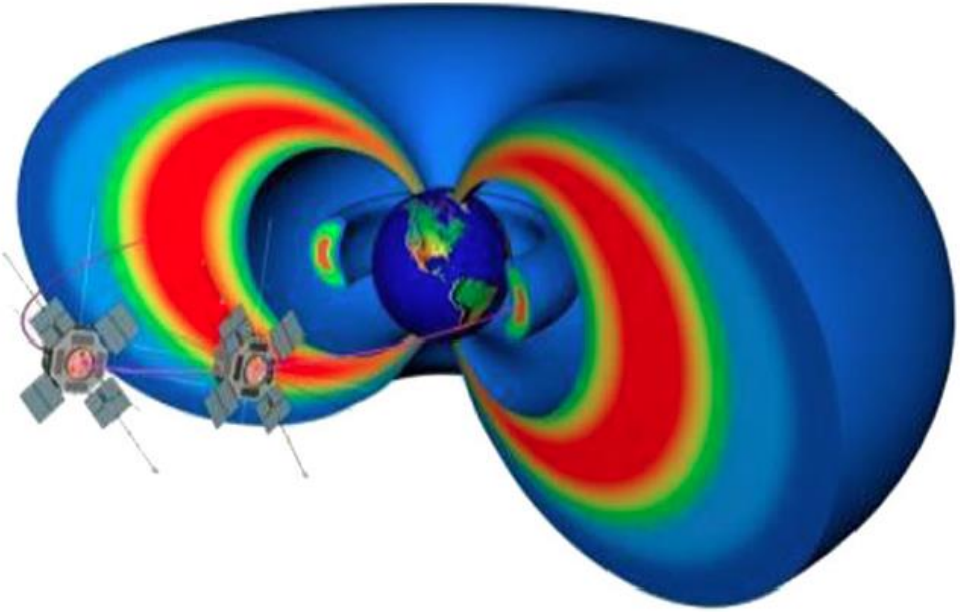
Van Allen Probes Mission and Applications

J. Mazur and P. O’Brien
The Aerospace Corporation

5 September 2017

Topics

- Van Allen Probes Mission
- Observables from the mission
  - *Electrons in the inner Van Allen belt*
  - *Inner belt protons up to ~ 1 GeV*
  - *Transitory 3rd electron belts*
- Summary

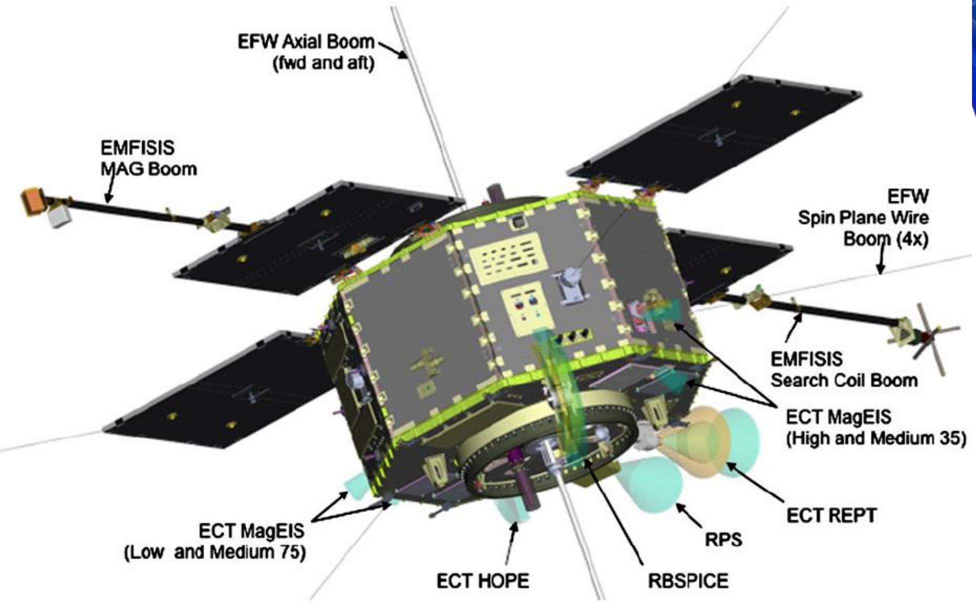


K. Kirby et al., Space Sci. Rev. 179:59-125, 2013

Our aim is to highlight examples of Van Allen Probes findings with a view to satellite applications.

