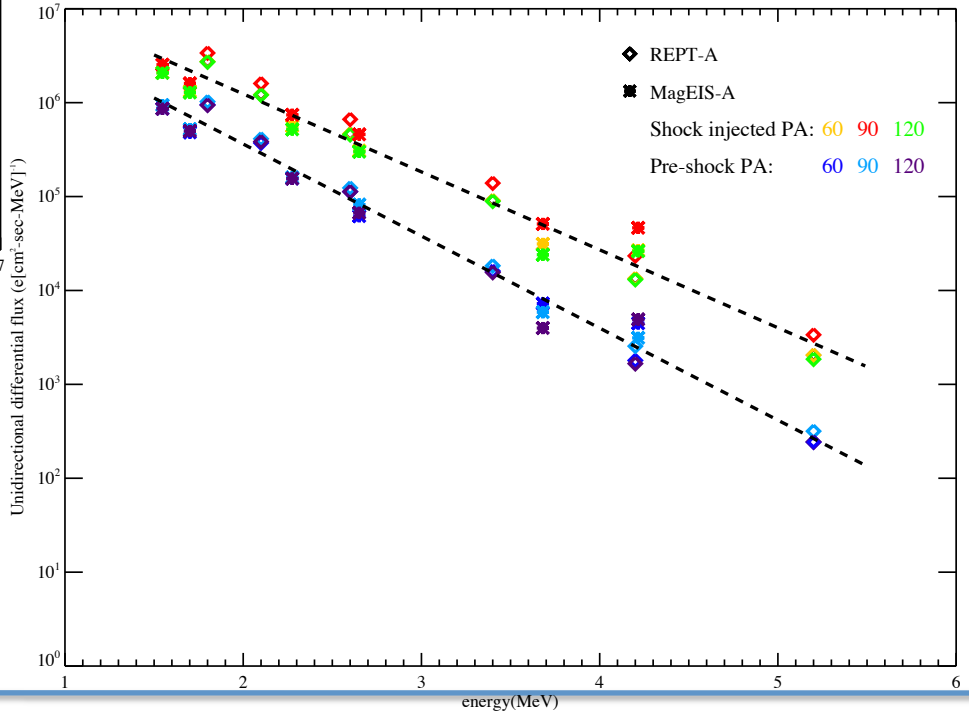



REPT A
REPT B
1.8 MeV
2.1 MeV
2.6 MeV
3.4 MeV
4.2 MeV
5.2 MeV
6.3 MeV
Alpha (degrees)
cm⁻²s⁻¹sr⁻¹MeV⁻¹
23:42 23:45 23:48 23:51 23:54 23:57
L 4.047 4.112 4.174 4.239 4.298 4.356
2017-09-06 (249) 23:42 to 23:59
23:40 23:45 23:50 23:55 00:00
L 5.705 5.692 5.676 5.657 3.000
2017-09-06 (249) 23:40 to 24:00

