Διαστημικό Περιβάλλον

Space Enviroment

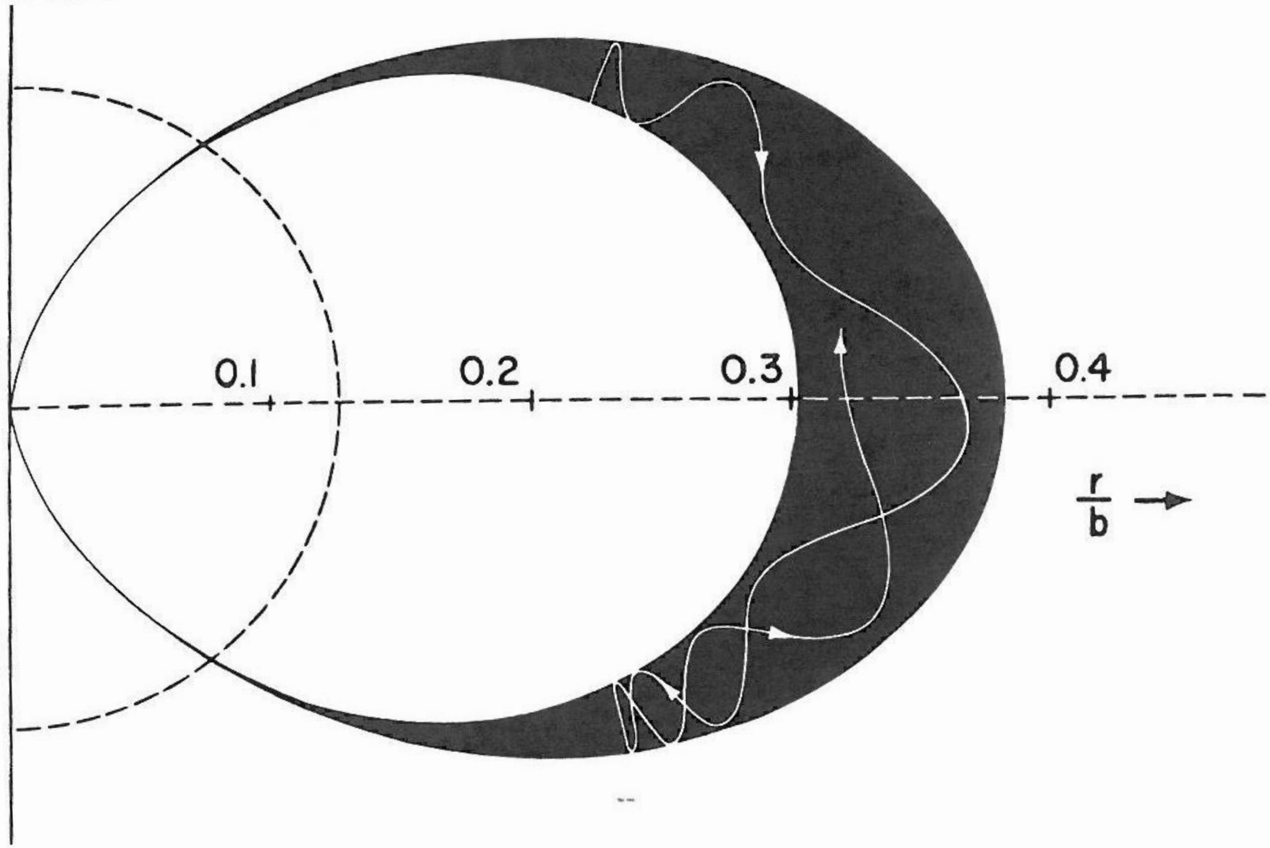
Space Environment
Lecture 10

Radiation belts
Space weather

Prior to 1958 scientists were aware that ions and electrons **could be trapped** by the Earth's magnetic field, but **not** that such trapped particles **actually existed**.

L
SEP

Van Allen's favorite figure in conceptualizing particle trapping in a dipole field (Stormer, **1907**)



Courtesy of Archives des Sciences, Muséum d'Histoire Naturelle, Geneva.

Fig. 4. A diagram, after Størmer [1907], illustrating the meridian projection of the spatial trajectory of an energetic, electrically charged particle in the field of a magnetic dipole and the boundaries of the theoretically rigorous trapping region. The quantity r/b *is the dimensionless ratio of the radial distance to a parameter of Størmer's theory of this motion. The earth is represented by the dashed semicircle.*

