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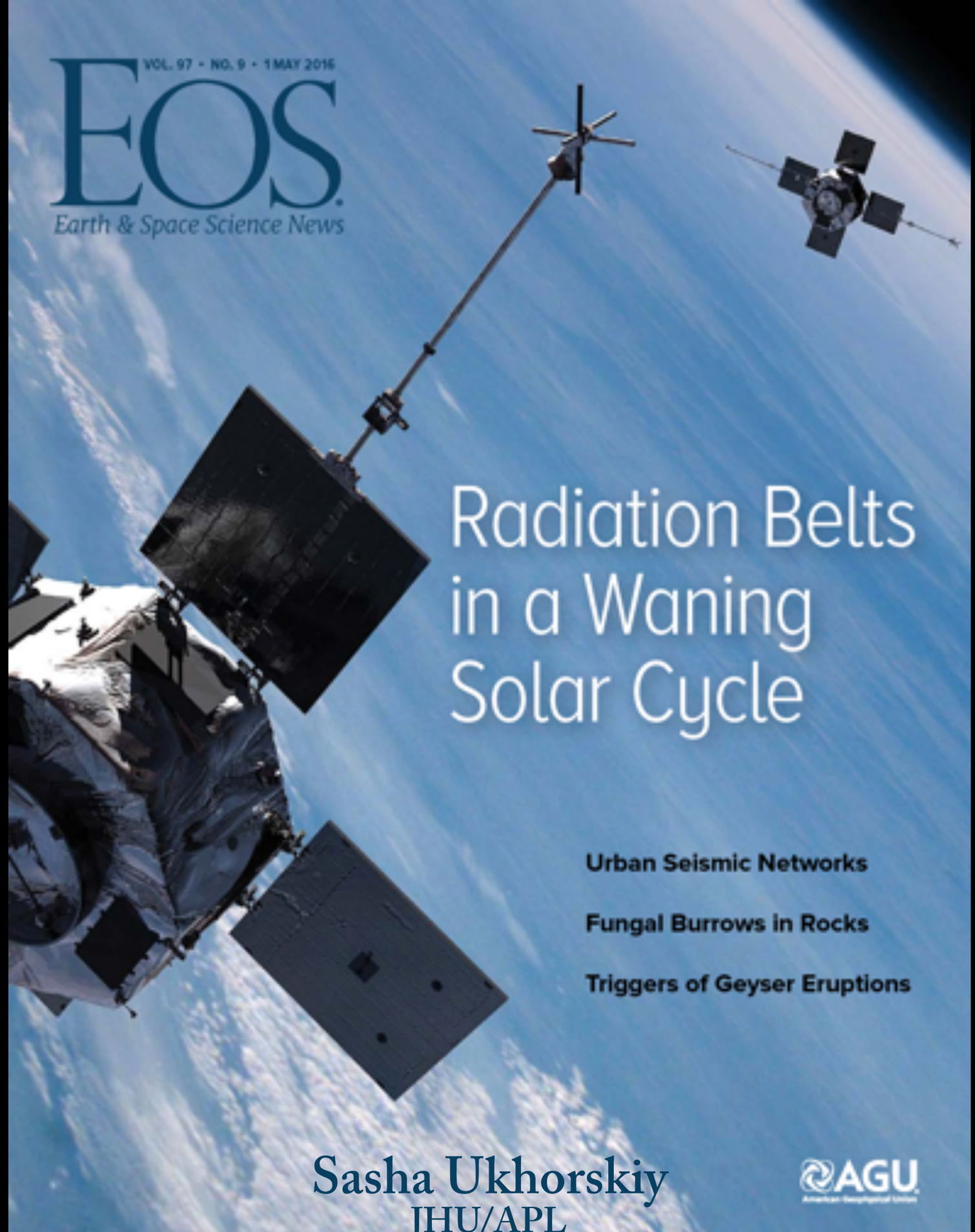
EOS

Earth & Space Science News



Radiation Belts in a Waning Solar Cycle

Urban Seismic Networks

Fungal Burrows in Rocks

Triggers of Geyser Eruptions

Sasha Ukhorskiy
JHU/APL

AGU
American Geophysical Union

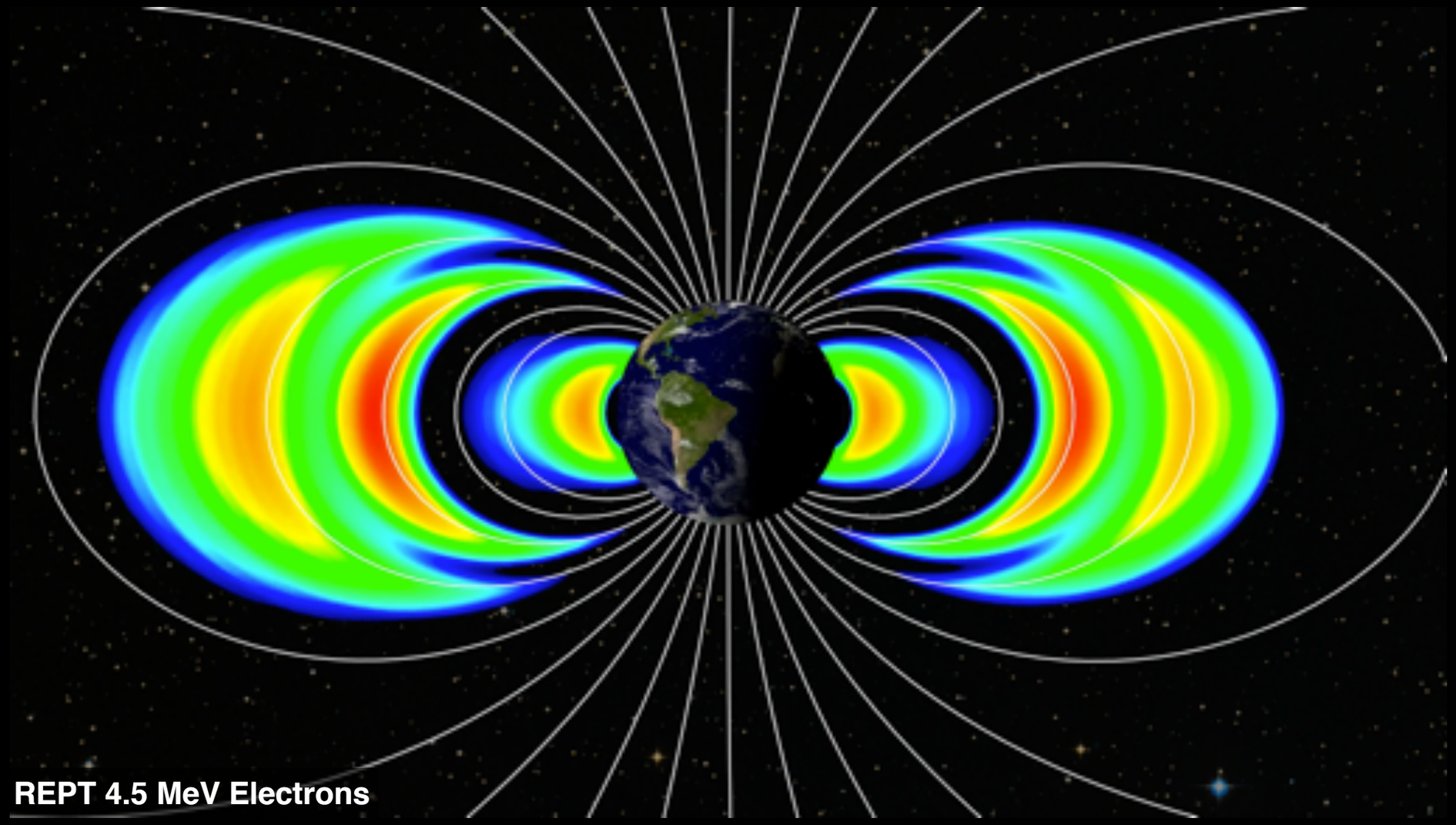
Van Allen Probes Mission

- Goals and design
- Unprecedented capabilities - New discoveries
- Systemwide understanding & Predictability
- Real-time space weather broadcast
- Science Gateway

Van Allen Probes (RBSP) Mission

Understand dynamic variability of the radiation belt and ring current environment in response to varying solar wind driving