Van Allen Probes Mission

- Launched 30 August 2012
- Sun-pointed spinners at 5 rpm
- GTO: ~600 x 30,000 km 10° inclination
- Orbit period ~9 hours
- Data are available online but I recommend talking to these POCs if you are thinking of using VAP data for applied research:

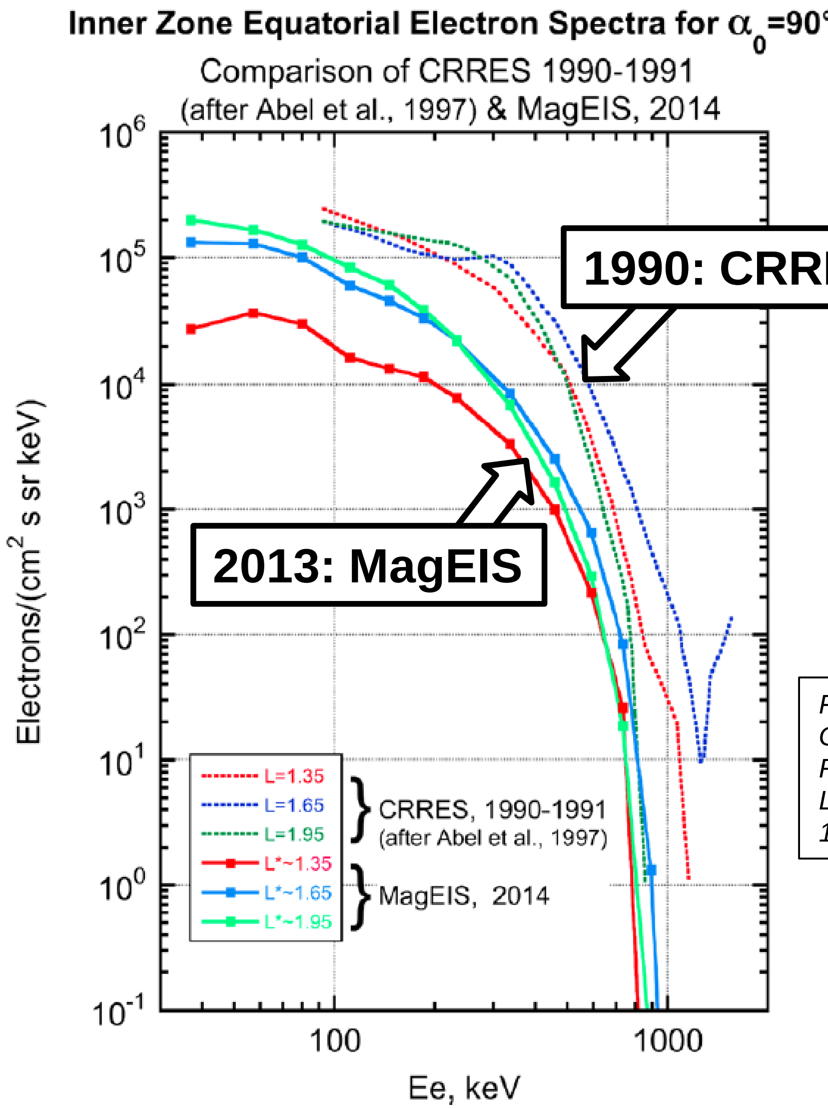


J. Stratton et al., Space Sci. Rev. 179:29-57, 2013

Investigation	Species and energy range	POC
ECT (Energetic particle, composition, and thermal plasma suite)	H: 1eV - 100 MeV e^-: 1eV - 10 MeV	H. Spence
RPS (Relativistic Proton Spectrometer)	H: 60 - 2000 MeV	J. Mazur

Topic: Inner Van Allen Belt Electrons

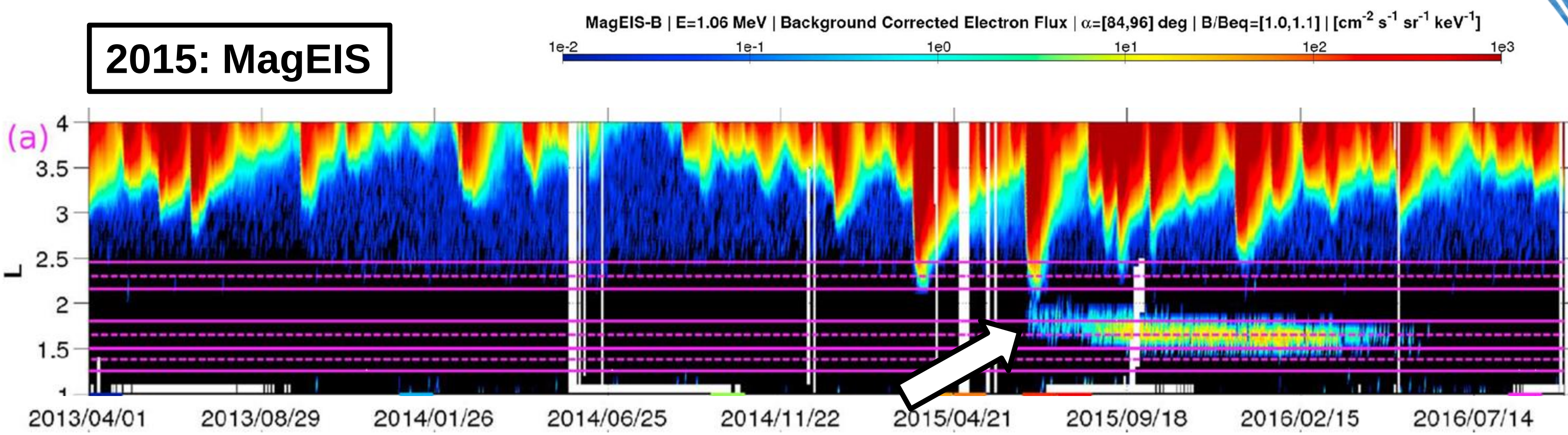
- MagEIS is designed to tease out inner belt electrons from penetrating proton background
- Findings just after VAP launch:
  - *No measurable flux above ~1 MeV*
  - *Lower fluxes than prior observations everywhere in the inner belt*



