Earth radiation environment on LEO orbits and its variability

Szymon Gburek

Seminarium IA Uwr
13 04 2015

Outline

- Low Earth orbits - LEO

- Constituents of Earth radiation environment at LEO

- Earth radiation environment Variability

- Instruments

Main constituents of Earth radiation environment at LEO

- Cosmic rays
- Trapped radiation

Cosmic rays

- Solar Cosmic Rays (SCRs)

Also called Solar Energetic Particles (SEPs)

Often considered as separate component of Earth radiation environment

- Galactic Cosmic Rays (GCRs)

- Anomalous cosmic rays (ACRs)

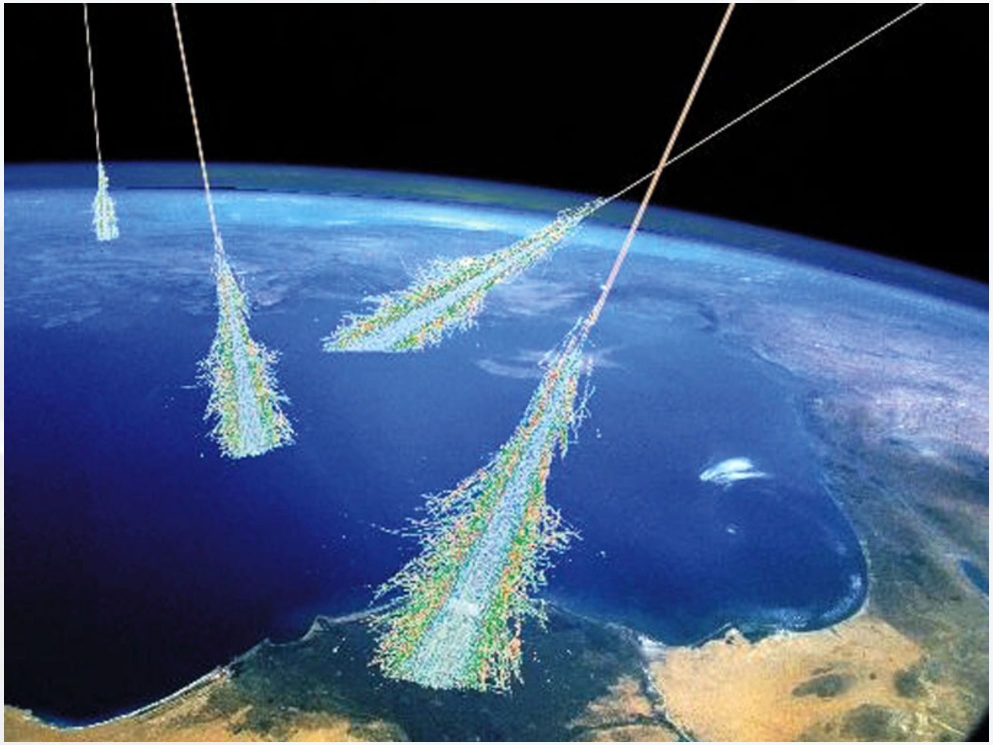
Cosmic rays detection methods

- Direct

Balloons

Rockets

Spacecraft mission



- Indirect

Ground experiments

Detection of secondary particels

Discovered in 1912 by Victor Hess in a balloon experiment.

Solar Cosmic Rays (SCRs)

- Origin – accelerated in solar flares / driven by coronal mass ejections CMEs
- Energies ~100 MeV – ~10 GeV
- Flux – strong, highly variable, ocasional
- Composition

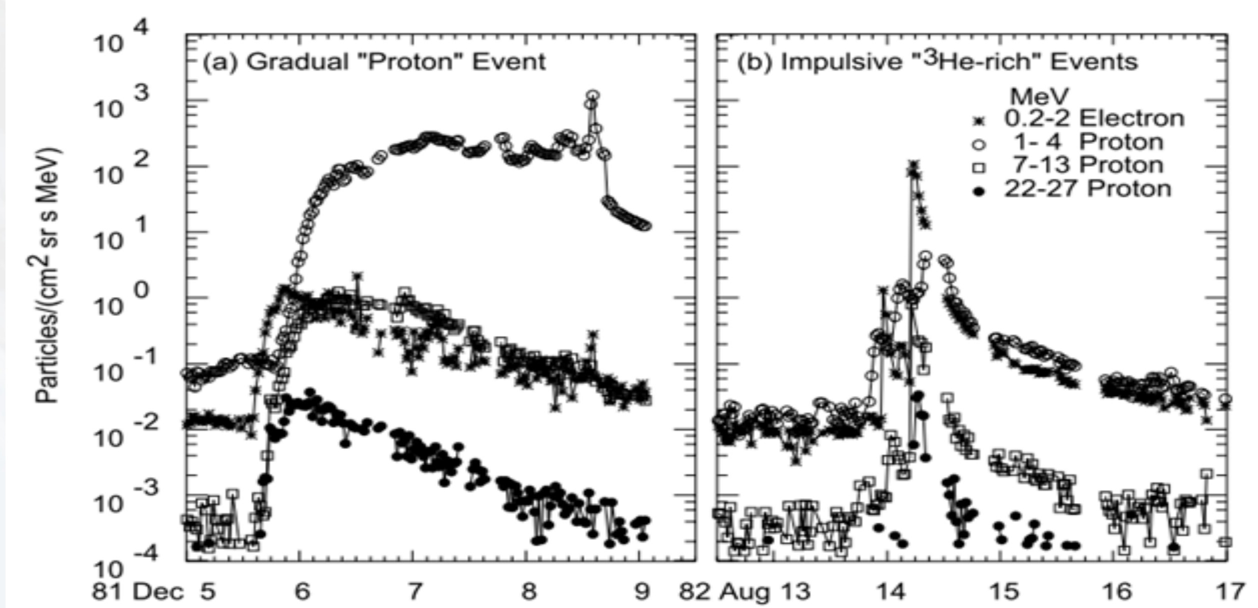
Ions electrons,

Protons are dominant

Depends of origin

CME driven

Flare accelerated



Galactic Cosmic Rays (GCRs)

- Origin – Galactic/Extra galactic (supernova explosions)
- Energies 100 MeV – 10 GeV,

  Ultra-High-Energy Cosmic Ray (**UHECR, E >** 10^{18}eV, most energetic particles up to ~10^{21}eV)

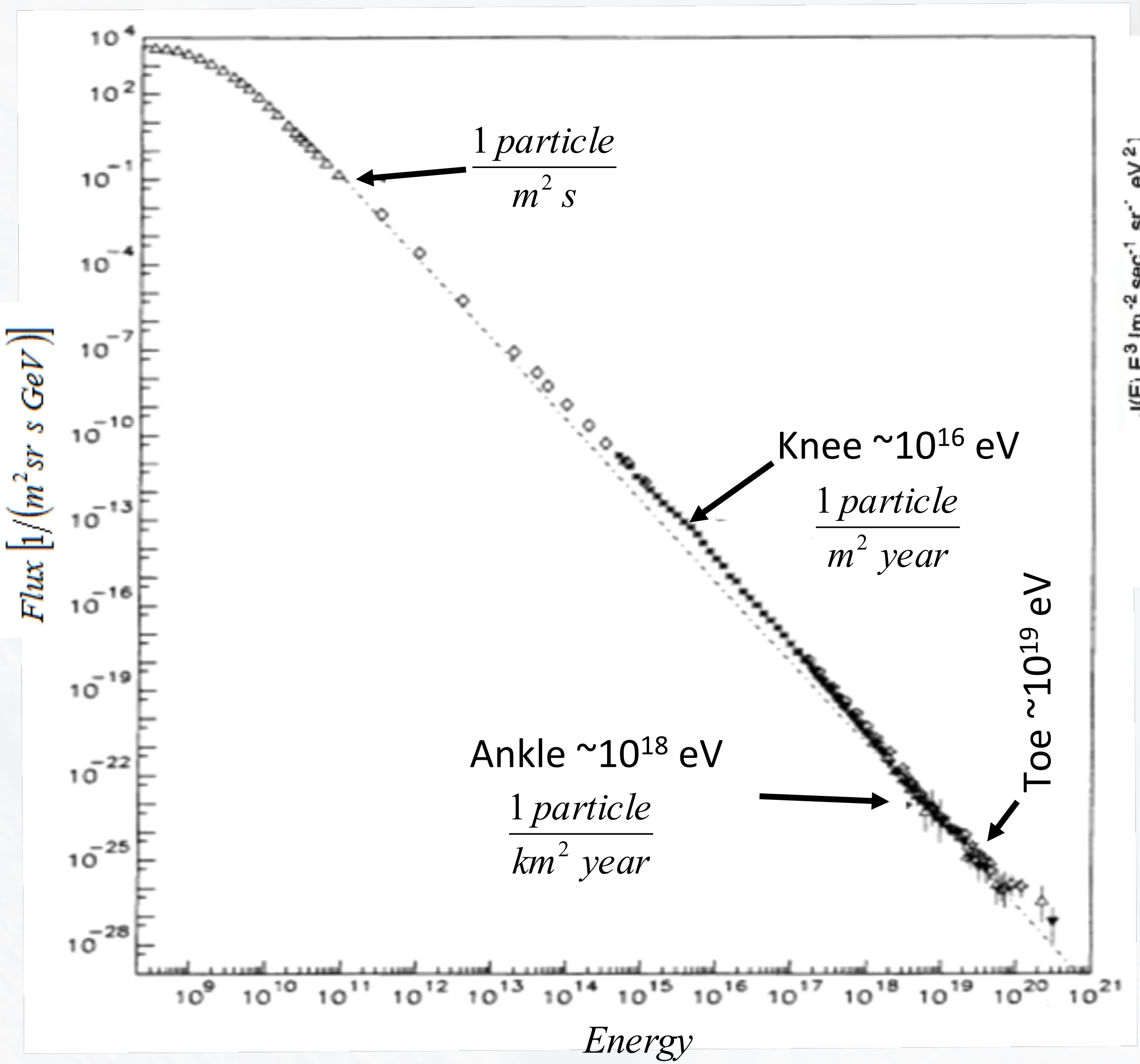
  The highest energy particles in nature