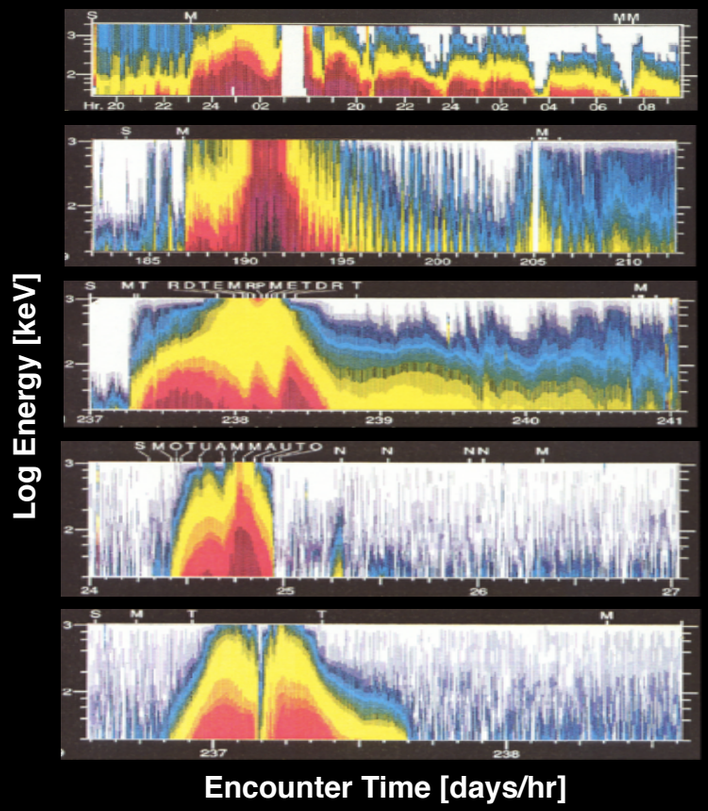
September 02, 2012 Geomagnetic Storm



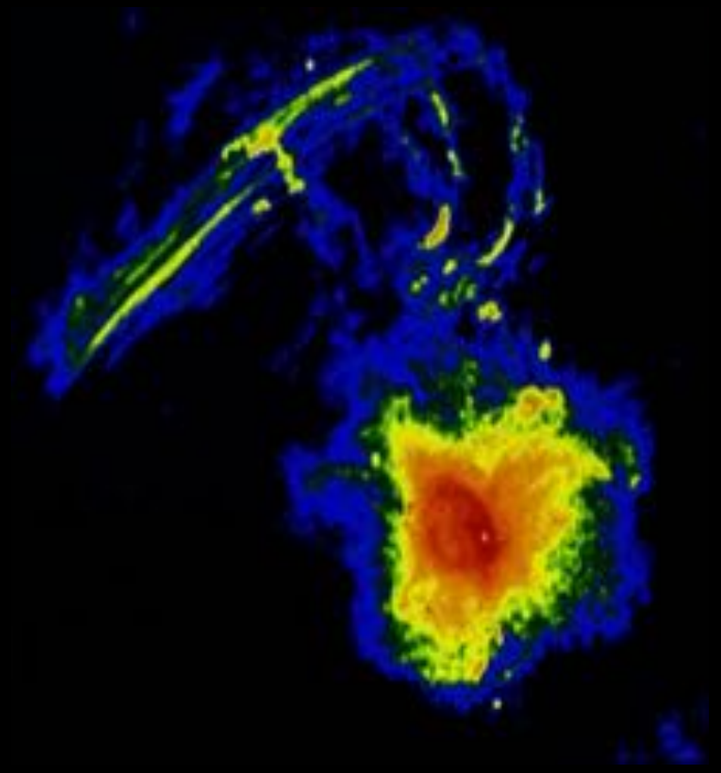
During geomagnetic storms the intensities of high-energy particles in the near-Earth space vary by orders of magnitude on the timescales from minutes to days. This dynamic variability is controlled by the shifting balance among multiple acceleration and loss mechanisms which interact with particle motion at various spatial and temporal scales.

Fundamental Physics with Practical Importance

Planetary Belts



Galactic Center



Space Weather

Fundamental Science: Earth's radiation belts are a natural laboratory for investigating how charge particles are accelerated to high energies at magnetized planets of the solar system and other astrophysical objects.

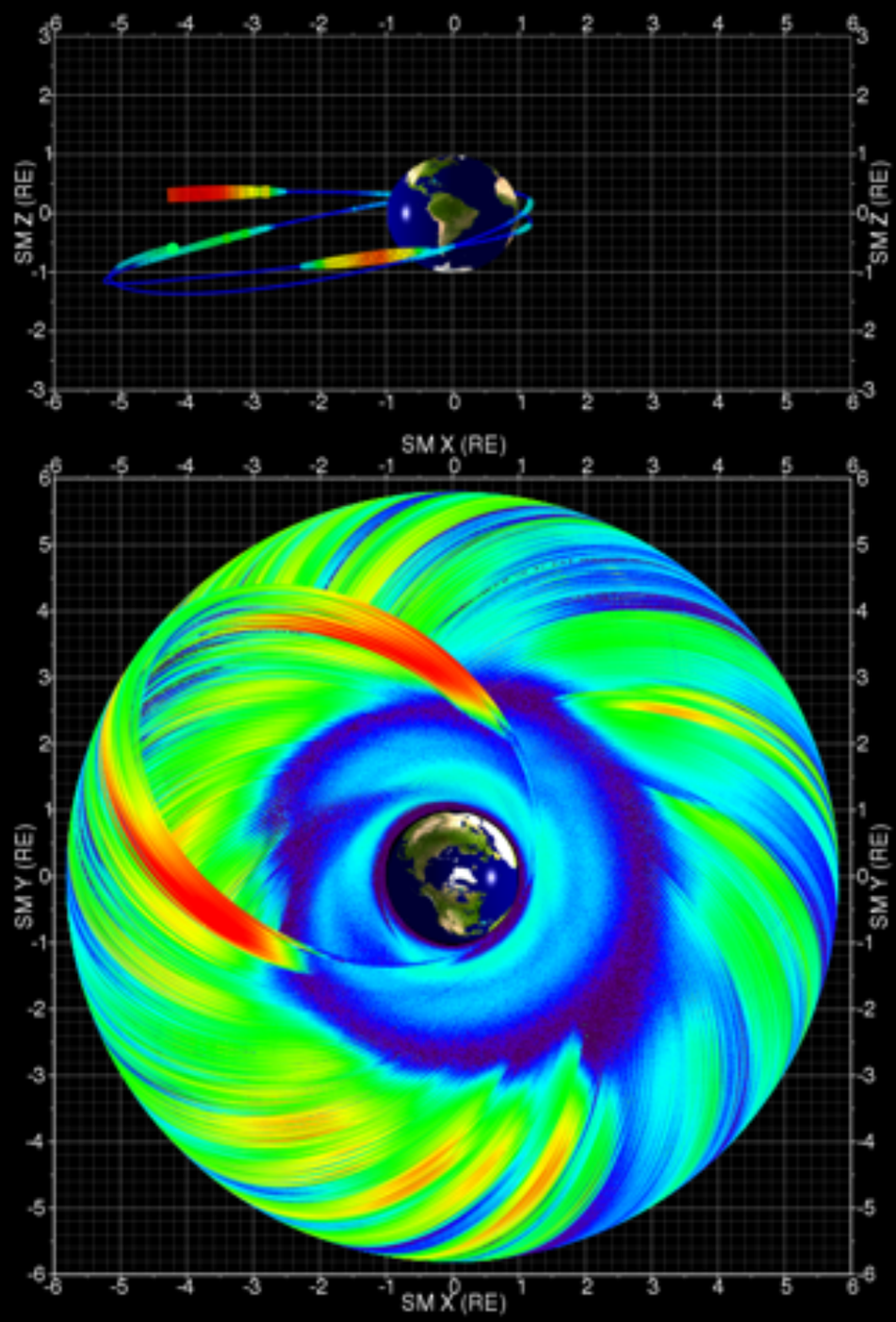
Space Weather: Nowcasting and predictive understanding of radiation belt dynamics is critical for mitigating hazardous effects of space radiation.

Mission Configuration and Science Investigation

<u>Near-equatorial orbit (10°)</u>
• direct measurements of the acceleration region

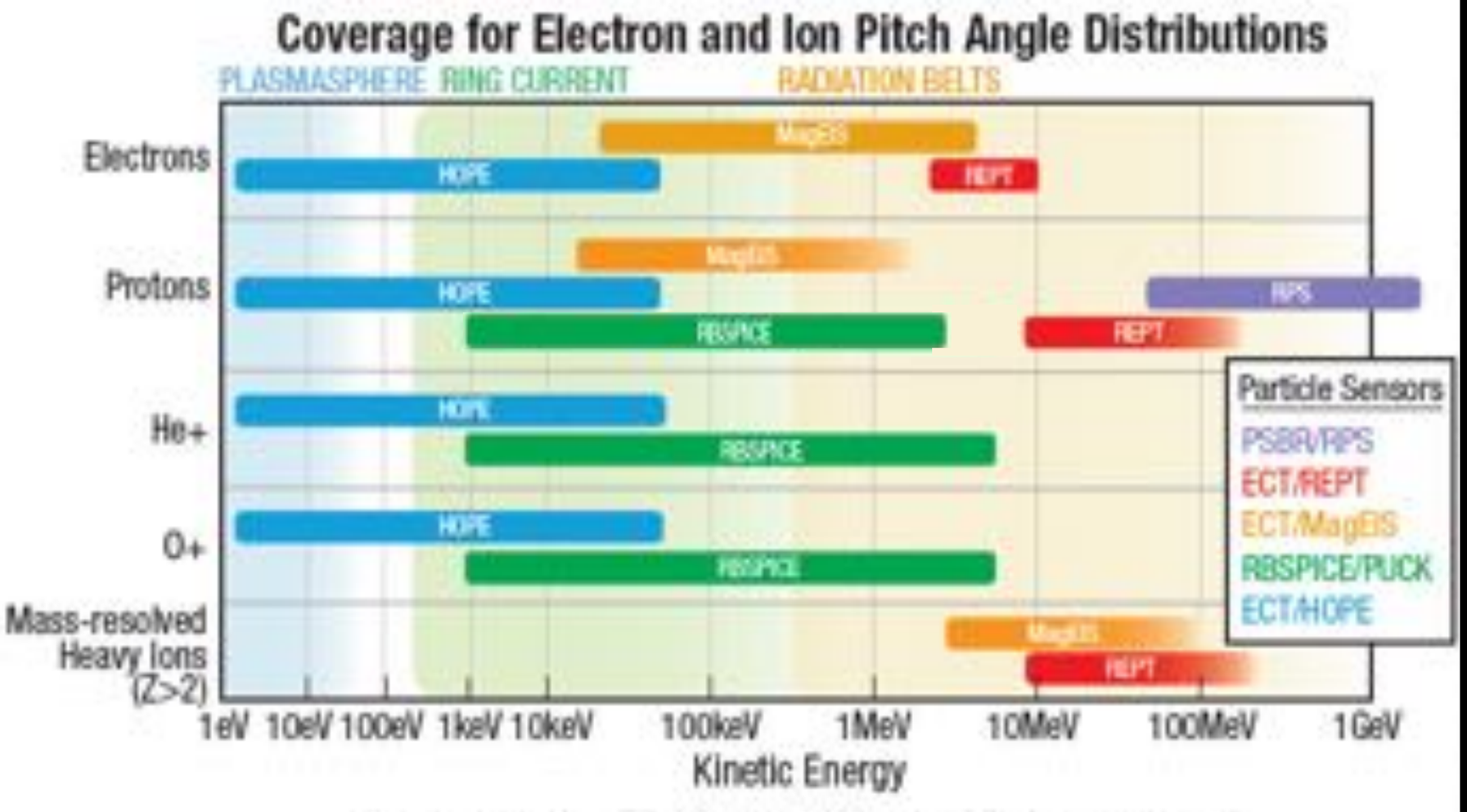
<u>Two identical spacecraft with variable separation (30 days)</u>
• separation of temporal and spatial effects
• sampling different scales/mechanisms

