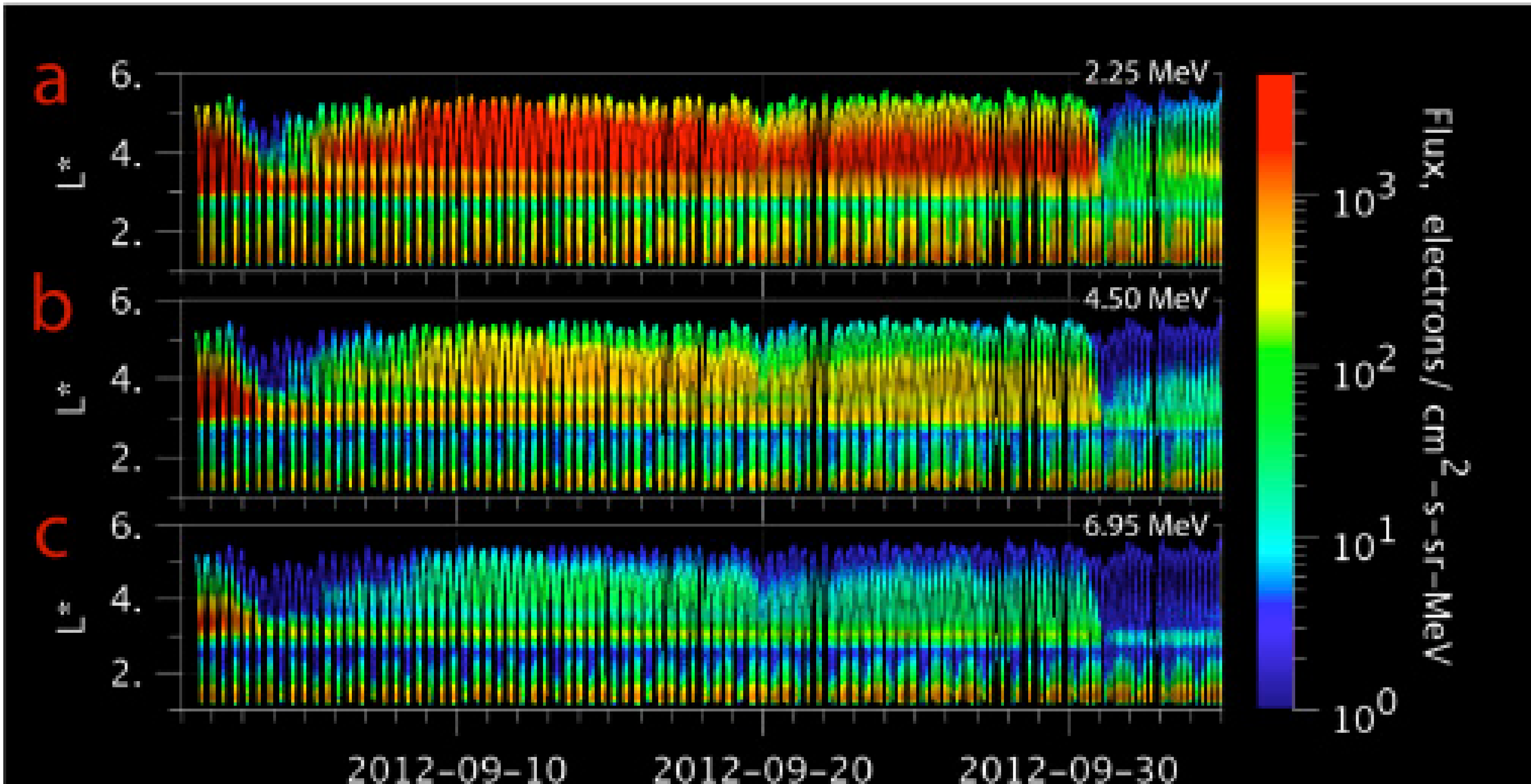
How are we doing so far in meeting the Mission Success Criteria?