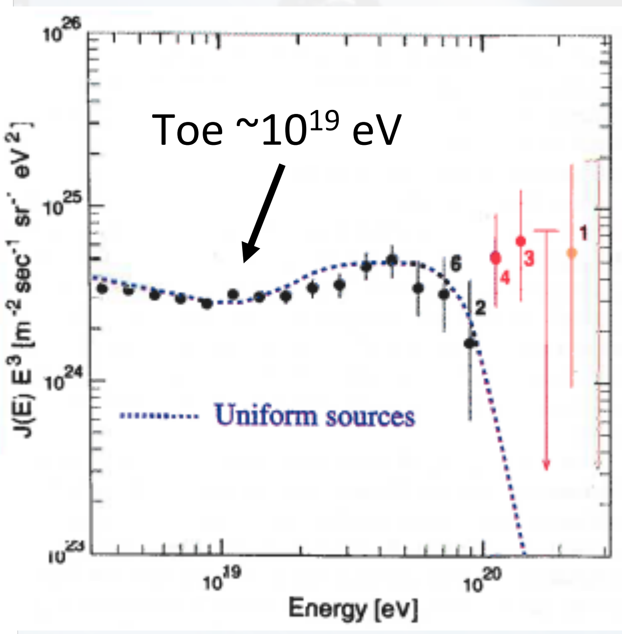
- Flux –isotropic, continous, steady
- Fully ionized
- Composition

Ions: ~90% H, 9% He, 1% heavier ions

Electrons ~1-2%

Spectrum of GCR





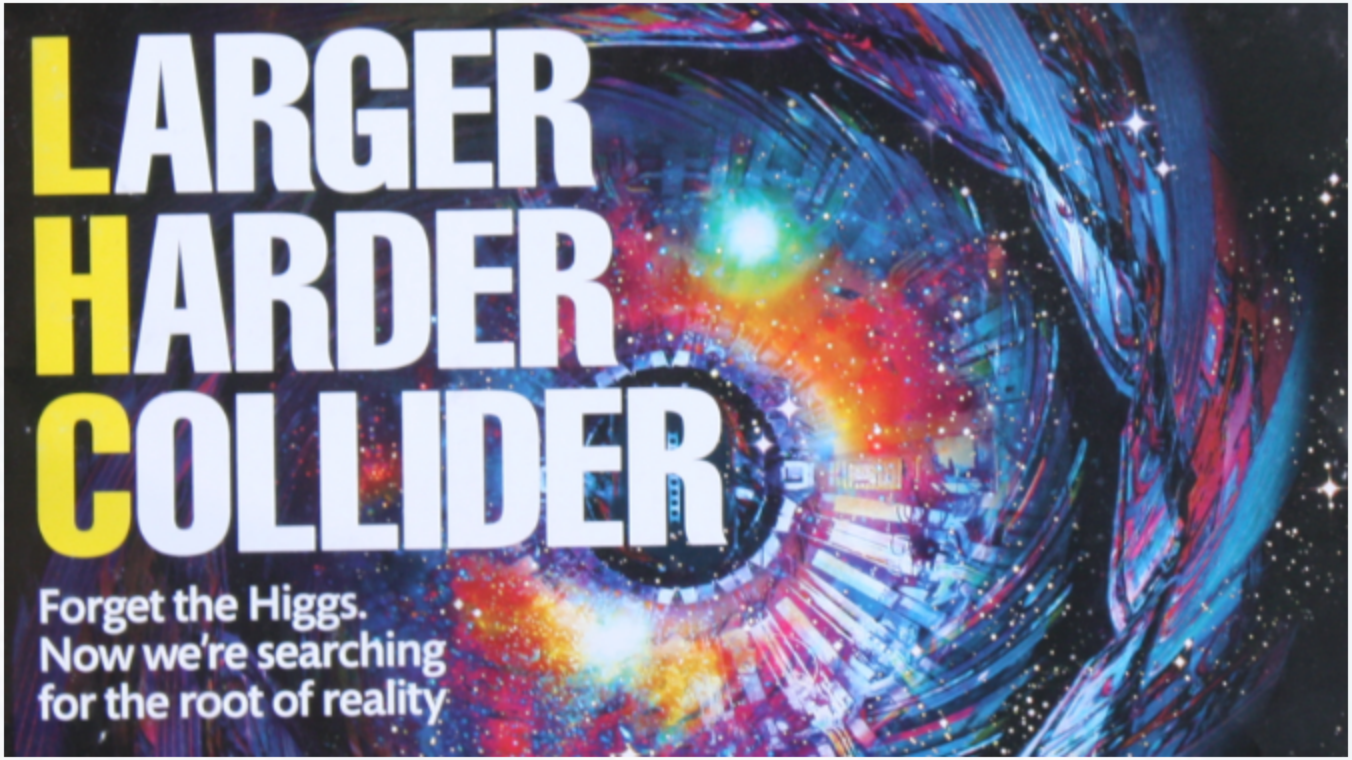
The dashed line indicates the spectrum that would be expected if **UHECR** were produced in sources distributed uniformly throughout the Universe

Particle energy limits at Earth

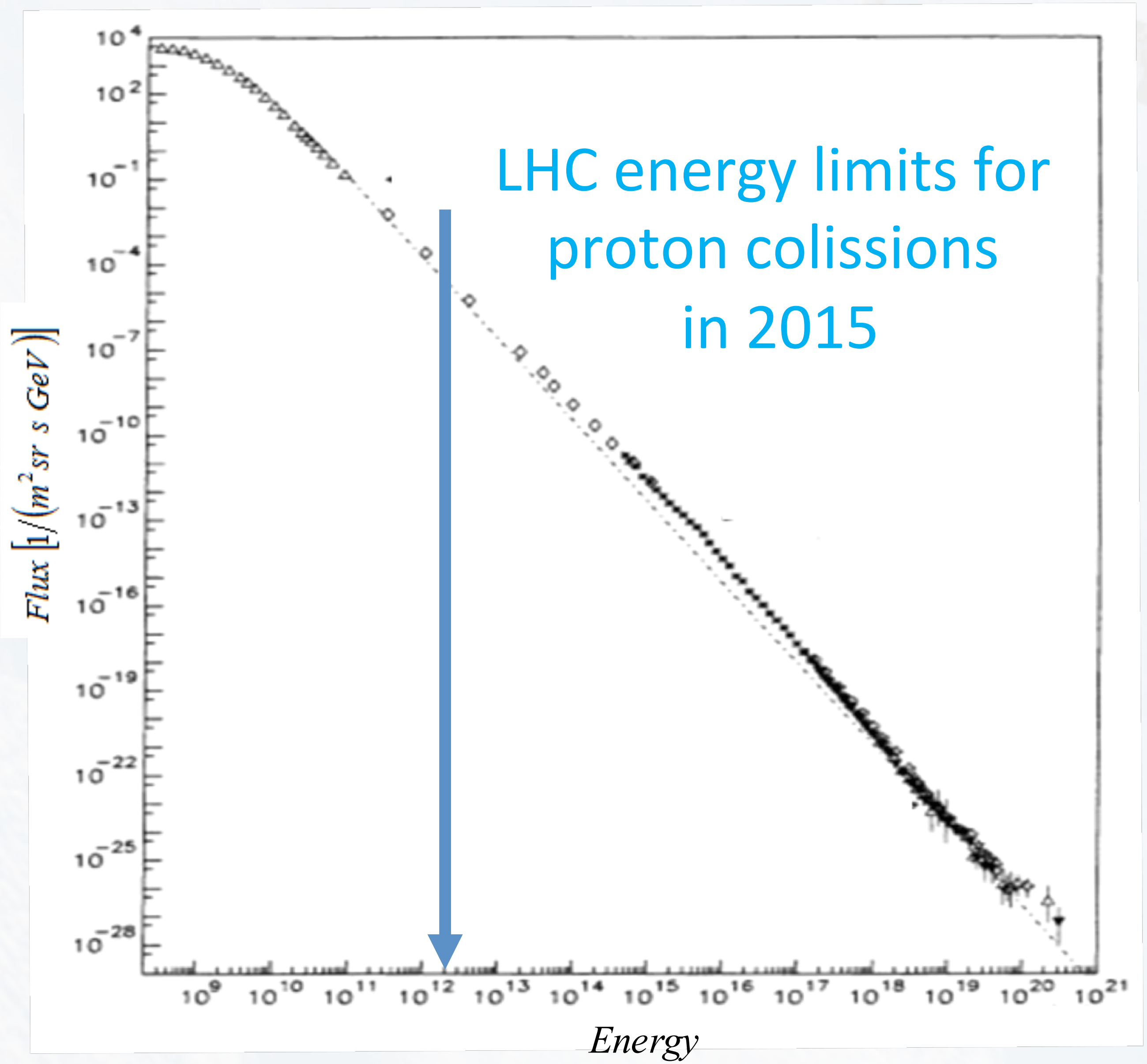
Large Hadron Collider after upgrade

13 TeV proton-proton collisions expected before summer

5 Apr 2015 commissioning with beam circulating in the collider



GCR vs LHC



LHC energy limits for proton colissions in 2015
Flux [1/(m² sr s GeV)]
Energy

Anomalous cosmic rays (ACRs)

- Flux: Isotropic, Continous, steady
- Energy - few MeV to hundreds of MeV.
- Singly ionized
- Composition

anomalous excesses of He, N, O and Ne.