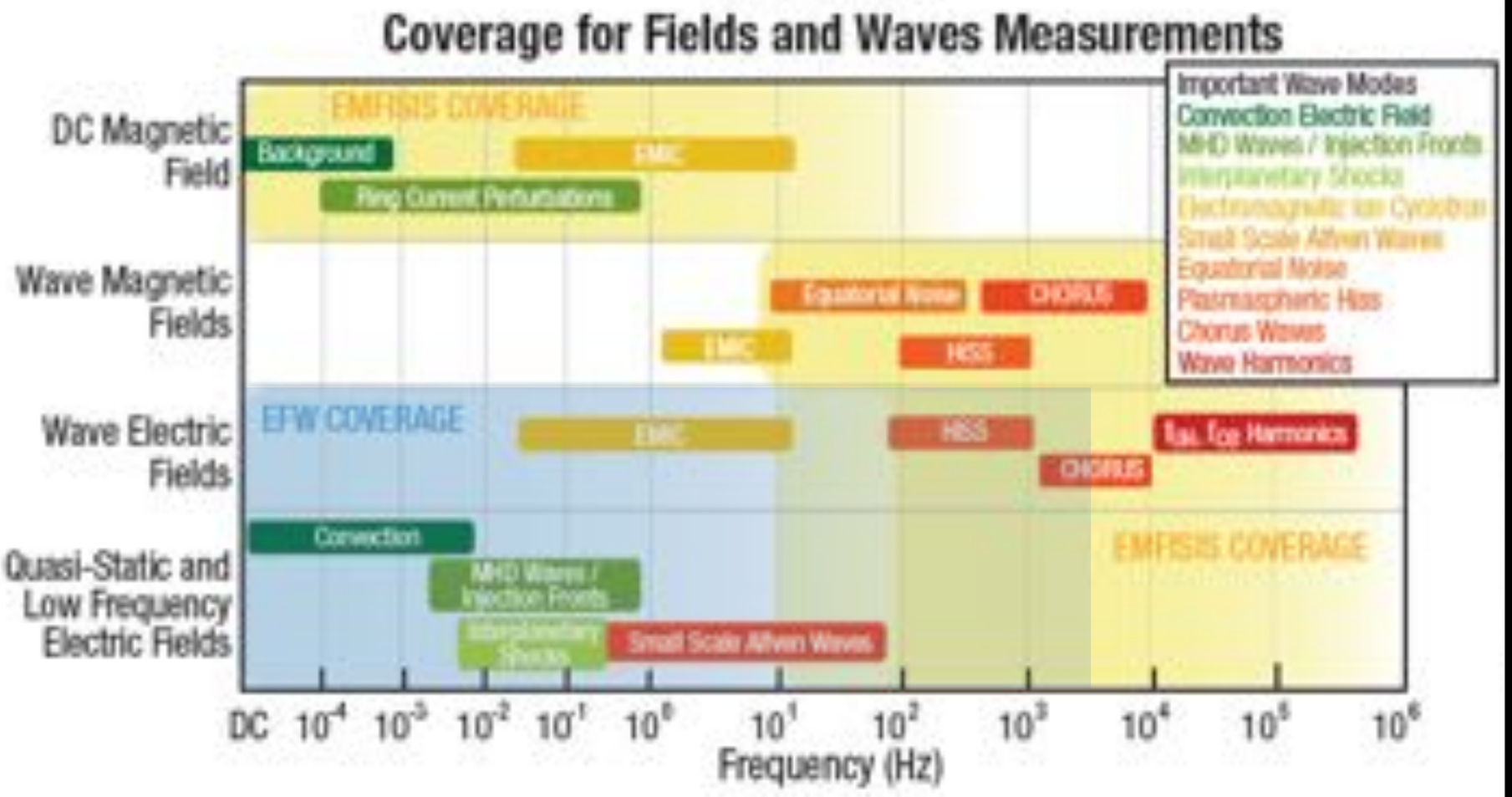
<u>Complete MLT coverage</u>
• spans different physical mechanisms/interaction regions



<u>Van Allen Probes Instrument Investigations</u>

Instruments	Science Teams
Energetic Particle, Composition and Thermal Plasma Suite (ECT), including: Helium, Oxygen, Proton, and Electron spectrometer (HOPE) Magnetic Electron Ion Spectrometer (MagEIS) Relativistic Electron-Proton Telescope (REPT)	**Harlan Spence**, PI, University of New Hampshire **Key Partners:** LANL, SwRI, Aerospace Corp., LASP Herbert Funsten, LANL J. Bernard Blake, Aerospace Corp. Daniel Baker, University of Colorado LASP
Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS)	**Dr. Craig Kletzing**, PI, University of Iowa **Key Partners:** NASA/GSFC, University of New Hampshire
Electric Field and Waves Instrument (EFW)	**John Wygant**, PI, University of Minnesota **Key Partners:** University of California, Berkeley; LASP
Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE)	**Louis Lanzerotti**, PI, New Jersey Institute of Technology **Key Partners:** JHU/APL, Fundamental Technologies
Relativistic Proton Spectrometer (RPS)	**Joseph Mazur**, PI, Aerospace Corp.
Balloon Array for RBSP Relativistic Electron Losses (BARREL)	**Robyn Millan**, PI, Dartmouth College





Instrument Performance

All instruments are healthy and returning quality data.

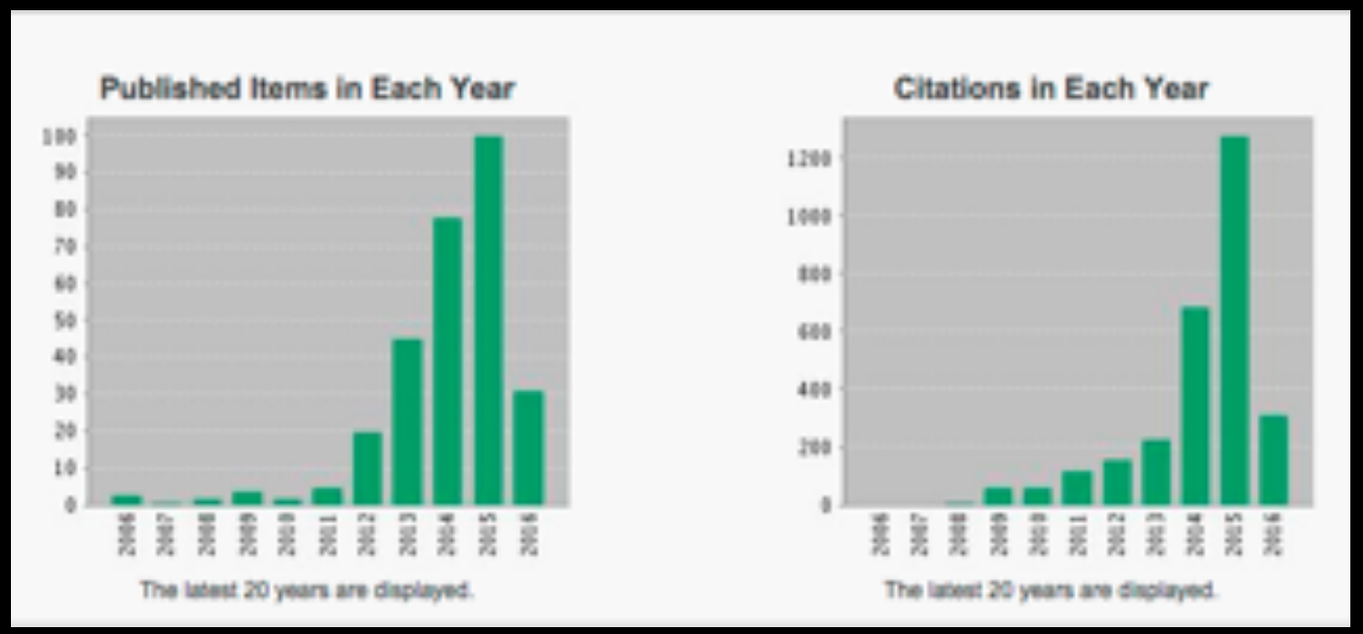
Overlapping energy/frequency ranges provide excellent basis for cross-calibration.

Data downlink increased by more than factor of 2 by modifying compression and on-board operation.