Spectra: Pre- and Post-injection 6 September

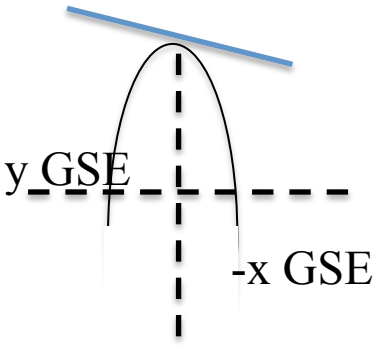






Ashley Greeley

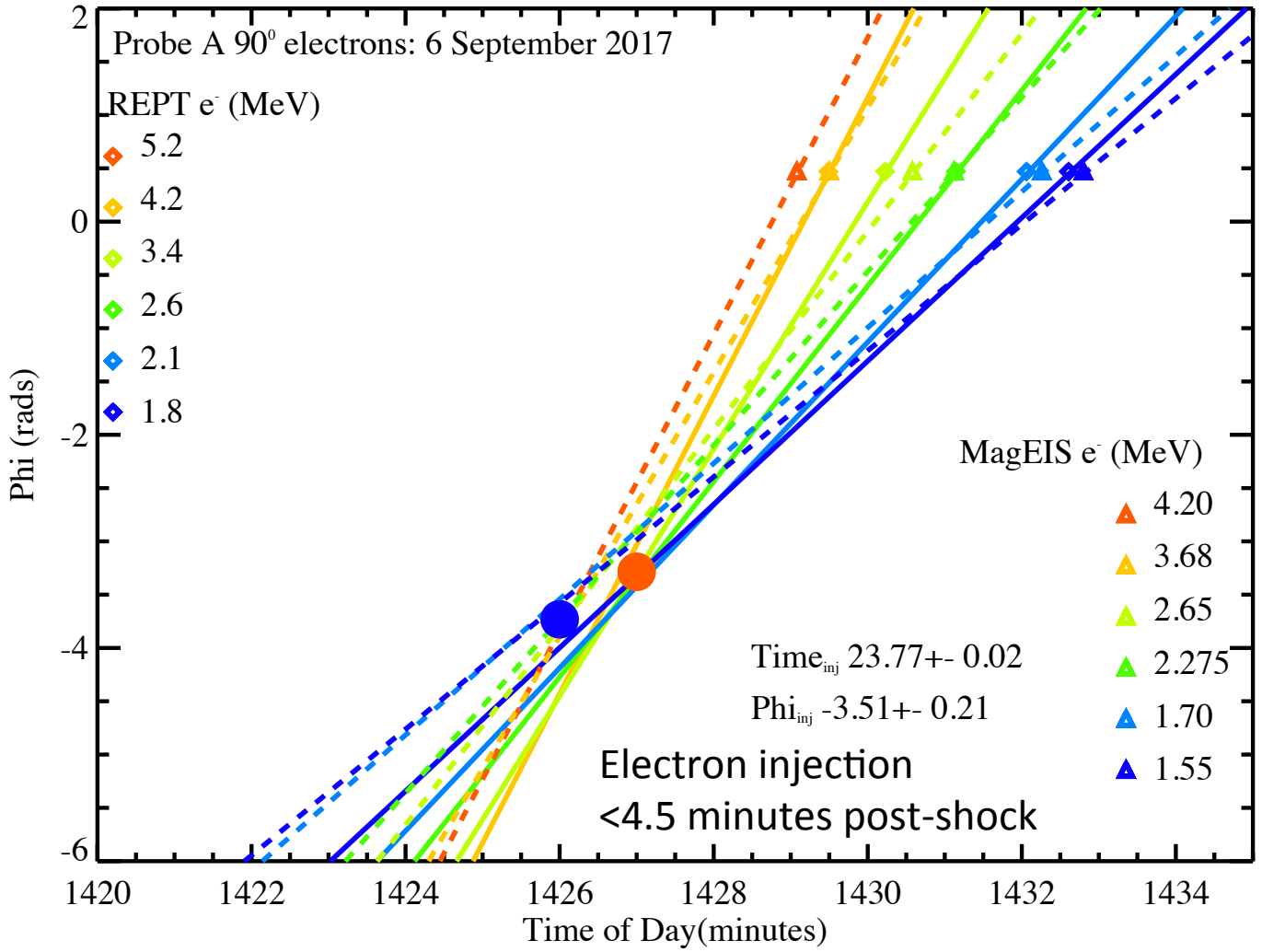
Shock Injection: Location and Timing



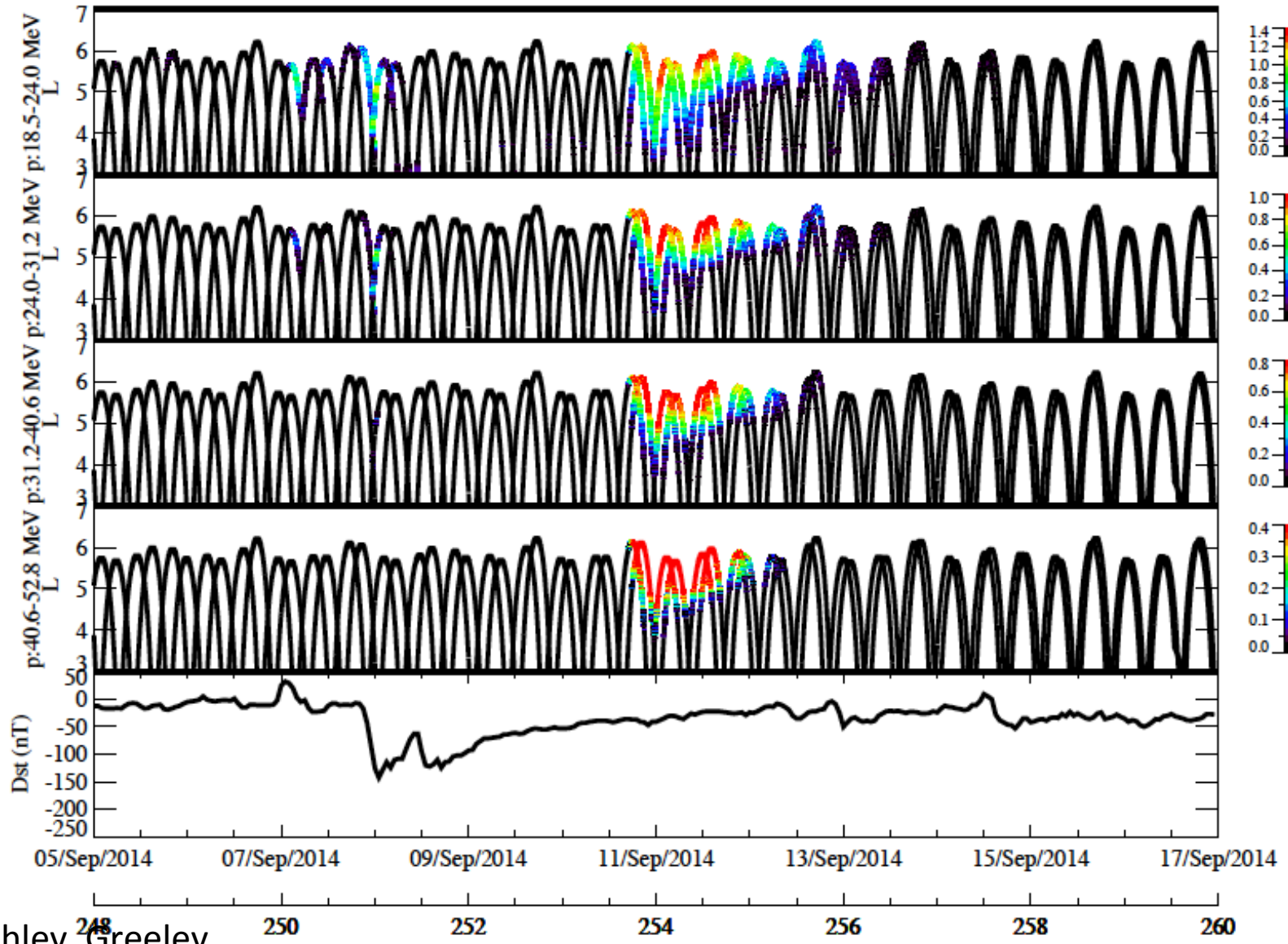
Shock ~ 11 MLT
Probe A ~10 MLT
GSE Shock Normal

