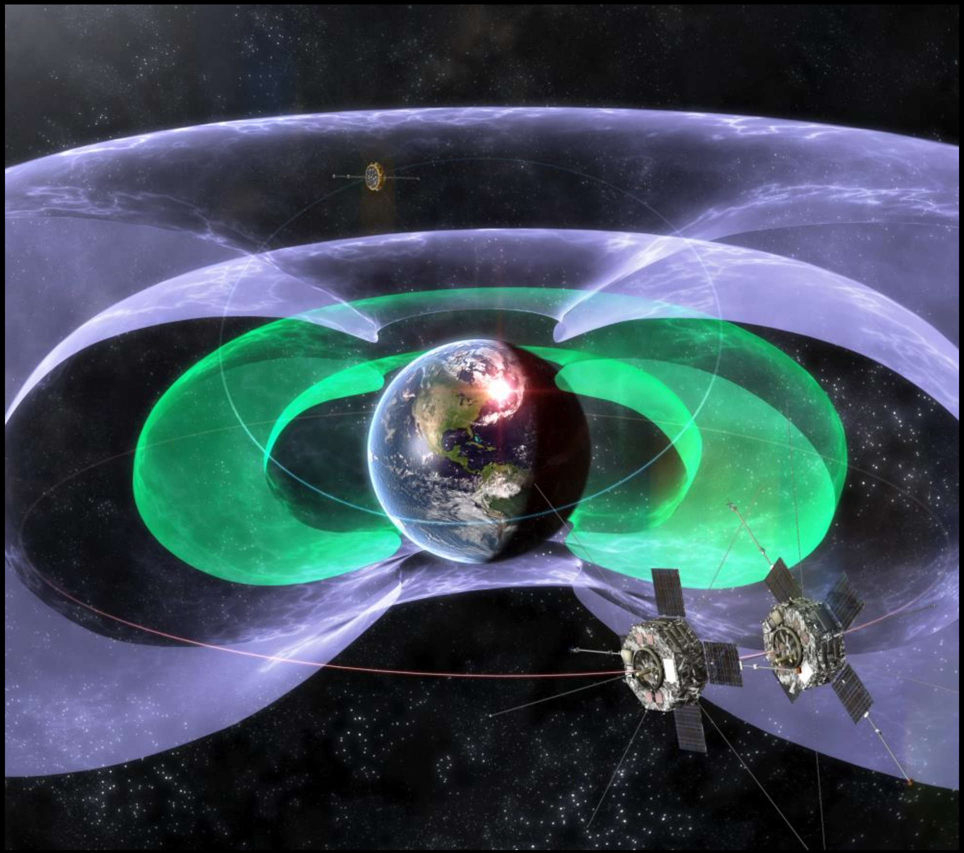


Multi-Year Observations of Ultra-Relativistic Electrons with the Van Allen Probes Mission

Daniel N. Baker
Laboratory for Atmospheric and Space Physics
University of Colorado – Boulder

Collaborators: V. Hoxie, H. Zhao, X.Li, A. Jaynes, S. Kanekal, and ECT Team

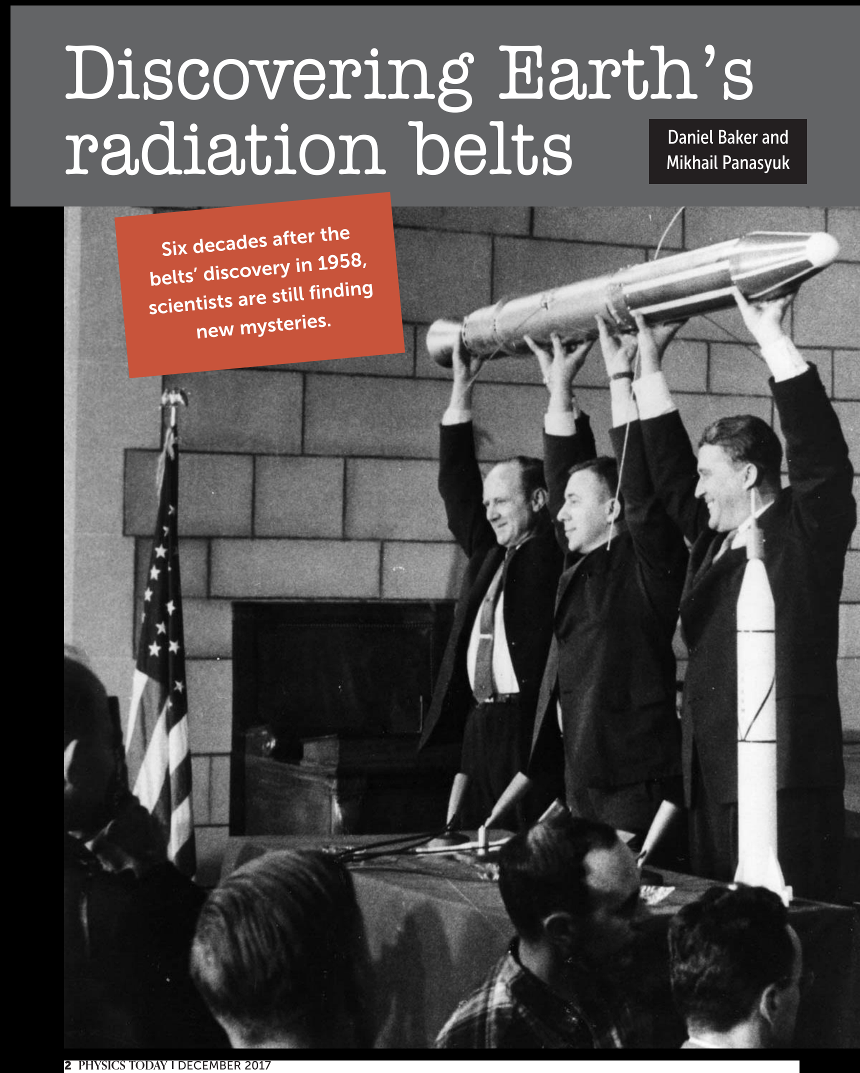
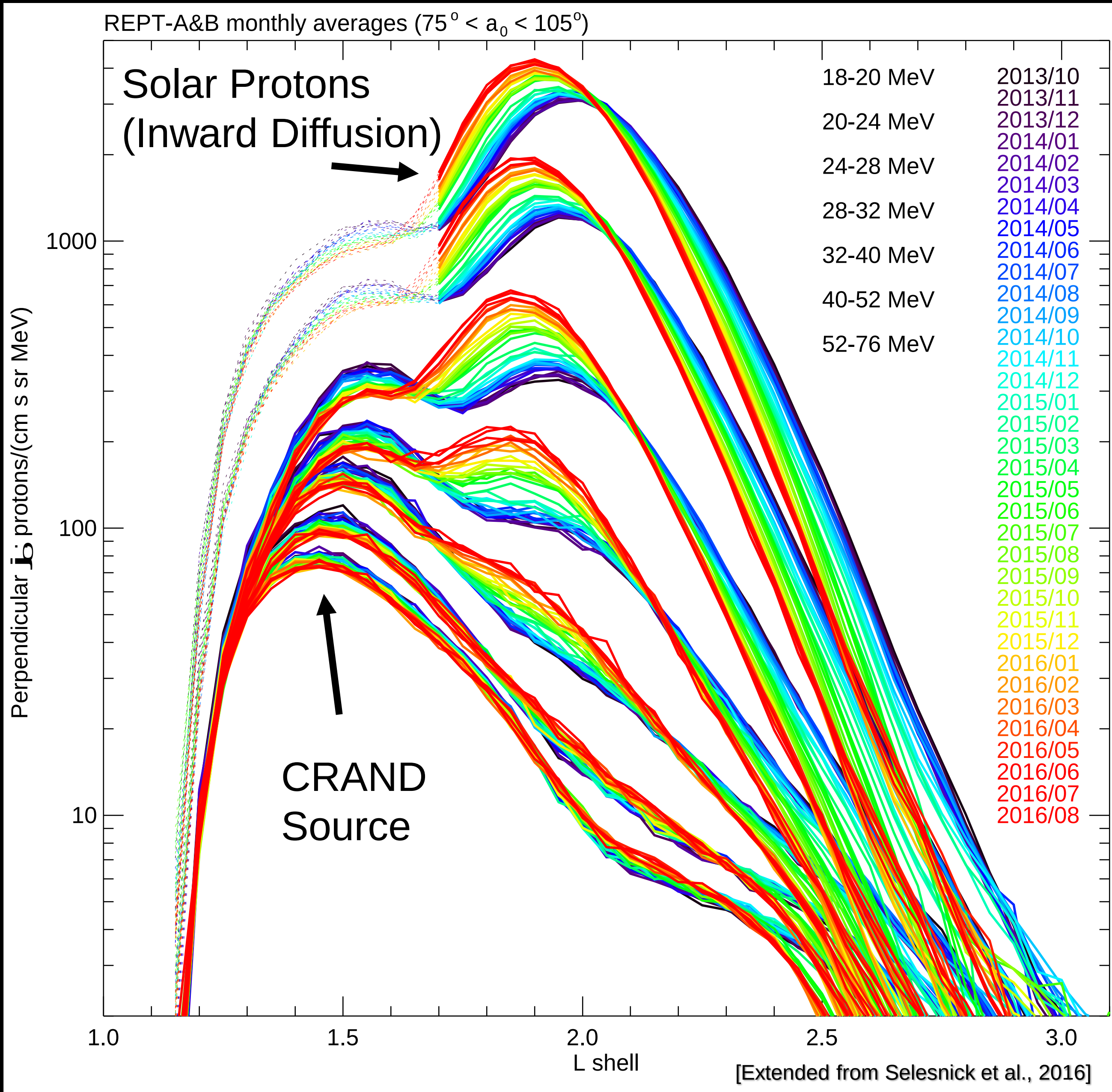