Scientific Success of Van Allen Probes

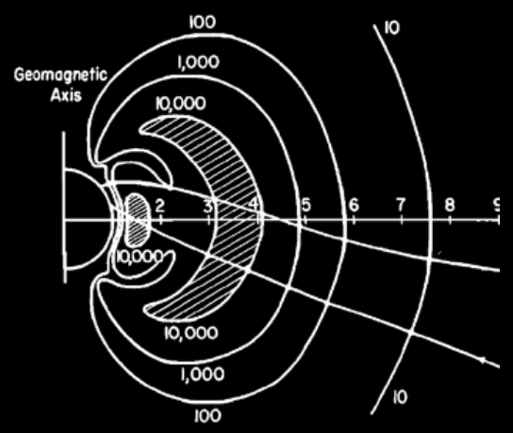
- More than 300 publications. More than 2900 citations
- More than 50% of publications are lead by authors not directly funded by Van Allen Probes
- H-index of 24 (Web of Science)
- High-profile results include: *Nature* (6 pub.), *Science* (2 pub.), *Nature Publishing Group* (4 pub.), *Physical Review Letters* (2 pub.)
- Special Issue of *Space Science Reviewers* (Volume 179, 2013)
- Special Issue of *Geophysical Research Letters* (26 pub.)
- 2 Special Issues of *Journal of Geophysical Research* (>50 pub.)
- Steady stream of press releases with new results featured on NASA and JHU/APL websites
- International press interest, popular science radio shows and magazine articles

Steady rise of publications and citations

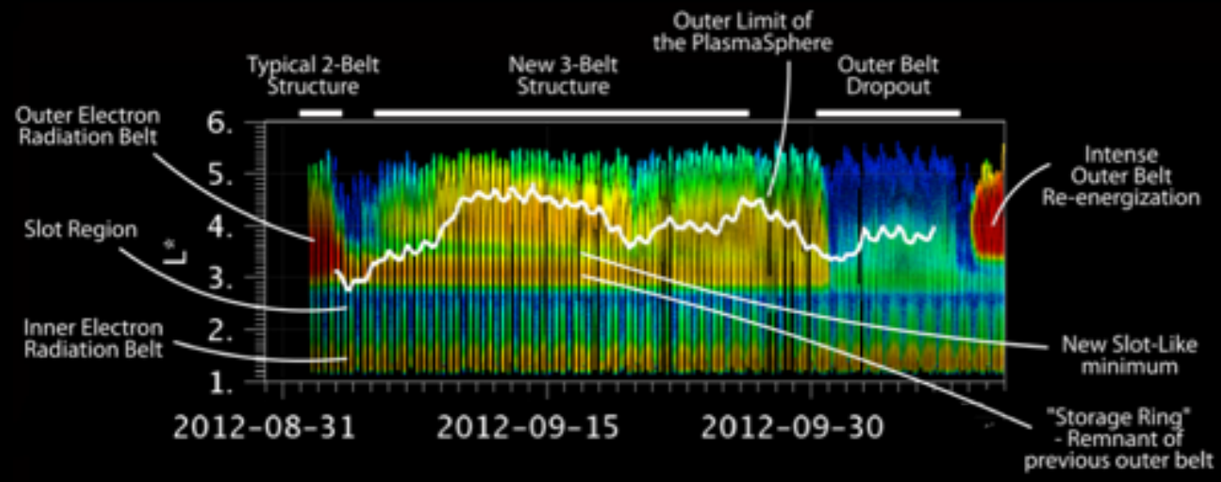


Unprecedented Measurement Capabilities - New Unexpected Discoveries

James Van Allen



Van Allen Probes

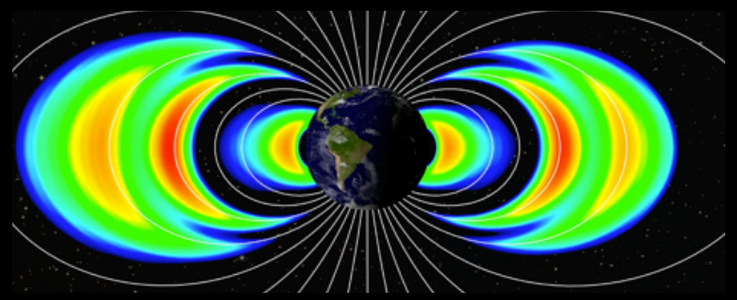


Explorer 1

[Van Allen, JGR 1959]

RBSP

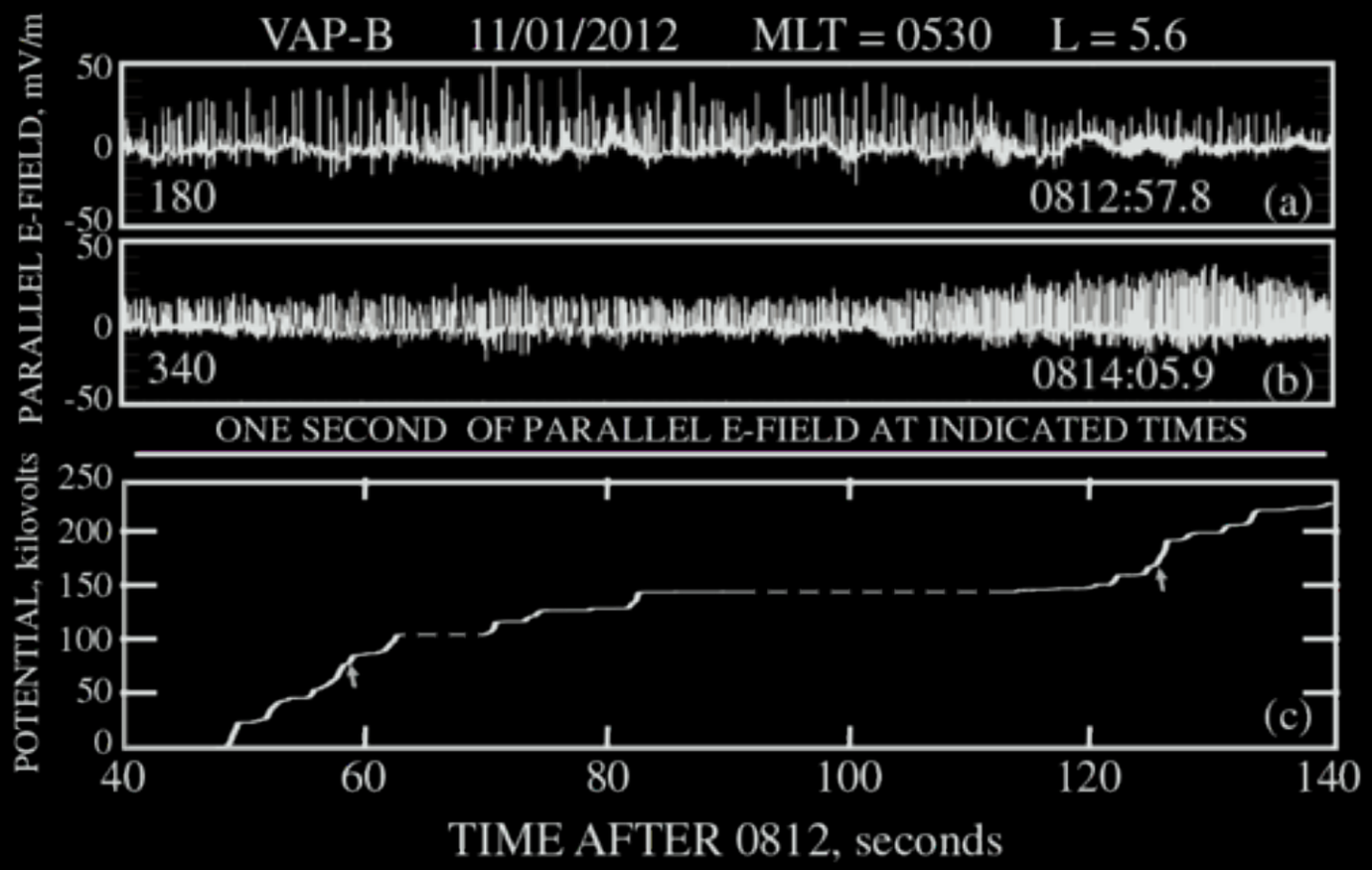
[Baker et al., Nature 2012]



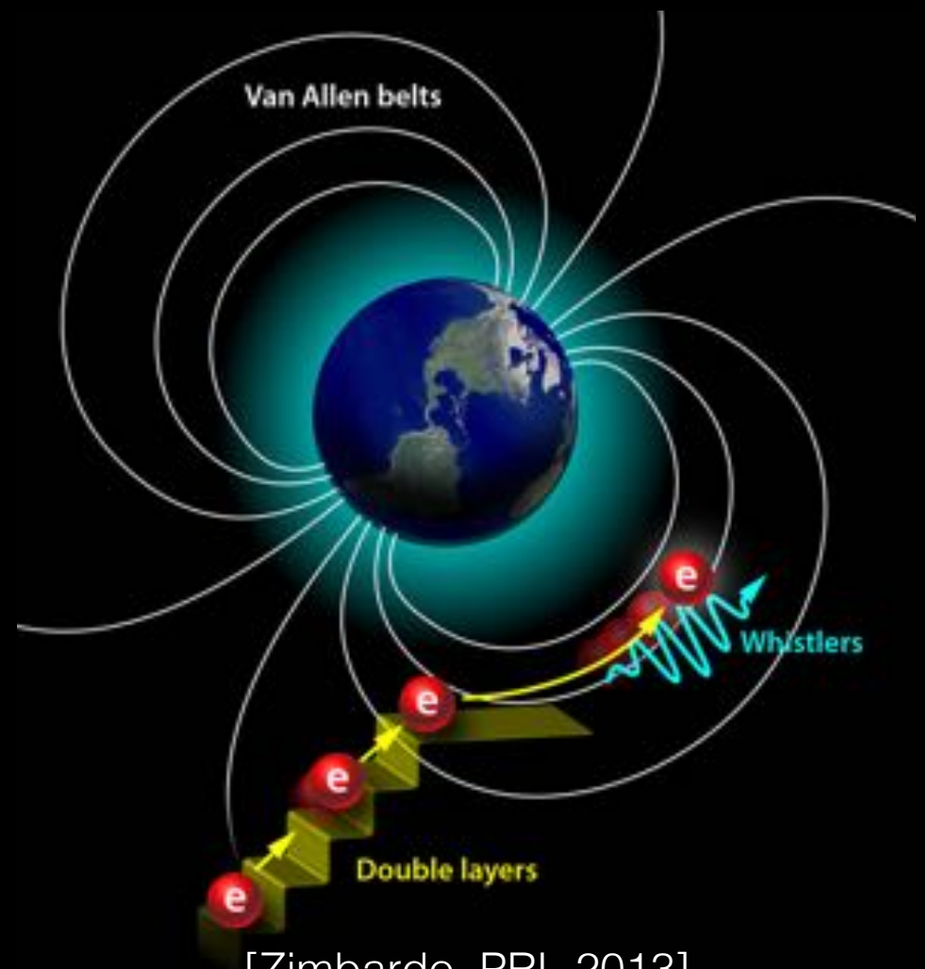
The Van Allen Probes unveiled several new and unanticipated structures, discovered new energization processes, and revealed the critical importance of dynamic hot plasma injections, which radically changed our understanding of Earth's inner magnetosphere and radiation belts.