N_x	−1.00	±	0.04
N_y	0.06	±	0.24
N_z	0.03	±	0.13

Lynn Wilson

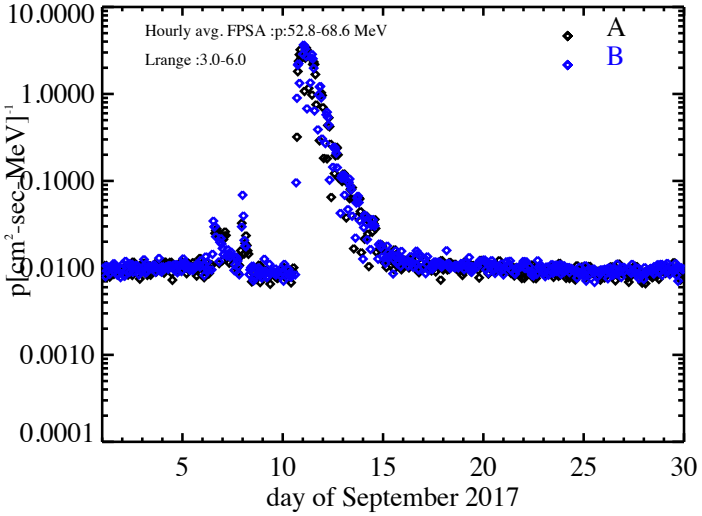


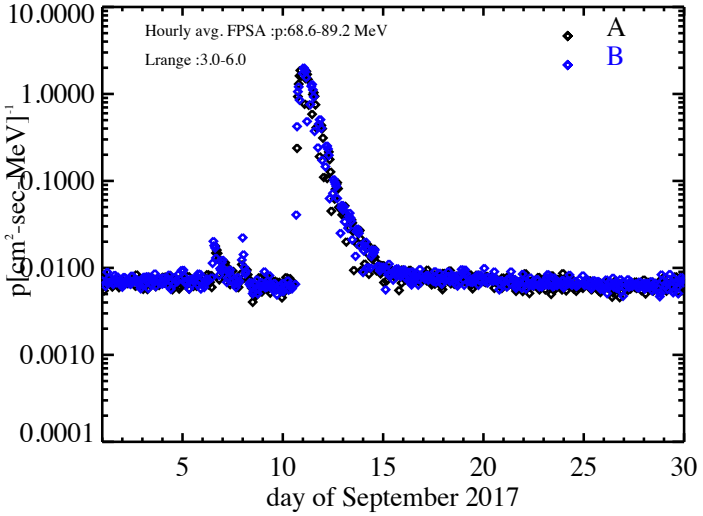
SEP event September 11 2017

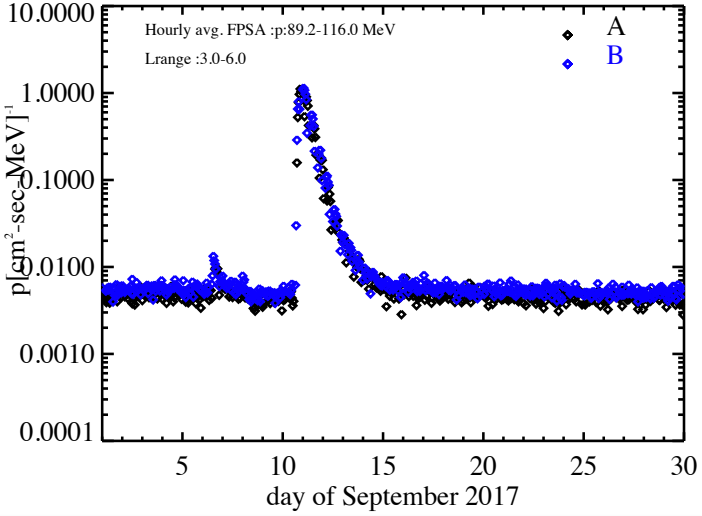


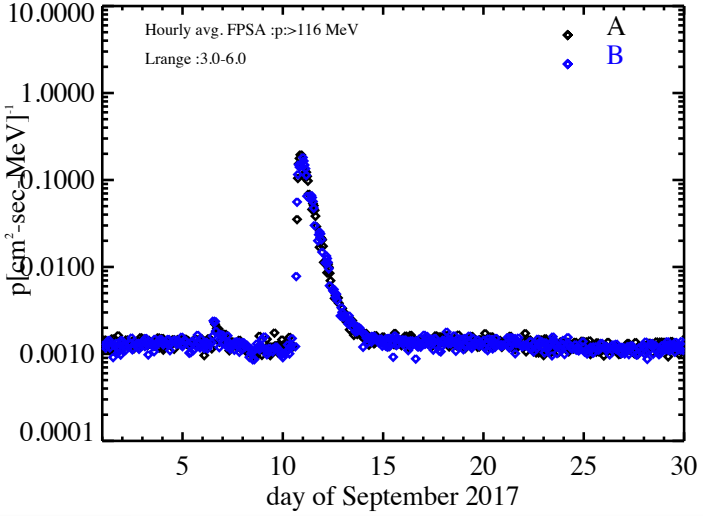
Ashley Greeley

SEP event September 11 2017

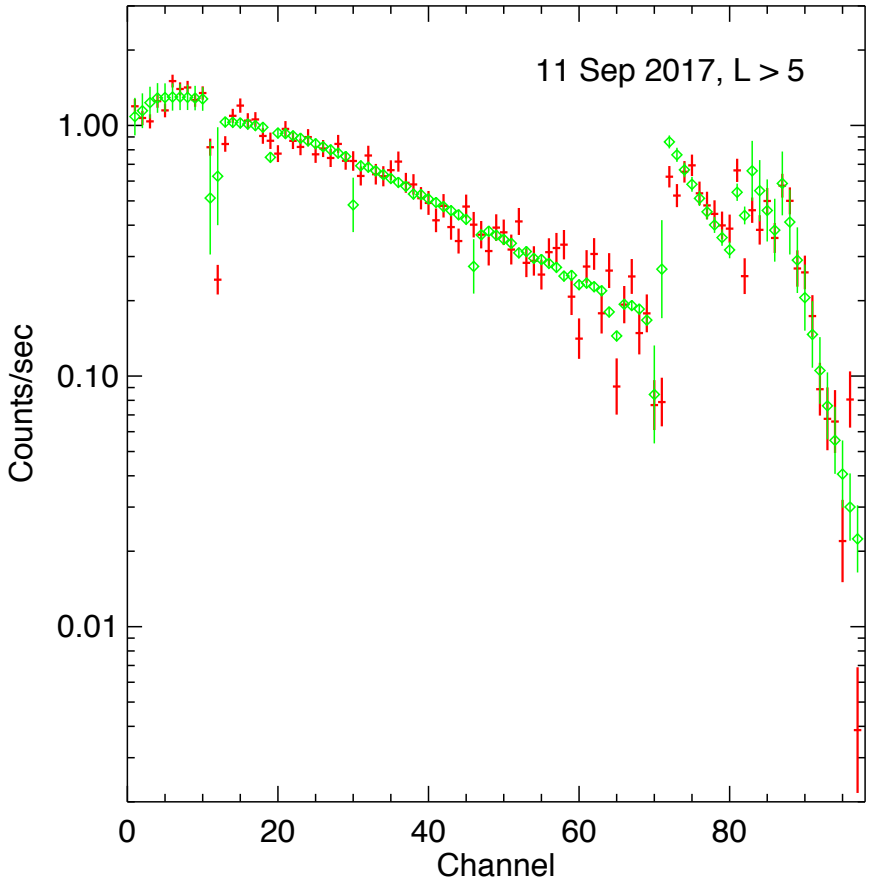


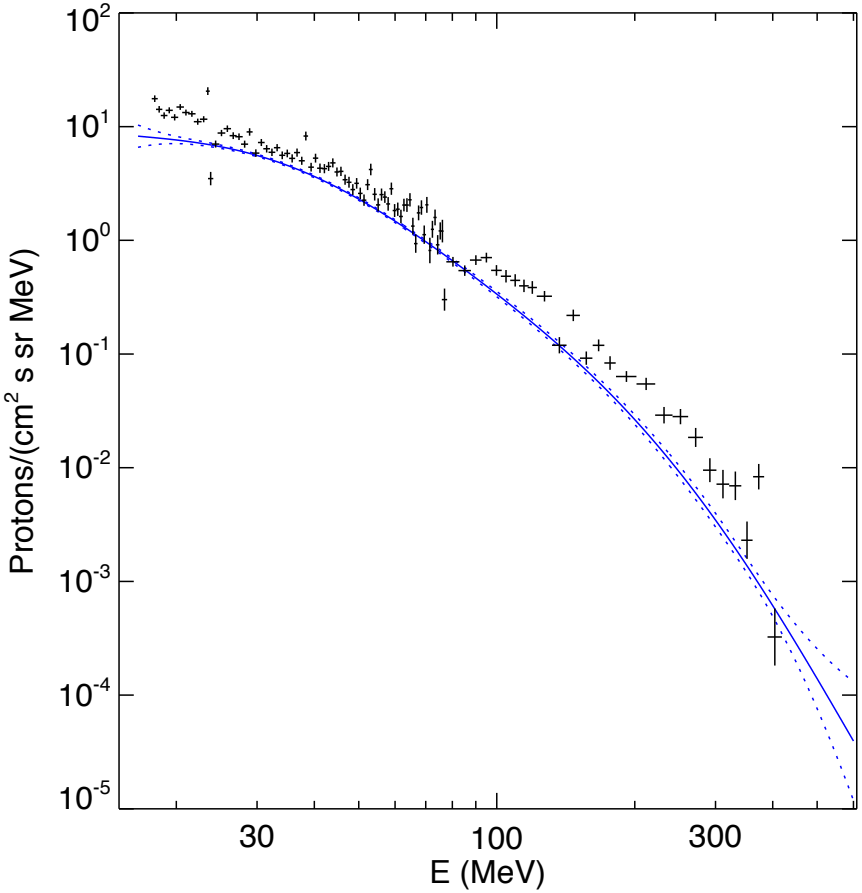






September 11 SEP spectrum: REPT PHA



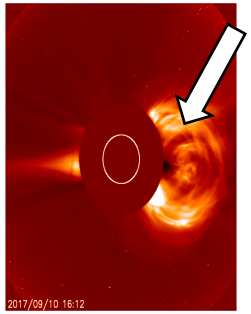


Richard Selesnick

Selesnick et al., 2017 in review

REPT PHA : 97 differential channels

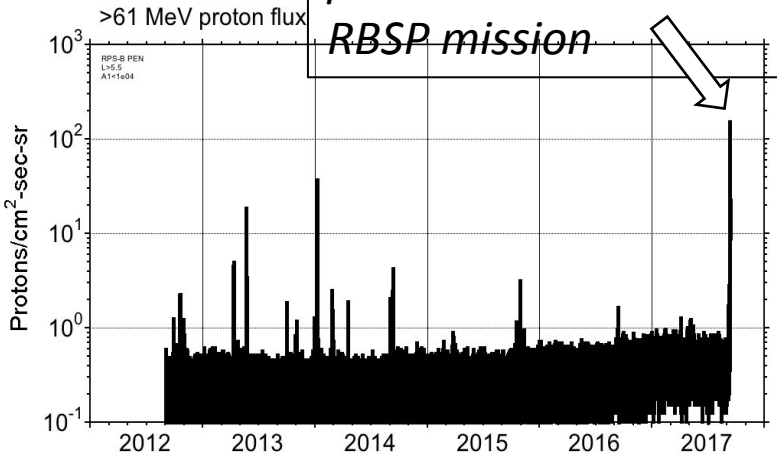
Solar Protons up to 1 GeV in the 9/10/17 CME Event