Mona Kessel, NASA HQ

New Discovery
could not be planned

A Long-lived Relativistic Electron Storage Ring Embedded in Earth's Outer Van Allen Belt

D. N. Baker et al

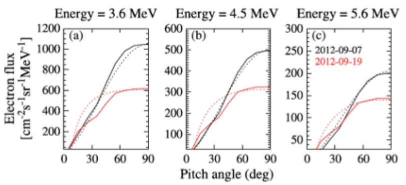


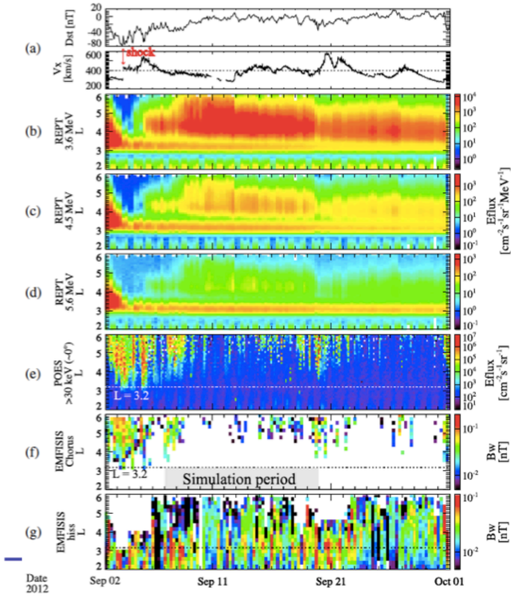
Van Allen Probes data and simulation explain longevity of storage ring

Evolution and slow decay of an unusual narrow ring of relativistic electrons near L ~ 3.2 following the September 2012 magnetic storm

Thorne et al., GRL

- Observations of Chorus and Hiss
- Location of plasmapause
- Scattering of electrons dependent on energy





Van Allen Probes confirms that radiation belt electron acceleration occurs locally and not just as a result of transport.

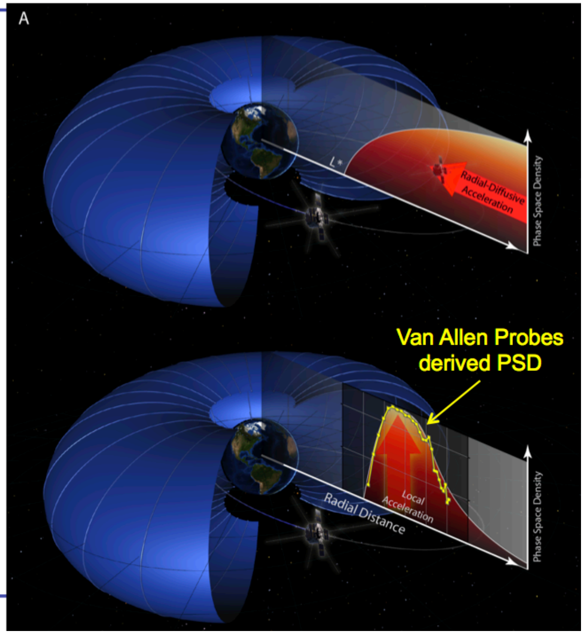
A fundamental unanswered question has been how electrons can be accelerated to such high energies.

Two classes of processes have been proposed:

- transport and acceleration of electrons from a source population located outside the radiation belts ("radial acceleration");
- acceleration of lower-energy electrons to relativistic energies in situ, in the heart of the radiation belts ("local acceleration").

Phase Space Density, PSD
PSD = electron flux/(momentum)^2

Reeves et al. (ECT)
Published in Science



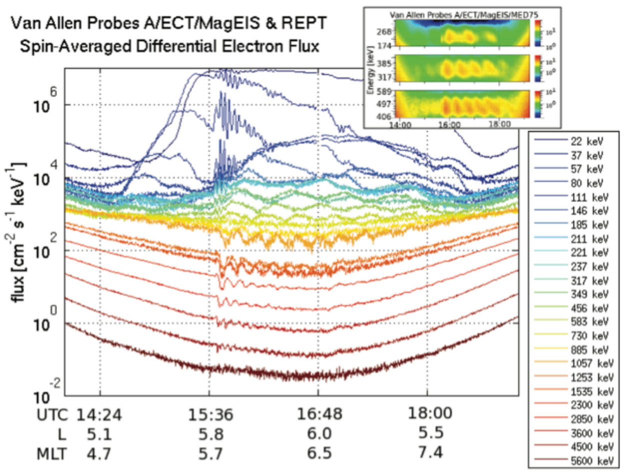
The Earth's Van Allen Radiation Belts: A Geophysical Synchrotron

The dominant processes responsible for relativistic electron acceleration, transport, and loss remain poorly understood.

This paper shows coherent acceleration due to resonance with ultra- low frequency (ULF) waves on a planetary scale.

