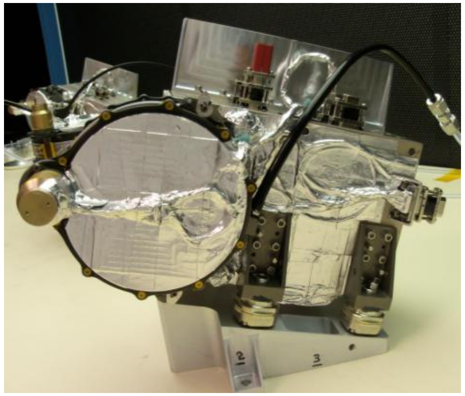
Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE) Instrument

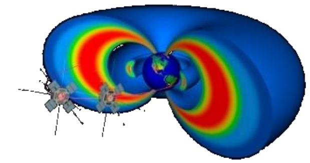
Kunihiro Keika [(1)], Louis J. Lanzerotti [(1)], and Donald G. Mitchell [(2)]

1) Center for Solar Terrestrial Research, New Jersey Institute of Technology, Newark, New Jersey

2) Space Department, The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland



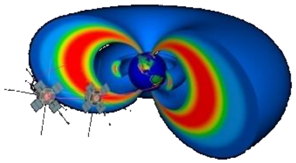
RBSPICE Organization



Louis Lanzerotti	**Principal Investigator**
Donald Mitchell	**Instrument Scientist**
Marian Titerence	**Instrument Lead Engineer**
Scott Cooper	**Instrument Lead Engineer**
Cindy Kim	**Instrument Program Manager**
Felicia Margolies	**NJIT Program Manager**

Co-Investigators

T. Armstrong	Fundamental Technologies
J. Manweiler	Fundamental Technologies
A. Ukhorskiy	JHUAPL
A. T. Lui	JHUAPL
P. Brandt	JHUAPL
M. Sitnov	JHUAPL
G. Ganguli	Naval Research Laboratory
D. Summers	University of Newfoundland
Y. Miyoshi	Nagoya University
N. Tsyganenko	St. Petersburg University



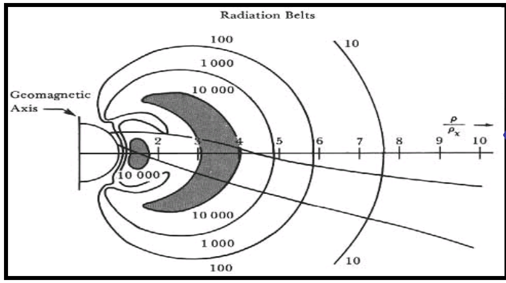
RBSP Mission Overarching Science Questions

- Which physical processes produce radiation belt enhancement events?
- What are the dominant mechanisms for relativistic electron loss?
- How do ring current and other geomagnetic processes affect radiation belt behavior?

RBSPICE makes critical contributions, by determining:

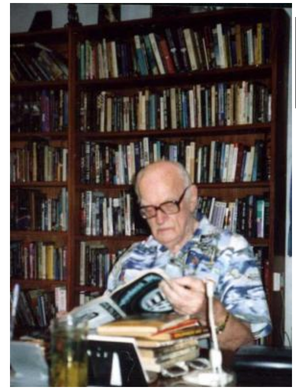
- **How does space weather create the storm-time ring current around Earth?**
- **How does the ring current supply and support the creation of the radiation belt populations?**
- **How can the ring current also quickly reduce radiation belt particle intensities?**

Trapped Radiation: Early Research Motivation



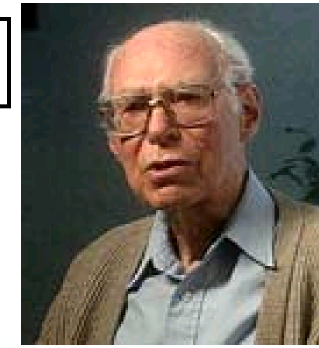
Early views of deleterious trapped radiation