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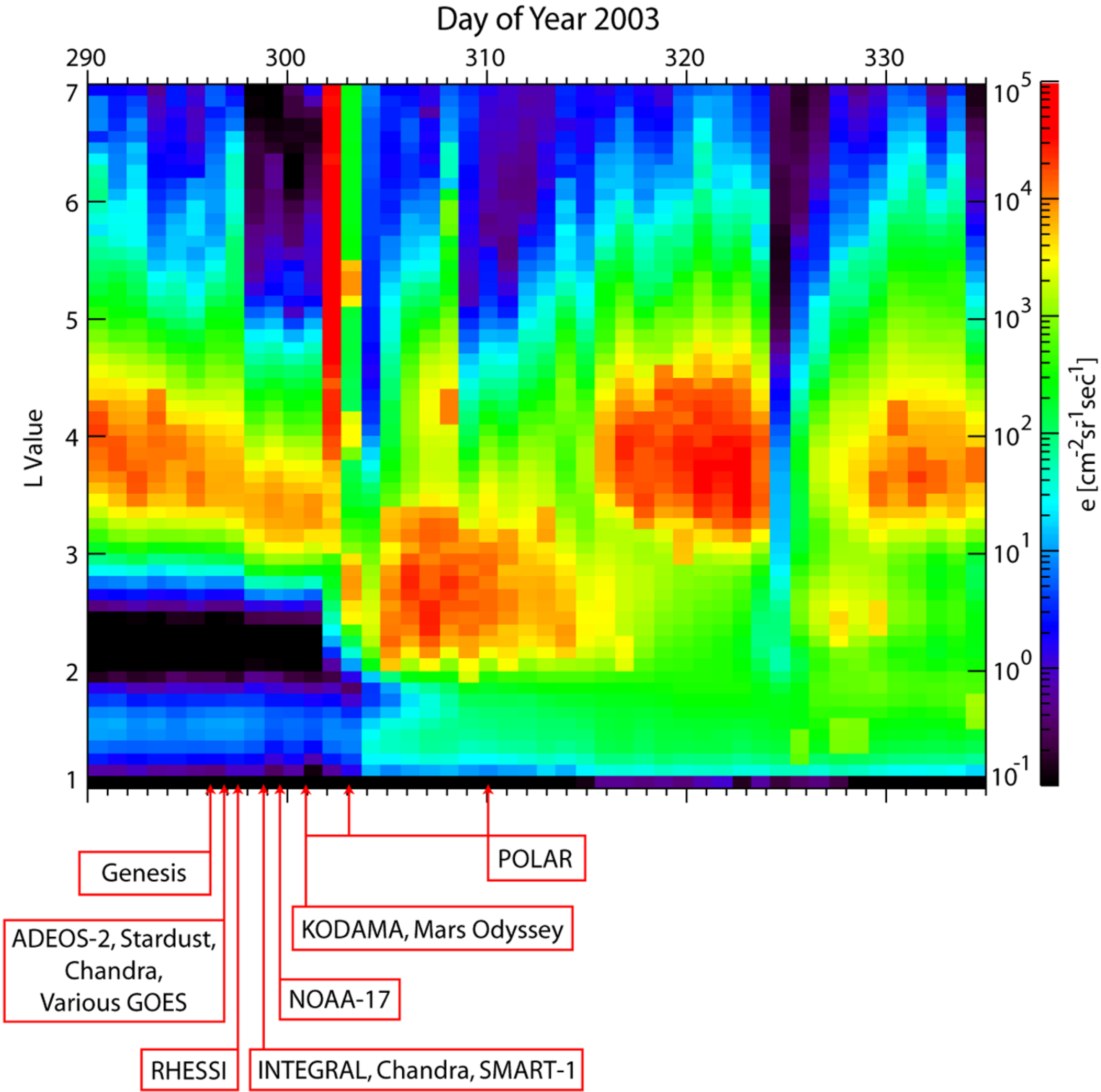
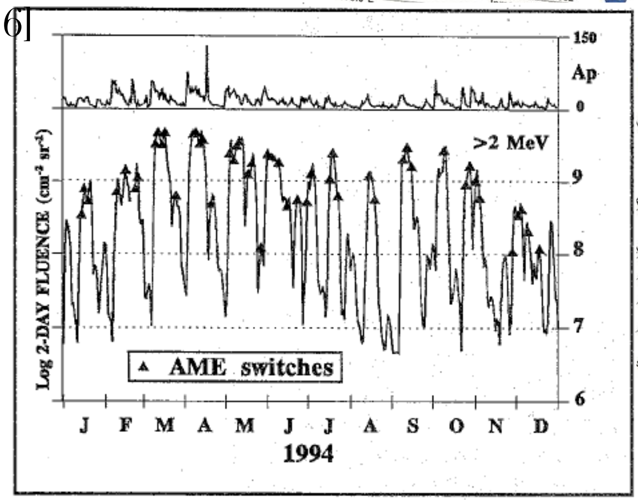
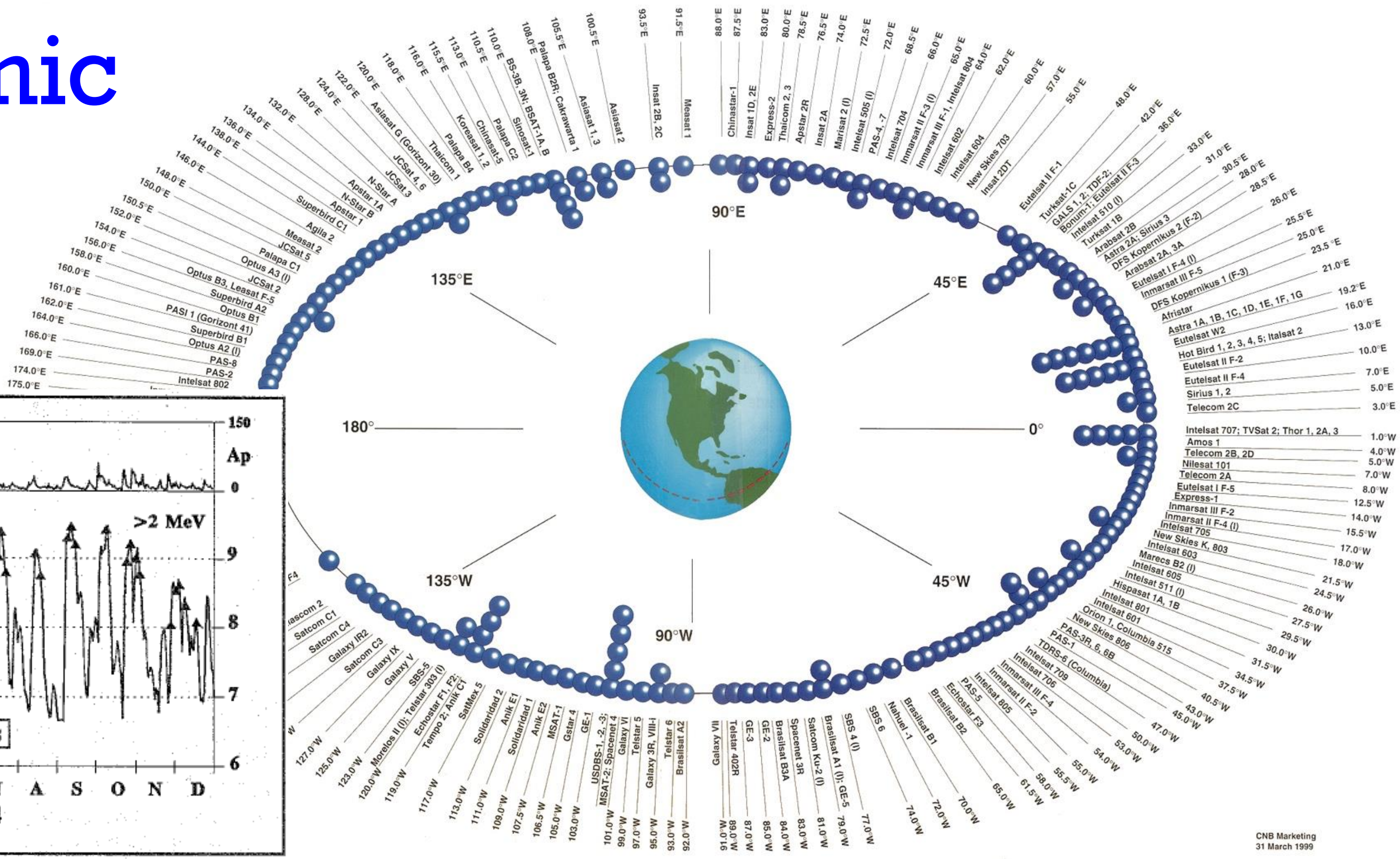
How these electrons come to be energized is the main theme of radiation belt research. The acceleration of charged particles is also of cosmic significance.