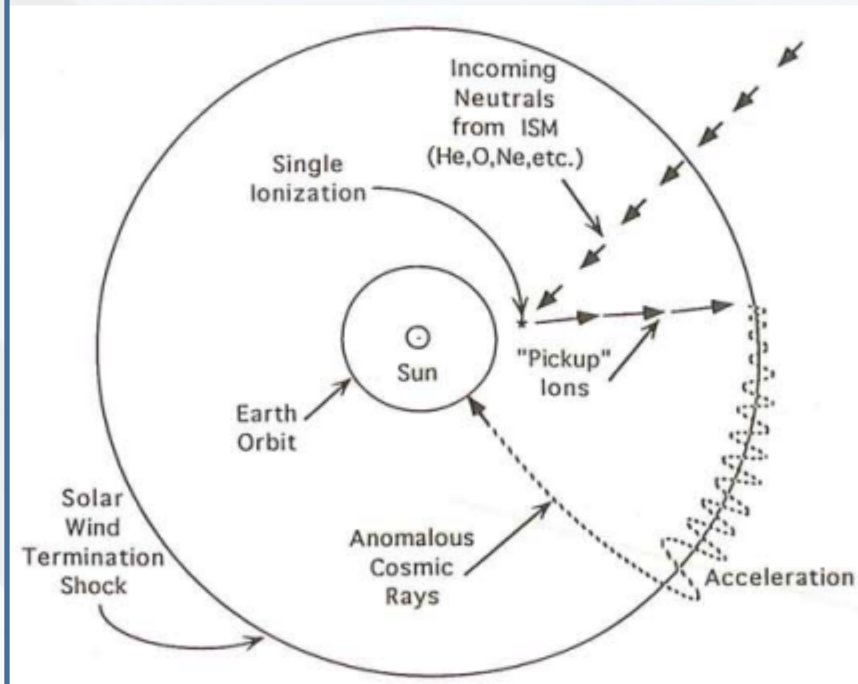
O/C ~ 30:1

He more abundant than H

By contrast in SEPs and GCR

O/C ~ 1:1, H/He ~ 10:1

Origins of ACR



Trapped radiation

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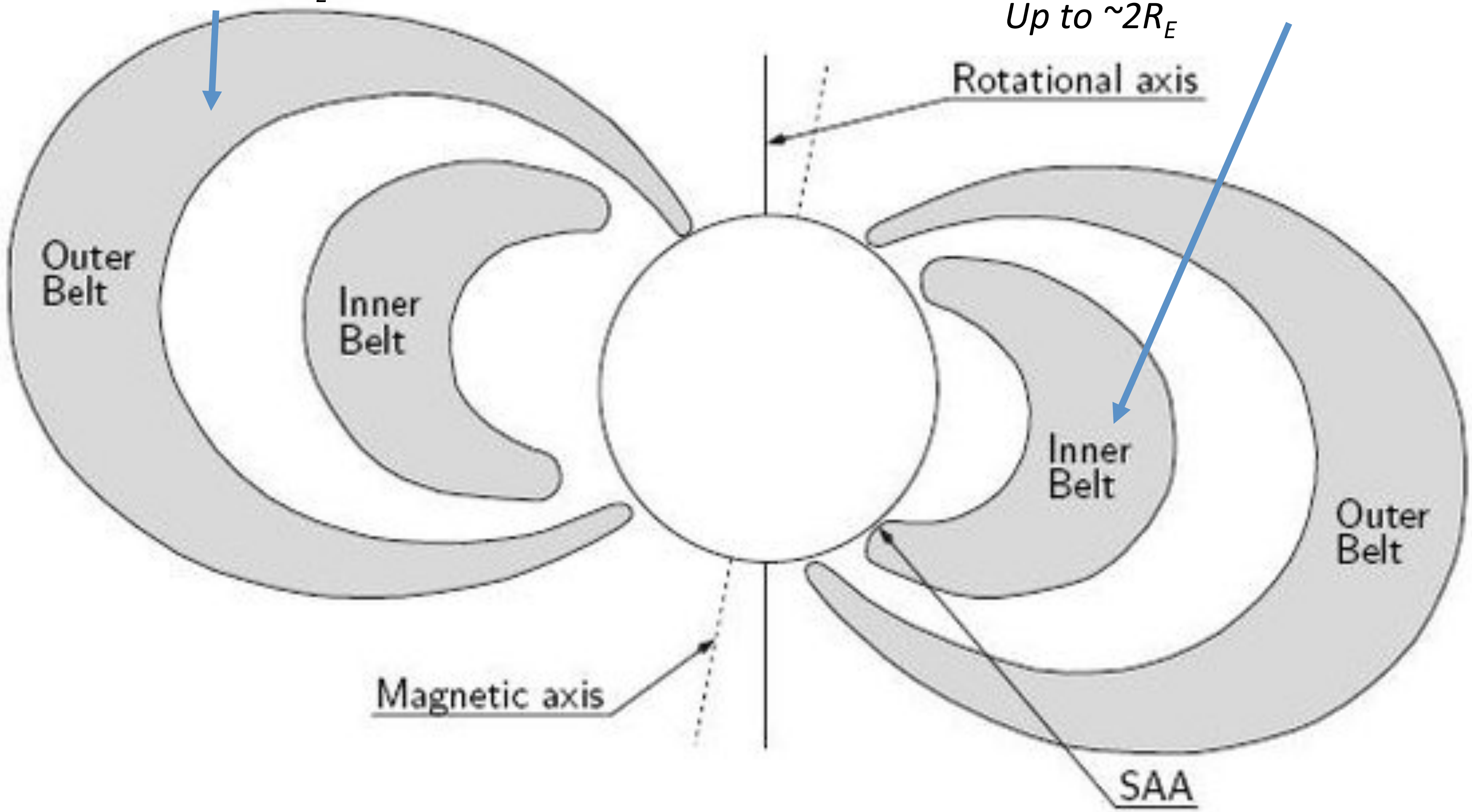
Radiation belts

The discovery of the belts is credited to James Van Allen

Earths radiation belts

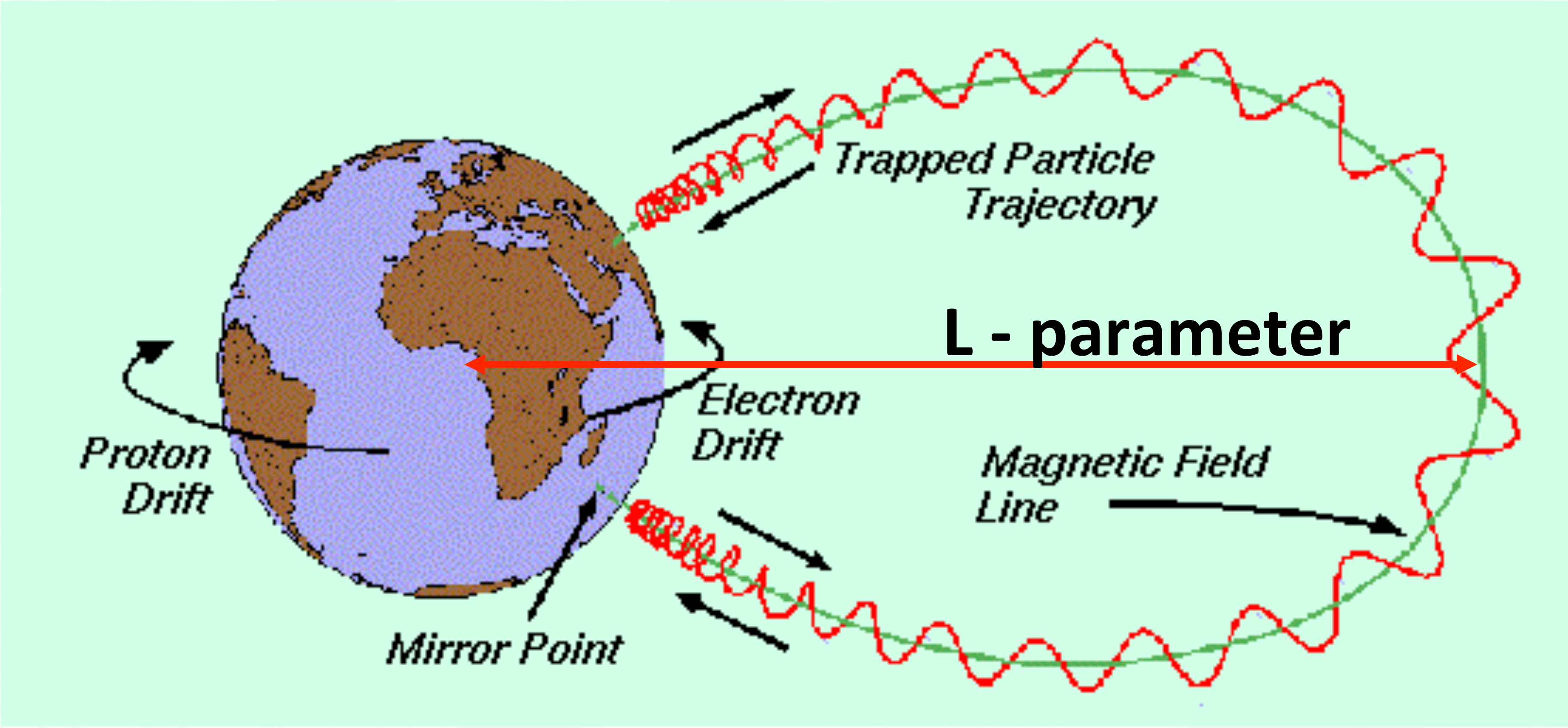
Mainly electrons 0.1–10 MeV
Max intensity ~4–5 R_E