Such coherent ULF acceleration is rather ubiquitous and far more common than either previously thought or observed. The observed modulations and energy dependent spatial structure indicate the action of a geophysical synchrotron

Mann et al. (ECT)
Submitted to Nature Comm.



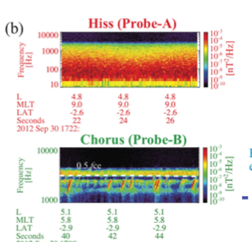
Also, Claudepierre et al. GRL

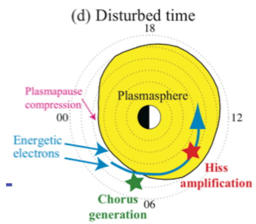
Hiss amplified in outer plasmasphere due to injected electrons

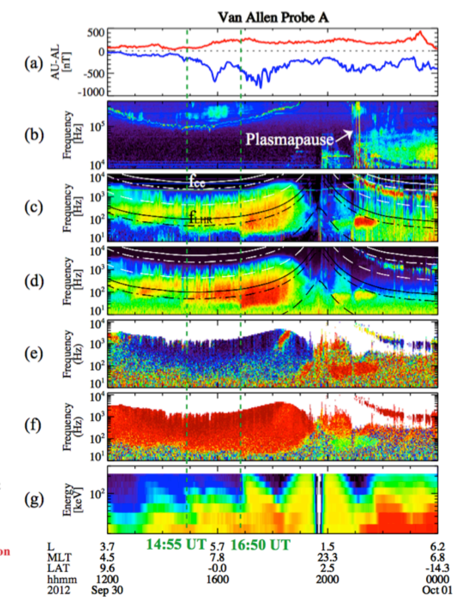
An unusual enhancement of low-frequency plasmaspheric hiss in the outer plasmasphere associated with substorm injected electrons

Li et al., GRL

Dispersed injections of energetic electrons were observed in the dayside outer plasmasphere associated with significant intensification of plasmaspheric hiss at frequencies down to ~20 Hz, much lower than typical hiss wave frequencies of 100−2000 Hz.







First unambiguous observation of drift resonance wave-particle interaction with fundamental mode polodial waves

Excitation of Poloidal standing Alfven waves through drift resonance wave-particle interaction

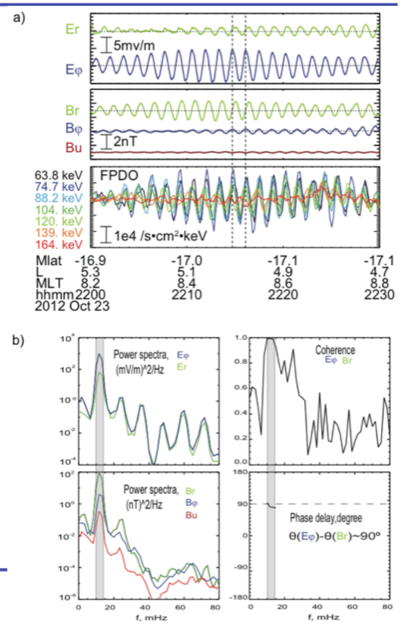
Dai et al., GRL

Fundamental mode standing Poloidal wave:

- Intense azimuthal electric field (Eφ) oscillations as large as 10mV/observed associated with radial magnetic field (Br) oscillations
- Observed wave period, Eφ/Br, of 84 sec
- 90 degree phase lag between Br and Eφ

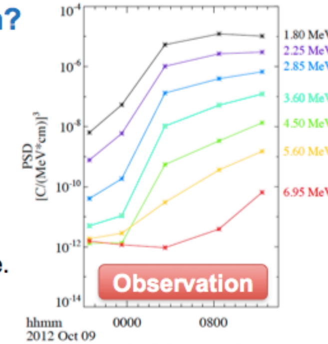
Ring current ion fluxes (63.8 to 164 keV) oscillated at same period as waves with an energy-dependent phase with respect to Eφ, characteristic of drift resonance.

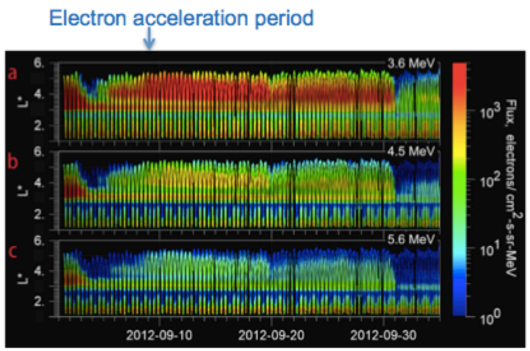
Drift-resonance instability is expected to absorb energy from the ring current ions and so affect affect the ring current evolution.