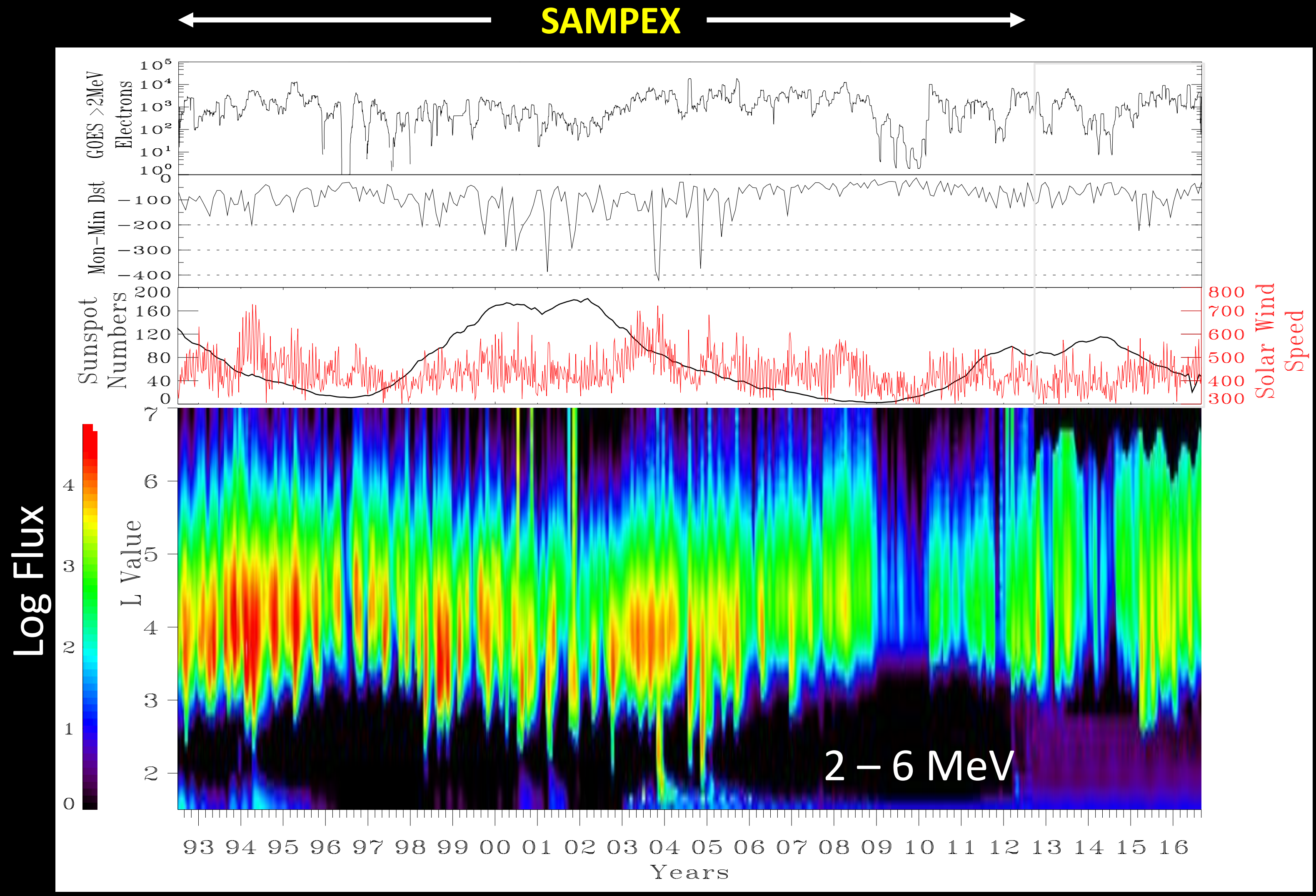
Photo taken at U.S. National Academy Building
(31 January 1958)

Explorer 1 Launch

Baker & Panasyuk
Phys. Today, December 2017

REPT Monthly Average Proton Flux
(October 2013 – August 2016)