Protons up to ~100 MeV
Electrons up to 10 MeV.
Up to ~2R_E

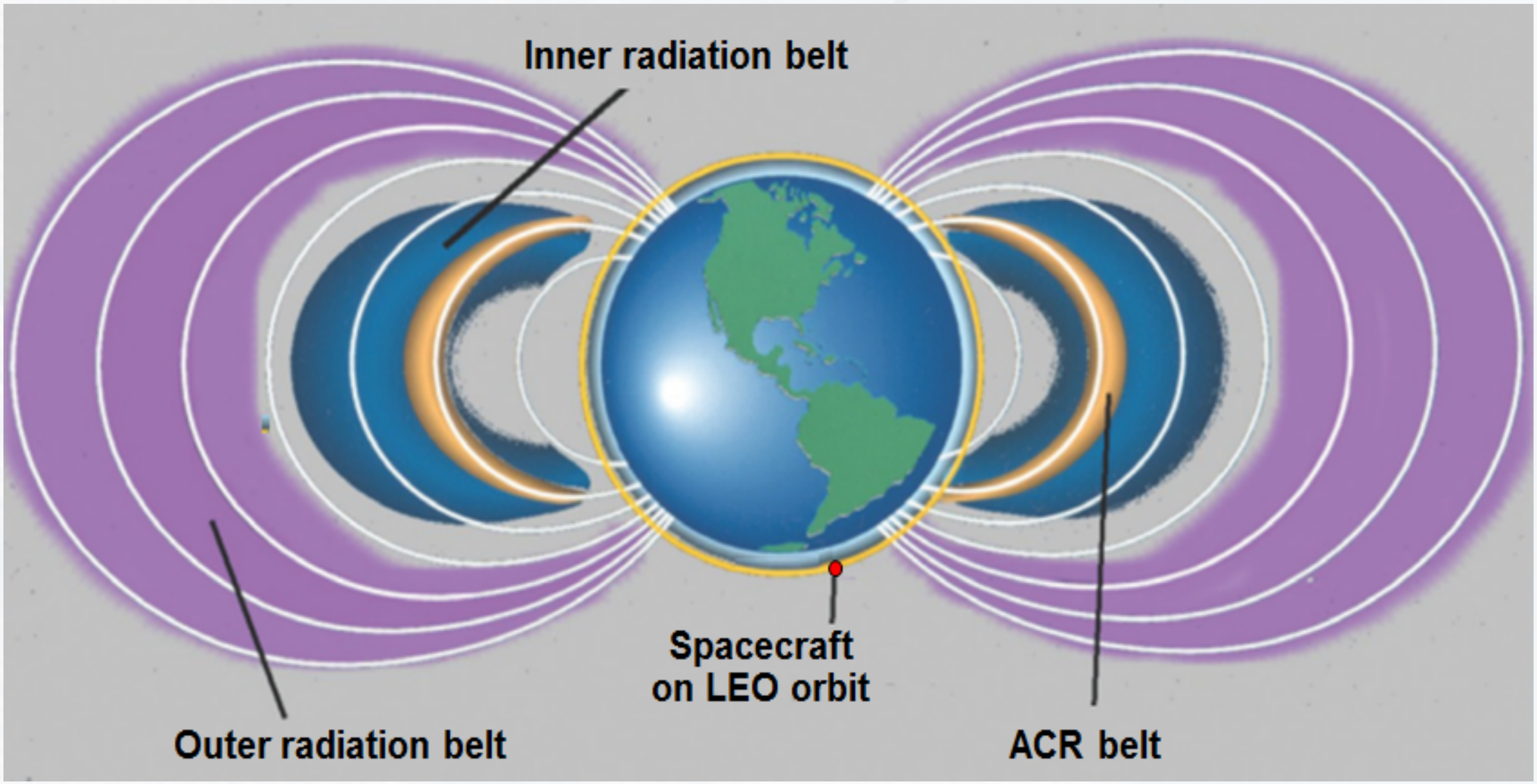


Motions of trapped particles

1) gyration about magnetic field lines;
2) movement of the gyration centre up and down magnetic field lines (guiding centre motion);
3) slow longitudinal drift of the guiding centre path around the Earth, westward for ions and eastward for electrons.

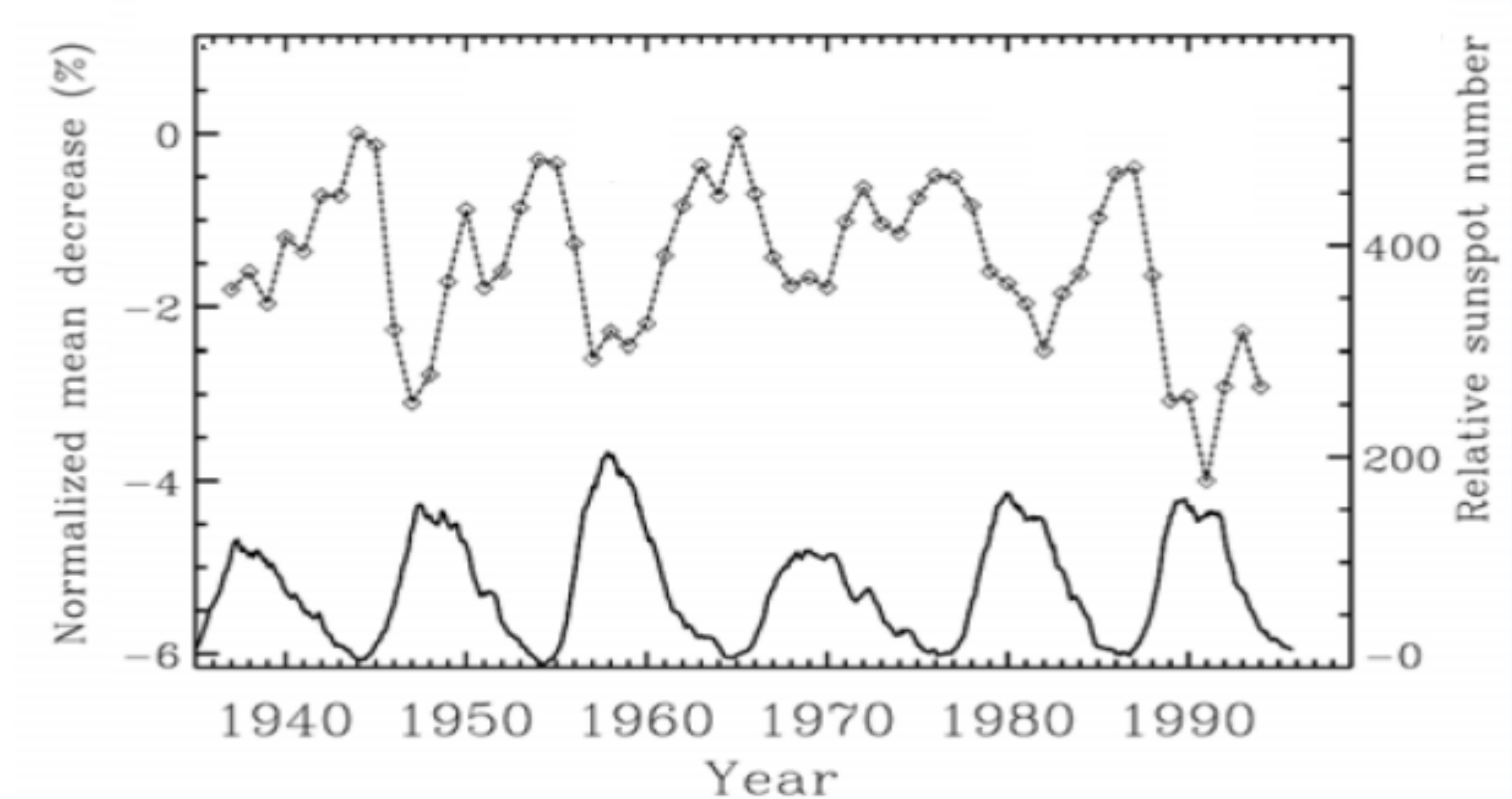


Anomalous cosmic rays also can be trapped in Earth's magnetic field, where they form a radiation belt composed of interstellar material