Radiation affects design and ops

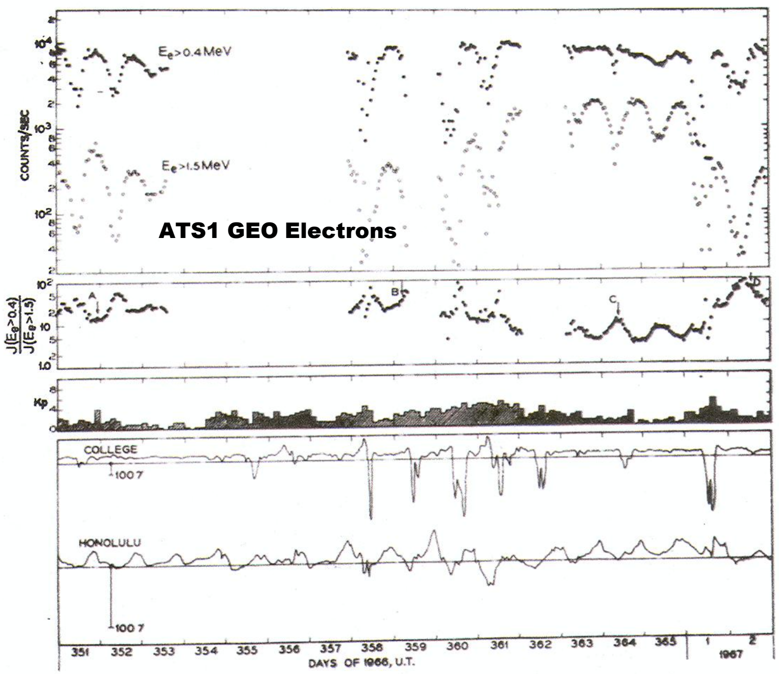


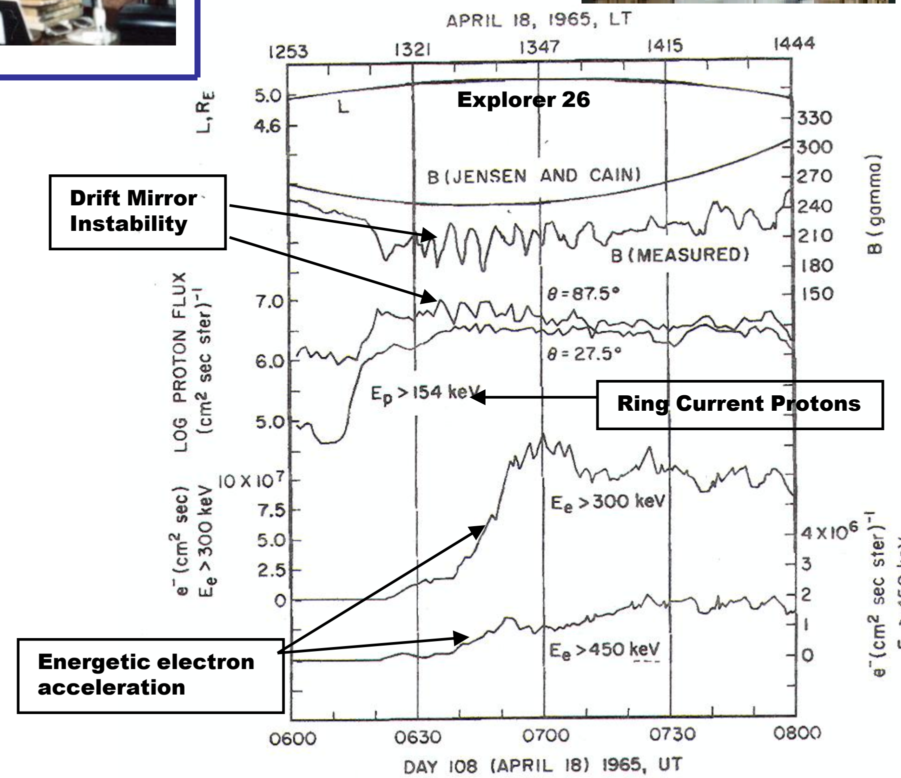
Sir Arthur Clark

Dr. John Pierce