Fennell, J. F., et al. Geophysical Research Letters 42.5 (2015): 1283-1289.

Early 2013 VAP measurements led us to speculate about the uniqueness of the current state of inner belt electrons.

Injections of Electrons Into the Inner Proton Belt



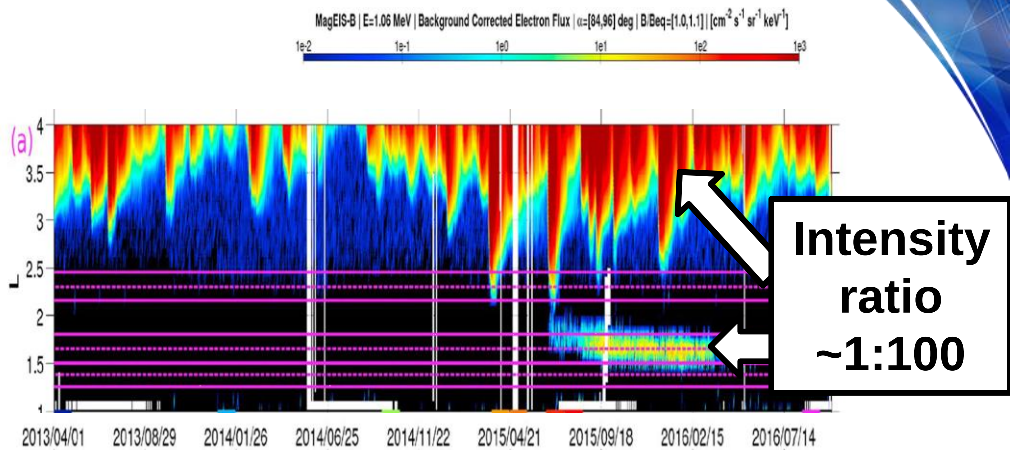
Claudepierre, Seth G., et al. *Journal of Geophysical Research: Space Physics* 122.3 (2017): 3127-3144.

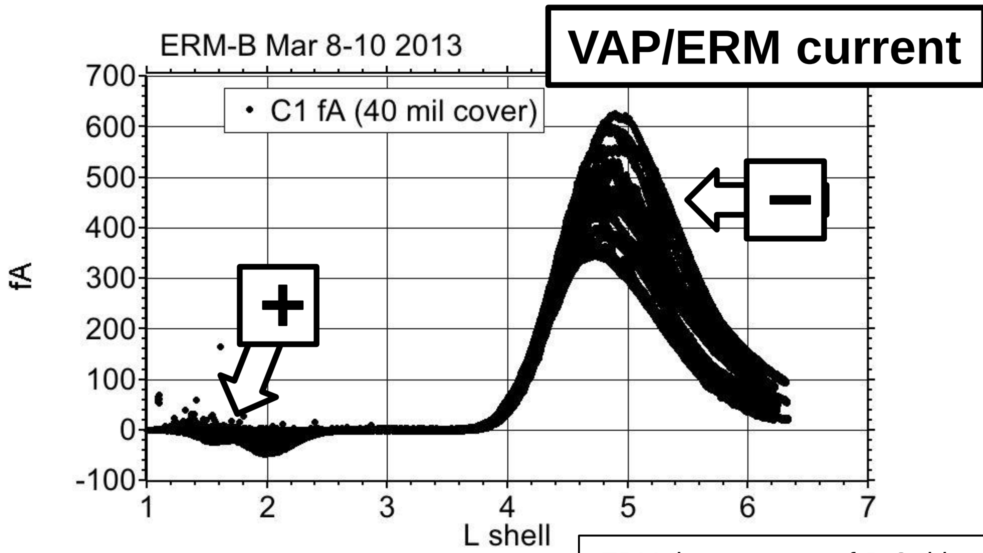
- More observation time and careful background rejection have revealed the hidden dynamics of the inner belt electrons
- Longer observation time and improved background rejection:
  - *Still showing lower intensity than CRRES*
  - *Still showing a sharply-falling energy spectrum and little-to-no flux above 1 MeV even accounting for observed injections like the 2015 March shock event*

VAP provides accurate observations of electrons in the challenging inner belt.