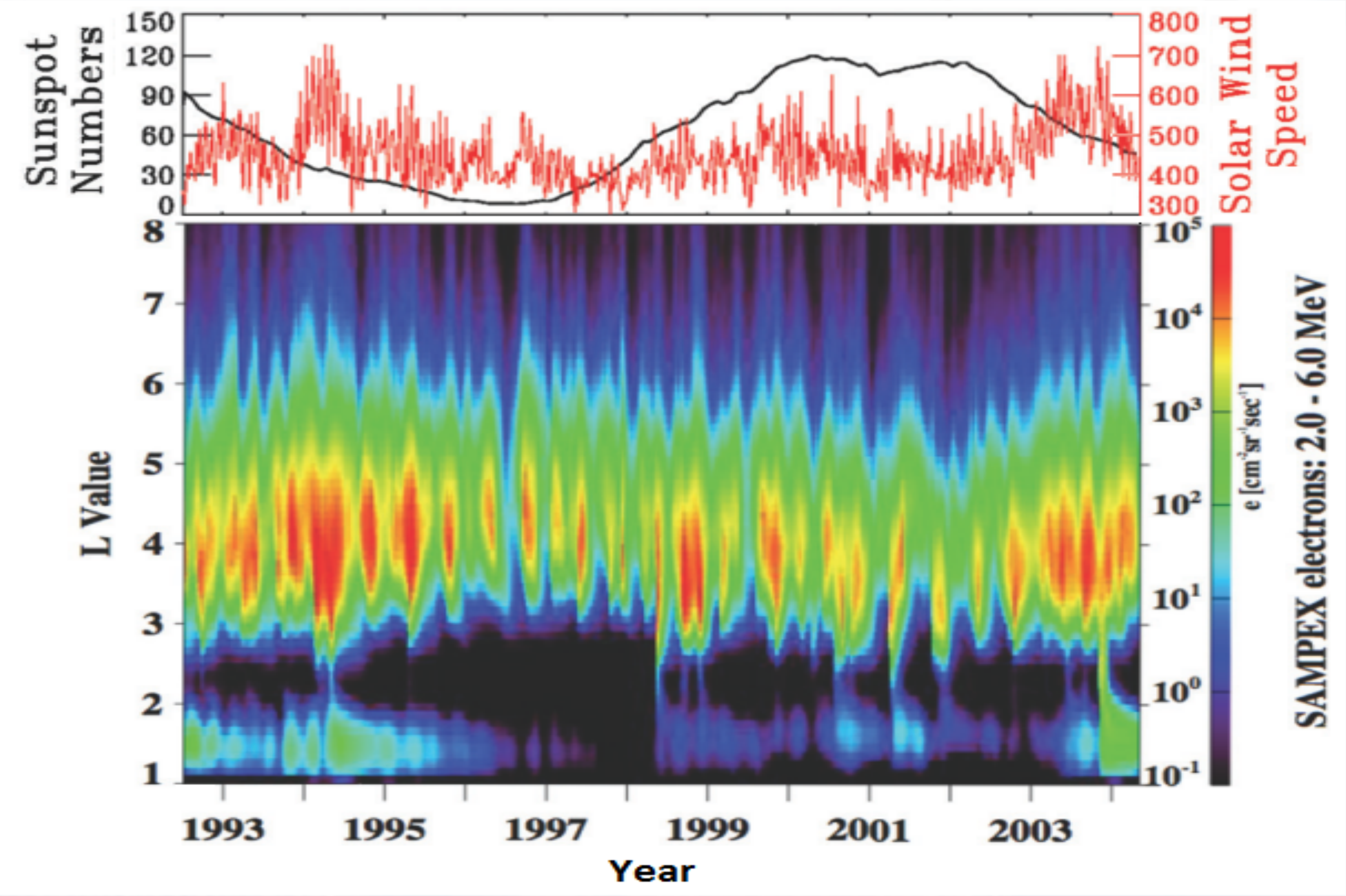
Variability of Earth particle environment