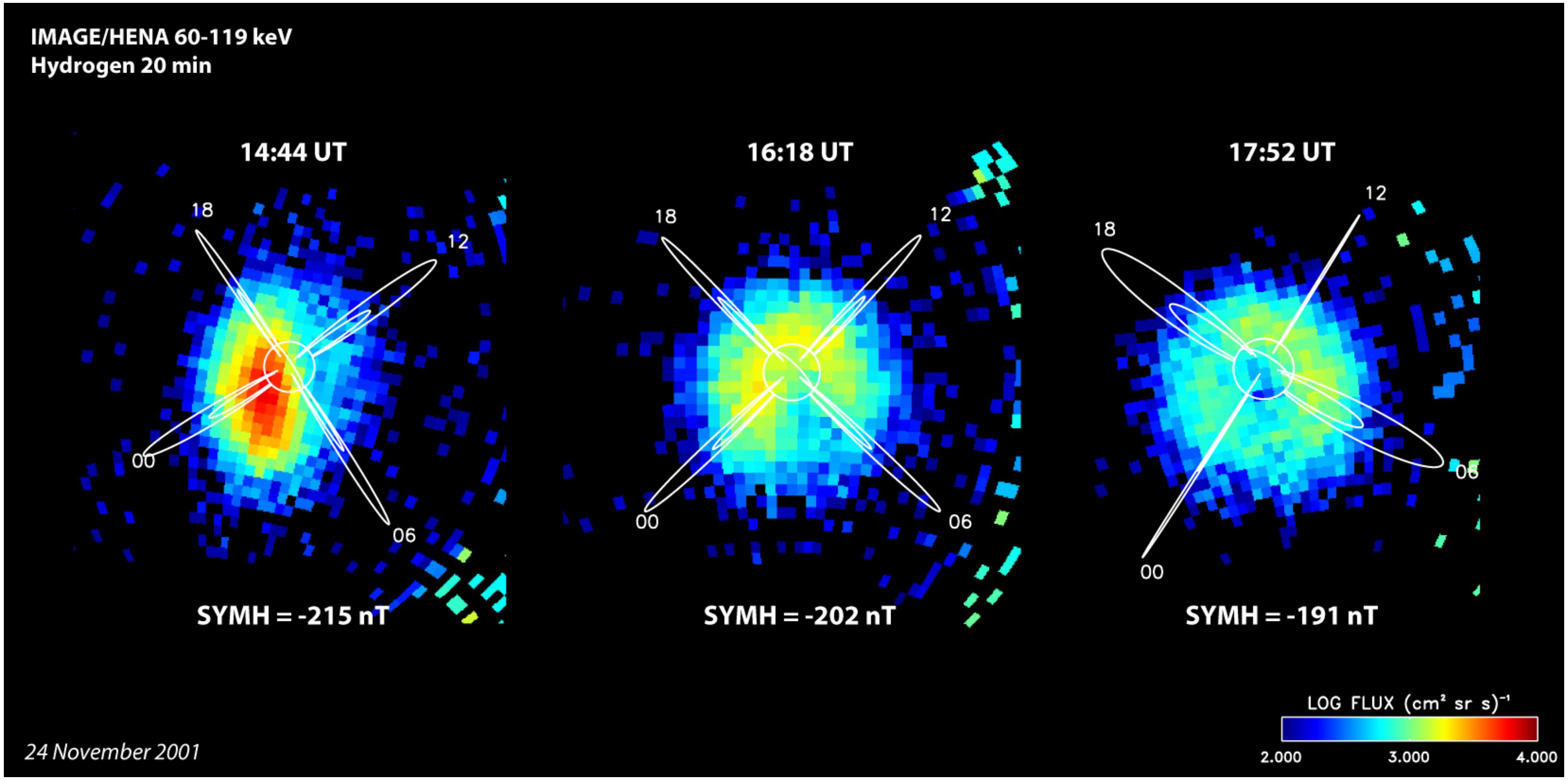
Pioneers of satellite communications



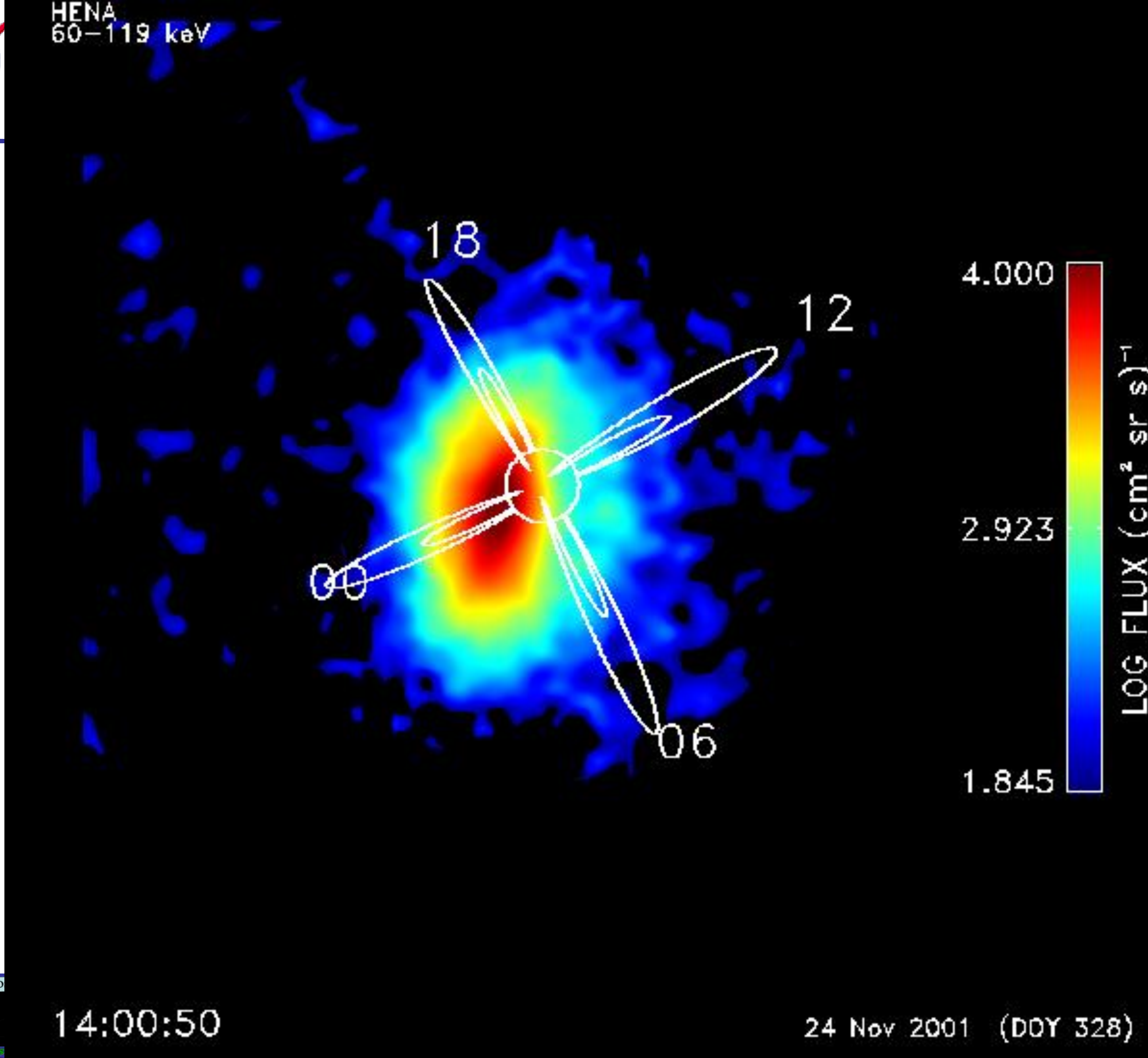


How does space weather create the ring current around Earth?