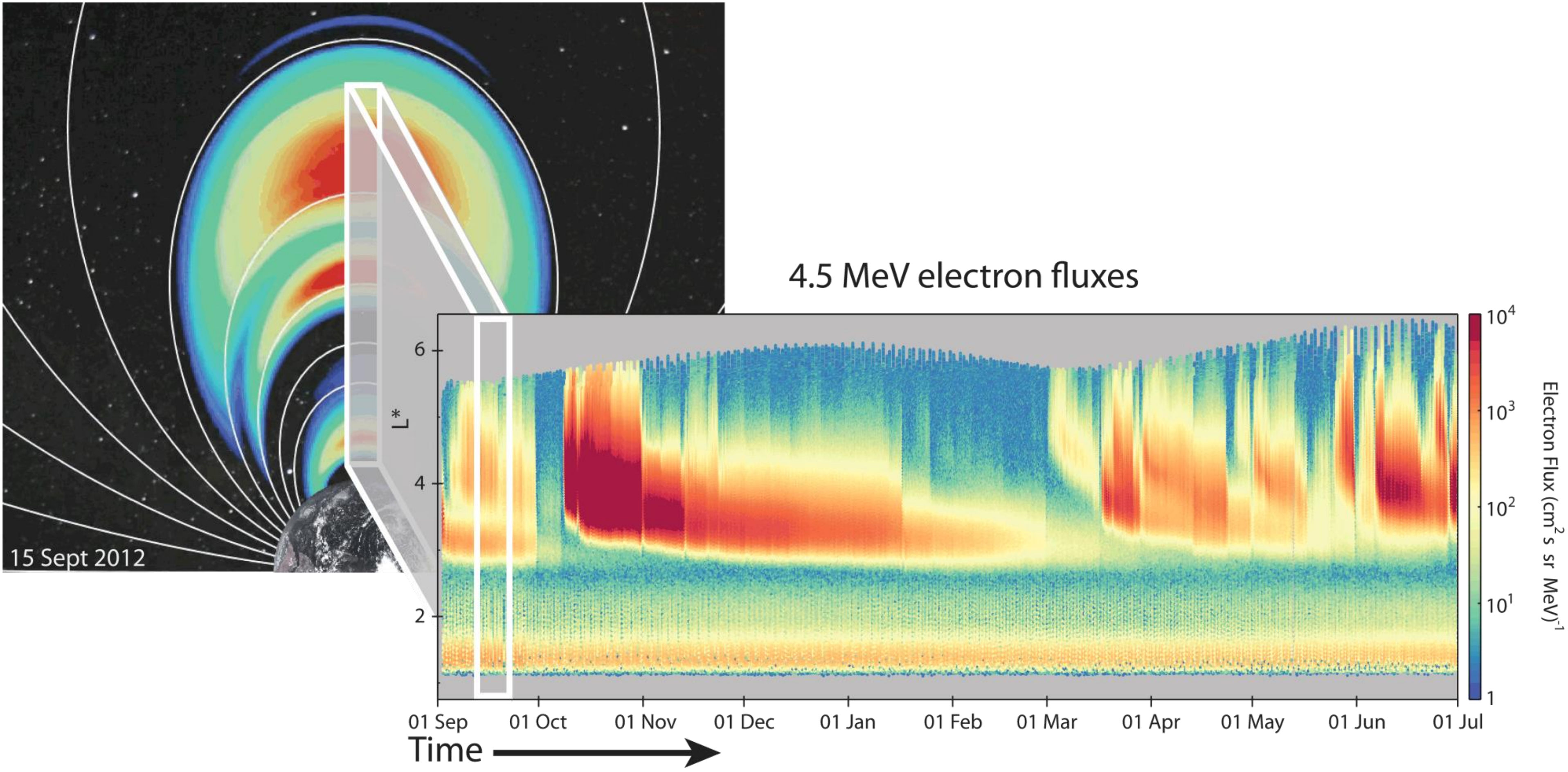




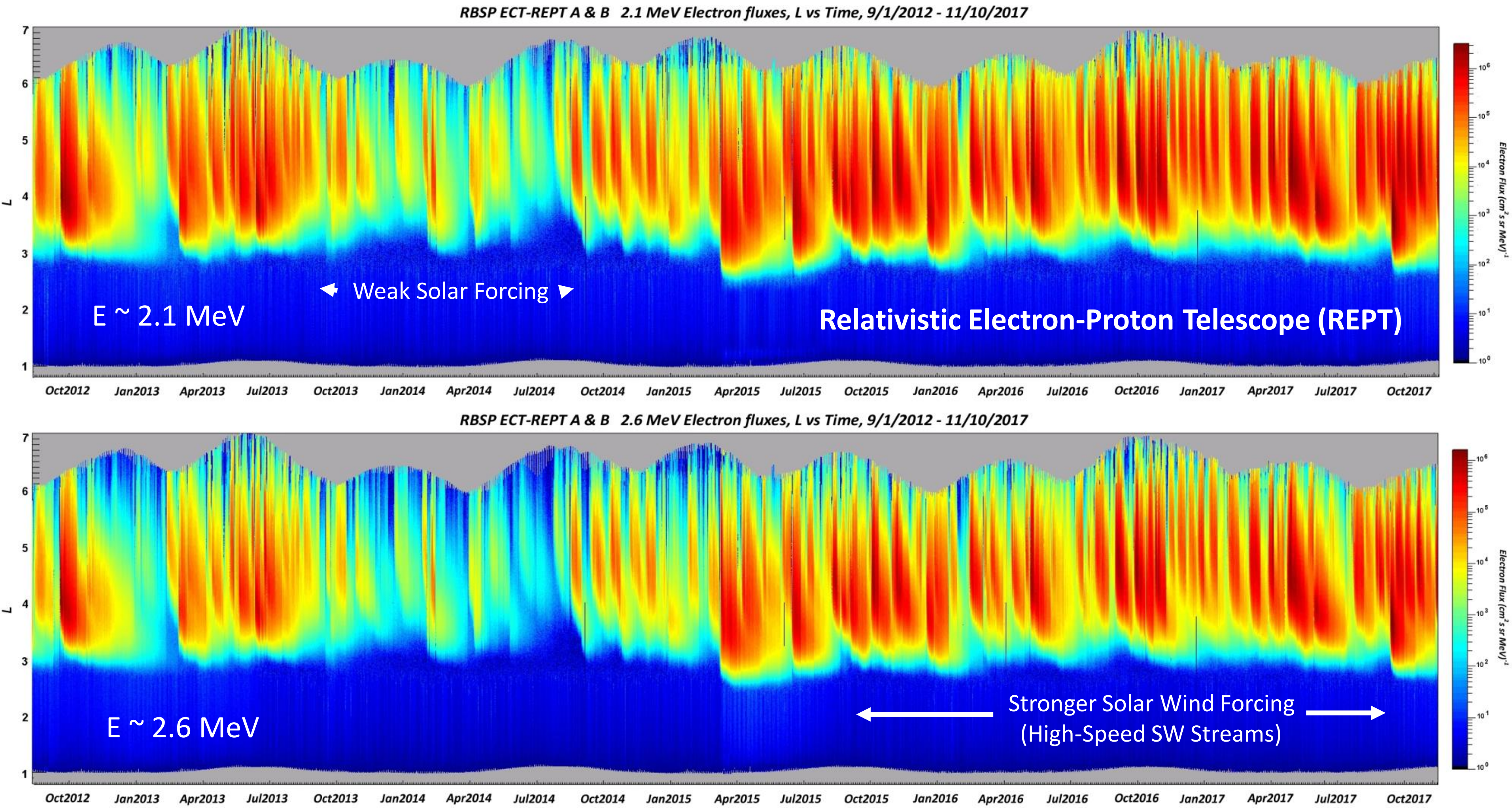
Courtesy: Xinlin Li

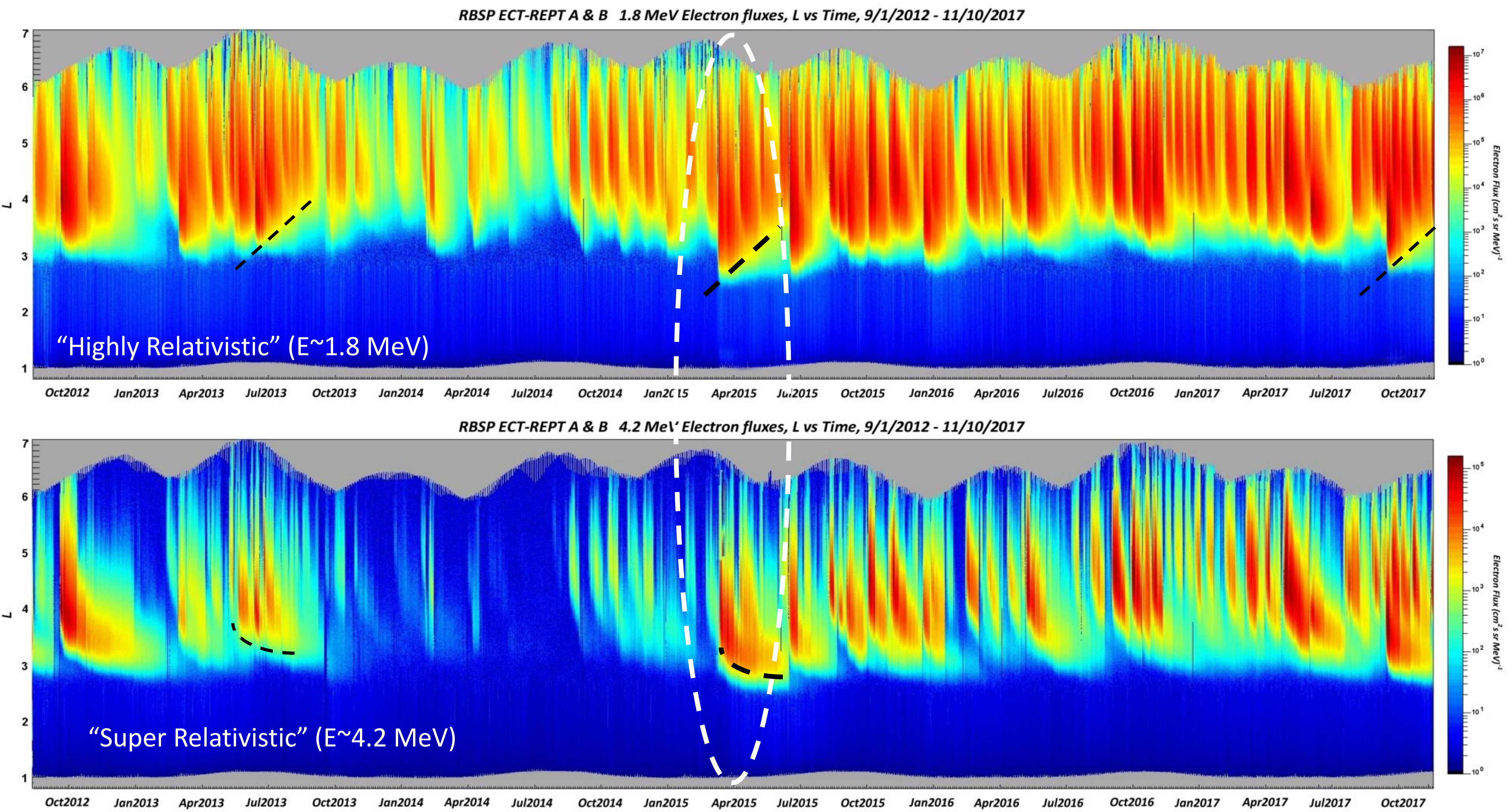
REPT Observations:

Acceleration, Remanence, and Sudden Loss



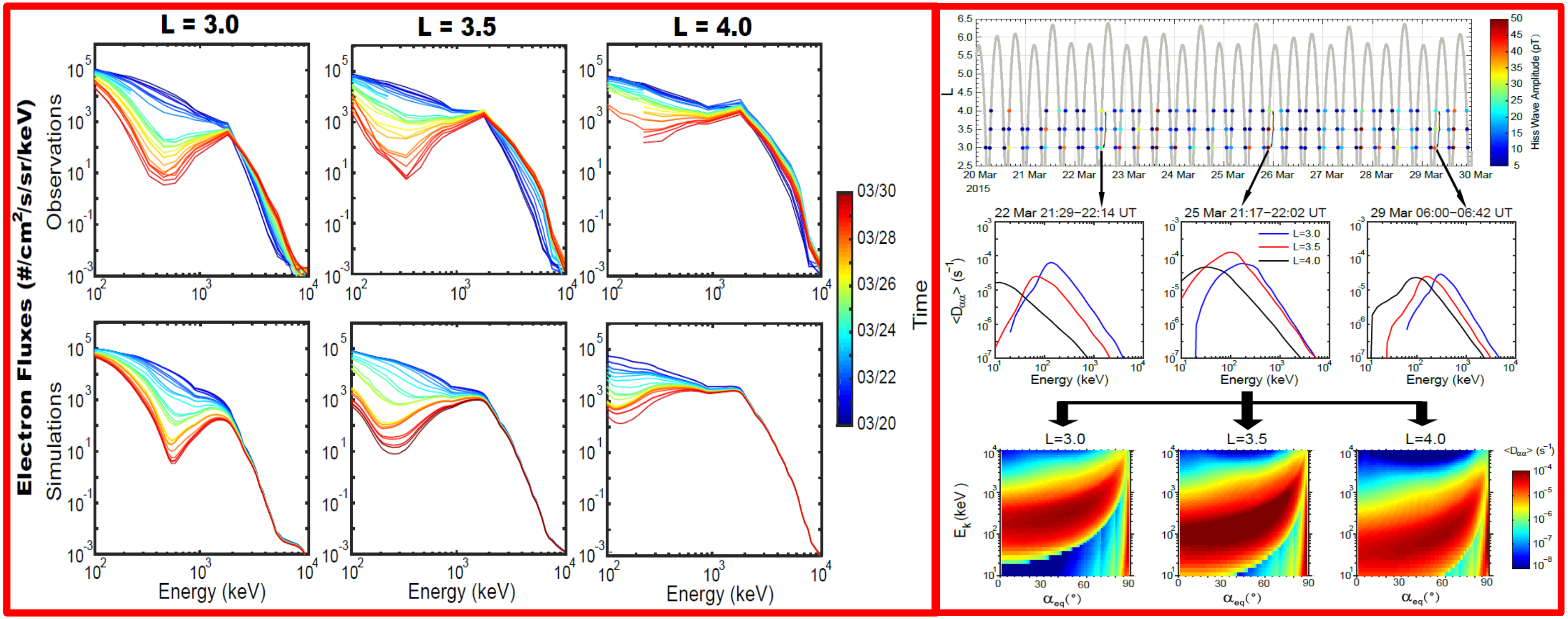
[D. N. Baker, ***American Scientist***, Sept.2014]


RBSP ECT-REPT A & B 2.1 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
Weak Solar Forcing
E ~ 2.1 MeV
Relativistic Electron-Proton Telescope (REPT)
Oct2012 Jan2013 Apr2013 Jul2013 Oct2013 Jan2014 Apr2014 Jul2014 Oct2014 Jan2015 Apr2015 Jul2015 Oct2015 Jan2016 Apr2016 Jul2016 Oct2016 Jan2017 Apr2017 Jul2017 Oct2017
RBSP ECT-REPT A & B 2.6 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
E ~ 2.6 MeV
Stronger Solar Wind Forcing
(High-Speed SW Streams)
Oct2012 Jan2013 Apr2013 Jul2013 Oct2013 Jan2014 Apr2014 Jul2014 Oct2014 Jan2015 Apr2015 Jul2015 Oct2015 Jan2016 Apr2016 Jul2016 Oct2016 Jan2017 Apr2017 Jul2017 Oct2017



RBSP ECT-REPT A & B 1.8 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
"Highly Relativistic" (E~1.8 MeV)
Electron Flux (cm² s sr MeV)⁻¹
Oct2012
Jan2013
Apr2013
Jul2013
Oct2013
Jan2014
Apr2014
Jul2014
Oct2014
Apr2015
Oct2015
Jan2016
Apr2016
Jul2016
Oct2016
Jan2017
Apr2017
Jul2017
Oct2017
RBSP ECT-REPT A & B 4.2 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
"Super Relativistic" (E~4.2 MeV)
Jan2015
Jul2015

Radiation Belt Electron Bump-On-Tail Distribution and Its Origin from Hiss Induced Scattering



[Courtesy of B. Ni, Wuhan University]