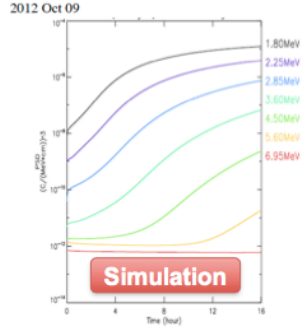


Can Quasi-linear whistler-electron interactions explain sudden electron acceleration?

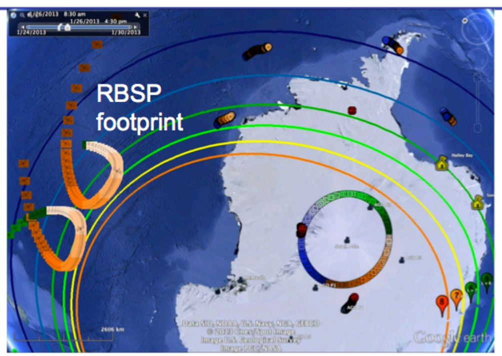
- Thorne et al. (ECT electrons + EMFISIS waves)
- Submitted to GRL
- Electron acceleration is faster than expected
- A critical question: Are electrons accelerated by non-linear or quasi-linear wave interactions?
- Theory using EMFISIS-observed whistlers suggests that quasi-linear interactions may suffice.





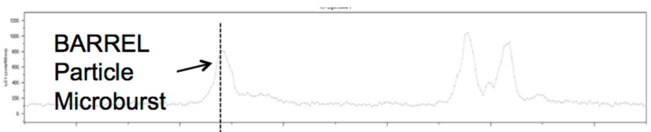


Chorus link with precipitation seen with BARREL and Van Allen/EMFISIS

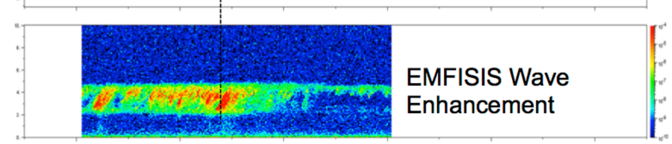


Millan, Hospodarsky, Breneman, Halford, Kletzing, Wygant et al

- BARREL observations in coordination with Van Allen Probes.
- BARREL + EMFISIS

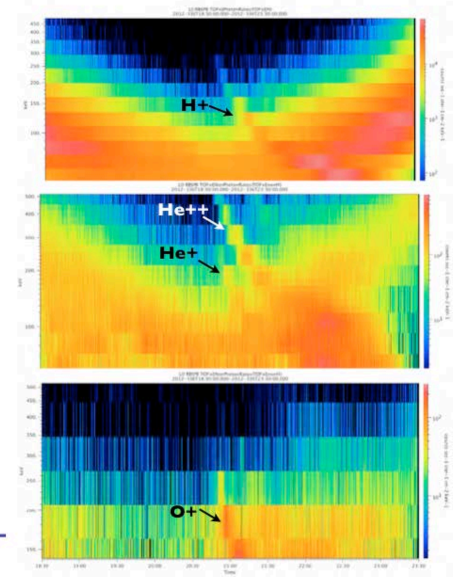


BARREL Balloon Bremsstrahlung X-ray Observations

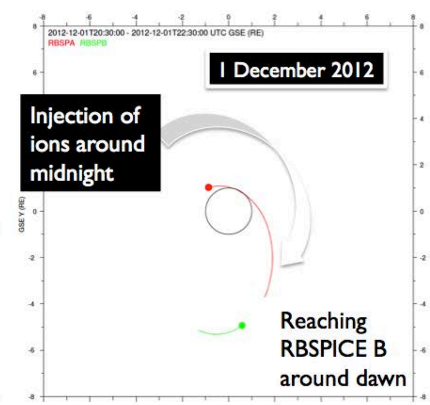


Van Allen Probes EMFISIS Chorus Emissions

First observation of multiple charge state species injections in the inner magnetosphere



Gkioulidou et al. (RBSPICE)