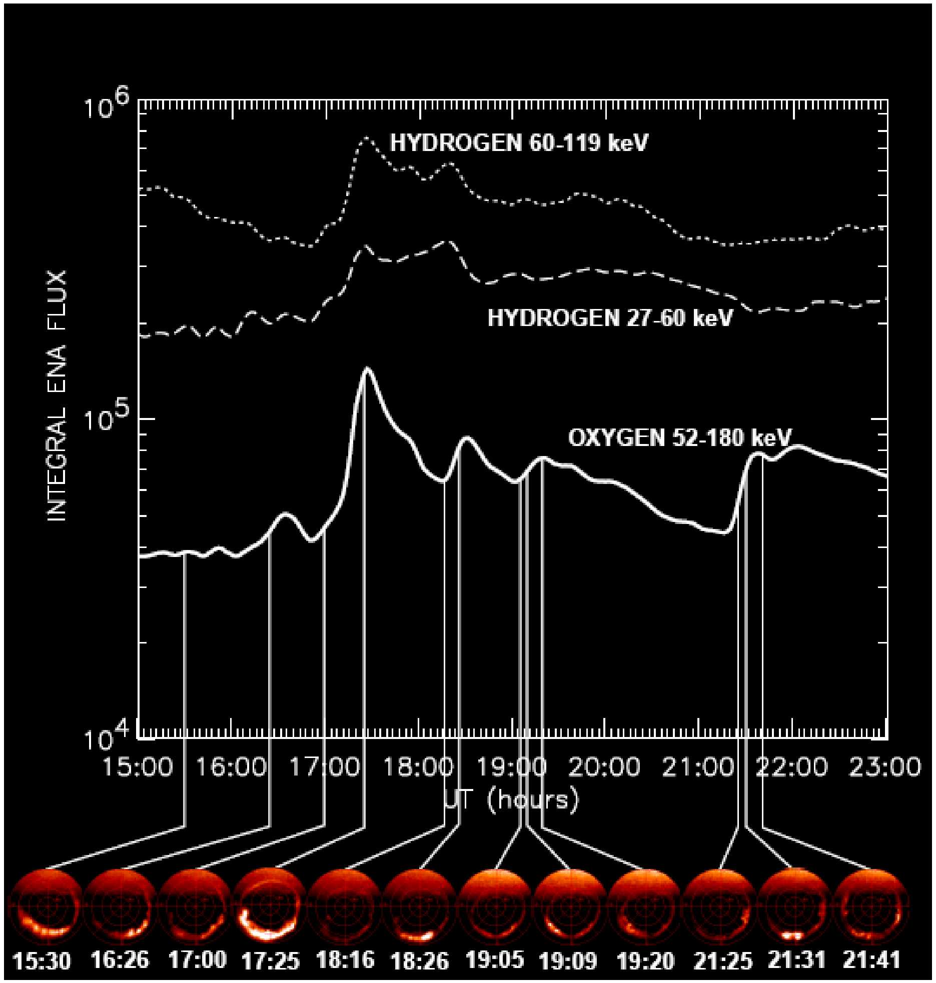
- Ring current intensity, composition, morphology can change dramatically within a few hours in geomagnetic storms.



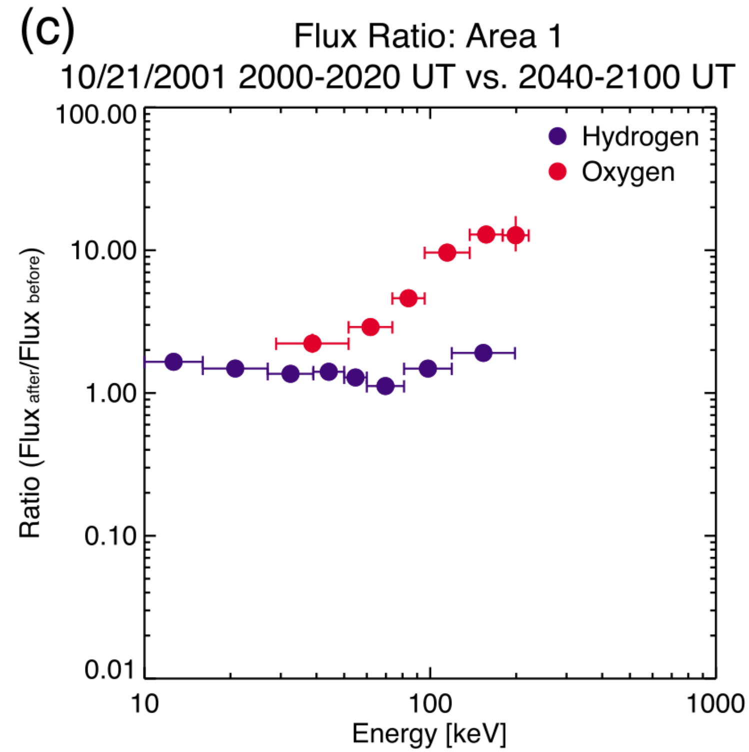
- These changes can produce profound effects on radiation belt electrons via local and global mechanisms.