GCR variability with solar cycle

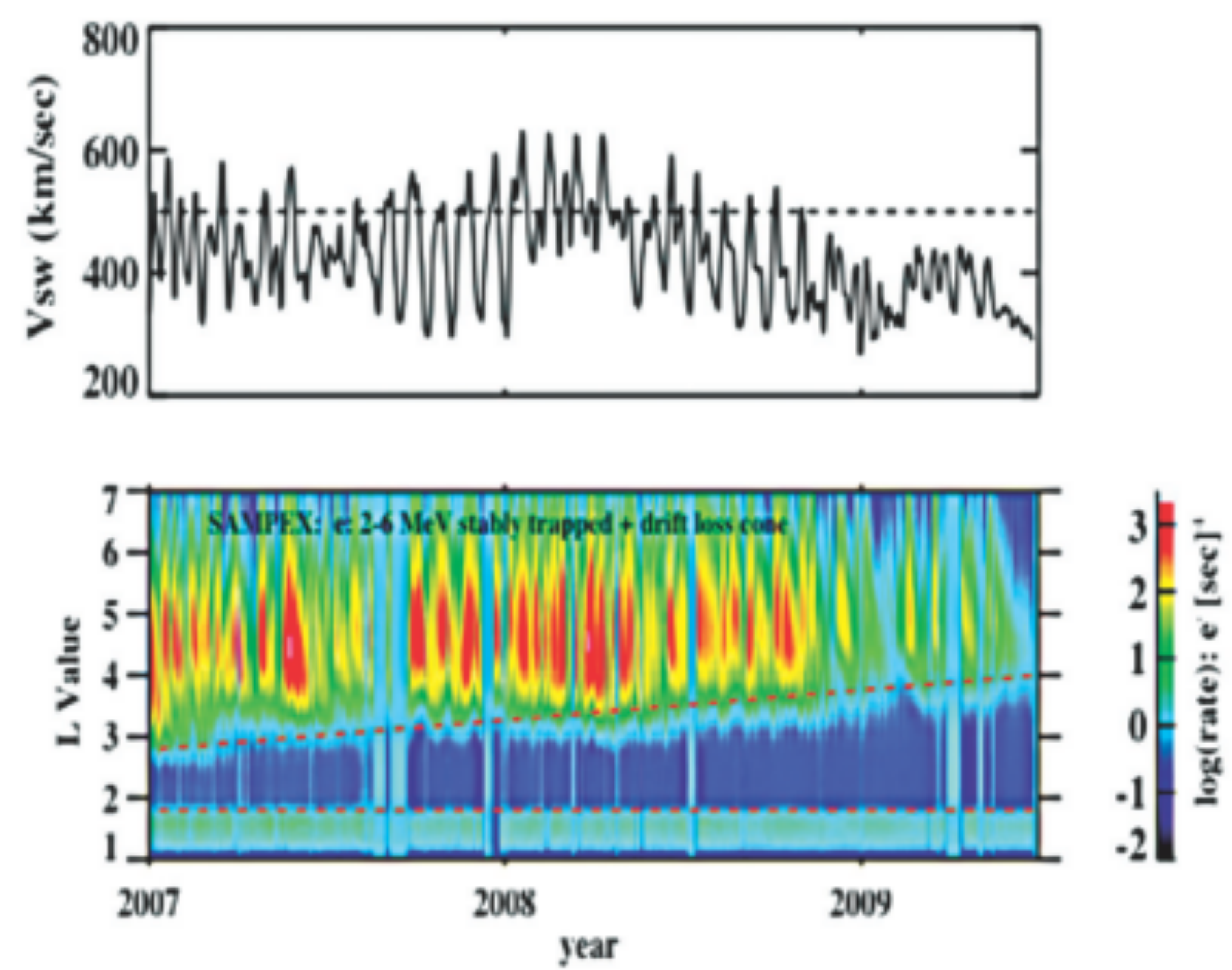


ACR are modulated an order stronger in magnitude

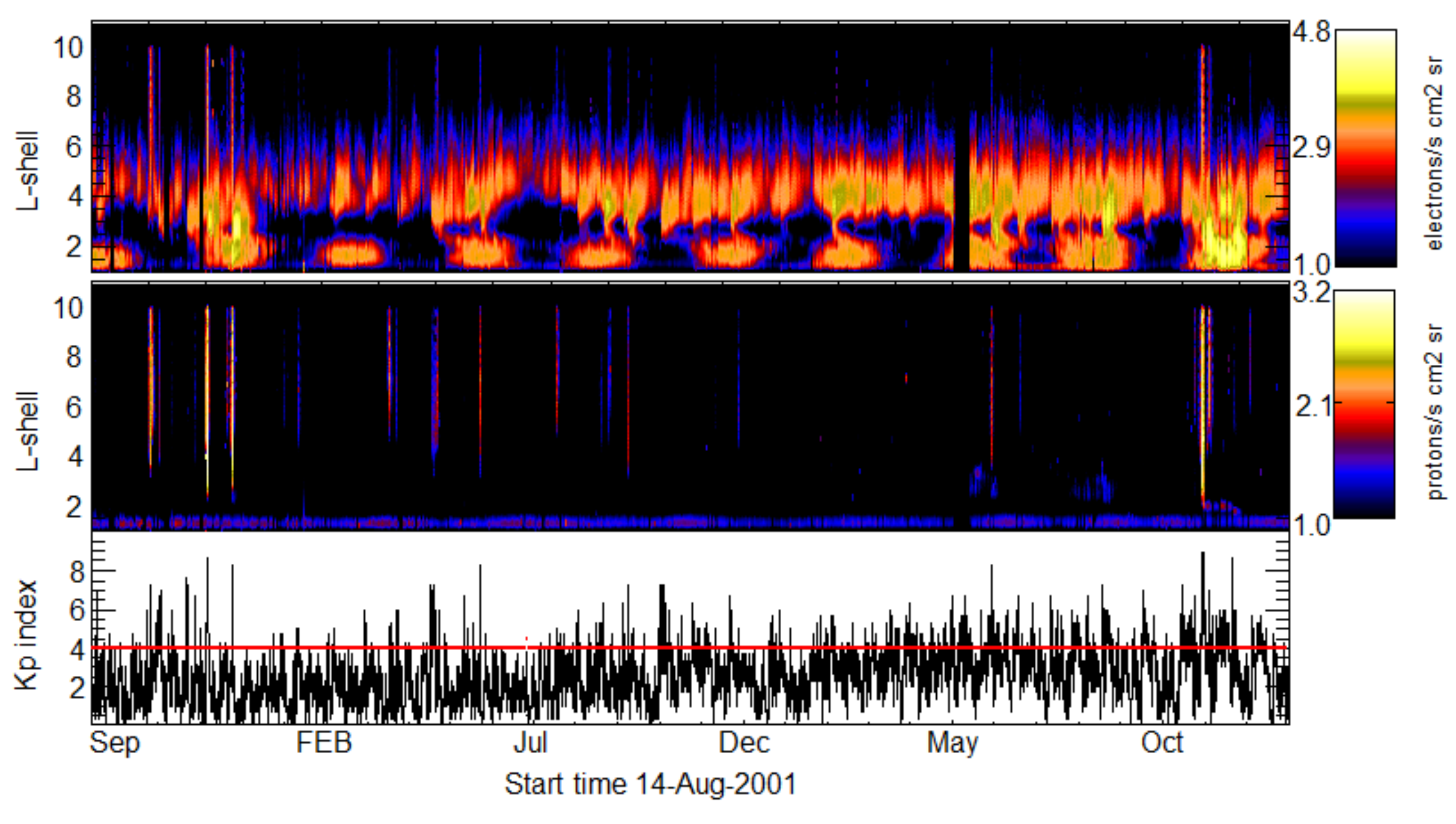
Variability electron of radiation belts



Enhancement of slot region in 2009

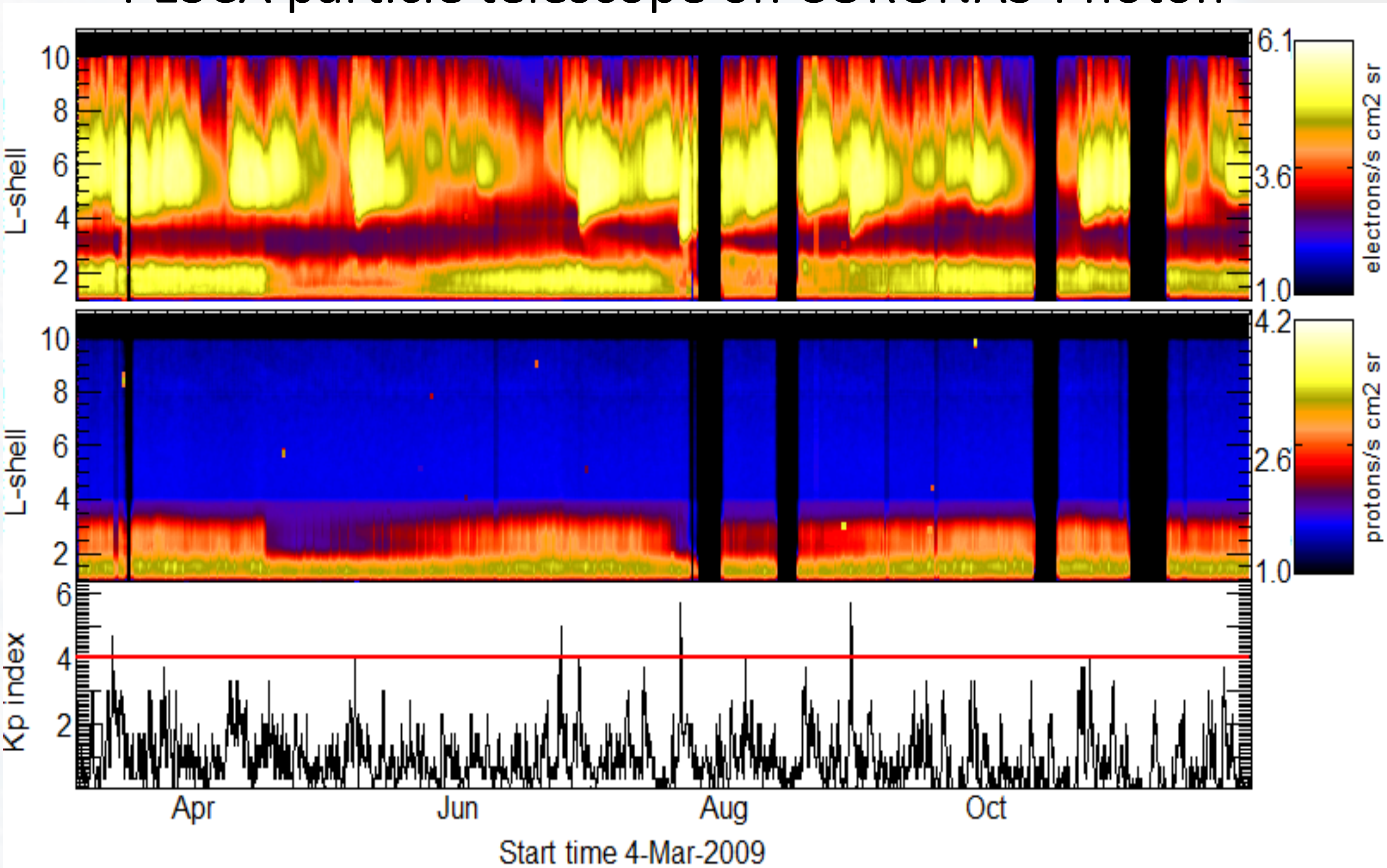


MKL particle telescope on CORONAS-F



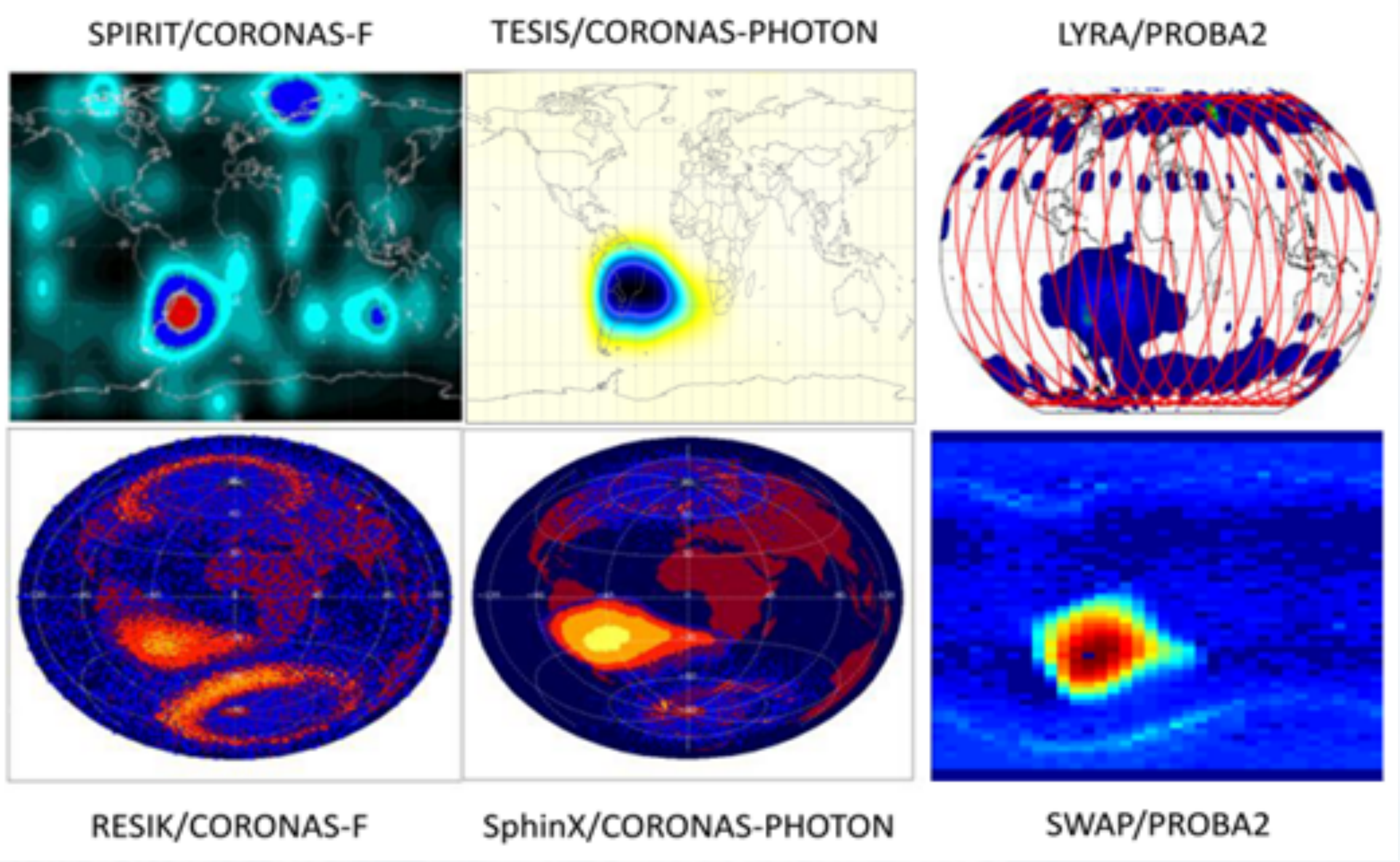
Fluxes of electrons (top) and protons (middle panel) for temporal interval covering descending phase of 23 solar activity cycle . Kp index changes with time are plotted in the bottom panel. Red line in the bottom panel shows space weather alert level (Kp = 4).