Mission Success = achieving (at least) Threshold Science Goals

Baseline Science Goals

1. Understand & quantify time history of energization, loss, transport
2. Distinguish between candidate processes
3. Understand how large-scale B and E fields are generated and evolve, effect on plasma environment
4. Understand & quantify production & propagation of waves (EMIC, chorus, hiss)
5. Determine convective/impulsive flows causing transport/energization
6. Determine types, characteristics of plasma waves (VLF, ELF, ULF) causing energization, loss; relative contributions; statistical maps
7. Convert particle measurements to magnetically invariant coordinate systems; infer loss cone; model effects of dB, dE on particles
8. Determine which shock-related pressure pulses produce significant acceleration; estimate relative significance

Threshold Science Goals

1. Understand & quantify time history of energization, loss, transport (electrons)
2. Distinguish between candidate processes
3. Determine convective/impulsive flows causing transport/energization
4. Determine types, characteristics of plasma waves (VLF, ELF, ULF) causing energization, loss; relative contributions; statistical maps
5. Convert particle measurements to magnetically invariant coordinate systems; infer loss cone; model effects of dB, dE on particles

Plus one of following:

1. Global electrodynamics
2. Wave-particle interaction physics
3. Proton radiation belt characteristics/sources
4. Physics of shock-related events

Measurements	Science	Publications
Spatial and temporal variations of med and high energy electron pitch angle and energy distributions (a) At recurrent separation distances (b) Inside/outside acceleration regions	• Quantify source populations • Determine how spatial and temporal variations are produced • Improved radiation belt models	Baker et al., Science Thorne et al., GRL
Spatial and temporal variations of electron radial psd profiles (a) Short timescales compared to storm main phase (b) Resolve spectral shape	• Distinguish between candidate processes of acceleration, transport, and loss • Statistically characterize as function of input conditions	Reeves et al., Science
Determine local steady and impulsive electric and magnetic field (a) Amplitude (b) Vector direction (c) Time history	• determine convective and impulsive flows • Determine propagation properties of shock-generated propagation fronts • infer total plasma densities	Gkioulidou et al.
Provide measurements to constrain (a) global convective electric field model (b) storm-time electric and magnetic field models	• convert particle measurements to magnetically invariant • infer loss cone size • model effects of global dB, dE on observed particle distributions	Morley et al., GRL
Spatial and temporal variations of electrostatic/electromagnetic waves amplitude, frequency, intensity (a) VLF/ELF (b) random, ULF, and quasi-periodic	• Importance of the waves in energization/loss of electrons • Diffusion coefficients/loss rates • ULF/irregular fluctuations contribution to radial transport • Statistical waves field maps	Mann et al., Nature C Claudepierre et al., GRL Dai et al., GRL Korth et al.

Success = All of the previous five and one of the following four

Measurements	Science	Publications
Global Electrodynamics (a) Position/dynamics of plasma boundaries, particle pressures, gradients (b) Distortion of inner magnetosphere, resulting loss of trapped particles	Understanding how large-scale magnetic and electric fields in the Earth's inner magnetosphere are generated and evolve	Nov 14, 2012 By distortion event
Wave-particle interactions (a) characteristics of particle distributions unstable to electromagnetic wave growth (b) characteristics of wave production, propagation and distribution that control resonant interactions with electrons	• Conditions that control production/propagation of waves (e.g. EMIC, whistler-mode chorus and hiss) • Acceleration/loss of energetic particles from non-linear interactions with large amplitude wave structures.	Thorne et al., GRL Mauk, GRL Millan et al.
Proton belt characteristics/sources Spatial/temporal variations of (a) medium and high energy proton pitch angle and energy distributions (b) radial phase space density profiles for medium and high-energy protons	• Source populations • Improved models • Relative importance of candidate processes of acceleration, transport, loss • Statistical characterization	
Physics of shock-related events Spatial/temporal variations of medium and high energy electron pitch angle and energy distributions and electric and magnetic field variations, including waves	Shock-related radiation belt events provide such unique and compelling opportunities for new scientific discovery that detailed measurements of only a single extreme shock-related event would produce scientific success	Baker et al., Science

Continue to add results and papers to these categories.

Feeds directly into the Senior Review proposal.

Van Allen at the Races

There were 97 drivers and 20 spectators in attendance at the Kansas City Region Sports Car Club of America's second solo racing event of the year in April.

Dr. Doug Patterson, a scientist on RBSPICE at Fundamental Technologies, realized this audience's technical interests and took the opportunity to introduce them to the Van Allen Probes mission.

The drivers and the spectators were very enthusiastic about the mission. In fact two young drivers immediately affixed the Van Allen Probes mission logo sticker to their racing kart and has remained there at every event since.