Inner Belt Electrons: Any Impacts?

- Possible issues: spacecraft charging and total dose
- Observational challenges should be a clue that any impact based on deposited charge will be minor compared to the proton environment
- Lower intensity than outer belt electrons at all orbits means probably not much impact
- Net charging in the inner belt can be *positive* because of stopping protons as shown by VAP/ERM



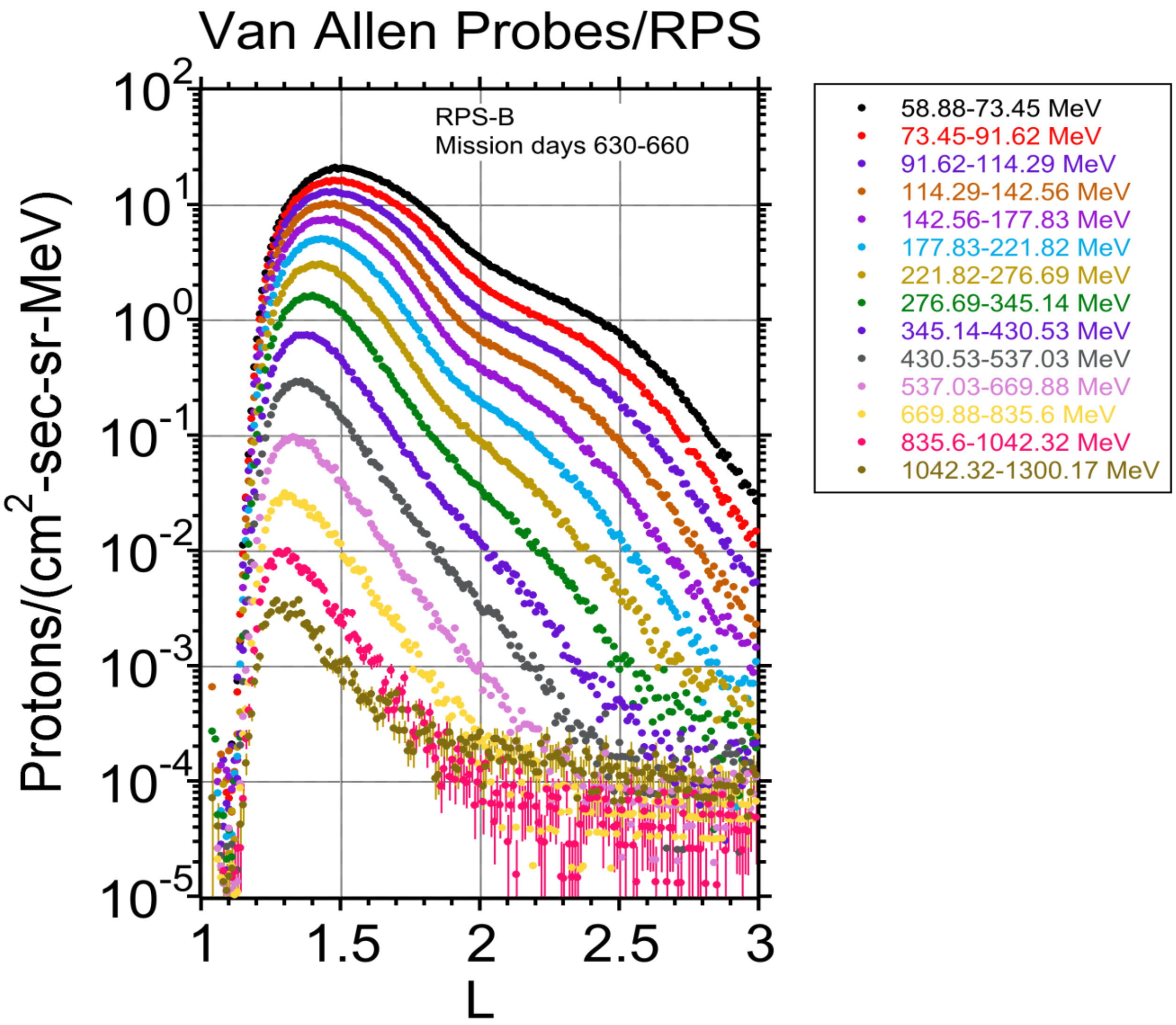


ERM data courtesy of J. Goldsten

Inner belt electrons that we have observed to date are unlikely to drive TID or charging concerns.