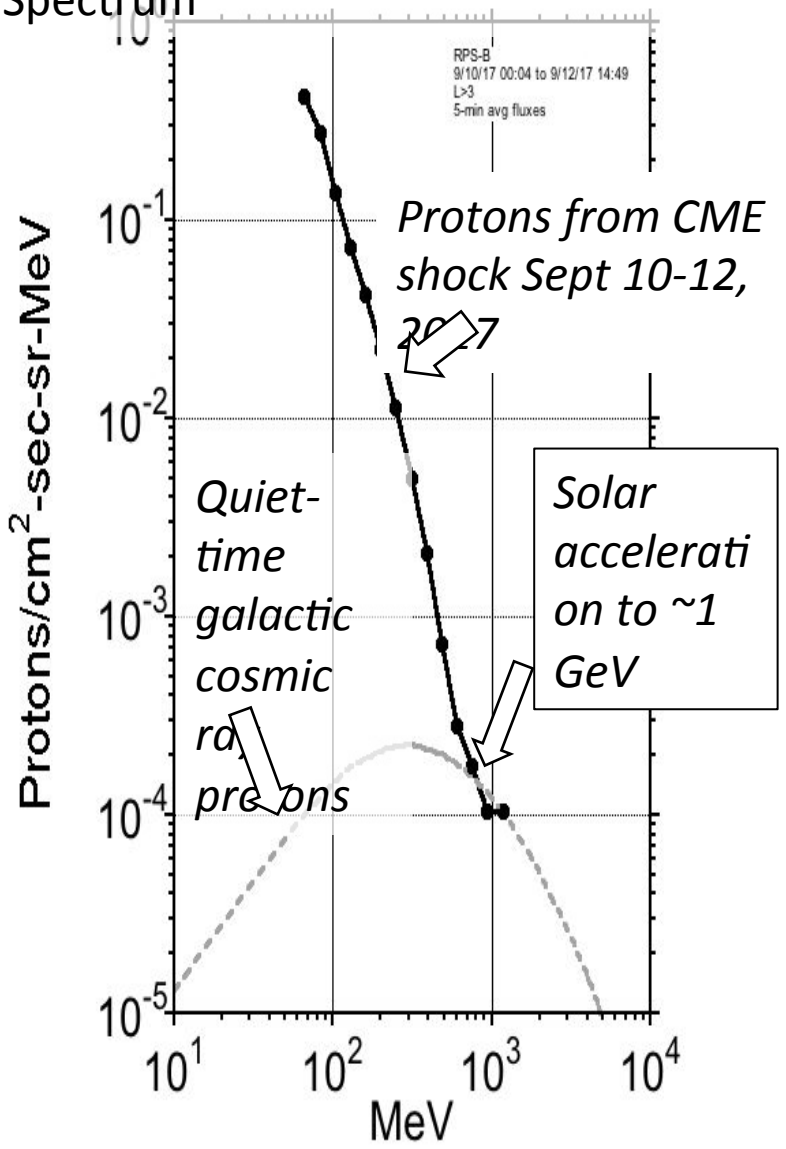
CME liftoff: 9/10/17 1600UT
Estimated speed: 1081 km/sec

www.spaceweather.gmu/edu

Most intense >60 MeV solar proton event seen during the RBSP mission

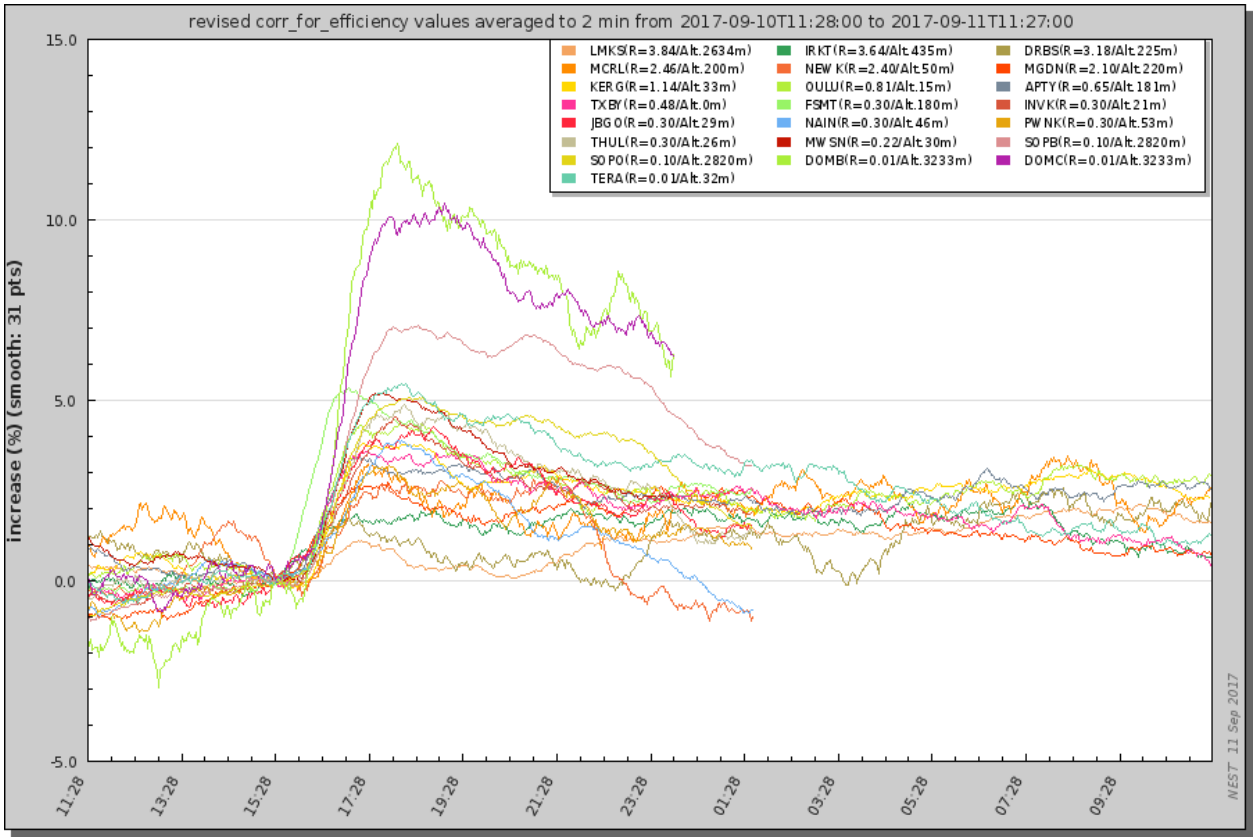


Van Allen Probes/RPS-B Proton Energy Spectrum



From Joe Mazur, Aerospace Corp

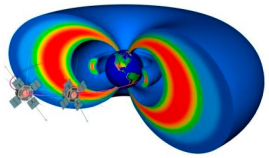
Neutron Monitor data



Cutoff rigidity 3.9 GV => 3.2 GeV protons

http://www.nmdb.eu/?q=node/501

Summary

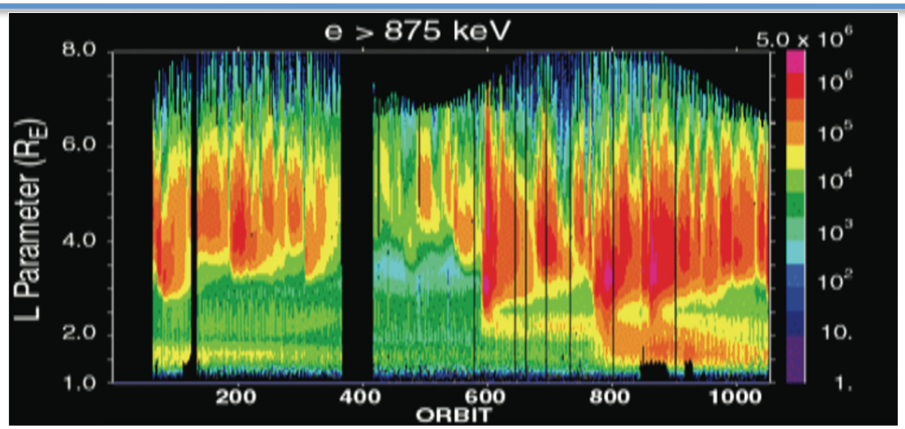


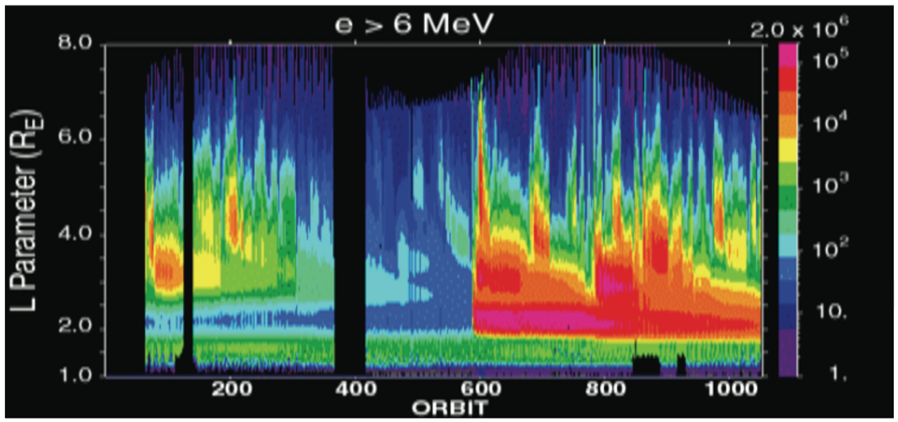
September 2017 extremely interesting period