HENA
60-119 keV
18
12
00
06
4.000
2.923
1.845
LOG FLUX (cm² sr s)⁻¹
14:00:50
24 Nov 2001 (DOY 328)

Dramatic change in the ring current: Differences between H+ and O+



Mitchell et al., *Space Sci. Rev.*, 2003.

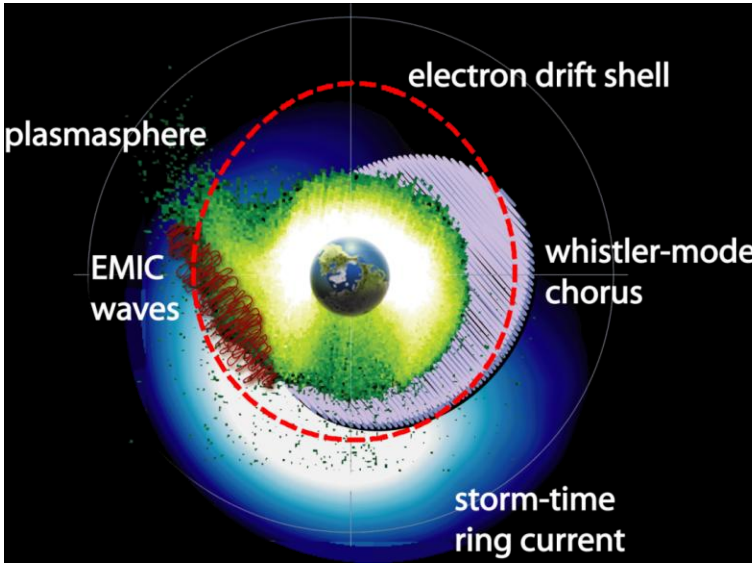


Keika et al., ***J. Geophys. Res.***, 2010.

Hydrogen and oxygen can have significantly different time & energy dependencies in their contribution to ring current dynamics.

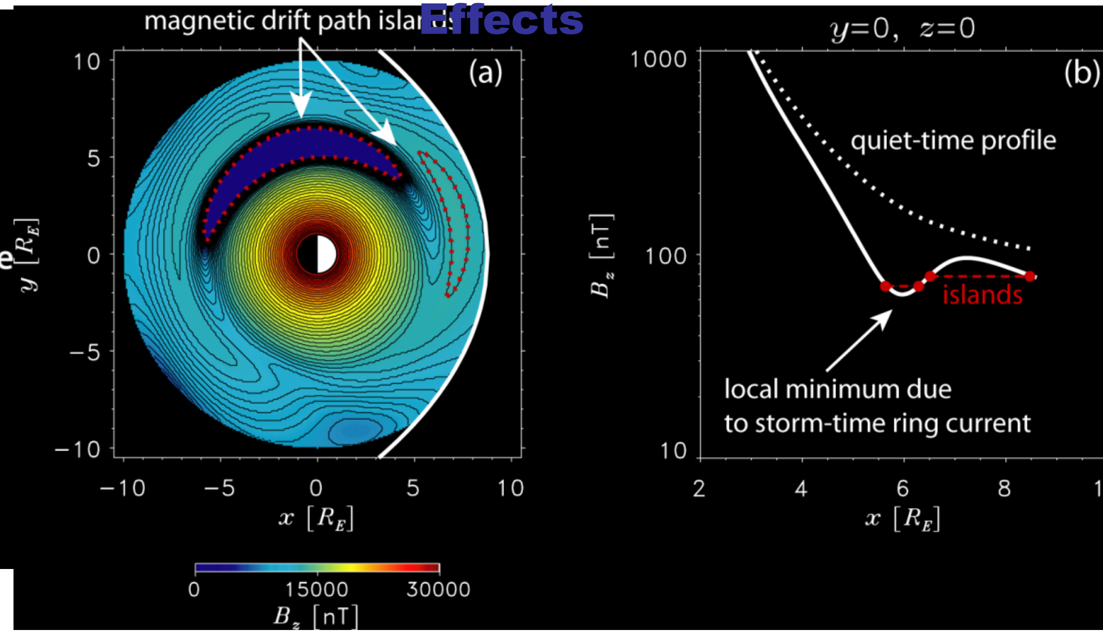
How does the ring current affect the dynamics of radiation belt populations?