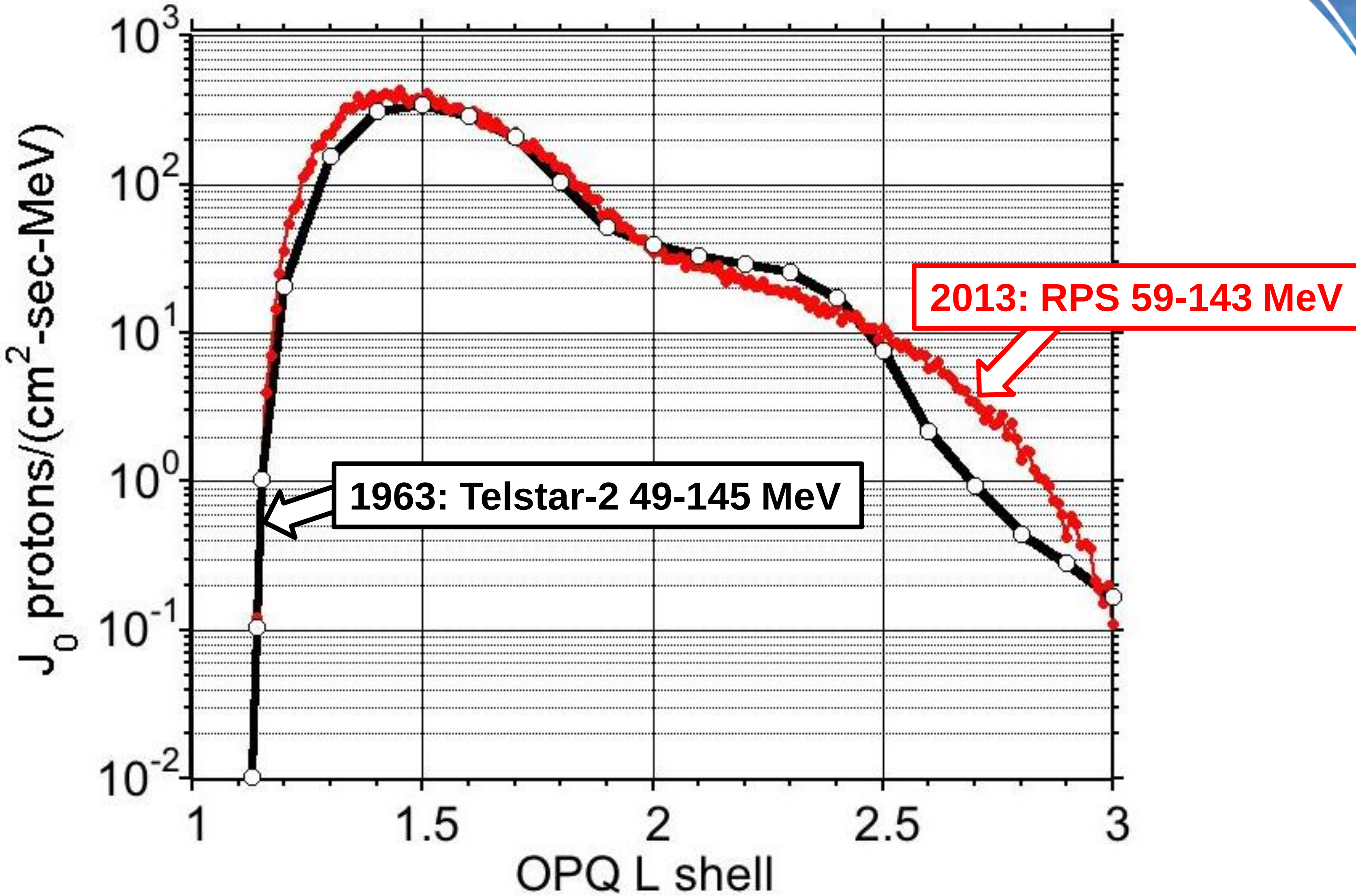
Topic: Inner Van Allen Belt Protons

- VAP/RPS provides the first long-duration measurements of the proton energy spectrum to ~GeV energies (at magnetic equator where intensity is maximum)
- Data being included in AP9 V1.5
- Research example: long-term stability of the inner belt (next charts)