Day of Year 2003
290
300
310
320
330
L Value
7
6
5
4
3
2
1
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
e [$cm^{-2}sr^{-1}sec^{-1}$]
Genesis
ADEOS-2, Stardust, Chandra, Various GOES
RHESSI
INTEGRAL, Chandra, SMART-1
NOAA-17
KODAMA, Mars Odyssey
POLAR

Economic Impact

Wrenn & Smith [1996]





- MeV el: internal charging; 0.1-100keV: surface charging; MeV ions: SEU
- ¾ satellite designers said that internal charging is now their most serious problem, 2001 ESA study [Horne, 2001]
- Examples: Intelsat K, Anik E1 & E2, Telstar 401, Galaxy IV
- Costs: ~$200M build, ~$100M launch to GEO, 3%-5%/yr to insure

Locations of Operational Space Environment Hazards

Single Event Effects (SEEs)

- inner (proton) belt and higher L shells with solar particle event
- quiet-times from galactic cosmic rays

Internal charging and resulting **electrostatic discharges (ESD)**

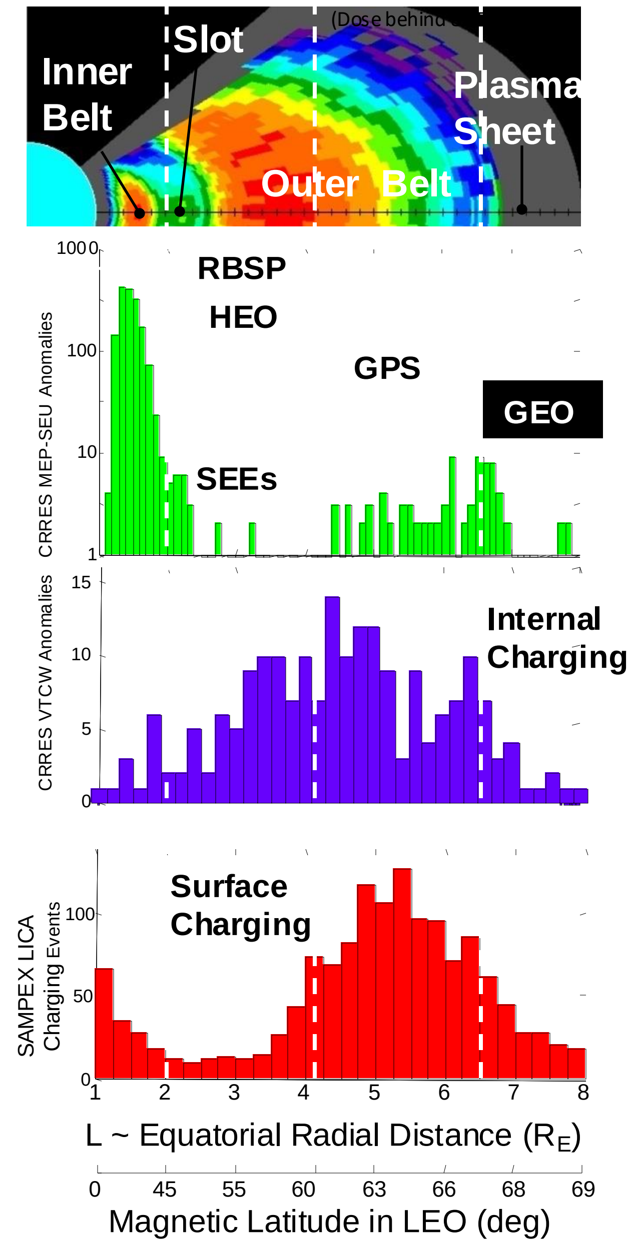
- broad range of L values
- corresponding to the outer belt
- where penetrating electron fluxes are high

Surface charging and resulting **ESD**

- spacecraft or surface potential elevated
- 2000-0800 local time in the plasma sheet
- regions of intense field-aligned currents
- observed, but not explained, at very low L

Total ionizing dose

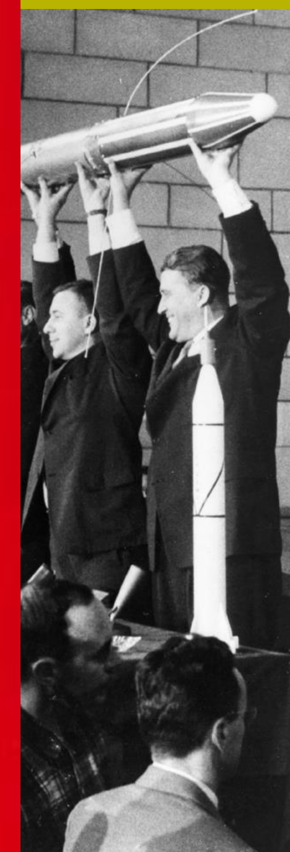
- electronics and solar panels degrade over time



Janet Green, 2013

Brief hi

Trapped p discovery
in space – orer!



(*Reprinted from* JET PROPULSION, *September, 1958*)

Observation of High Intensity Radiation by Satellites 1958 Alpha and Gamma[1]

J. A. VAN ALLEN,[2] G. H. LUDWIG,[3] E. C. RAY[4] and C. E. McILWAIN[5]
State University of Iowa, Iowa City, Iowa

Introduction

THIS is a preliminary report of results obtained concerning radiation intensities measured with a single geiger tube carried by the artificial earth satellites 1958 α and 1958 γ.[6]

The counting rate of the counter in 1958 α was transmitted continuously, and the data were recorded only when the satellite was quite near one of the 16 receiving stations distributed over the earth.

The data collected by 1958 γ were also telemetered continuously. In addition, a small magnetic tape recorder stored the data obtained during each entire orbit. Then, as the satellite passed near one of the receiving stations, a radio command from the ground caused these data to be read out.

A preliminary study of the data obtained from 1958 α and several interrogations of 1958 γ has been carried out, with the following results.