Local Effects



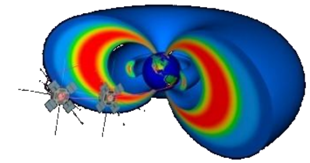
Waves producing particle transport and loss during electron azimuthal drift orbit

Global Effects

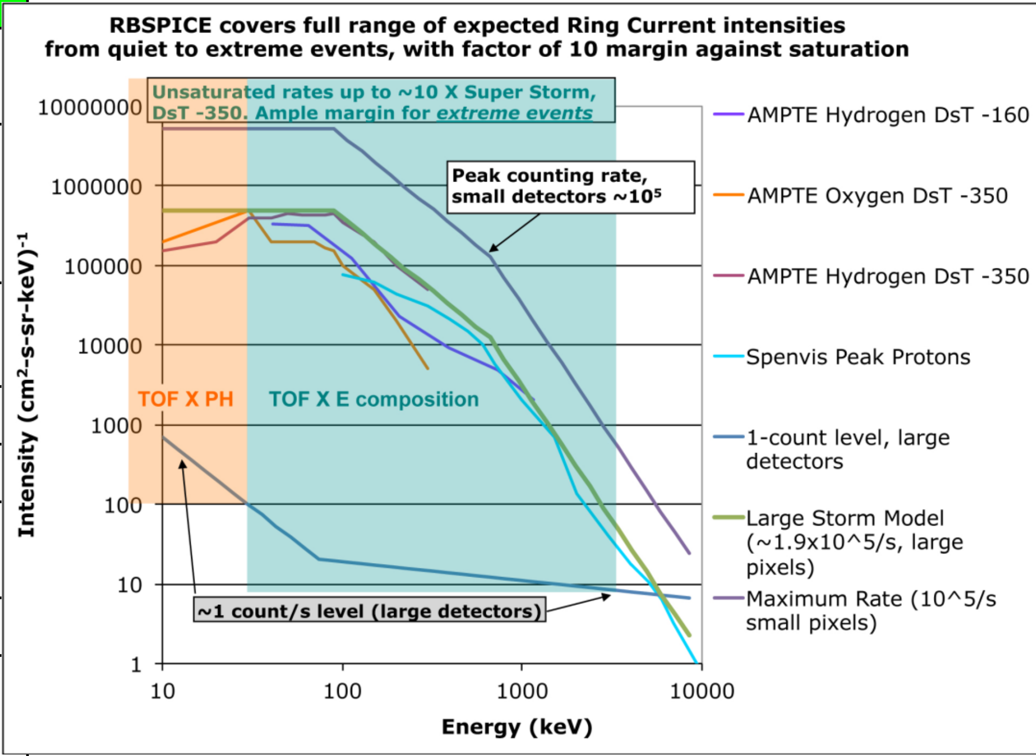


Storm-time ring current produces significant distortion of the magnetic field, affecting electron drift paths and in turn transport and loss