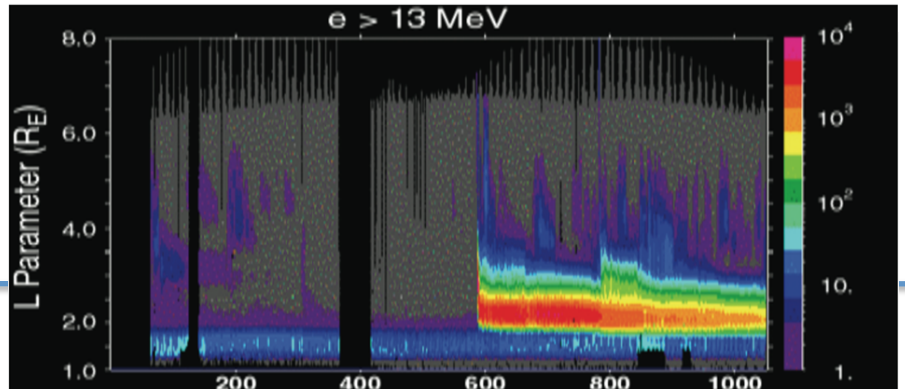
- ➢ Multiple IP shocks, and CMEs
  - ✧ rapid shock injections to highly relativistic energies
  - ✧ gradual energization of outer zone electrons
  - ✧ multiple belt structure

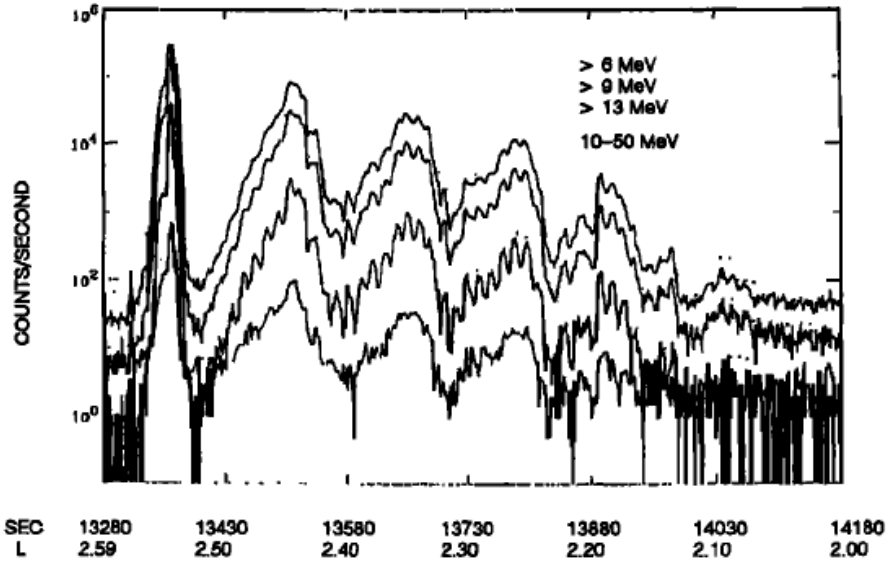
- ➢ Largest SEP event so far
  - ❖ GLE with up to 3 GeV solar protons