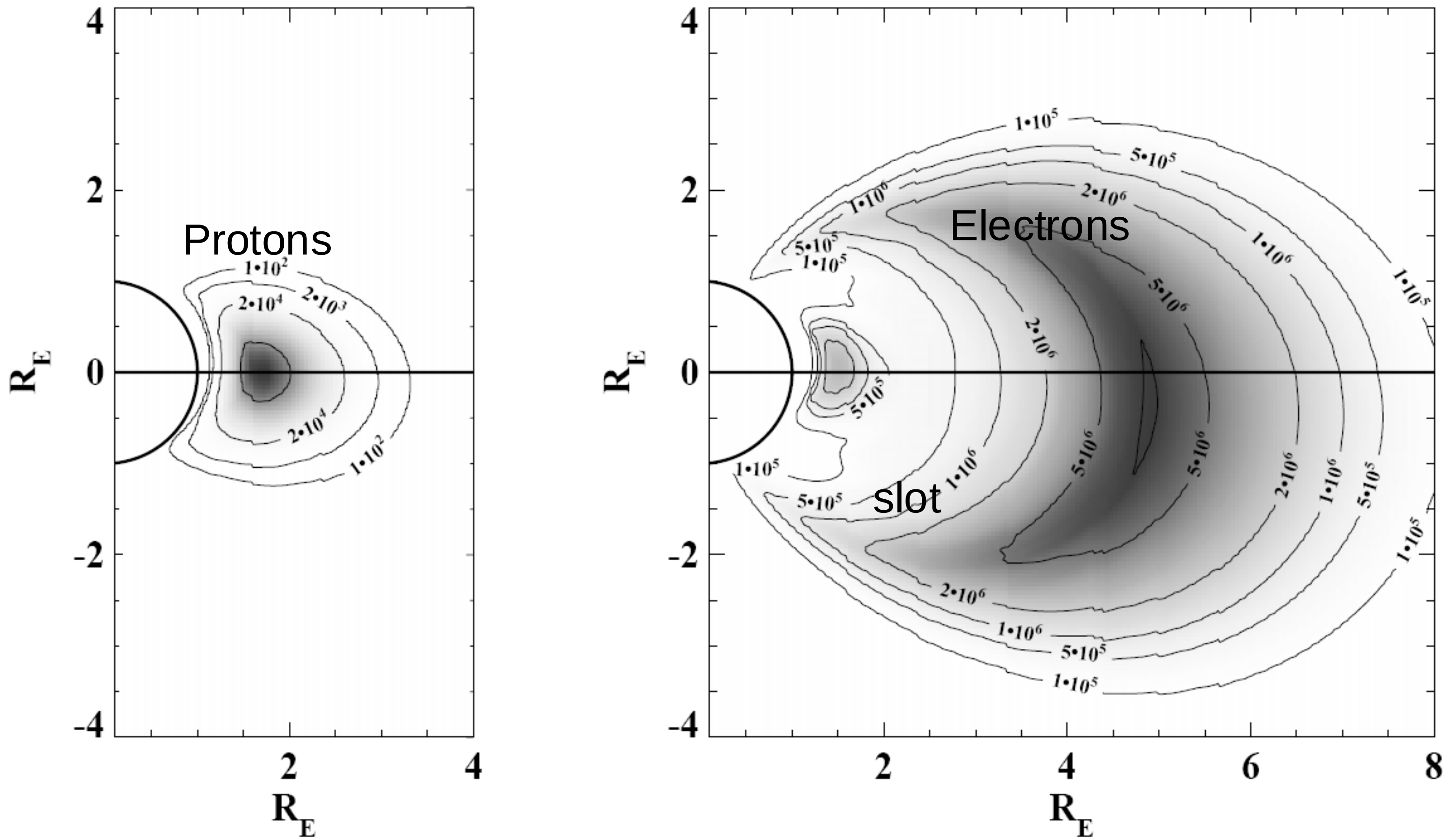
Reasonable cosmic ray counting rates have been obtained

storms. In addition, a rough calculation suggests that the radiation may be sufficiently intense to contribute important heating to the upper atmosphere. It will be important to investigate the amount of atmospheric ionization, light and radio noise which would be produced, under various assumptions as to the nature of the radiation.

1 Instrumentation for 1958 α and 1958 γ

The instrumentation for 1958 α consisted essentially of a single Geiger Mueller tube, a scaling circuit for reducing the number of pulses to be worked with, and telemetry systems for transmitting the scaler output to the ground receiving stations. The system contained in 1958 γ was identical, with the addition of a miniature tape recorder for storing the data for the duration of each orbit and a command system to cause the