PESCA particle telescope on CORONAS-Photon

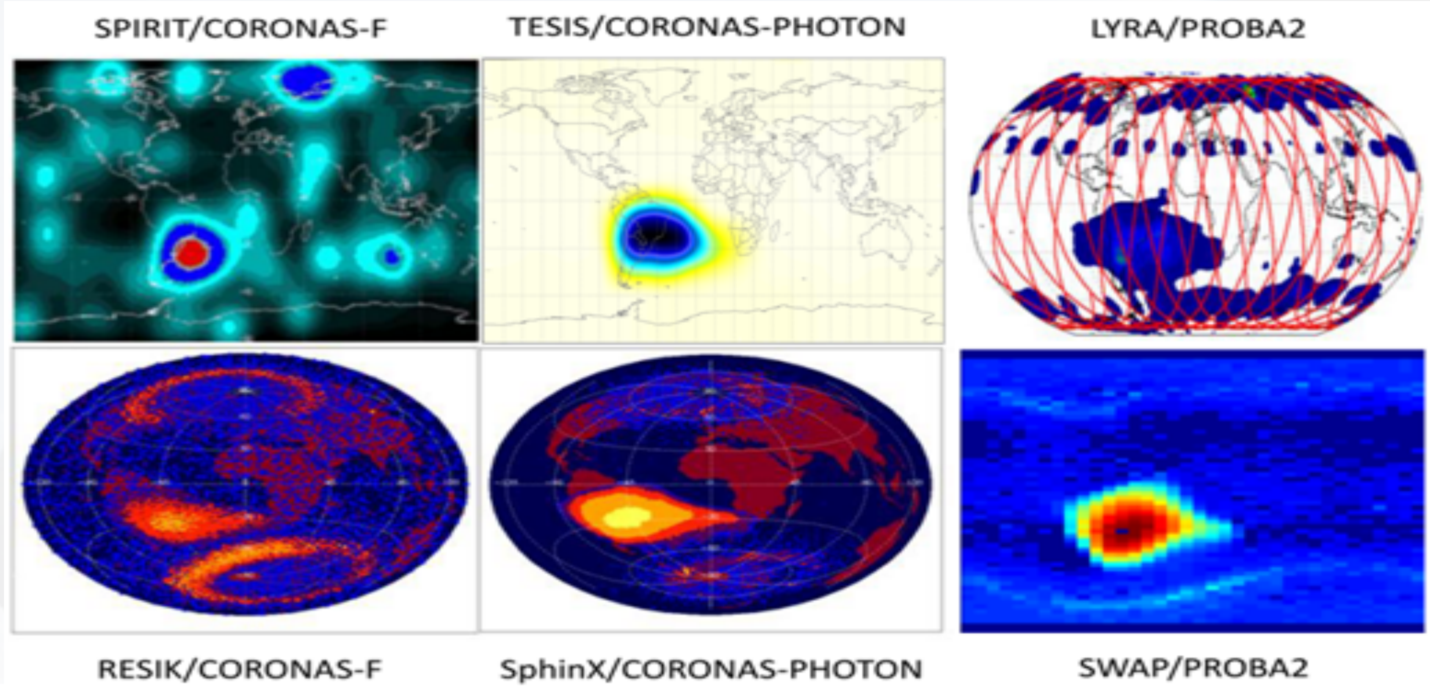


Fluxes of electrons (top) and protons (middle panel) for temporal interval covering deep minimum of solar activity cycle in 2009. Kp index changes with time are plotted in the bottom panel. Red line in the bottom panel shows space weather alert level (Kp = 4).