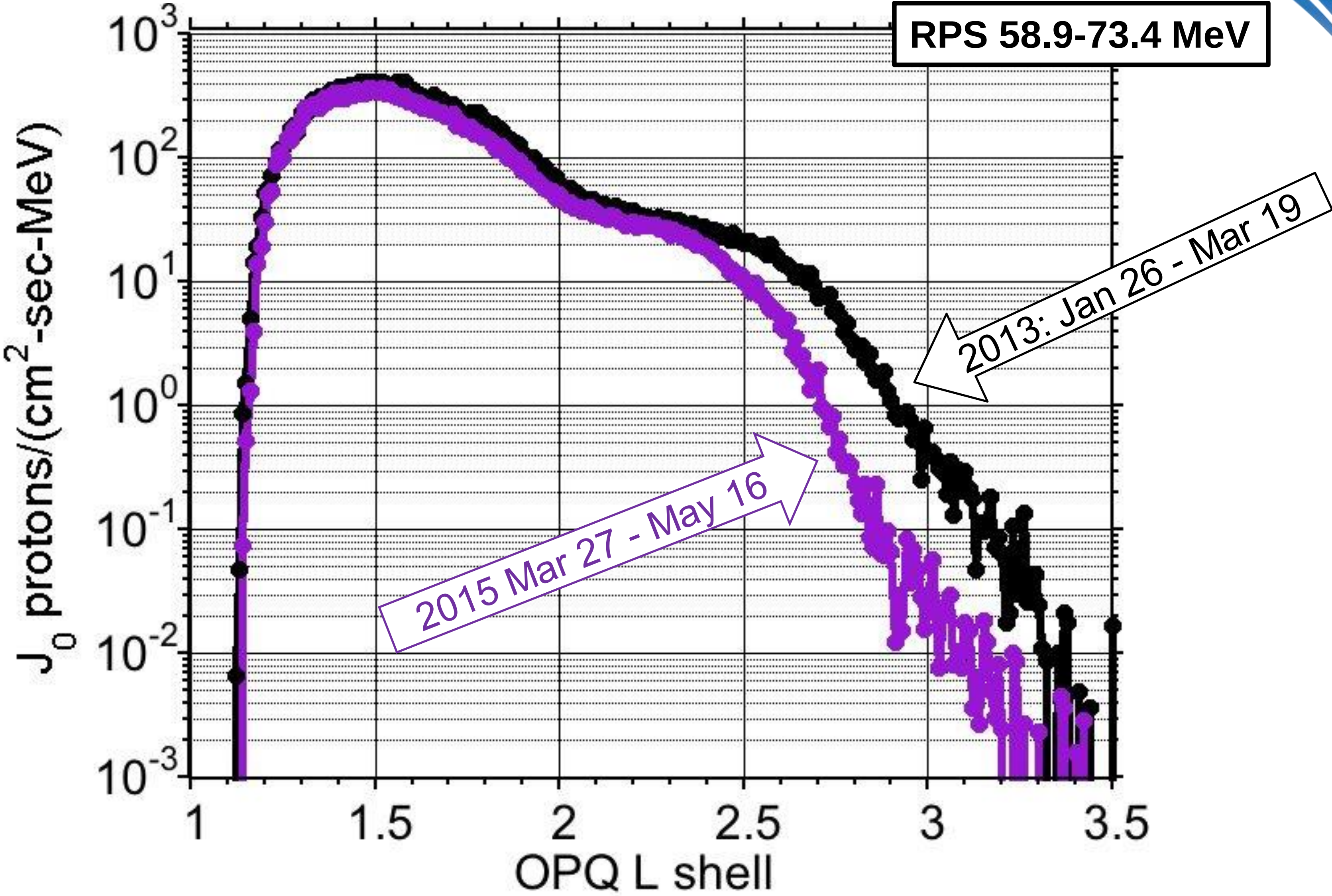
RPS is achieving its mission of characterizing the inner belt up to ~1 GeV.

Glimpse of the Inner Belt From 50 Years Ago



Fifty year separation in measurements yet the Telstar-2 and RPS fluxes are within ~30% of each other below L=2.5

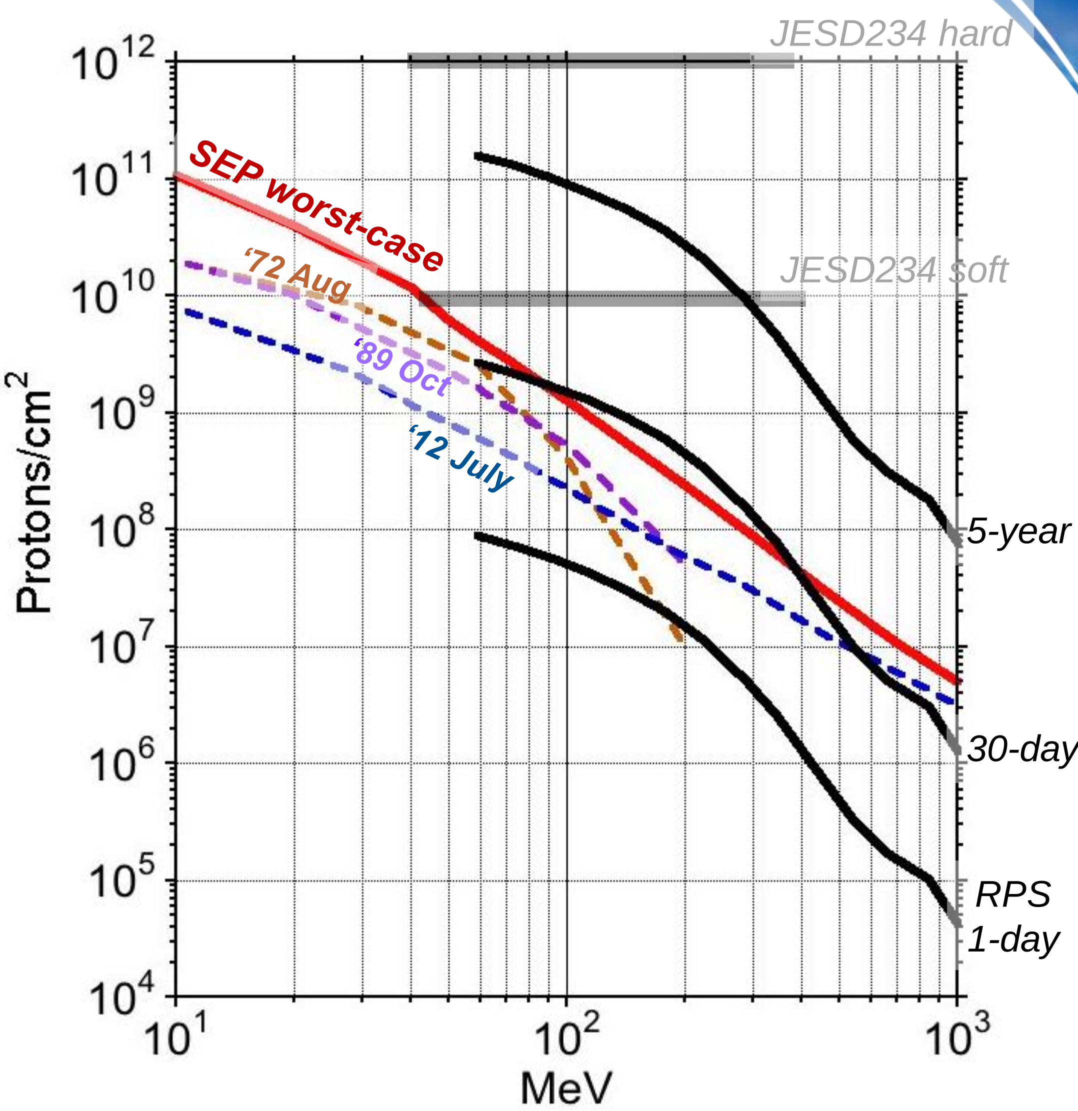
Interplanetary Shock in 2015 Changed the Inner Belt