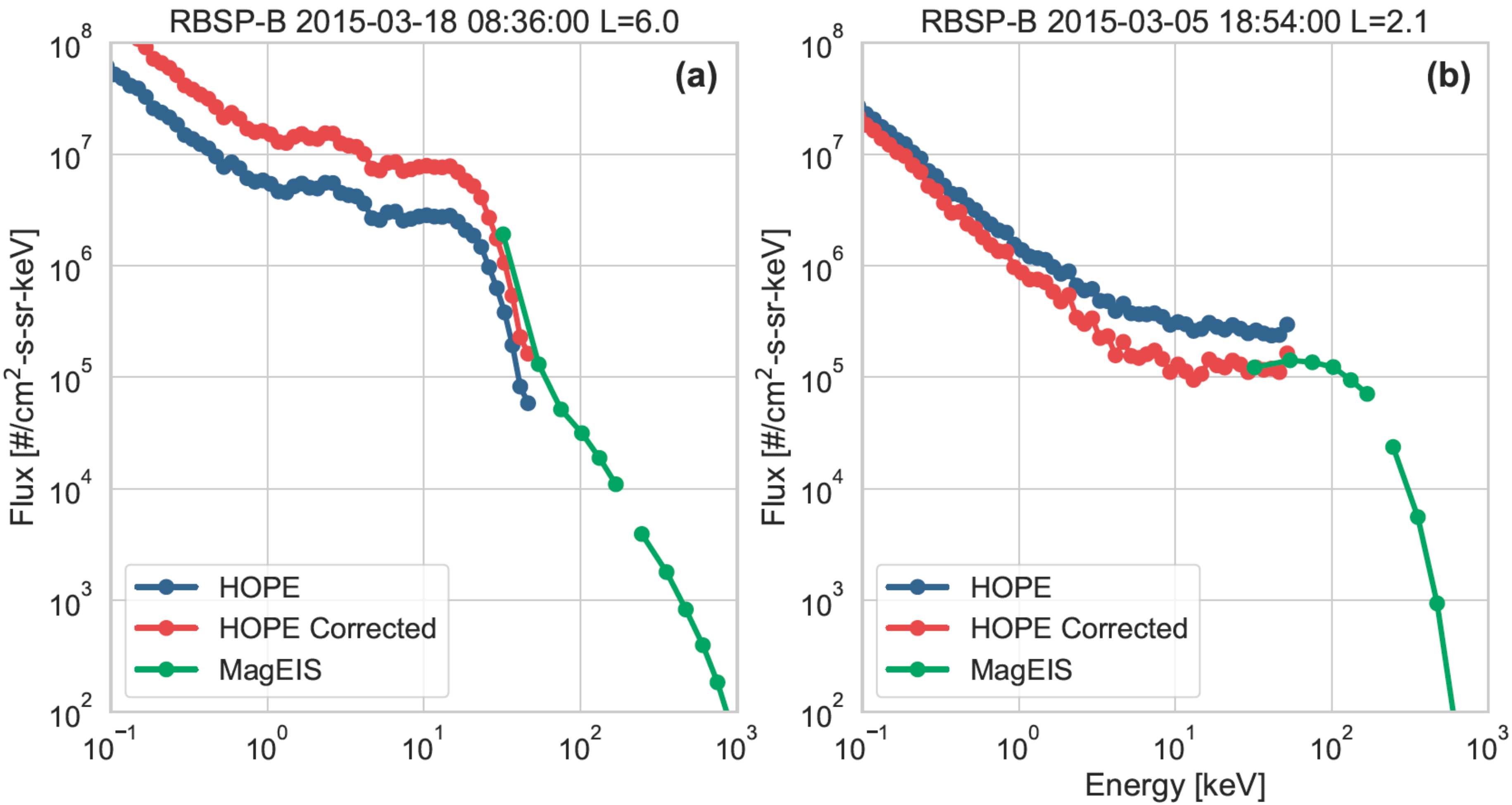
Radiation Belts: Inner and Outer



$1.2 < L < 2.5$ (highly energetic H^+, energetic e^-)

$2 < L < 3$ (minimum of high-energy e^-)

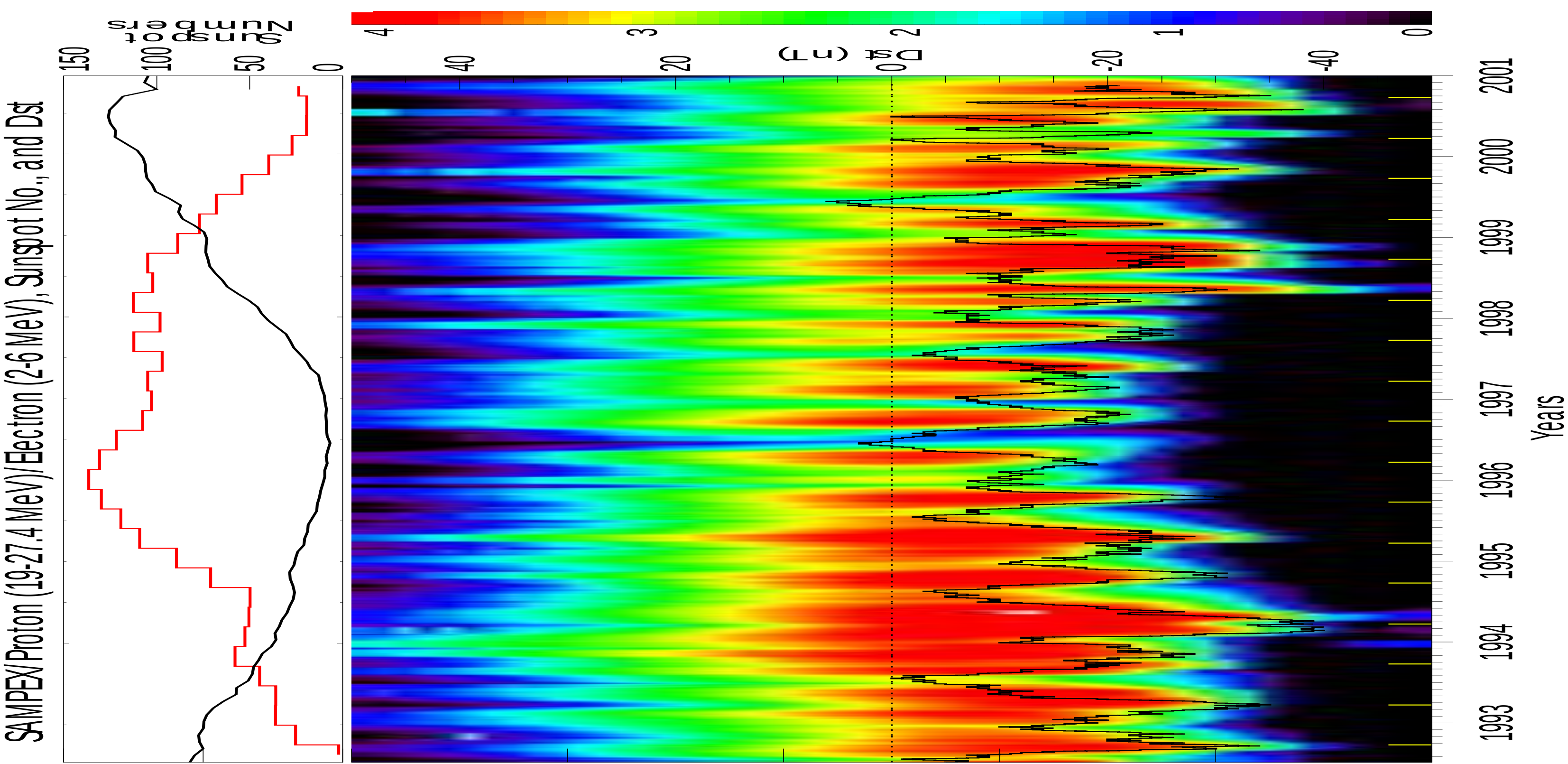
$3 < L < 7$ (energetic H^+, highly energetic e^-)