March 1991 Shock injected > 50 MeV electrons





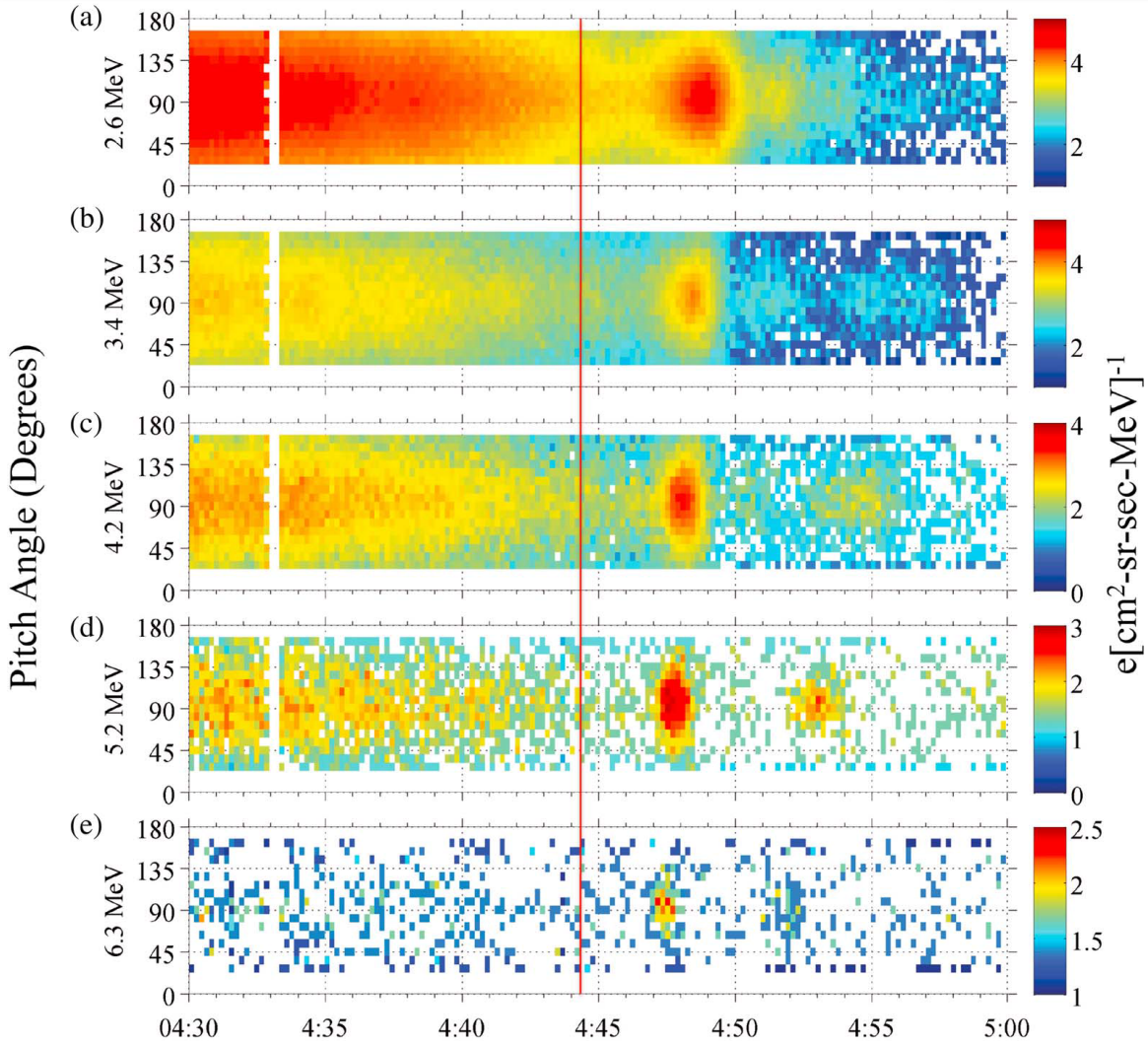


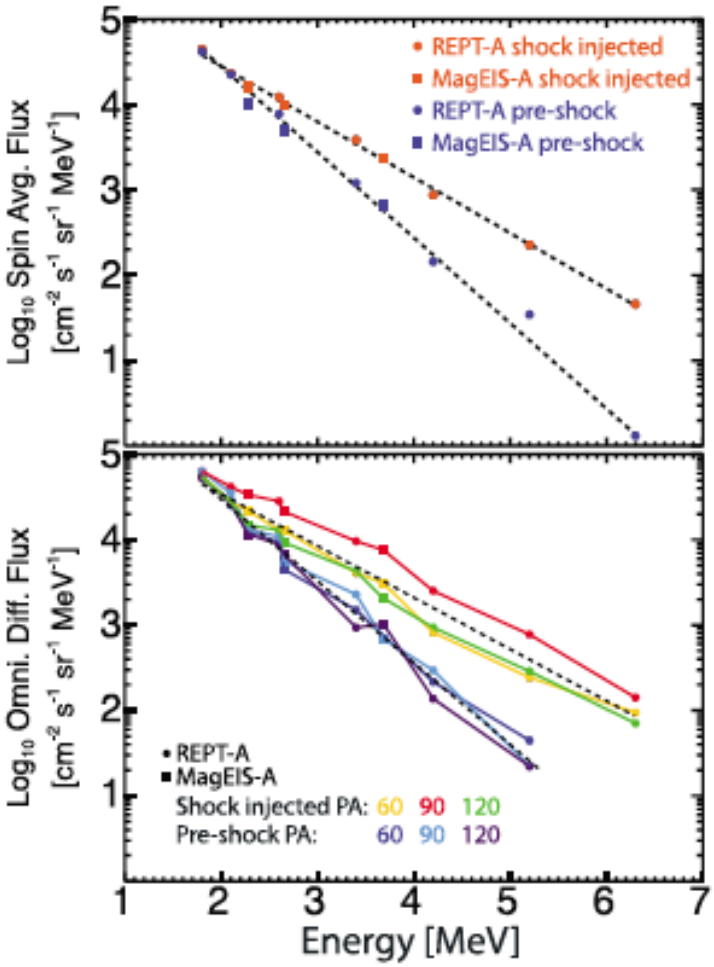


The injection event of 24 March was truly amazing, and the observation is unique for its location, magnitude, and energy during the 35 years of space research.