We've seen a change in the outer edge of the inner belt from the Mar 17, 2015 shock, suggesting that the RPS-Telstar-2 difference above L=2.5 is probably real.

High Proton Fluence In Perspective

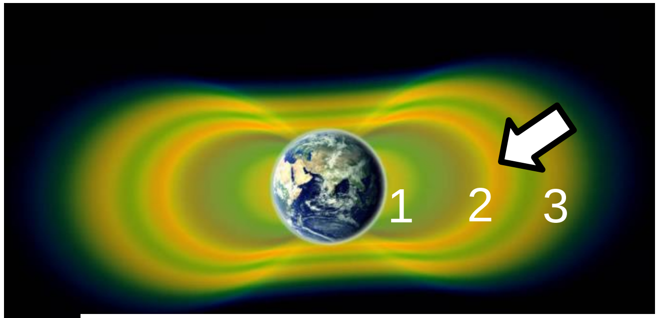
Source of high fluence	Source of fluence values	References
Beams used for SEE screening	Test standards	JESD234 (2013)
Solar particle events	Space measurements and worst-case statistics	Jiggens et al. 2014; Mewaldt 2006
Inner Van Allen belt	Van Allen Probes	RPS (Mazur) ECT (Spence)



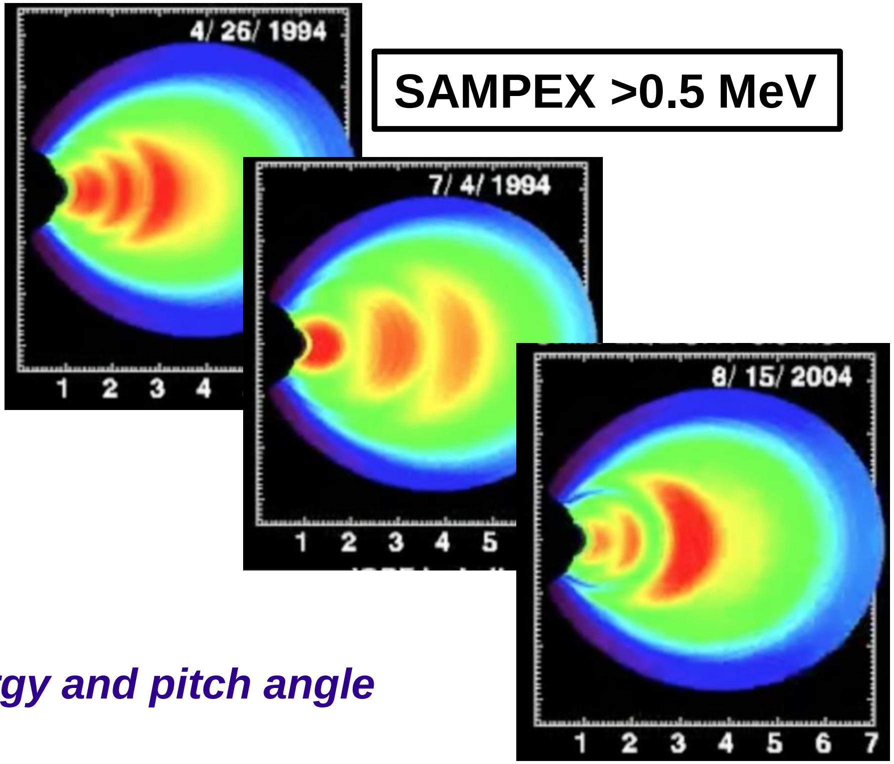
Proton test fluences represent a year or more exposure in GTO. VAP sees a worst-case solar proton fluence about every month.