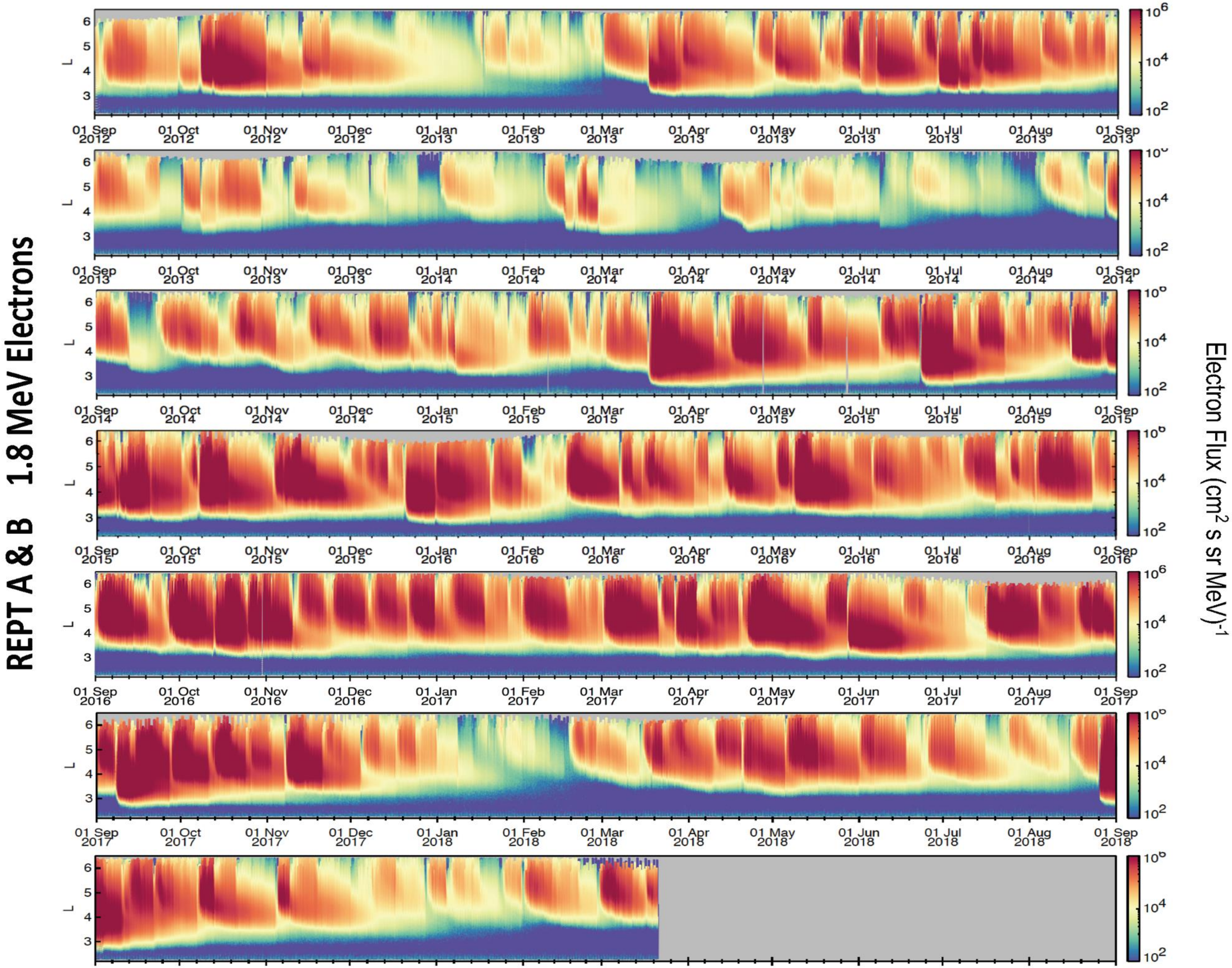


RBSP-B 2015-03-18 08:36:00 L=6.0
(a)
Flux [#/cm^2-s-sr-keV]
HOPE
HOPE Corrected
MagEIS
RBSP-B 2015-03-05 18:54:00 L=2.1
(b)
Flux [#/cm^2-s-sr-keV]
HOPE
HOPE Corrected
MagEIS
Energy [keV]

Flux variability in the radiation belts

- Solar cycle: years / Solar rotation: 27 days
- Storm recovery: days / Storm main phase: hours
- SSC: minutes