2015/03/20 – 03/30 Comparisons

Top: BOT observations

Bottom: BOT simulations

Hiss Induced Scattering 2015/03/20 – 03/30

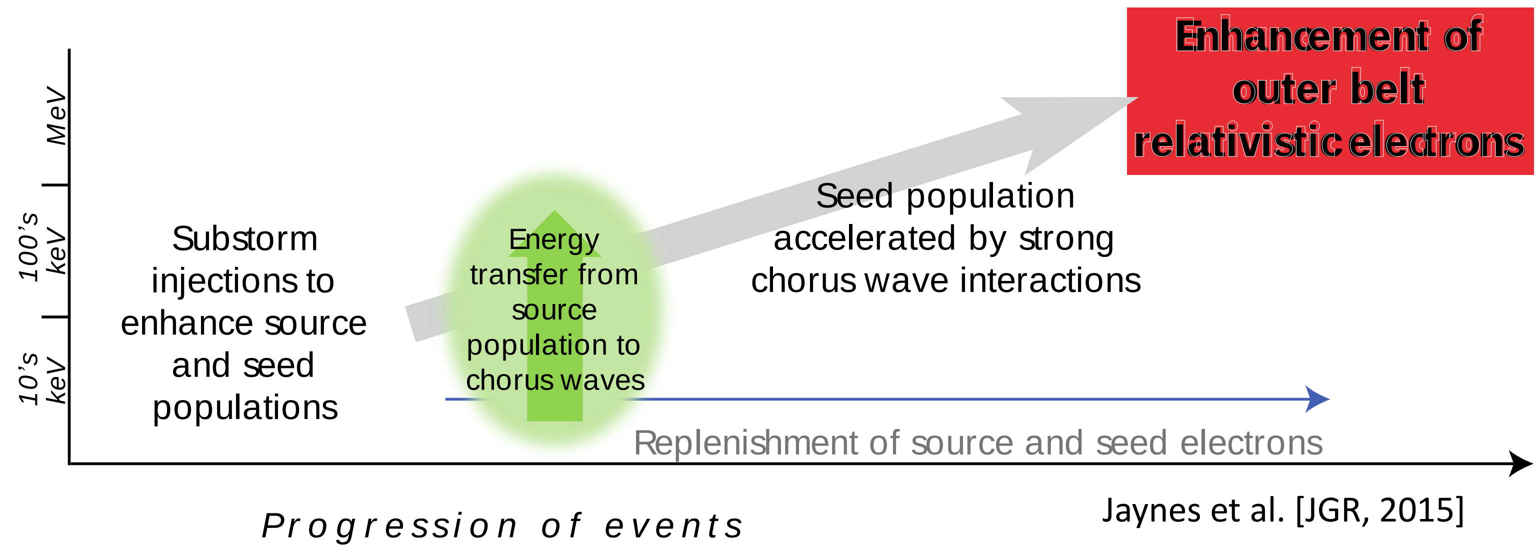
Top: 10-day Hiss wave data

Middle: $\langle D_{\alpha\alpha} \rangle$ at loss cone at three time intervals

Bottom: 2-D plot of $\langle D_{\alpha\alpha} \rangle$ at one time interval

Work led by Hong Zhao and B.Ni

Electron Acceleration Sequence in the Inner Magnetosphere

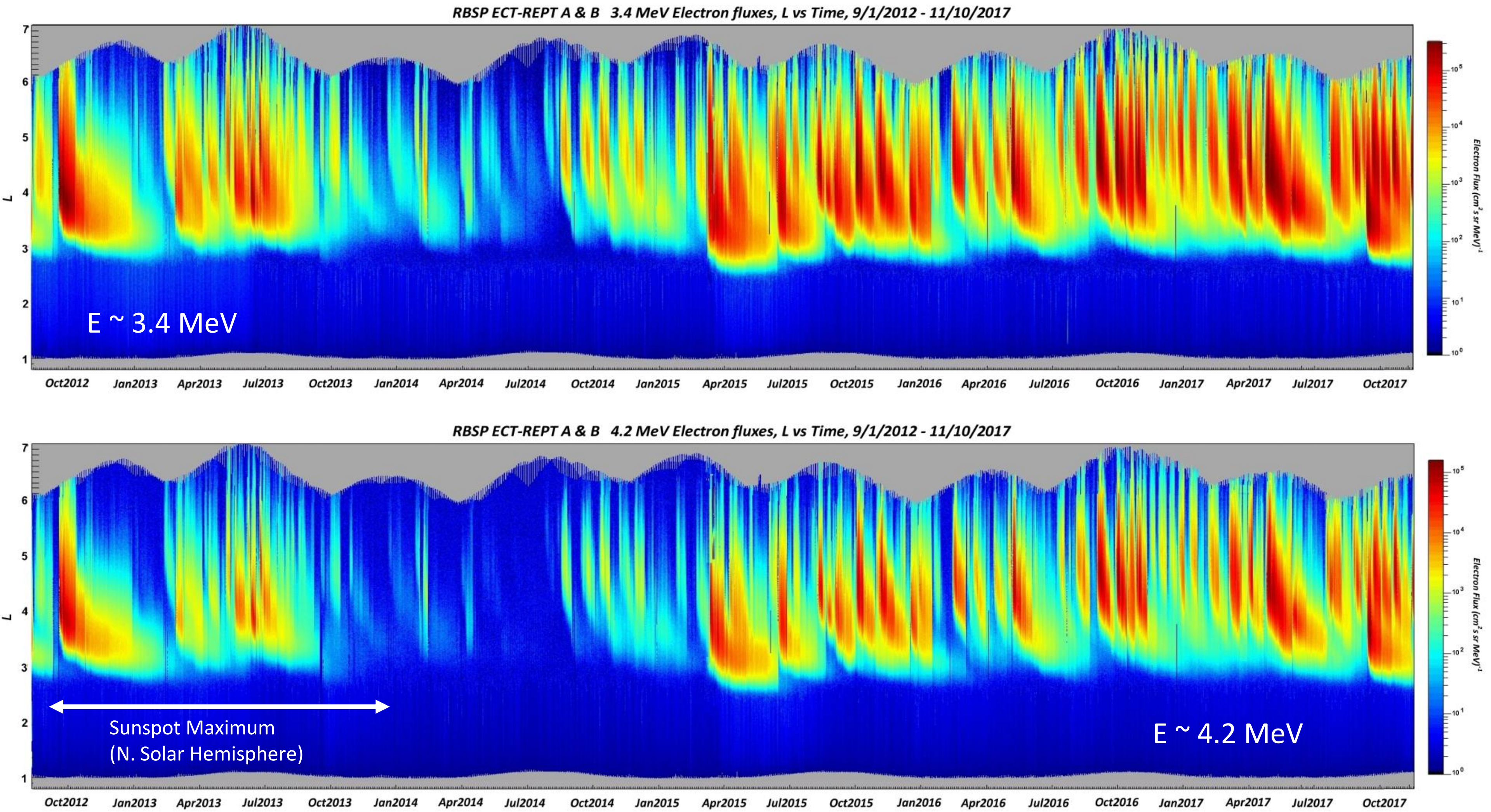


Jaynes et al. [JGR, 2015]

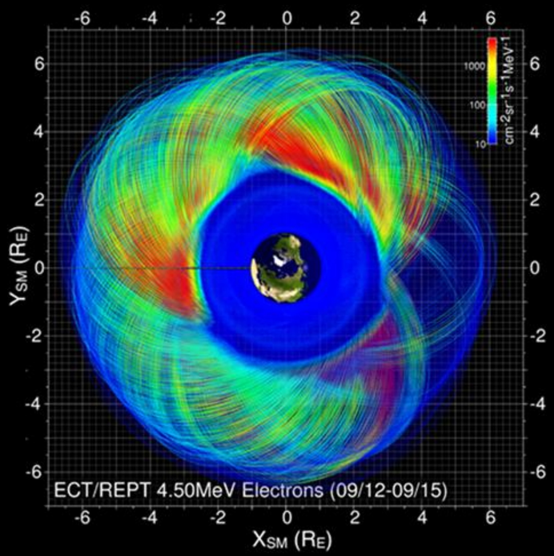
Source: 10's of keV
Seed: 100's of keV
Rad Belt: > 1 MeV

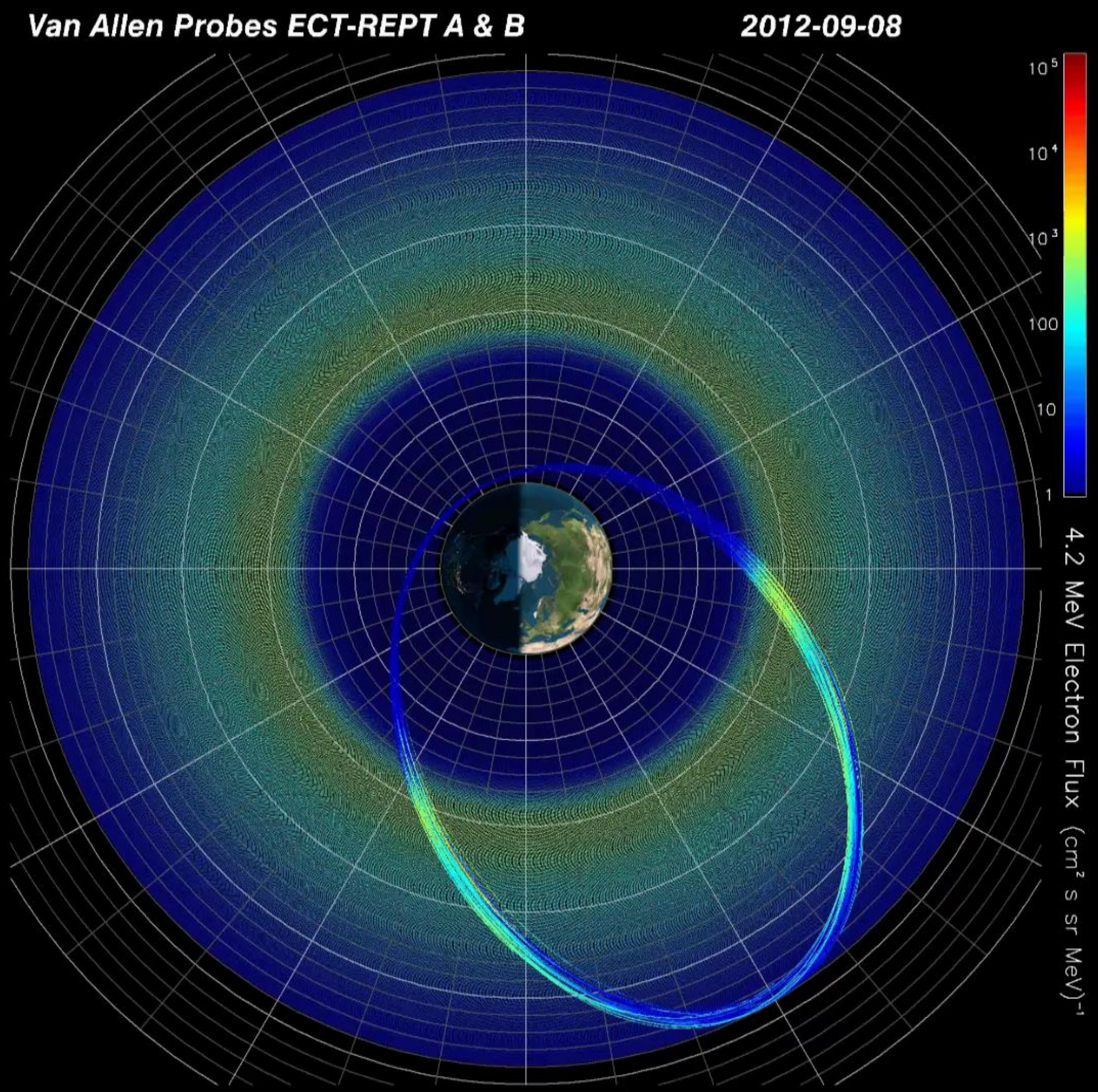
Crucial Role for Magnetopheric Substorms