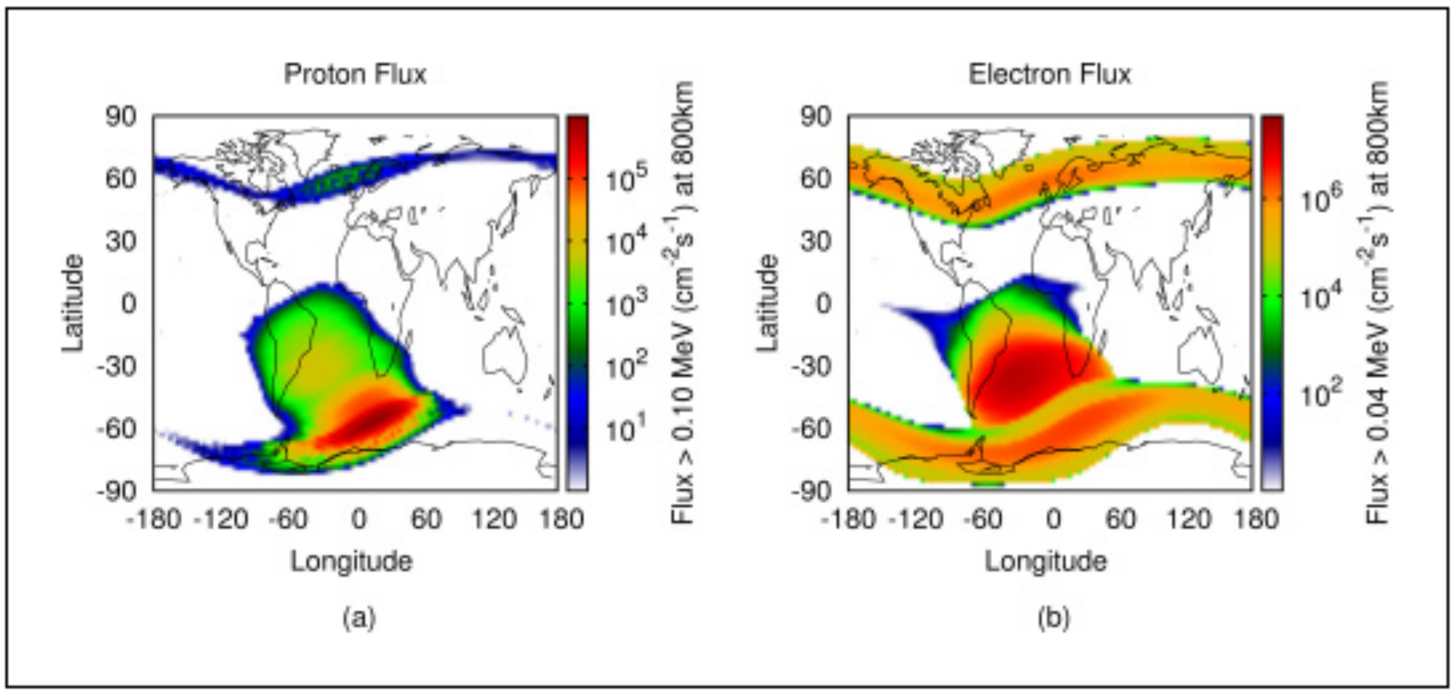
Shift of SAA – observed vs models



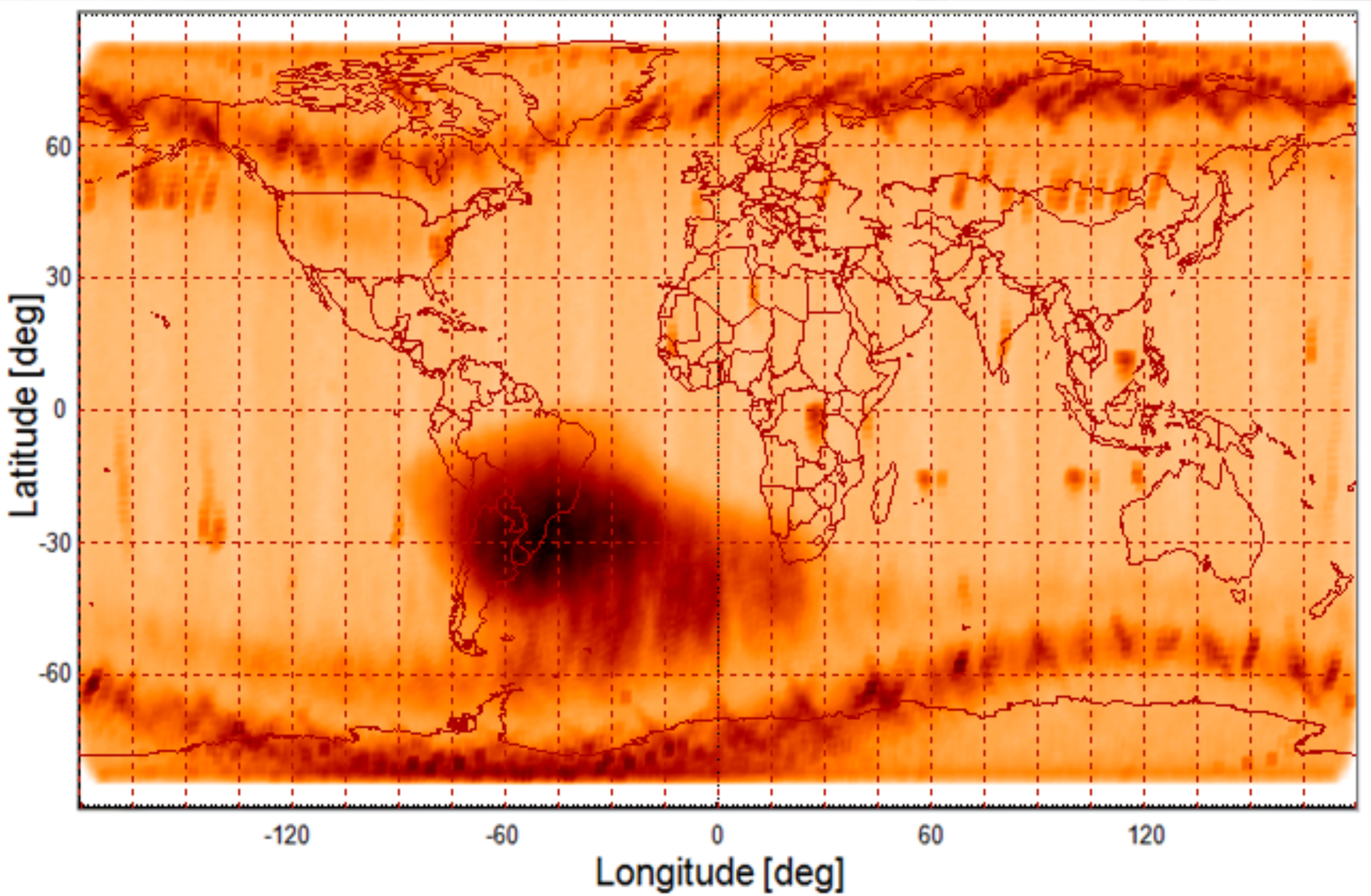
Data



AP-8, AE-8 Models



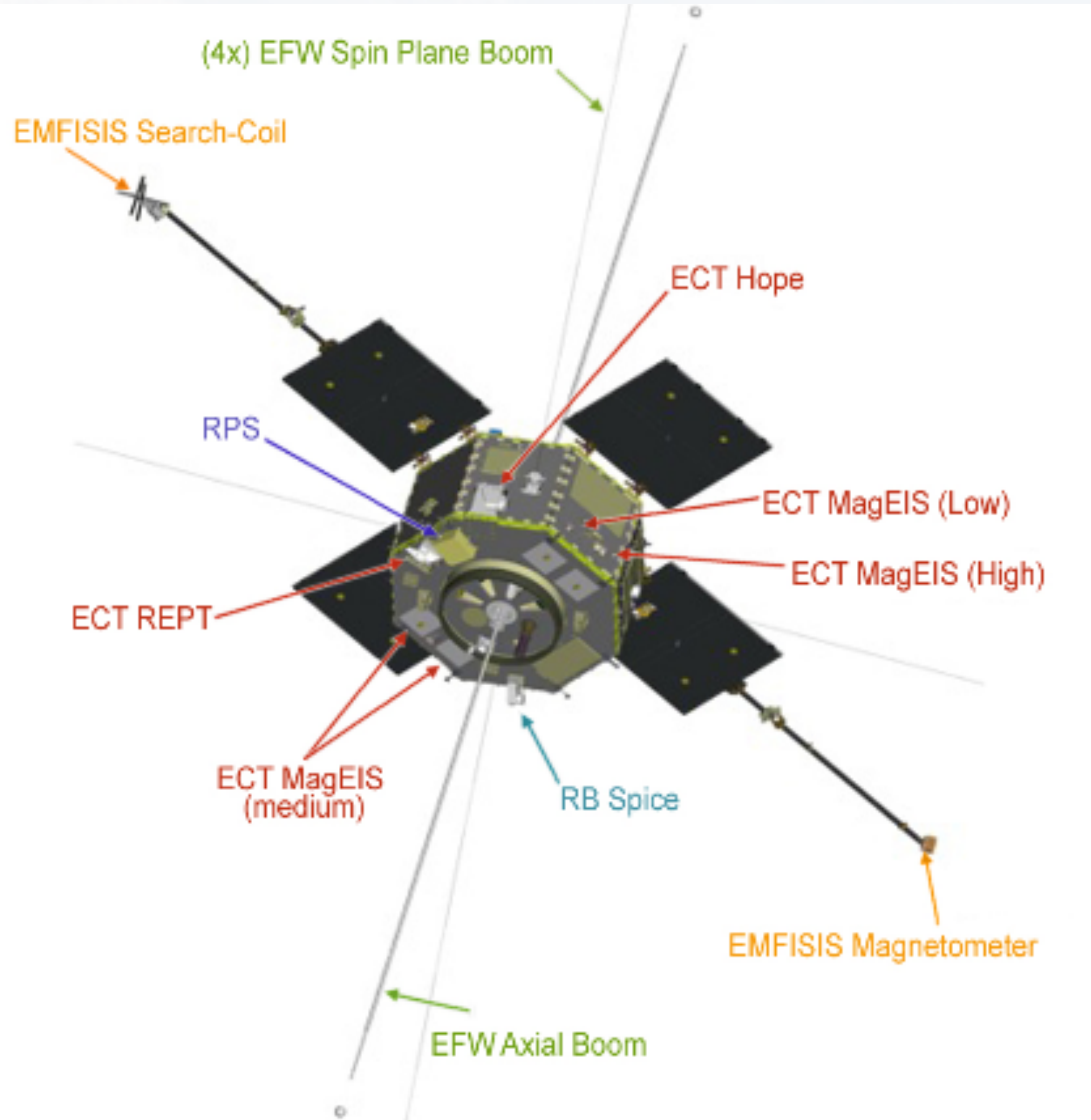
Radiation environment as seen by SphinX in deep minimum of 2009



Van Allen Probes

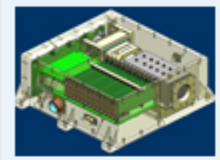
A new mission to study radiation belts

The Van Allen Probes (formerly known as the Radiation Belt Storm Probes (RBSP)). There are two spacecrafts. Single moving spacecraft cannot discern whether any changes it observes are due to traveling disturbances, or if the spacecraft simply flew through two static, but differing, regions. Two spacecraft with identical instruments, however, can distinguish between these possibilities.
http://www.nasa.gov/mission_pages/rbsp/mission/

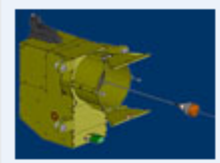


Instruments

RBSP Ion Composition Experiment (RBSPICE)



Relativistic Proton Spectrometer (RPS)



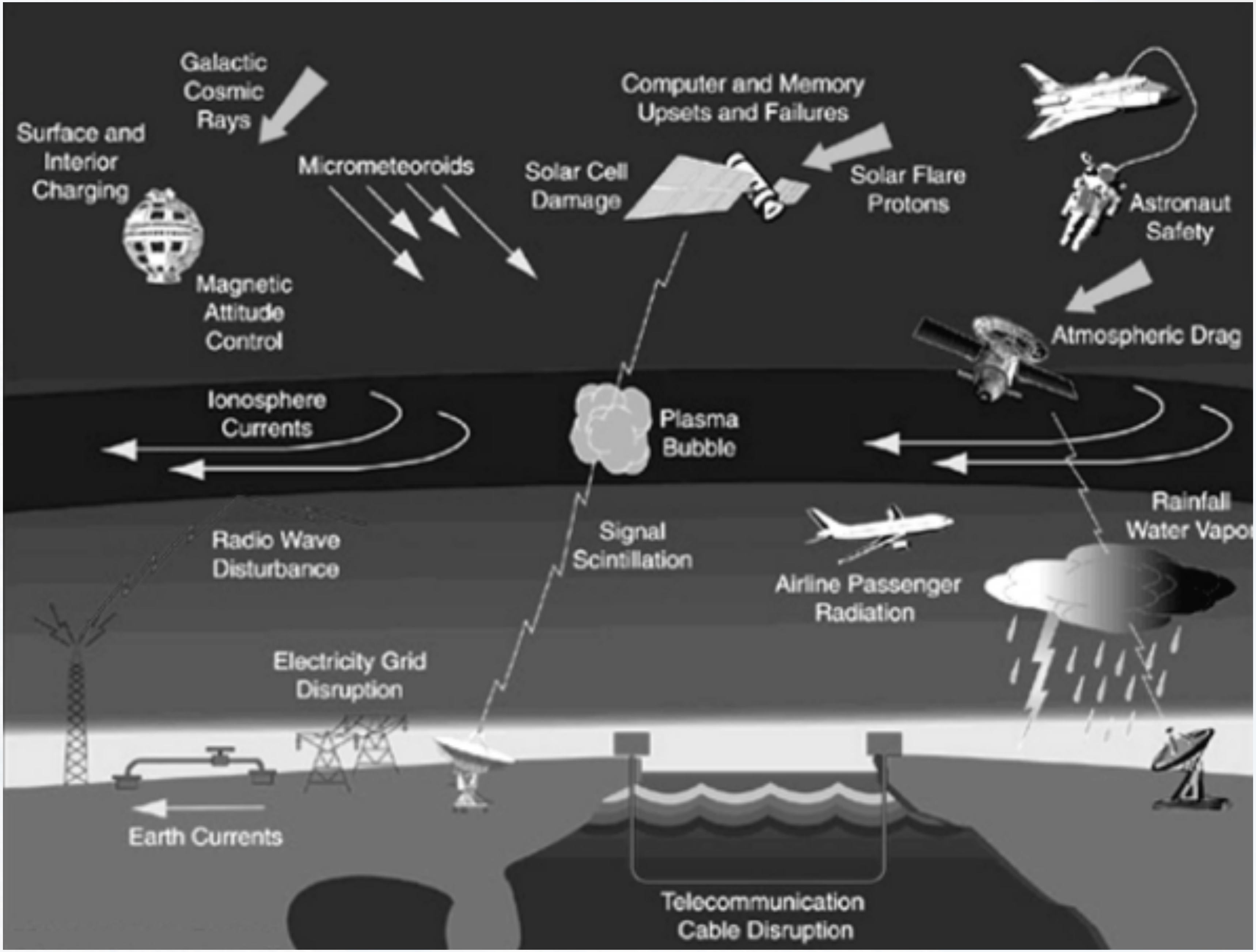
Electric Field and Waves Suite (EFW)

Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS)

Energetic Particle, Composition, and Thermal Plasma Suite (ECT)

Van Allen mission's scientific objectives

- º Discover which processes -- singly or in combination -- accelerate and transport the particles in the radiation belt, and under what conditions.
- º Understand and quantify the loss of electrons from the radiation belts.
- º Determine the balance between the processes that cause electron acceleration and those that cause losses.
- º Understand how the radiation belts change in the context of geomagnetic storms.



Summary of the known space weather effects (from Lanzerotti, 1997)