Double Layers - New Rapid Acceleration Mechanism

Unprecedentedly high data rate burst mode & "scientist in the loop" approach



[Mozer et al., 2013; 2014; 2015; 2016]



[Zimbardo, PRL 2013]

Abut 7000 double layers were observed in one minute. Each double layer is detected as an electric field spike of a duration of ~0.45 ms and a potential step of about 30 V. The double layers propagate along the magnetic field lines at 3100 km/s, the speed of an electron acoustic waves that can exist in a plasma containing both hot and cold electron populations.

Electron acceleration can be described as a two-step process: first, electrons are accelerated to keV energy by the potential drop due to streams of double layers. Once they have enough energy, they can interact resonantly with whistler waves and be quickly accelerated to MeV energies.

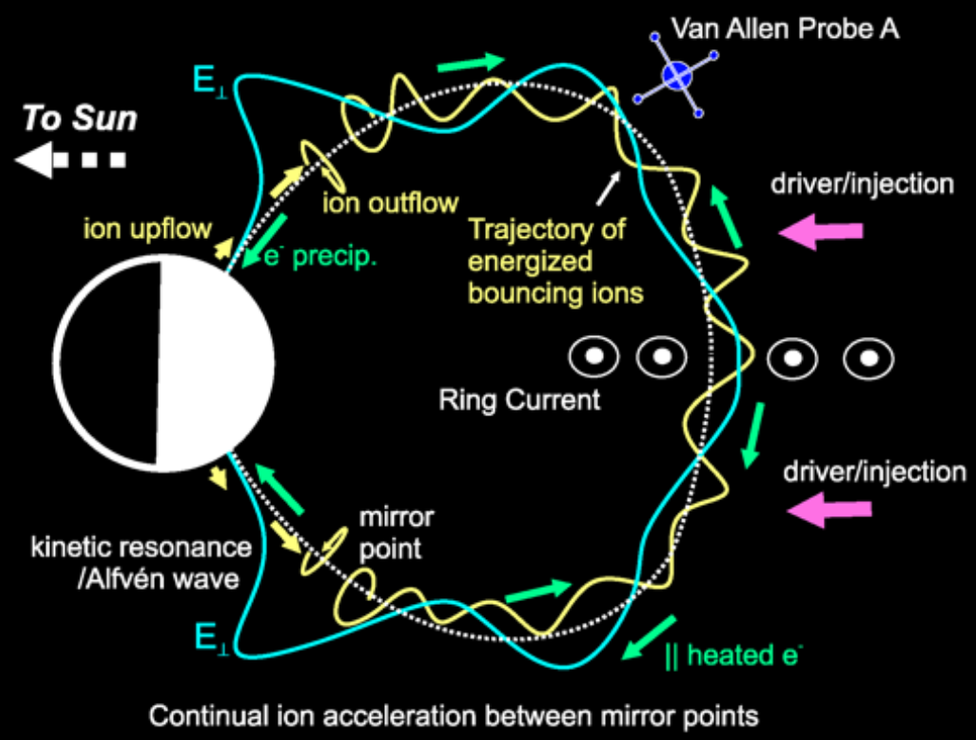
Kinetic Alfvén Waves (KAWs)

Newly discovered prevalent wave activity deep in the the inner magnetosphere

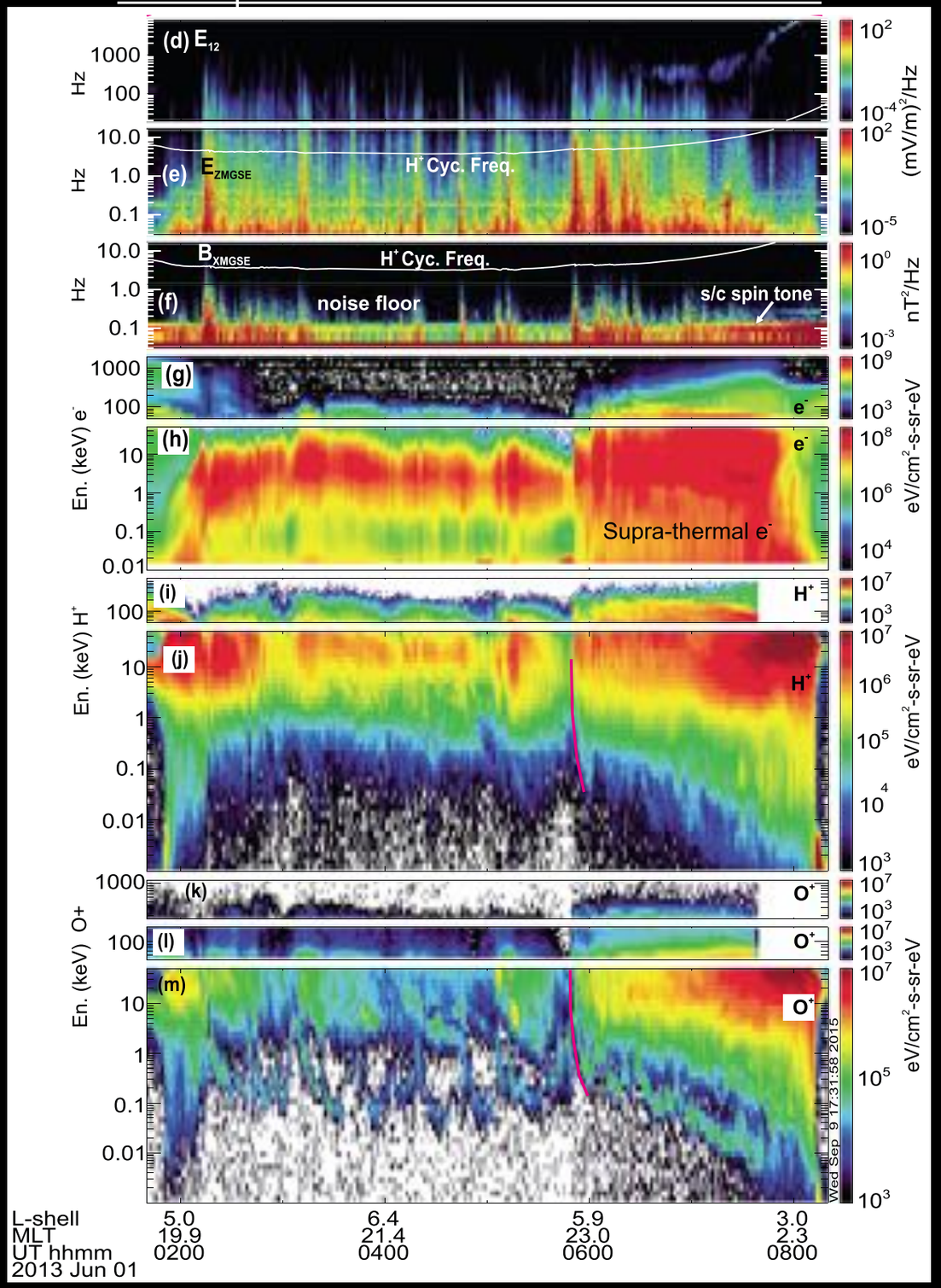
Van Allen Probes observed large-amplitude KAWs in association with plasma injections [Chaston et al., 2015a] and shock-induced magnetopause compressions [Malaspina et al., 2015].