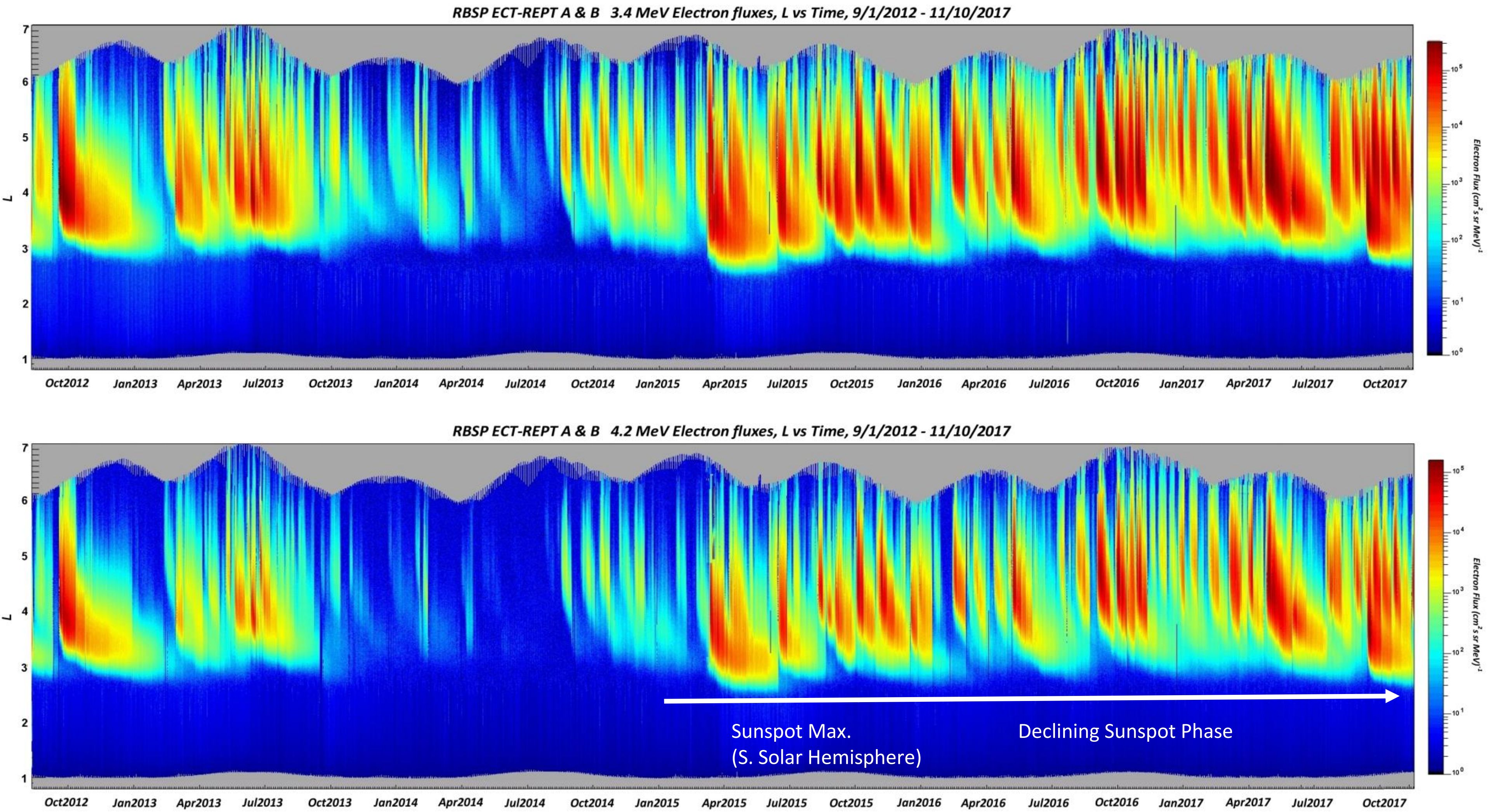
Jaynes et al. (JGR, 2015)


RBSP ECT-REPT A & B 3.4 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
E ~ 3.4 MeV
L
Electron Flux (cm^2 s sr MeV)$^{-1}$
Oct2012
Jan2013
Apr2013
Jul2013
Oct2013
Jan2014
Apr2014
Jul2014
Oct2014
Jan2015
Apr2015
Jul2015
Oct2015
Jan2016
Apr2016
Jul2016
Oct2016
Jan2017
Apr2017
Jul2017
Oct2017
RBSP ECT-REPT A & B 4.2 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
Sunspot Maximum
(N. Solar Hemisphere)
E ~ 4.2 MeV