Blake et al., 1992

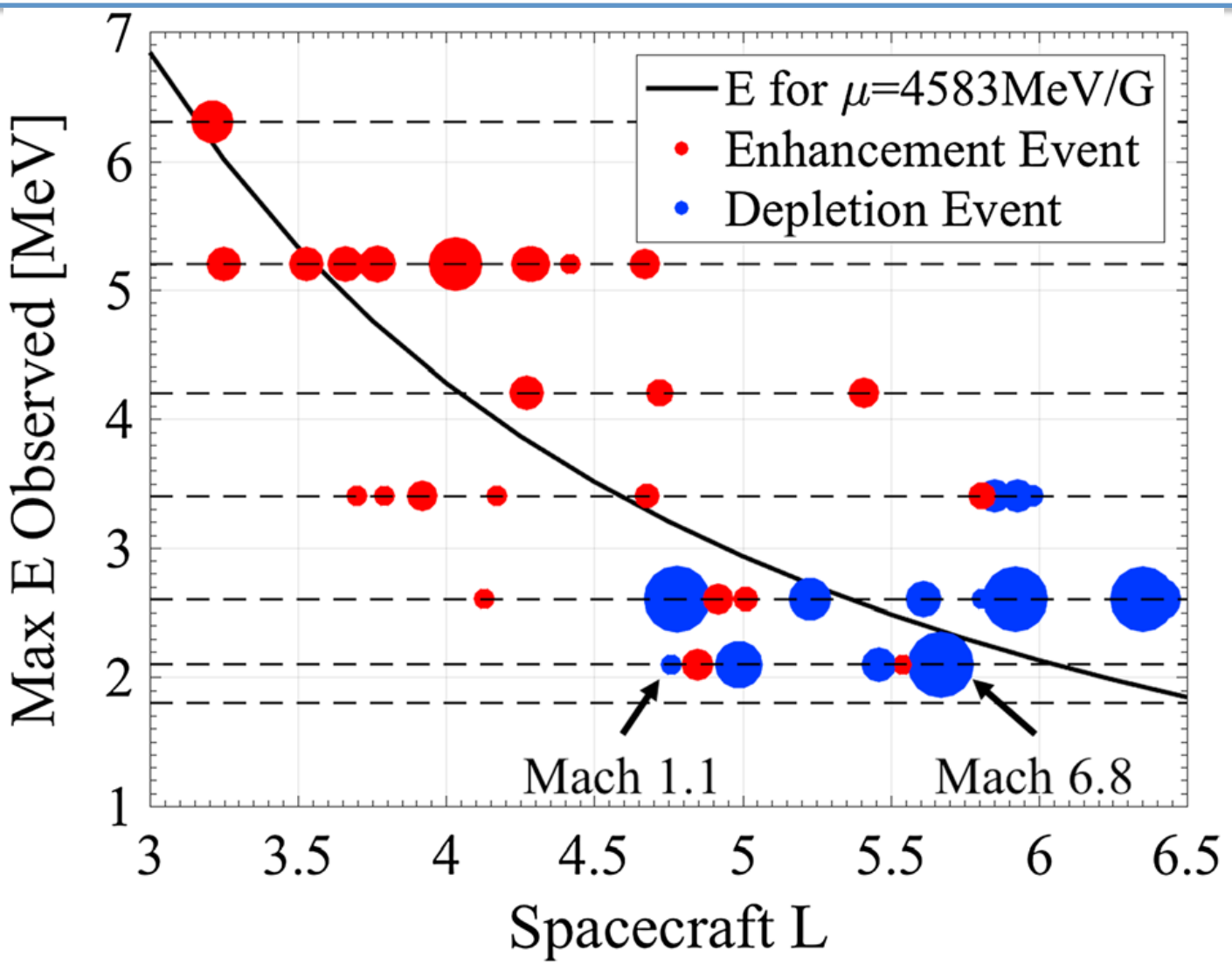
March 2015 IP shock



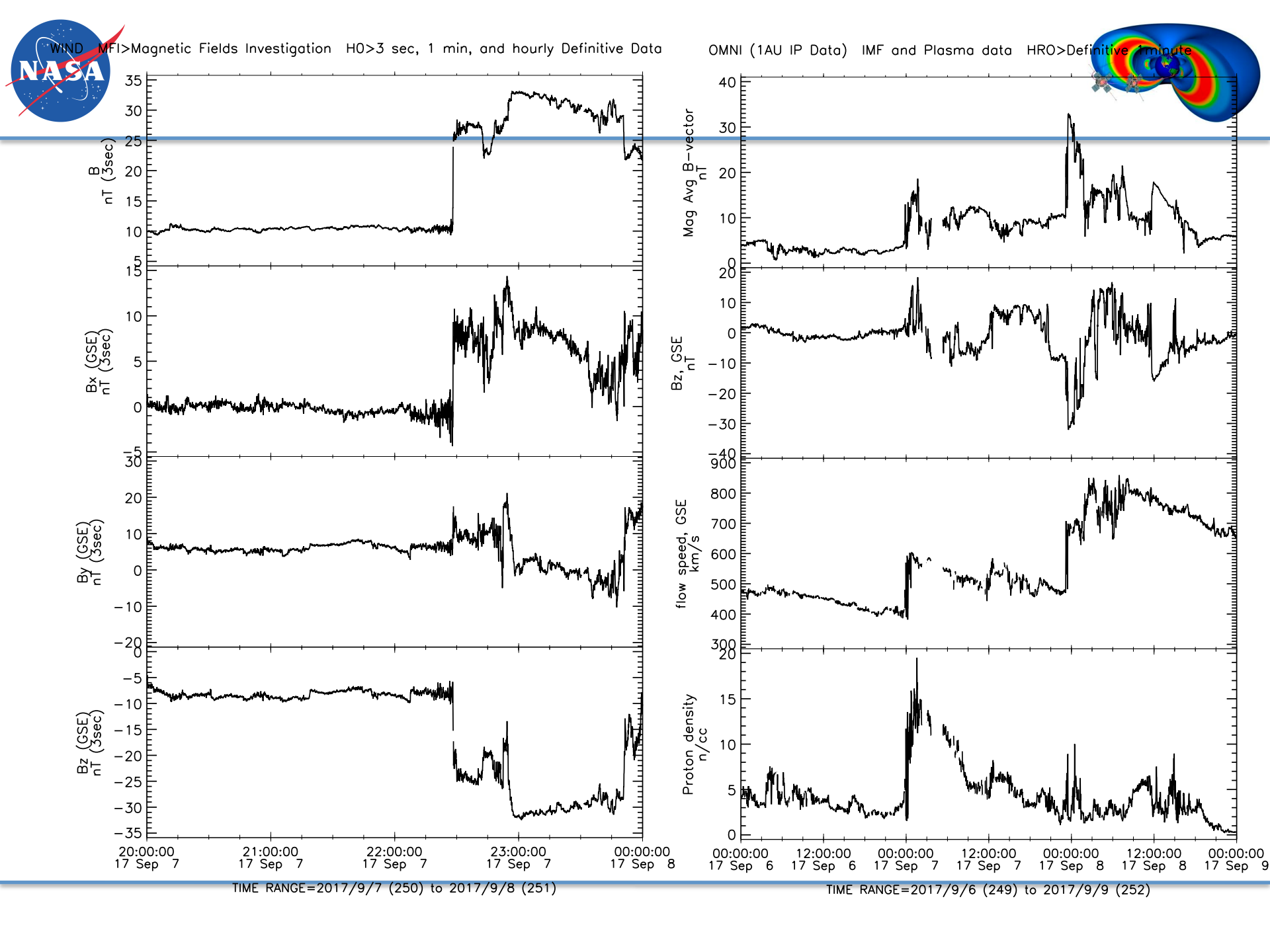


Kanekal et al., 2016

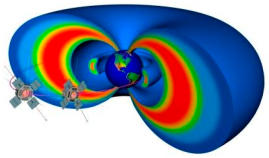
Relating shock parameters to electron injections