REPT A & B 1.8 MeV Electrons
Electron Flux (cm2 s sr MeV)-1
L
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
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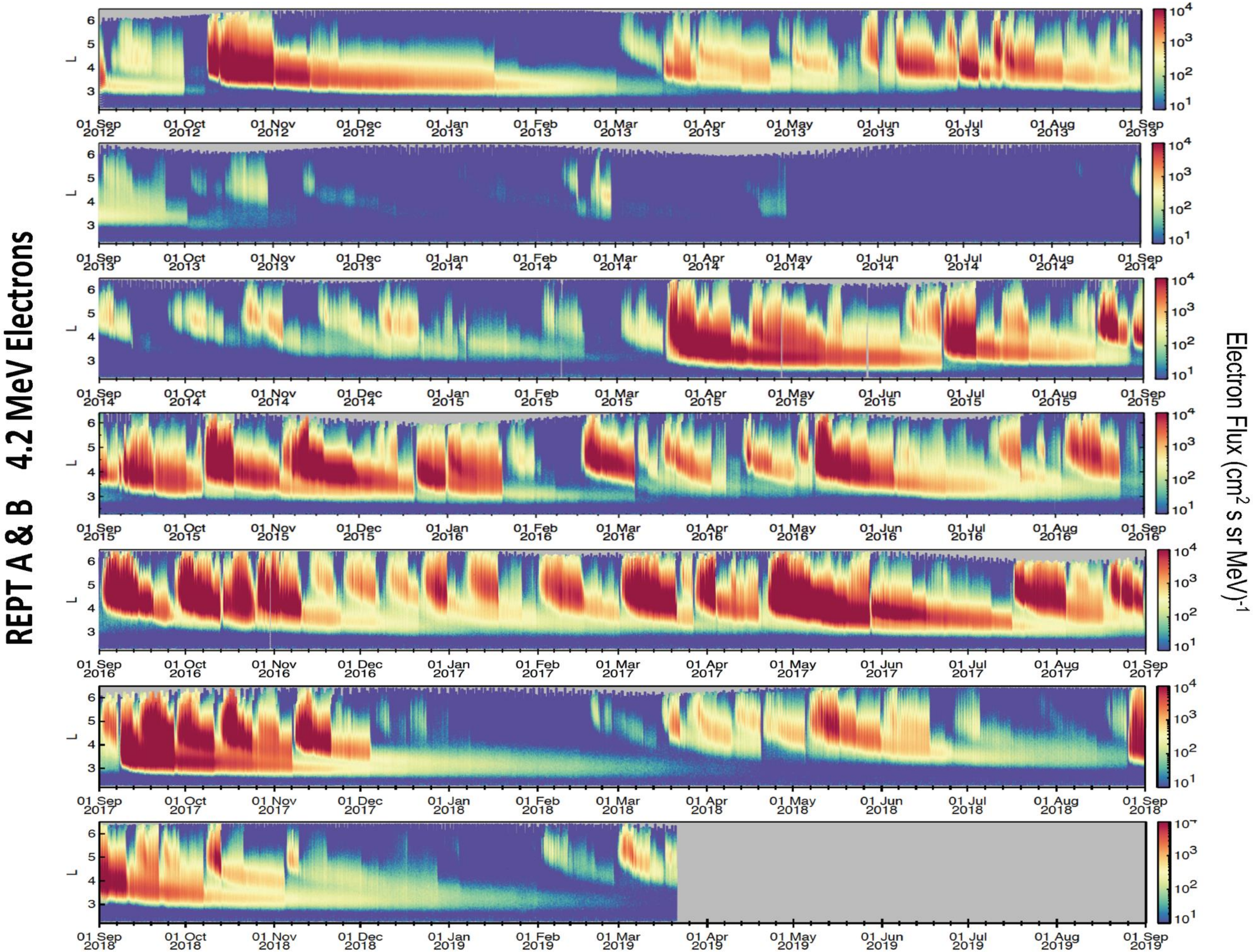
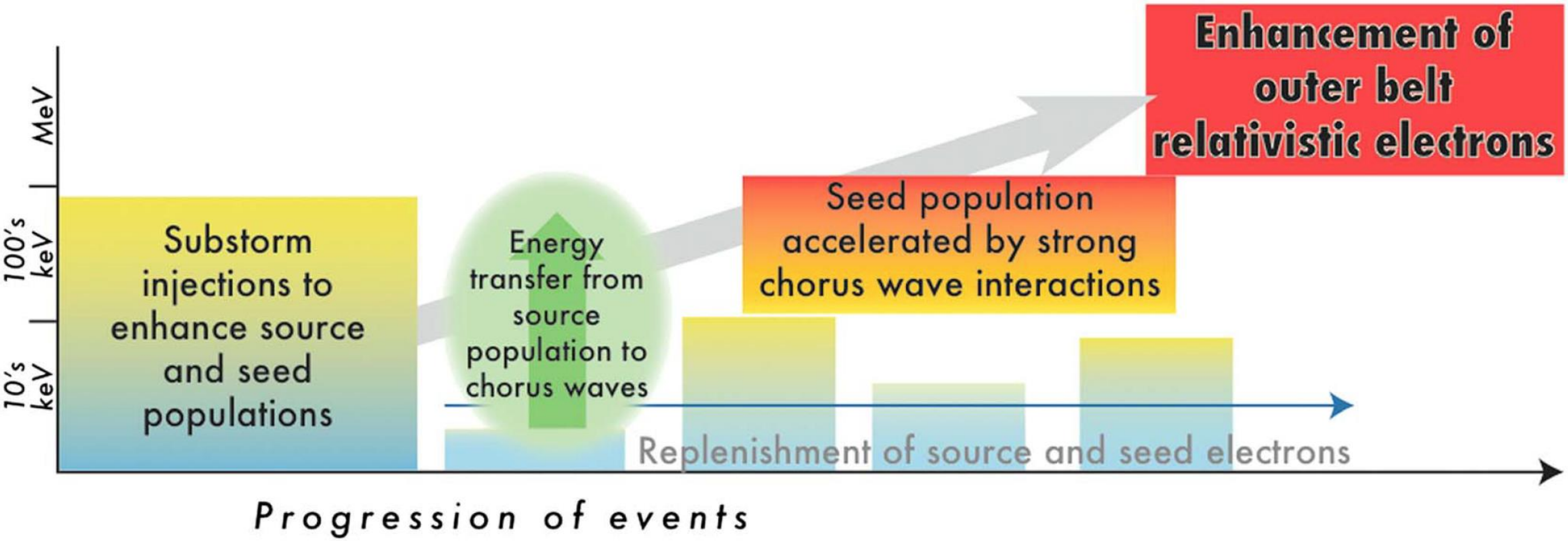
01 Sep 2018