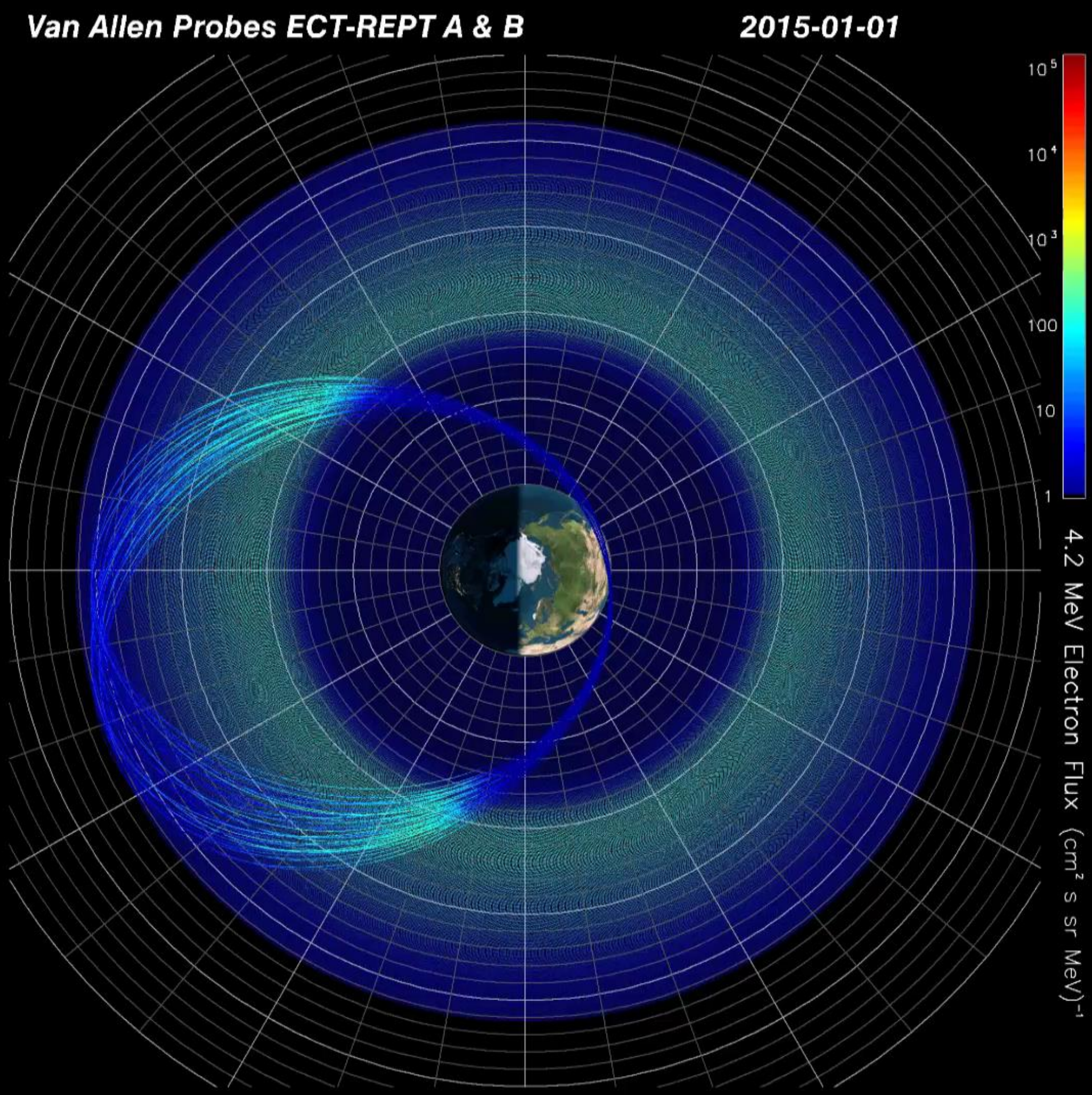
REPT – The Movie

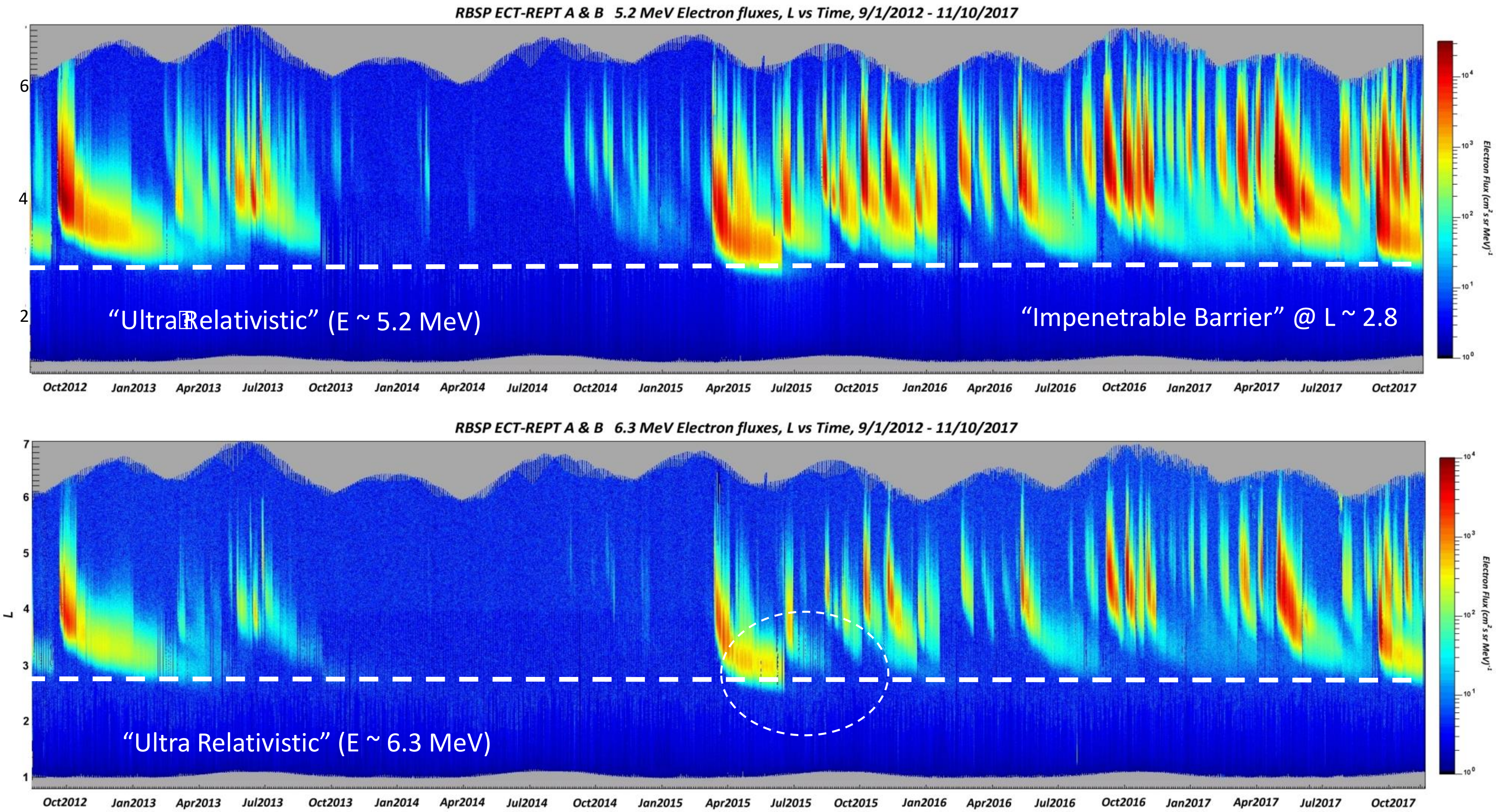


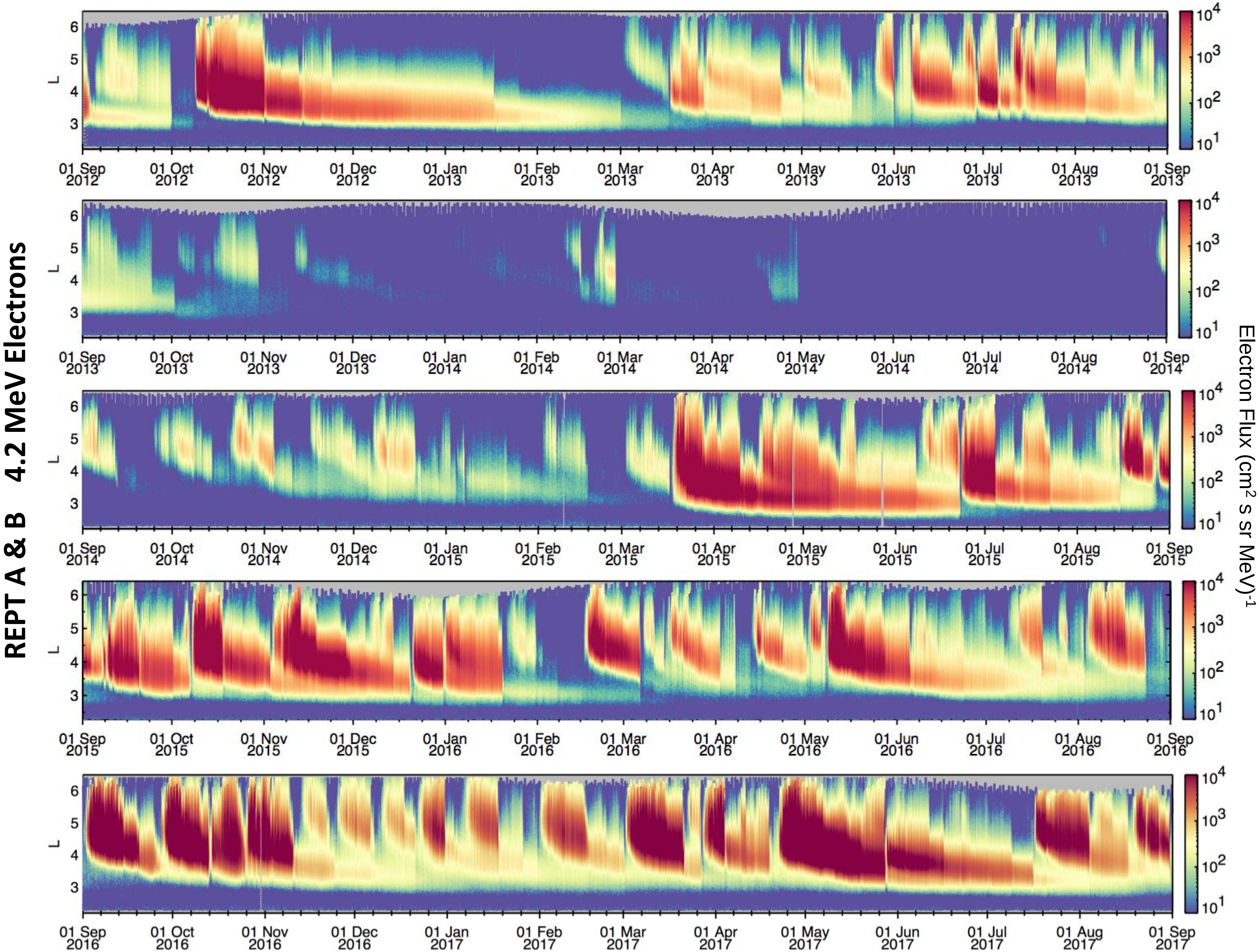



RBSP ECT-REPT A & B 3.4 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
L
Electron Flux (cm² s sr MeV)⁻¹
Oct2012 Jan2013 Apr2013 Jul2013 Oct2013 Jan2014 Apr2014 Jul2014 Oct2014 Jan2015 Apr2015 Jul2015 Oct2015 Jan2016 Apr2016 Jul2016 Oct2016 Jan2017 Apr2017 Jul2017 Oct2017
RBSP ECT-REPT A & B 4.2 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
L
Electron Flux (cm² s sr MeV)⁻¹
Sunspot Max.
(S. Solar Hemisphere)
Declining Sunspot Phase
Oct2012 Jan2013 Apr2013 Jul2013 Oct2013 Jan2014 Apr2014 Jul2014 Oct2014 Jan2015 Apr2015 Jul2015 Oct2015 Jan2016 Apr2016 Jul2016 Oct2016 Jan2017 Apr2017 Jul2017 Oct2017

REPT – 2015 to 2017




RBSP ECT-REPT A & B 5.2 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
"Ultra-Relativistic" (E ~ 5.2 MeV)
"Impenetrable Barrier" @ L ~ 2.8
Electron Flux (cm² s sr MeV)⁻¹
Oct2012 Jan2013 Apr2013 Jul2013 Oct2013 Jan2014 Apr2014 Jul2014 Oct2014 Jan2015 Apr2015 Jul2015 Oct2015 Jan2016 Apr2016 Jul2016 Oct2016 Jan2017 Apr2017 Jul2017 Oct2017
RBSP ECT-REPT A & B 6.3 MeV Electron fluxes, L vs Time, 9/1/2012 - 11/10/2017
L
"Ultra Relativistic" (E ~ 6.3 MeV)
Electron Flux (cm² s sr MeV)⁻¹
Oct2012 Jan2013 Apr2013 Jul2013 Oct2013 Jan2014 Apr2014 Jul2014 Oct2014 Jan2015 Apr2015 Jul2015 Oct2015 Jan2016 Apr2016 Jul2016 Oct2016 Jan2017 Apr2017 Jul2017 Oct2017