KAWs can dramatically affect relativistic electron and energetic ion populations by:

- Pitch-angle scattering and atmospheric loss of MeV electrons
- Multiple-bounce acceleration of ring current ions to >50 keV
- Field-aligned heating of thermal electrons to 1 keV



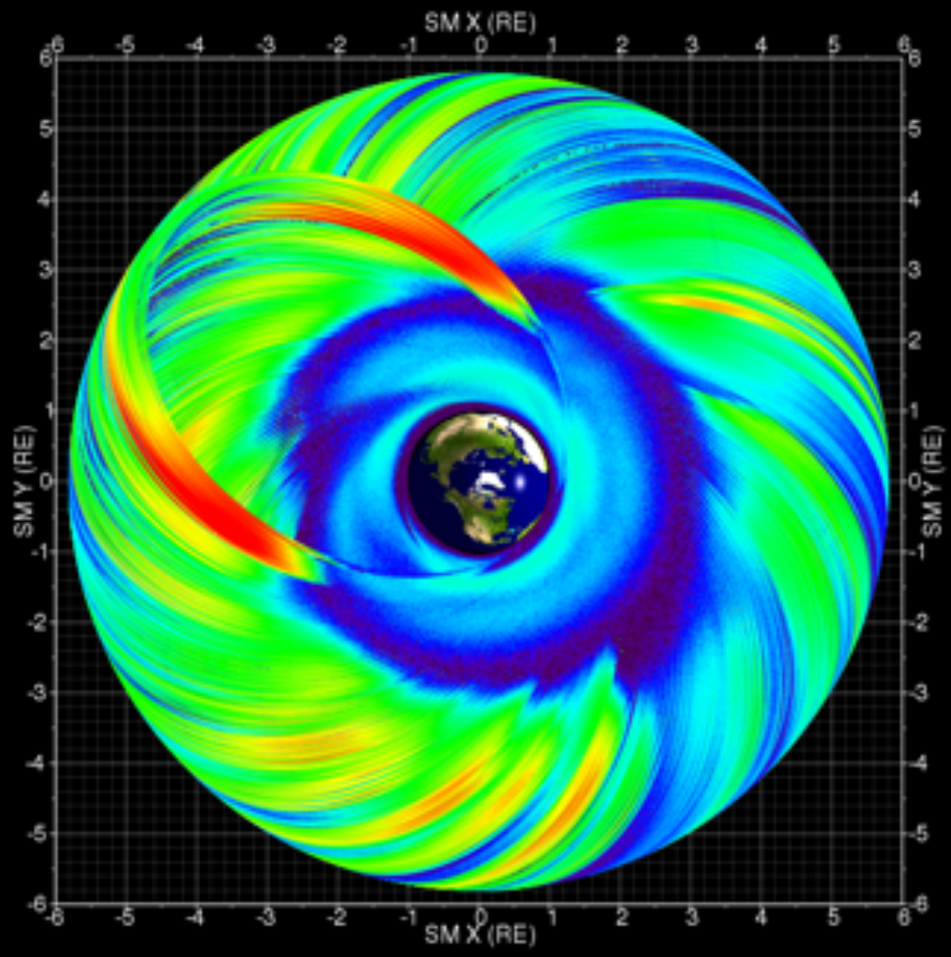
Main phase of 1 June 2013 storm

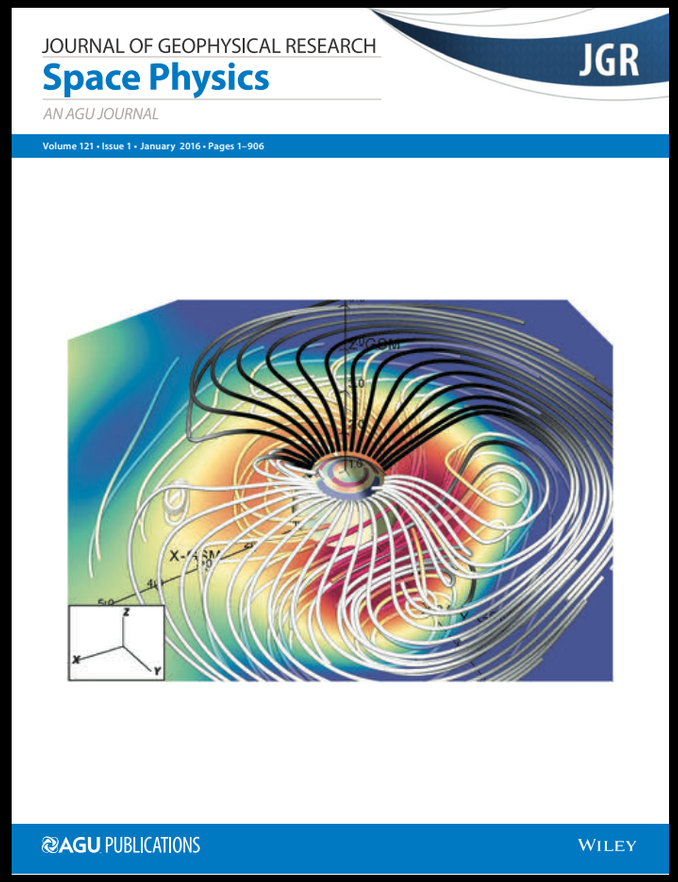


[Chaston et al., 2015b]

Comprehensive Dynamics-Configuration Sampling - Systemwide Understanding & Predictability

Almost 4 yr, 2x full MLT coverage, >65 geomagnetic storms



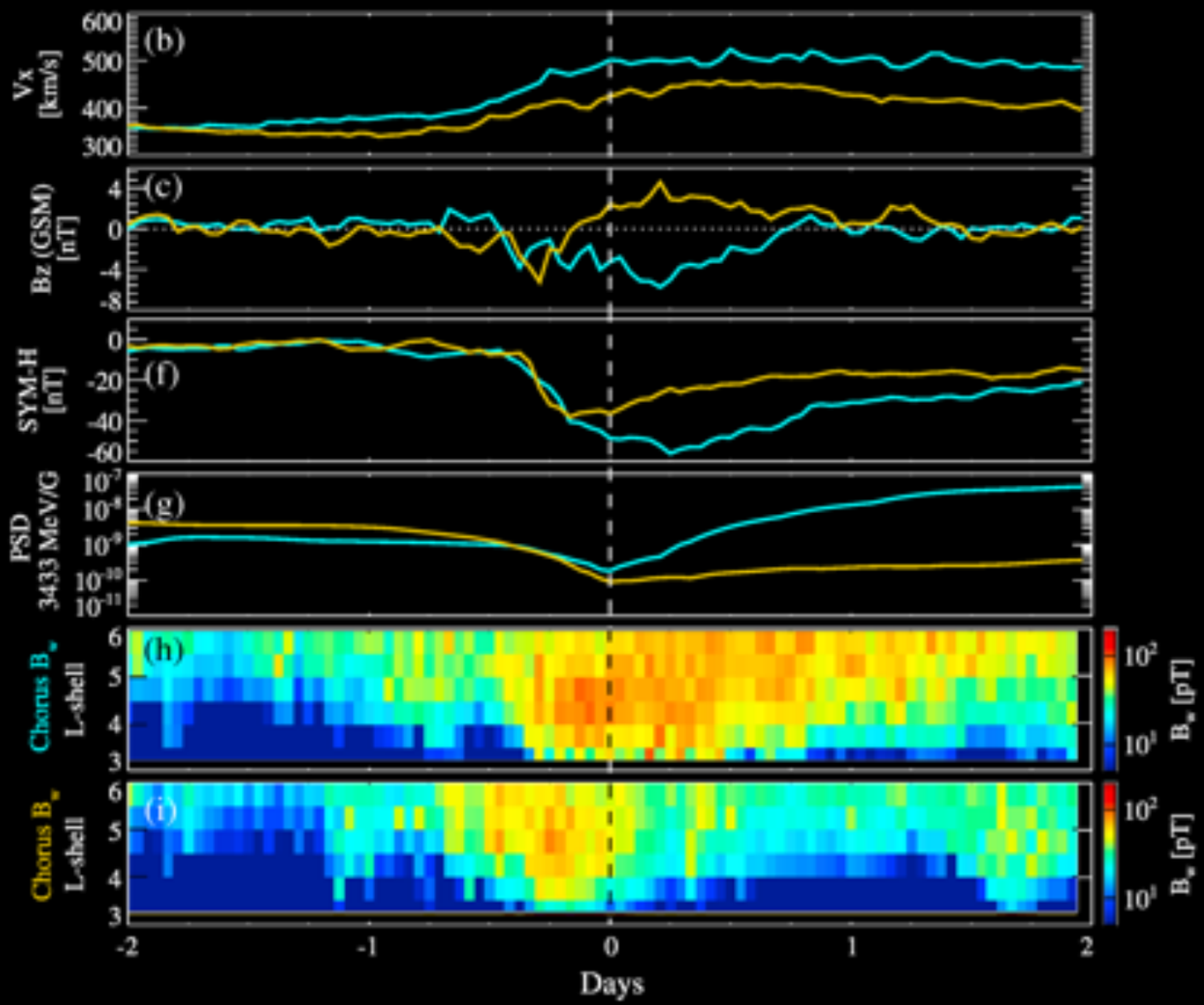


[Stephens et al., 2016]

Over past 4 years the Van Allen Probes lines of apsides made 2 full circles around Earth providing comprehensive measurements of the inner magnetosphere over more than 65 geomagnetic storms. This unprecedented dynamics-configuration sampling enabled: (1) major development of key empirical models; (2) unveiling the the solar wind drivers of the radiation belt activity critical for the development of predictive models.