New Electron Radiation Belts

- NASA press release Feb 2013:
  - *“Van Allen Probes Discover a New Radiation Belt”*
  - *“…revealing the existence of unexpected structures and processes within these hazardous regions of space“*
- The phenomenon is not new
- VAP is providing better information about these transitory belts



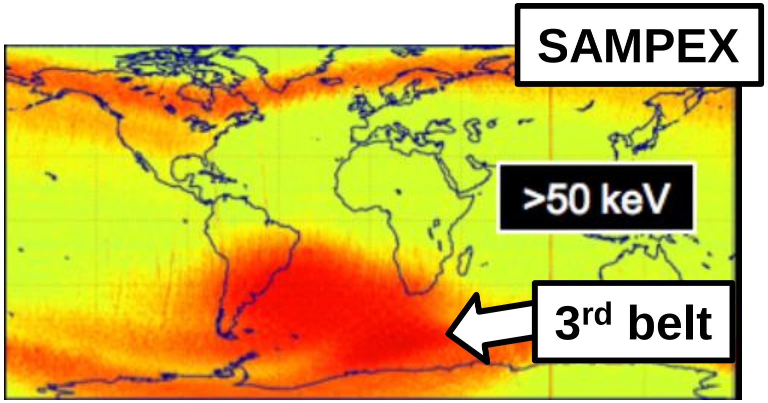
NASA/Van Allen Probes/Goddard Space Flight Center

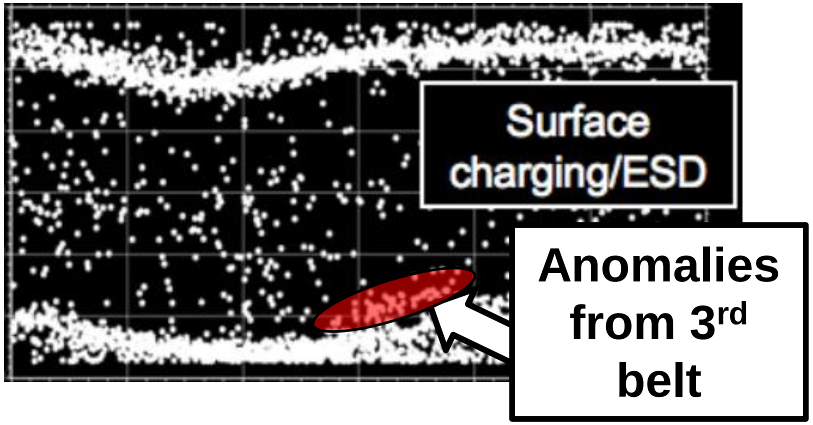


VAP can better quantify the new belts in energy and pitch angle than previous missions.

New Electron Radiation Belts: Any Impacts?

- Potential issues: spacecraft charging and total dose
- Probably not too large an impact on satellites
  - *Non-equatorial orbits will see more intense electrons in transits of the outer belt to drive charging specifications*
  - *Inner/outer belts dominate TID*
- SAMPEX/LICA had surface charging anomalies from a 3rd belt
  - *57 out of 3,381 (1.6%) occurred in the slot*
  - *Most of these occurred in Aug 2004, just one month out of a 20-year mission*
- AE9 captures the statistics of observed events for satellite design





Third (or fourth, or more) new electron belts won't drive satellite designs via total dose or vehicle charging unless the orbit is circular, equatorial, and stays near L=2.

Summary

- Van Allen Probes has been on-orbit for 5 years
- The scientific productivity continues with an extended science mission now in its 5th year
- The applications impact so far has primarily been in the new data for the AP9/AE9/IRENE climatological models
- The science and engineering communities can exploit more from the mission for satellite applications

Proton Fluence For Quantifying SEE

- Risk: SEE from nuclear interactions with any material in the semiconductor
- Application issue: what is the right proton fluence to use for SEE testing?
  - *Aim is to irradiate all sensitive volumes with "high statistical confidence"*
  - *Not easy to answer because there isn't one value for the areal density of sensitive volumes in a device (Ladbury 2016)*
  - *Trade-offs between number of parts to test, total dose, and SEE perceptivity*
- JEDEC standard (JESD234, 2013):
  - *1e10 (soft devices), 1e12 (hard devices)*
  - *Minimum of 100 errors*
  - *"Impractical" for rare events*