REPT A & B   4.2 MeV Electrons
Electron Flux (cm^2 s sr MeV)$^{-1}$
L
6
5
4
3
10^4
10^3
10^2
10^1
01 Sep 2012
01 Oct 2012
01 Nov 2012
01 Dec 2012
01 Jan 2013
01 Feb 2013
01 Mar 2013
01 Apr 2013
01 May 2013
01 Jun 2013
01 Jul 2013
01 Aug 2013
01 Sep 2013
01 Oct 2013
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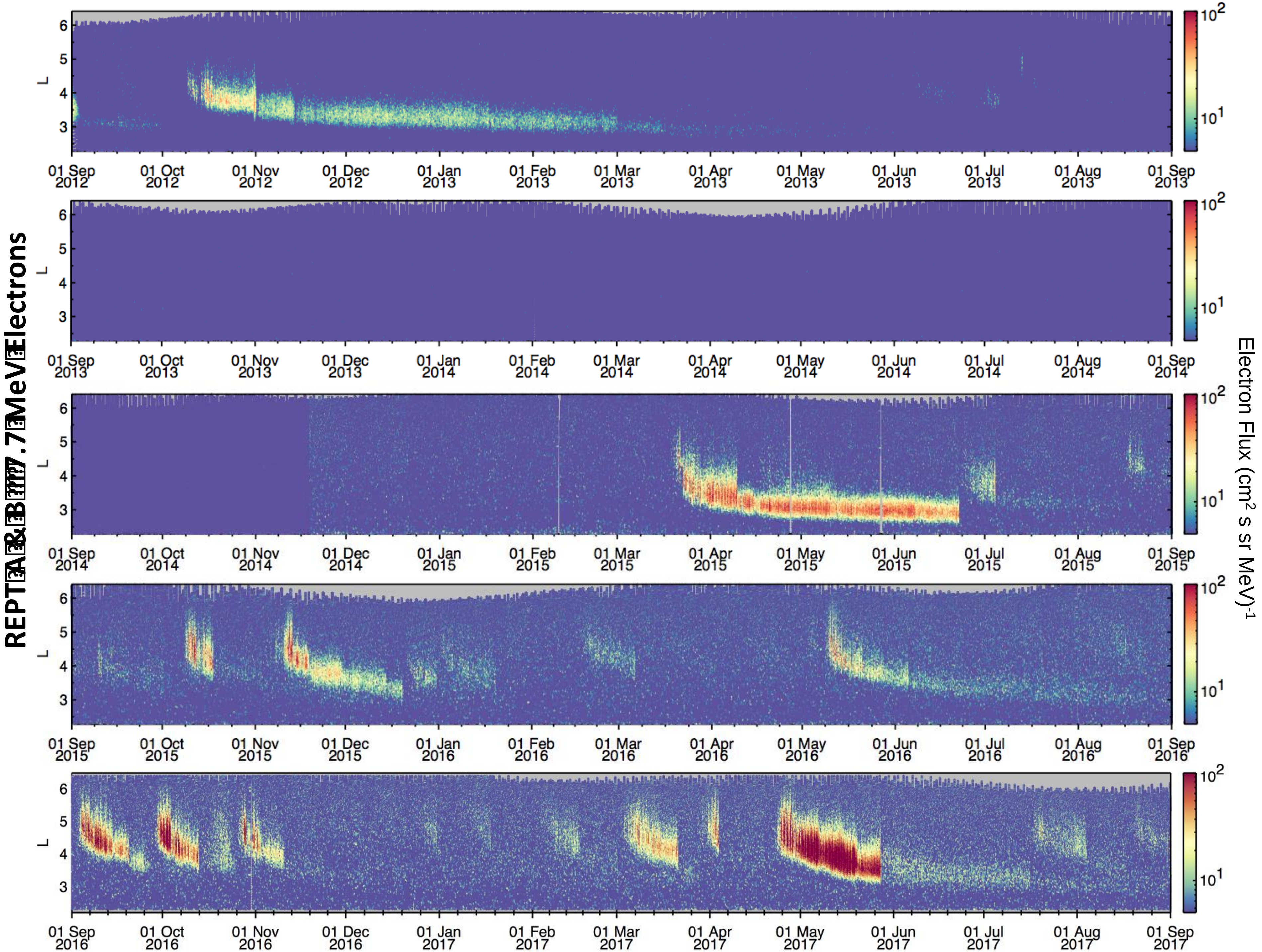
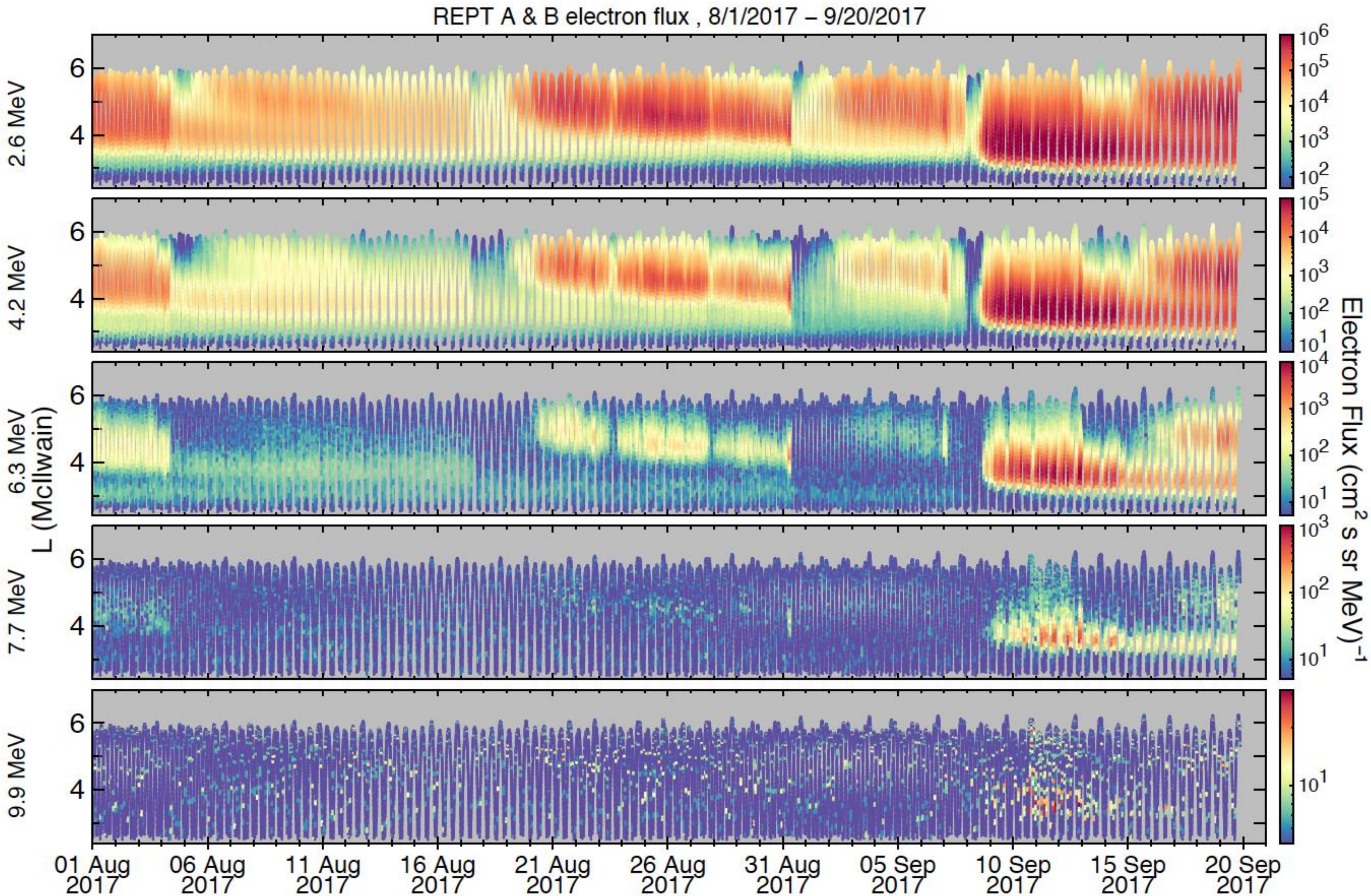
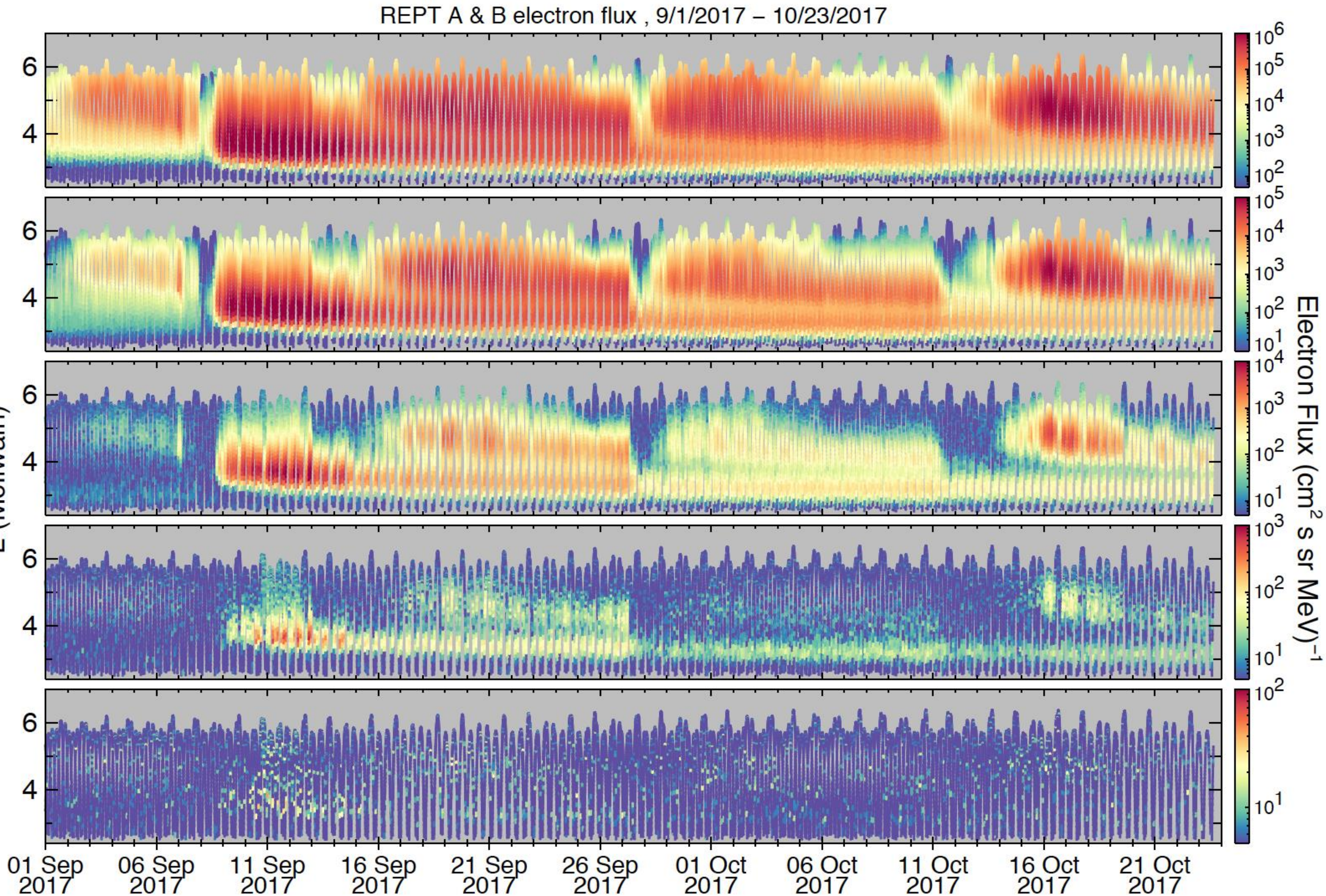
01 Jul 2017
01 Aug 2017
01 Sep 2017



Electron Flux (cm^2 s sr MeV)$^{-1}$
L
01 Sep 2012
01 Sep 2013
01 Sep 2014
01 Sep 2015
01 Sep 2016
01 Sep 2017



REPT A & B electron flux , 8/1/2017 – 9/20/2017
2.6 MeV
4.2 MeV
6.3 MeV
7.7 MeV
9.9 MeV
L (McIlwain)
Electron Flux (cm^2 s sr MeV)^-1
01 Aug 2017
06 Aug 2017
11 Aug 2017
16 Aug 2017
21 Aug 2017
26 Aug 2017
31 Aug 2017
05 Sep 2017
10 Sep 2017
15 Sep 2017
20 Sep 2017



REPT A & B electron flux , 9/1/2017 – 10/23/2017
2.6 MeV
4.2 MeV
6.3 MeV
7.7 MeV
9.9 MeV
L (McIlwain)
Electron Flux (cm^2 s sr MeV)$^{-1}$
01 Sep 2017
06 Sep 2017
11 Sep 2017
16 Sep 2017
21 Sep 2017
26 Sep 2017
01 Oct 2017
06 Oct 2017
11 Oct 2017
16 Oct 2017
21 Oct 2017

Conclusions

- Results from the Van Allen Probes mission demonstrate remarkable, previously unobserved features about radiation belt structure, acceleration, transport, and rapid loss.