Solar Wind Drives of Radiation Belt Dynamics

Superposed epoch analysis of 2.5 yr of the RBSP data identified key solar wind drivers of relativistic electron acceleration

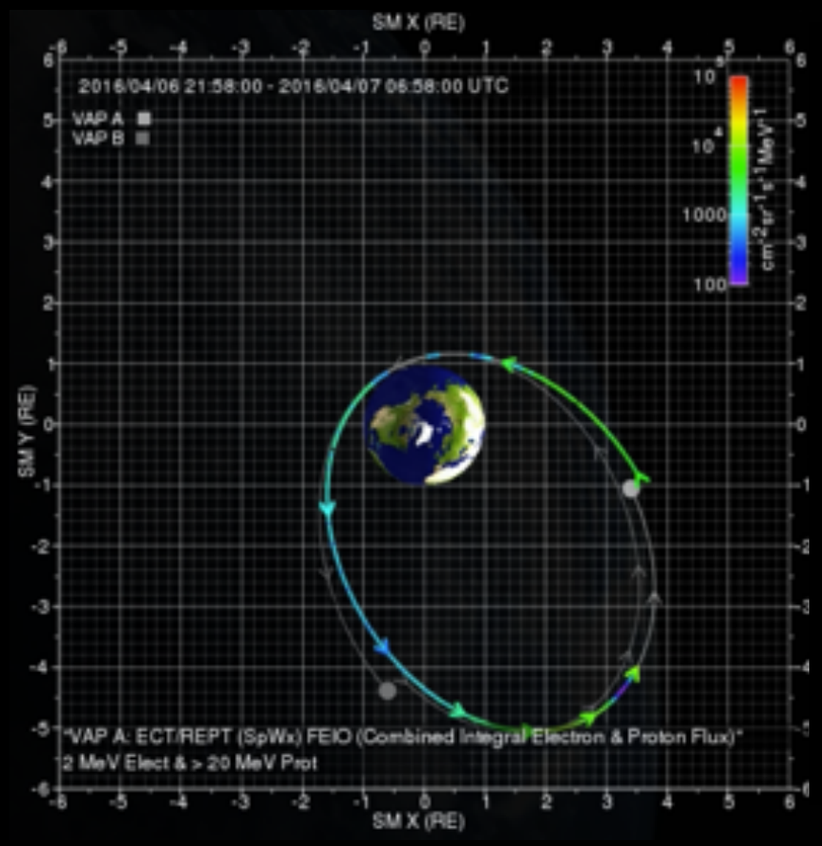


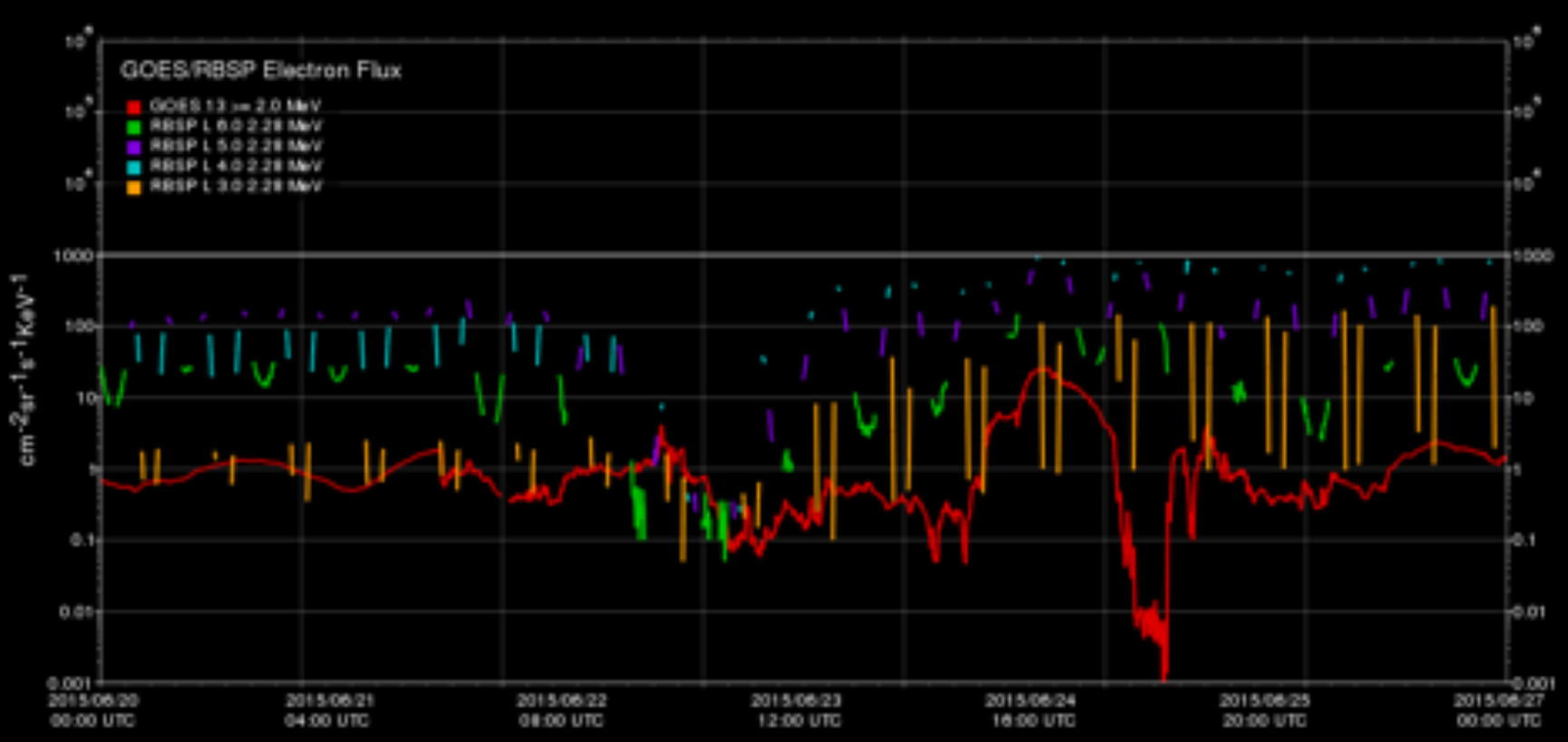
[Li et al., 2015]

(1) Prolonged southward Bz: enhanced magnetospheric convection, seed population
(2) High solar wind speed: ULF activity, radial transport and acceleration
(3) Low SW dynamic pressure: no magnetopause losses
(4) Enhanced chorus activity: local acceleration

Real Time SpWx Data from Radiation Belts

Predict the response of the radiation belts to solar storms to protect space assets in the near-Earth space

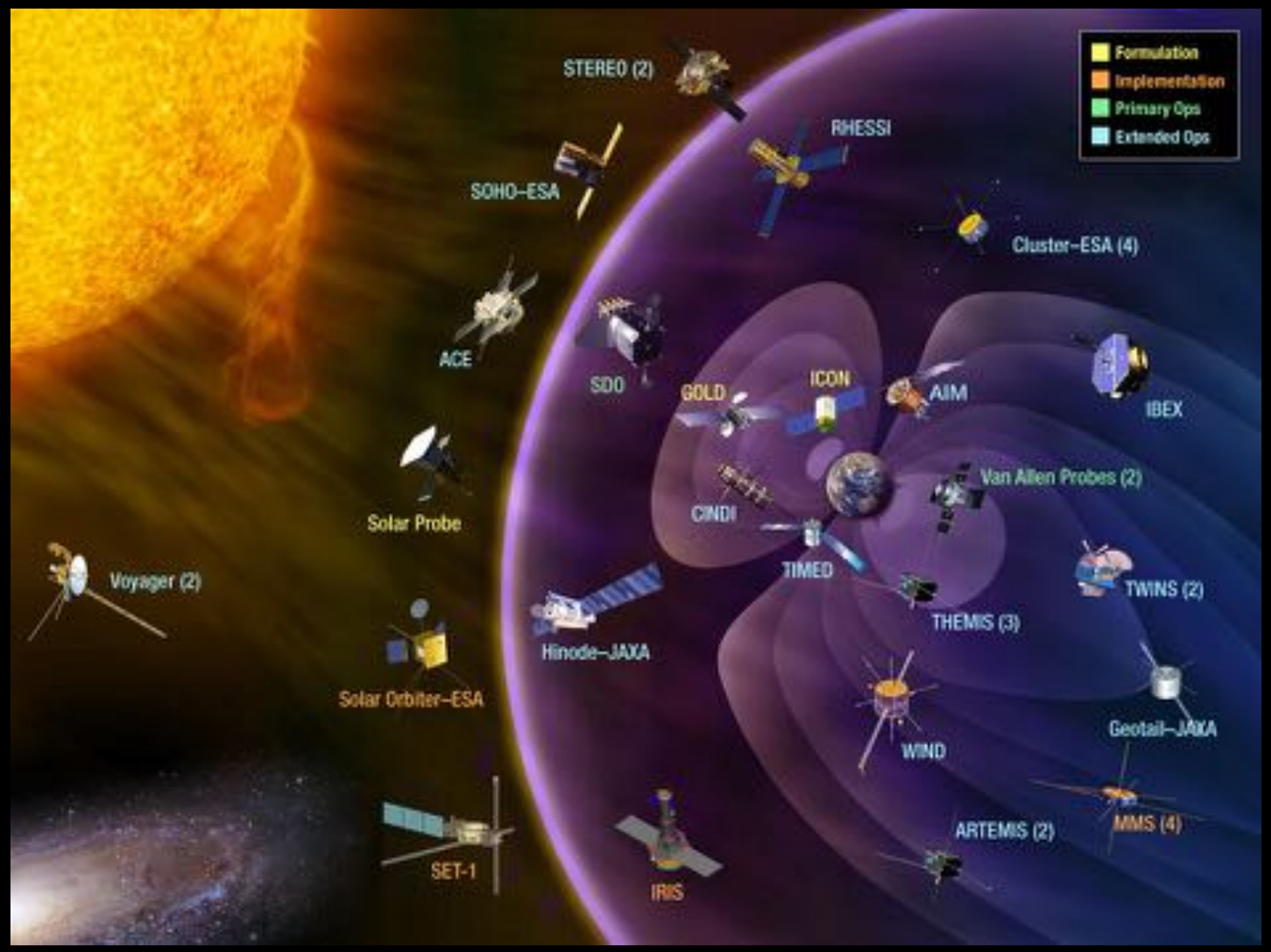




Van Allen Probes near-real-time data products soon to be re-broadcasted by NOAA SWPC

- All instruments continuously broadcast a subset of their science data in real time
- Van Allen Probes partners with three foreign institutions who operate ground stations that receive the broadcast:
  - Korea Astronomy and Space Science Institute (KASI)
  - Institute of Atmospheric Physics, Czech Republic
  - National Commission for Space Activities (CONAE), Argentina
  - National Institute of Space Research (INPE), Brazil
- The data are collected and processed at APL and then disseminated via Science Gateway tools