RBSPICE : Key Instrument Measurements/Performance

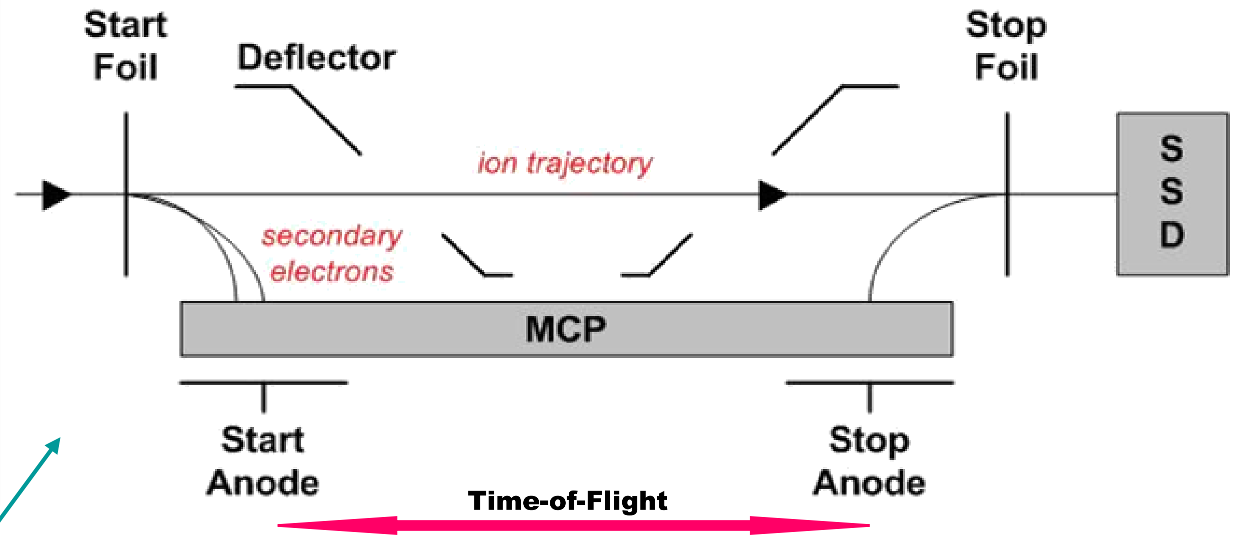


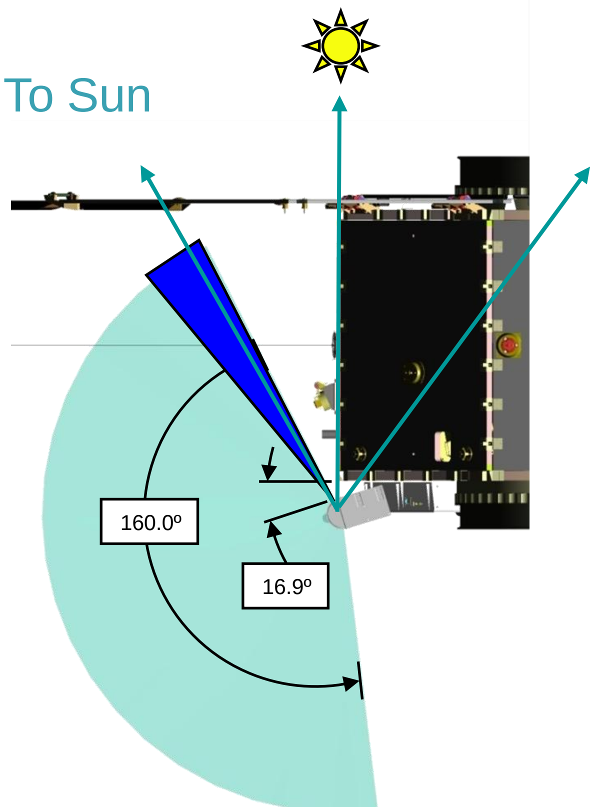
Parameter	Goal (Capability)
Electron Energies	25 - 1000 keV (NOT REQUIRED)
Ion Energies	H: 10 - 10000 keV He: 25 -10000 keV O: 40 - 10000 keV
Energy Resolution	20% for required energy range. 50% above and below required energy
Time sampling	0.33 sec (1/36 spin)
Angle resolution	15 ° x 12 °
Pitch Angle (PA) Coverage	0° -90° or 90° -180°
Time for Full PA	1 spin
Ion Composition	H above 10 keV He above 50 keV O above 45 keV
Electron Sensitivity: I=Intensity (1/cm^2.sr)	Sensor-G:0.0036-0.00018 (cm^2.sr) Pixel-G: 0.0007-0.000035 (cm^2.sr) Up to 6E5 1/s counting
Ion Sensitivity	Sensor-G:0.0036-0.00018 (cm^2.s.sr) Pixel-G: 0.0007-0.000035 (cm^2.s.sr) Up to 3.5E5 1/s counting (TOF)



- Measurement quality independent of the angle between the B- Field and the spin axis (α)
- Ion composition energy range low enough to determine complete Ring Current energy density
- High angle and energy resolution provide detailed energy spectra and pitch angle.

RBSPICE: A Time-of-Flight (TOF) versus Energy (E) measurement system





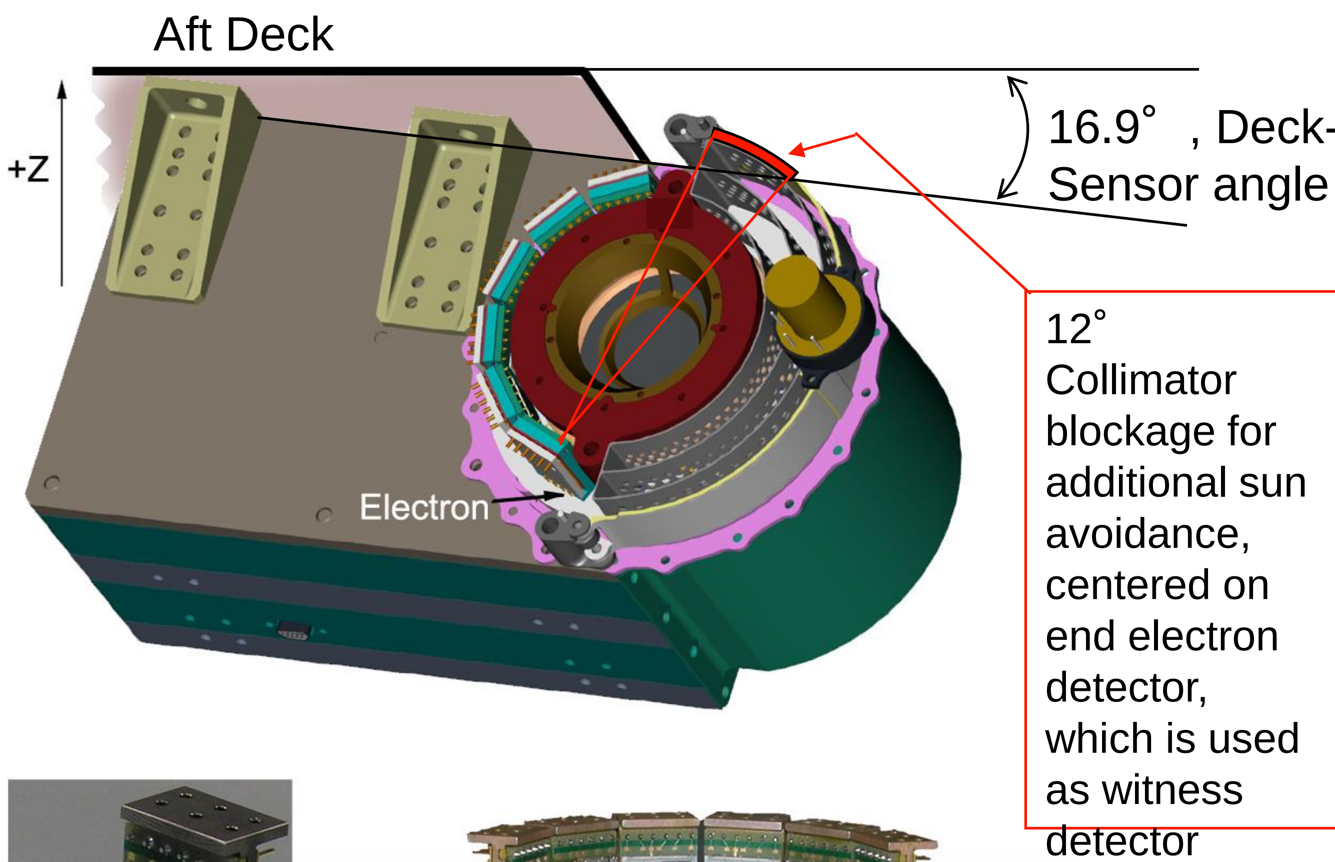
- **Total particle energy measured with solid state detectors (SSDs).**
- **Ion velocity determined by measuring particle flight time through the sensor: its "time-of-flight" (TOF)**
  - A microchannel plate (MCP) records a particle's passage as it knocks secondary electrons off very thin foils at the sensor entrance and exit (Start Foil and Stop Foil).