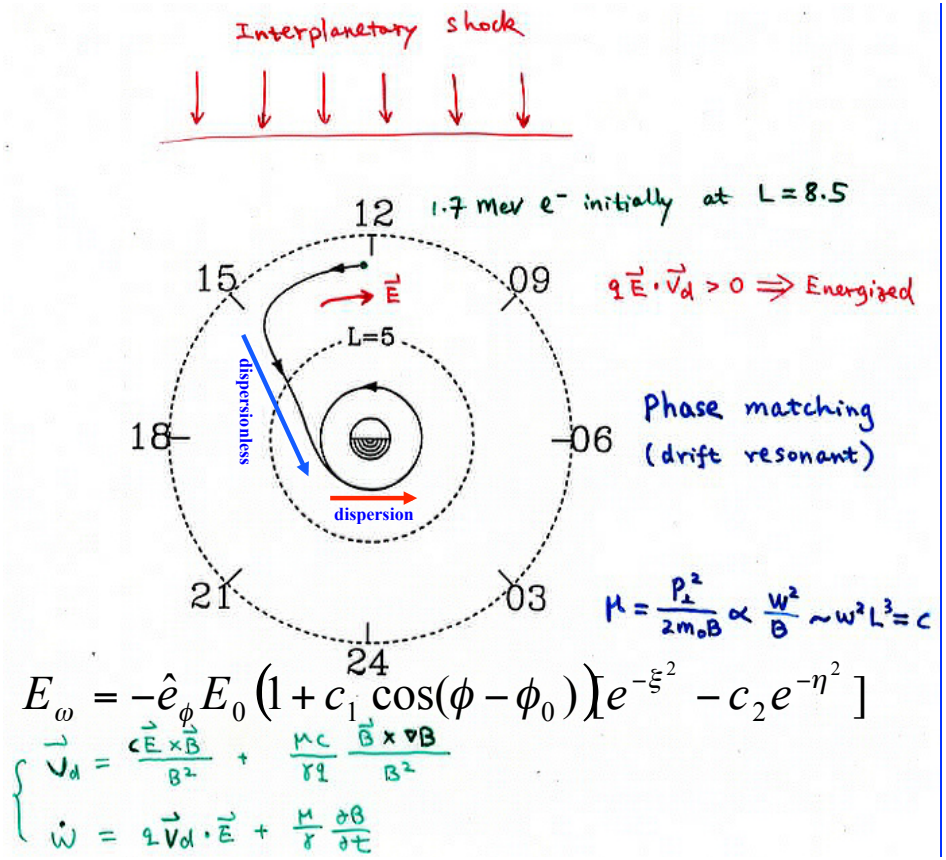


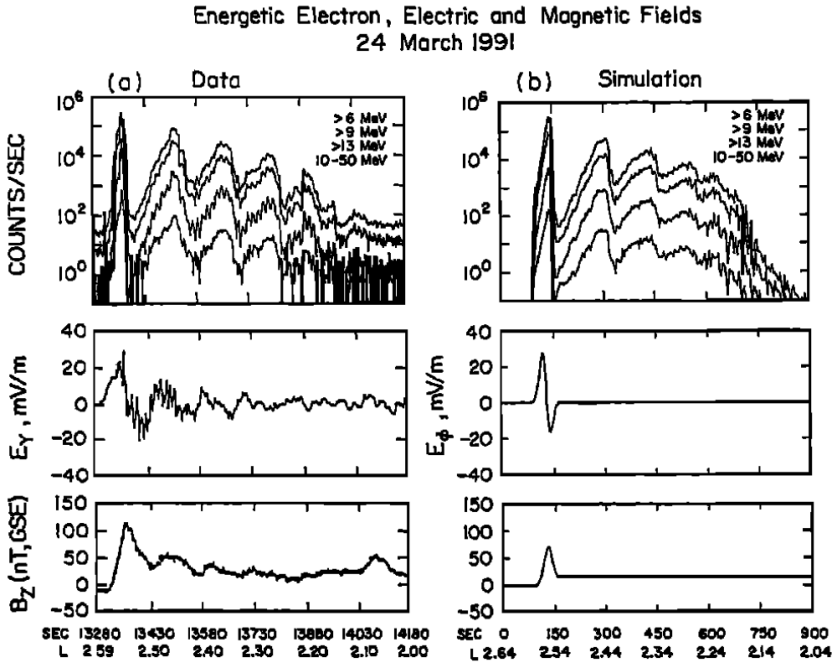
Schiller et al., 2016

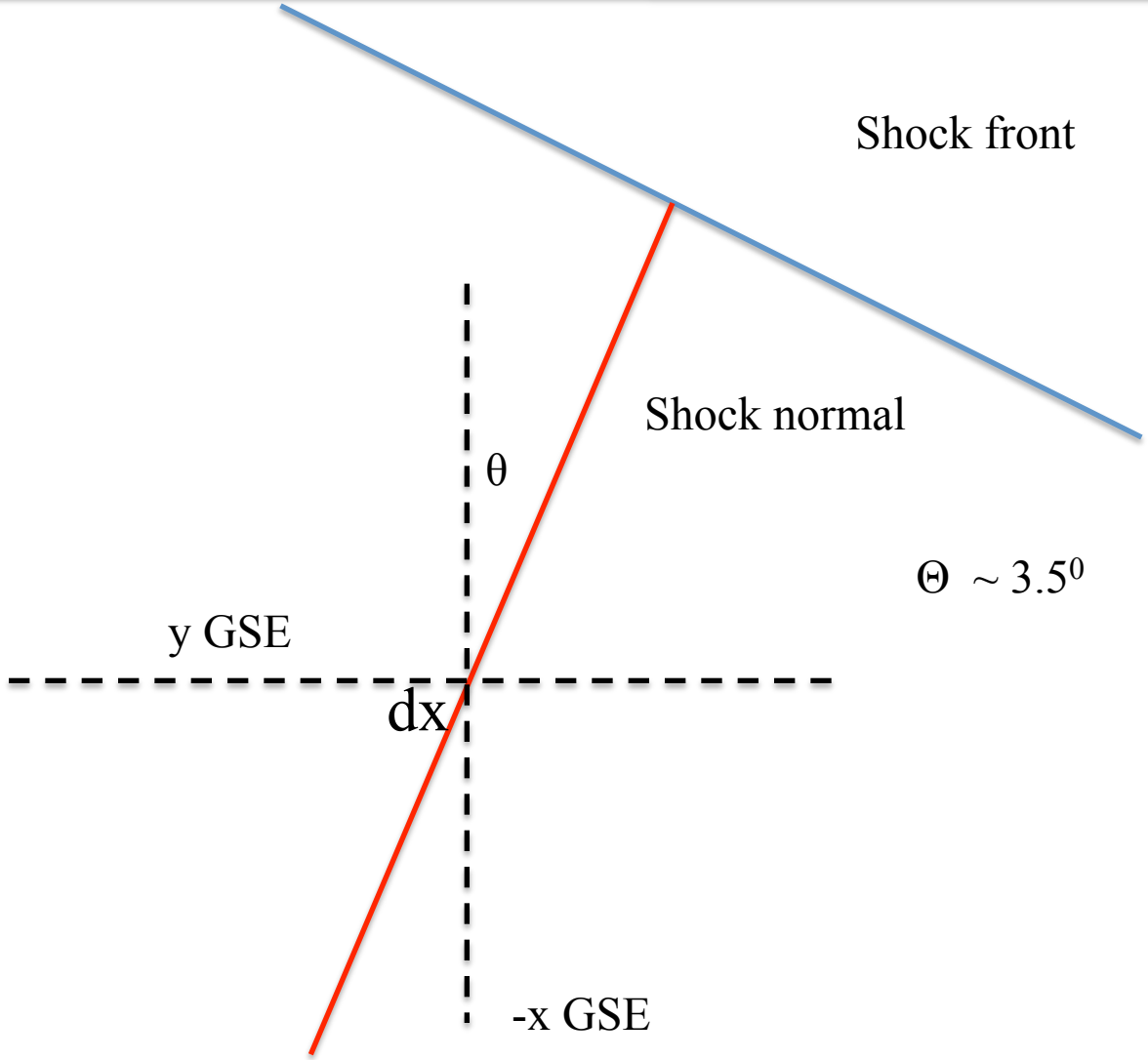

WIND MFI>Magnetic Fields Investigation H0>3 sec, 1 min, and hourly Definitive Data
B nT (3sec)
Bx (GSE) nT (3sec)
By (GSE) nT (3sec)
Bz (GSE) nT (3sec)
20:00:00 17 Sep 7
21:00:00 17 Sep 7
22:00:00 17 Sep 7
23:00:00 17 Sep 7
00:00:00 17 Sep 8
TIME RANGE=2017/9/7 (250) to 2017/9/8 (251)
OMNI (1AU IP Data) IMF and Plasma data HRO>Definitive 1minute
Mag Avg B-vector nT
Bz, GSE nT
flow speed, GSE km/s
Proton density n/cc
00:00:00 17 Sep 6
12:00:00 17 Sep 6
00:00:00 17 Sep 7
12:00:00 17 Sep 7
00:00:00 17 Sep 8
12:00:00 17 Sep 8
00:00:00 17 Sep 9
TIME RANGE=2017/9/6 (249) to 2017/9/9 (252)

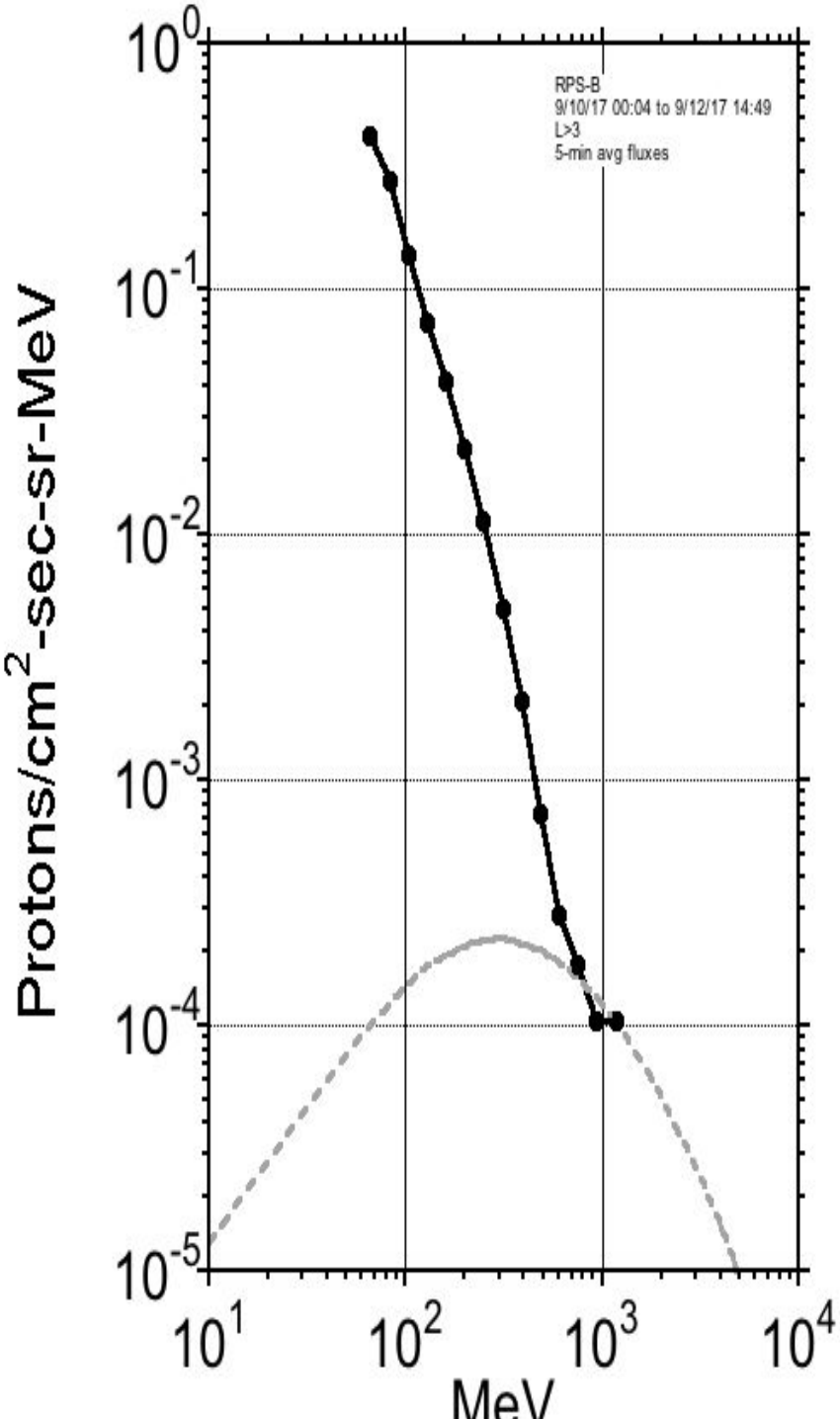
Shock Injection and velocity dispersion








Shock front
Shock normal
θ
Θ ~ 3.5⁰
y GSE
dx
-x GSE


RPS-B
9/10/17 00:04 to 9/12/17 14:49
L>3
5-min avg fluxes
Protons/cm^2-sec-sr-MeV
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^1
10^2
10^3
10^4
MeV