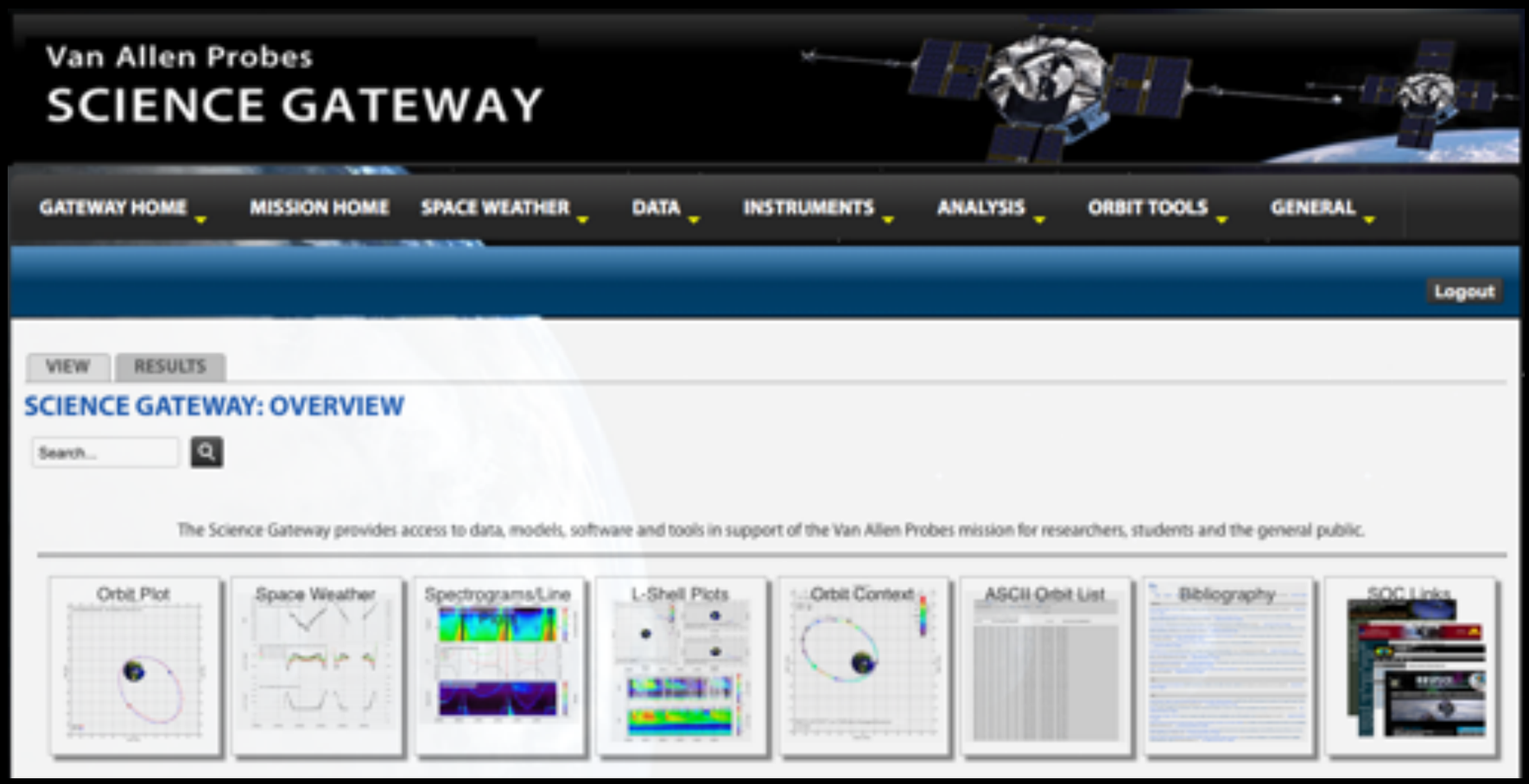
Van Allen Probes Central Place in HSO



- Perfectly positioned in the inner magnetosphere to observe the causal link in the chain from the Sun to the Earth.
- Exquisitely complete particle and fields observation capabilities. Real-time space weather data.
- Measures global distributions of high-energy electrons and ions over 2-4 hr.
- Missions observing solar influences (ACE, SDO, Wind, MMS), magnetotail connections (THEMIS, MMS), as well as other inner magnetosphere aspects (TWINS), all participate in Van Allen Probes Science.

Science Gateway

http://rbspgway.jhuapl.edu

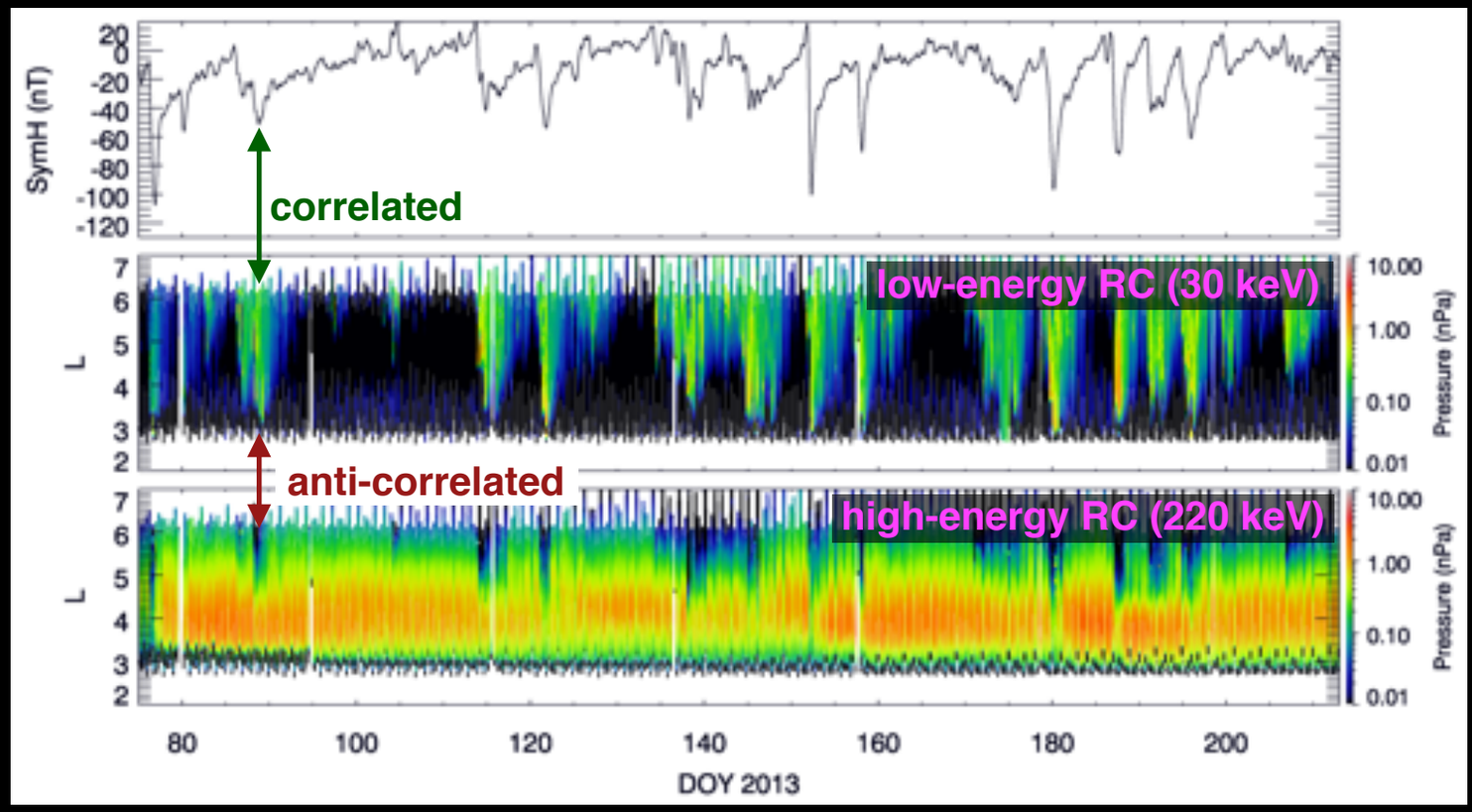


- Interactive plotting of all high-level data products from all instrument teams
- Digital data download (CDF)
- Latest (TS07D) magnetic field model, magnetic ephemeris, and adiabatic invariants
- SpWx data
- Multi-mission orbit tools
- Bibliography

Backup Slides

High-Energy Ring Current

RBSPICE revealed persistent ring current attributed to high-energy protons



[Gkioulidou et al., 2016]

The magnitude and the phase of geomagnetic storms are quantified with the ground-based Sym-H index, which had been associated with the strength of the near-Earth ring current carried by energetic (keV) ions injected from the magnetotail by large-scale electric fields (convection).

High-resolution wide-energy-range ion measurements by RBSPICE provided long-term tomographic reconstruction of the energy composition of the ring current.

It showed that while the lower-energy (<80 keV) component is highly correlated with Sym-H and varies on the timescale of magnetospheric convection, the higher energy component (>100 keV) is anti-correlated with Sym-H and varies on much longer timescales similar to radiation belt electrons.

High-energy ring current persists and grows in quiet time after the storm decay to energy levels comparable to the energy of the total storm-time current.

Van Allen Probes Reveal the Structure of Electric Currents in the near-Earth Space

Empirical models based on *in situ* magnetic field measurements from past and present spacecraft missions provide a robust framework for modeling and forecasting storm-time electrodynamics of Earth's magnetosphere.

Van Allen Probes addition to the HSO dramatically increased the sampling of the inner magnetosphere. Magnetic field measurements collected by the Probes provided the first data-derived reconstruction of the three-dimensional current system inside 4 R_E, which could not be resolved with the data from previous missions.

JGR (vol 121) cover shows a data-derived reconstruction of the inner magnetosphere-ionosphere current system from [Stephens et al., 2016] .