REPT A & B 4.2 MeV Electrons
Electron Flux (cm² s sr MeV)⁻¹
L

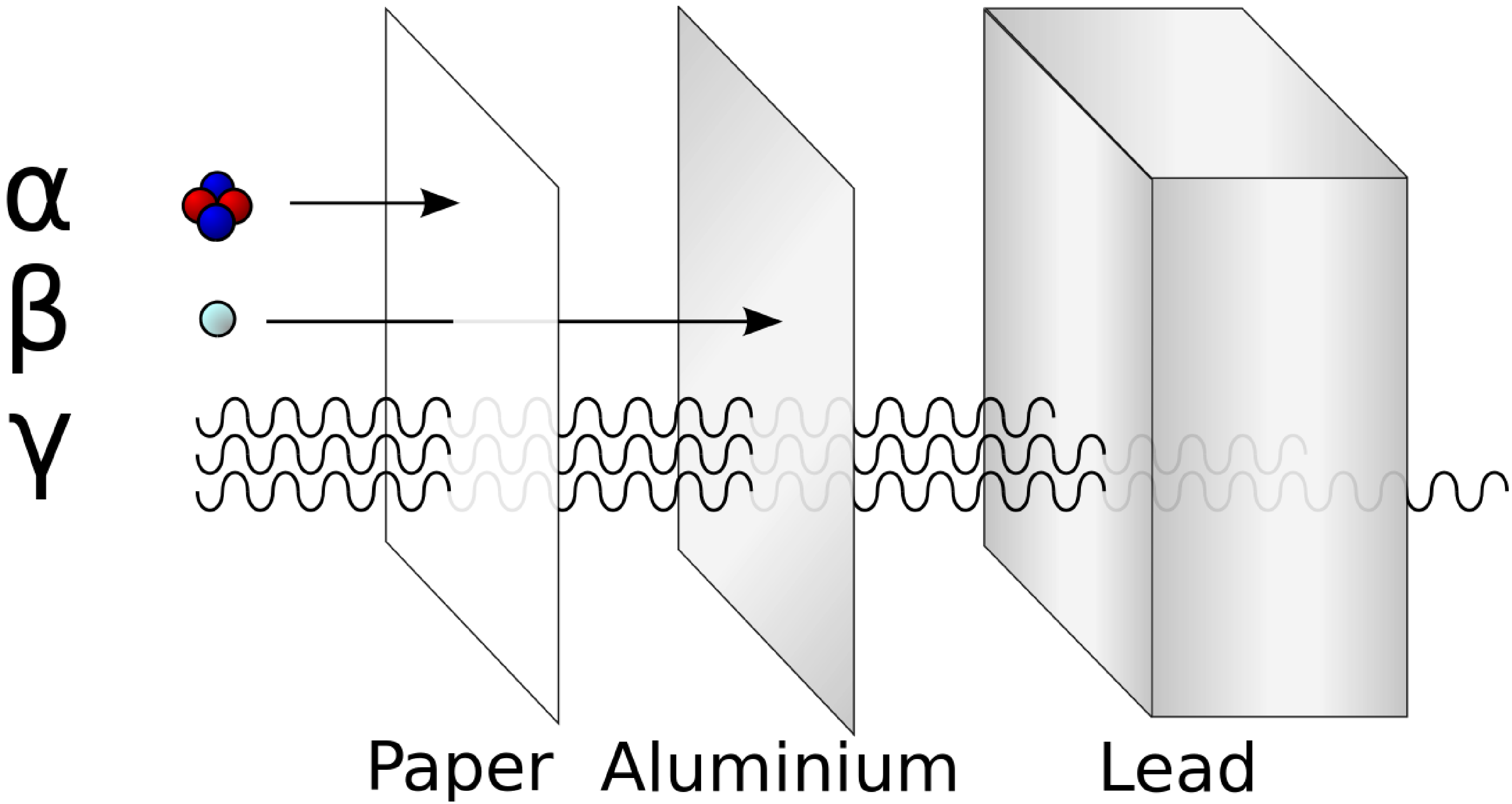


Enhancement of outer belt relativistic electrons
Seed population accelerated by strong chorus wave interactions
Substorm injections to enhance source and seed populations
Energy transfer from source population to chorus waves
Replenishment of source and seed electrons
MeV
100's keV
10's keV
Progression of events

WHAT IS RADIATION?

- As an energetic particle passes through matter it will create atomic displacements and/or ionize atoms in the material.
- As a result the material properties will be altered.
- Radiation can be thought of as anything that deposits energy in a material.
  - Charged particles (electrons, protons)
  - Uncharged particles (neutrons)
  - Photons (gamma rays, x-rays)

Penetrating radiation



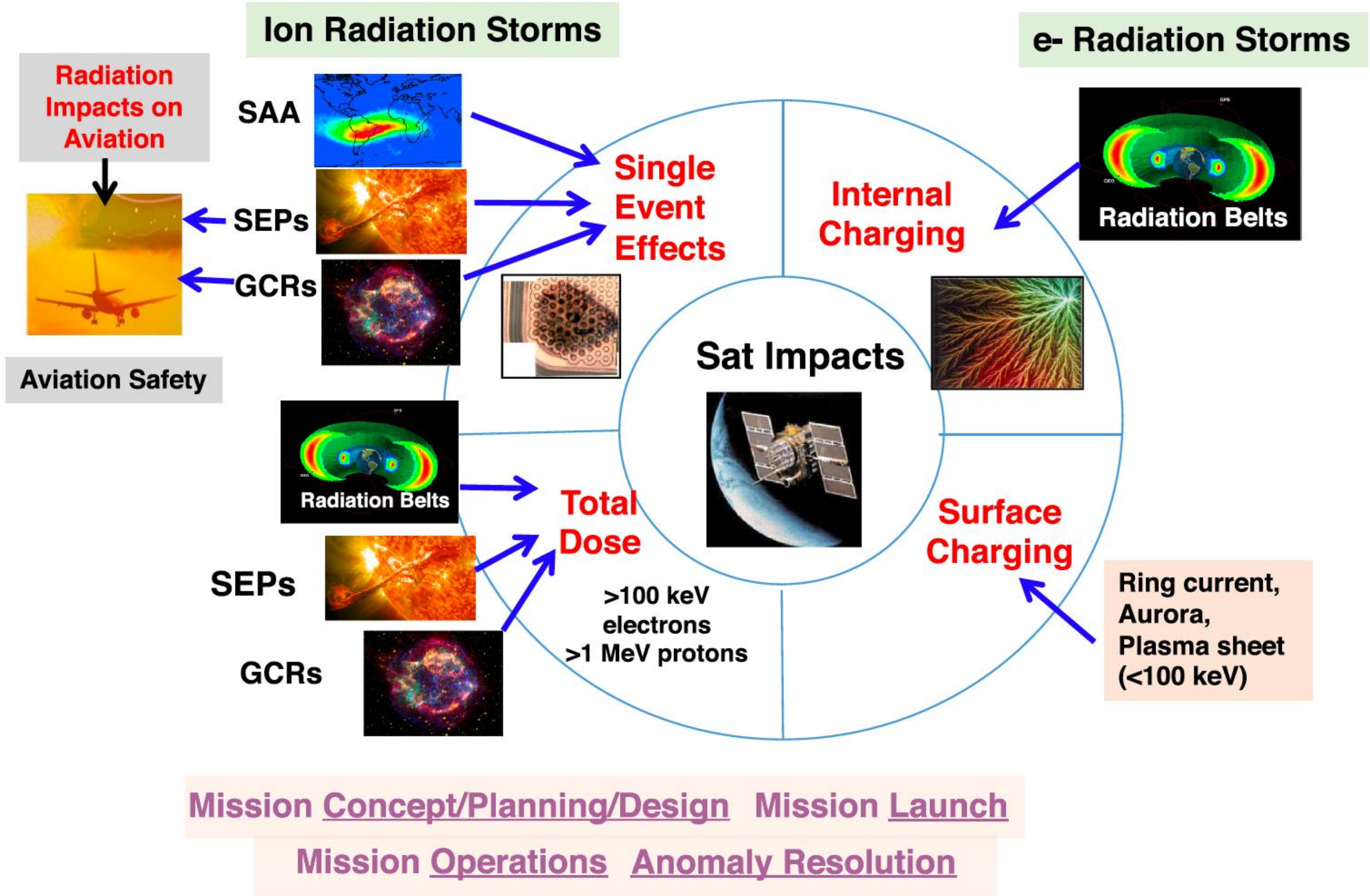


Figure 2. Space radiation and plasma impacts and their sources.

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