- Long-term observations reveal distinctive behavior: Multi-belt structure and impenetrable barrier to inward penetration of ultra-relativistic electrons at L ~2.8: No cases of high fluxes of E > 1.5 MeV electrons inside of L ~ 2.5 in over five years of measurements.

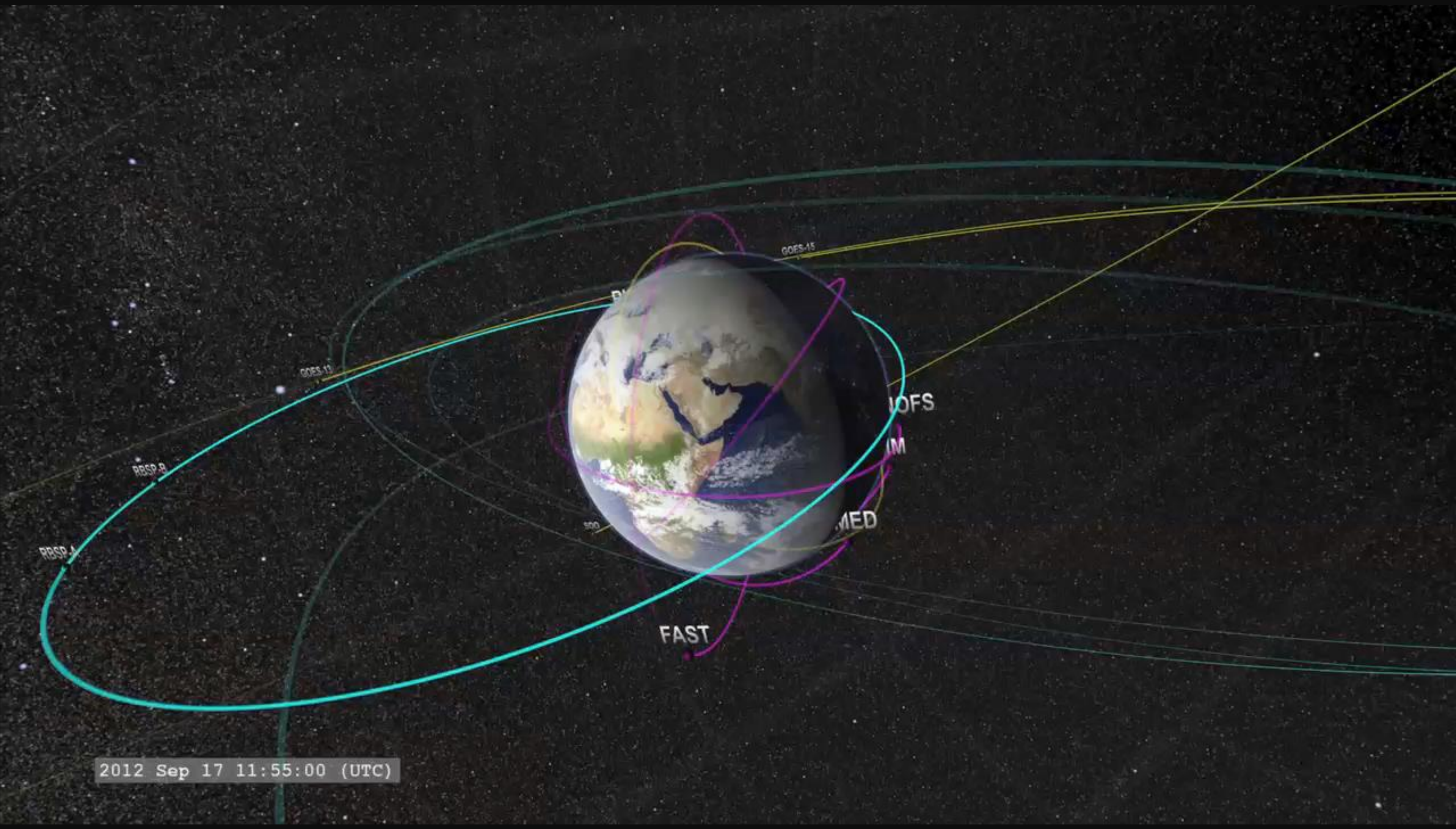
- Van Allen Probes data clearly show there are extended periods of gradual change in the (super- and ultra-) relativistic electron populations punctuated by abrupt losses and rapid subsequent acceleration.

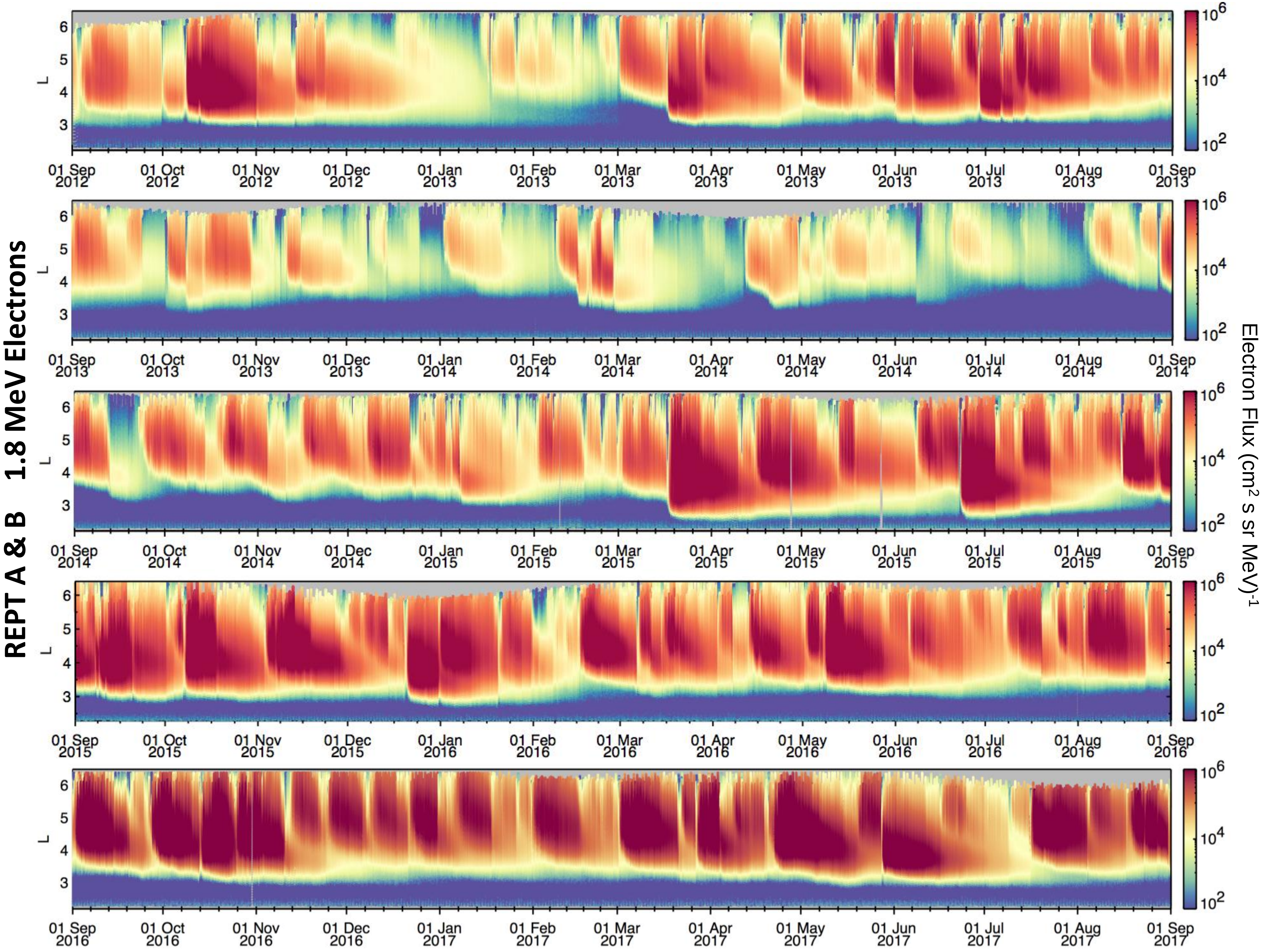
- REPT instruments show that ultra-relativistic electrons were low around 2014 sunspot max and have now been increasing dramatically due to strong solar wind streams in declining sunspot phase (southern solar hemisphere).

Questions?

The Geospace Observatory Fleet

[redacted]





REPT A & B 1.8 MeV Electrons
Electron Flux (cm^2 s sr MeV)$^{-1}$
L
10^2
10^4
10^6
01 Sep 2012
01 Oct 2012
01 Nov 2012
01 Dec 2012
01 Jan 2013
01 Feb 2013
01 Mar 2013
01 Apr 2013
01 May 2013
01 Jun 2013
01 Jul 2013
01 Aug 2013
01 Sep 2013
01 Oct 2013
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