Design Drivers and Approaches

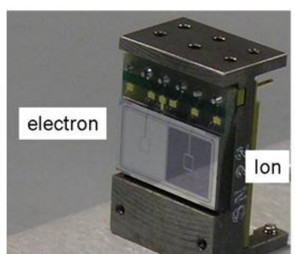
Design Drivers and Approaches	
High radiation - Electronics	• High Z housing reduces environment to ~25 krad • Significant parts testing program
Intense natural particle Environment	• Dynamic range of foreground rates (fast timing circuitry, two ranges of SSD) • High electron rates (same above + particle trajectory modeling with GEANT4, extra 4.5 gr/cm2 shielding, “witness” SSD)
High temporal and angular resolution	• Fast binning • Multiple view sectors • Sufficient telemetry allocation
High energy resolution	• Low detector noise • High TOF resolution • Sufficient telemetry allocation

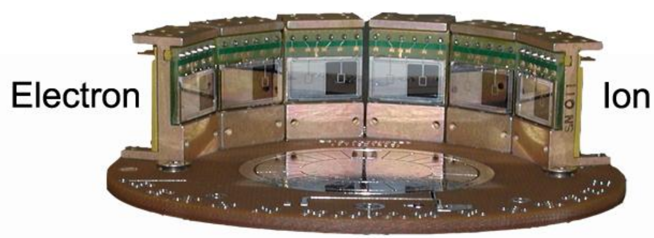
RBSPICE uses a small electron pixel as "witness" detector to measure penetrating backgrounds

RBSPICE	
Mass	6.6 kg
Telemetry	5.4 kbps
Power	2.0 W



Electron measurements are not required by science, but necessary for measuring background. (up to 500 keV)





Telemetry Products

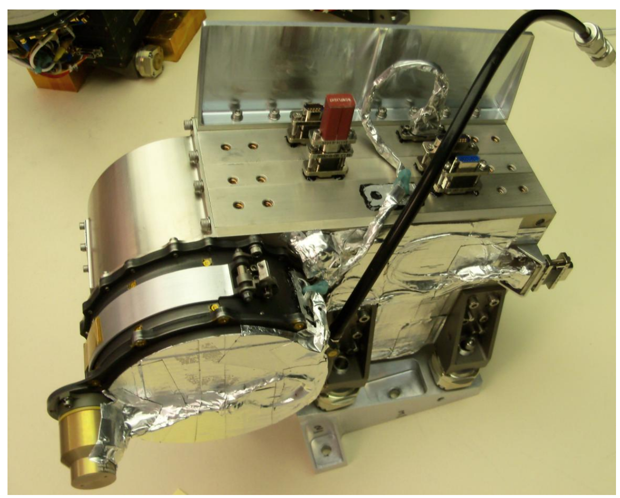
[#E bins, #polar, #azimuthal, time resolution]

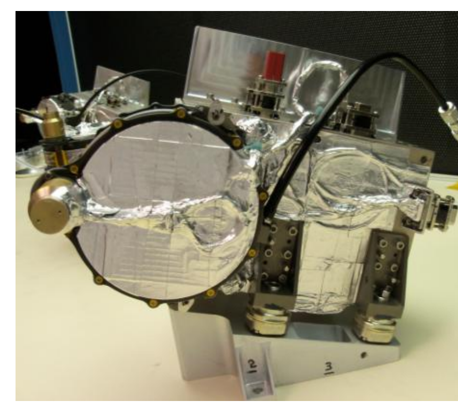
- **Ion energy spectra: SSD only, No composition**
  - 64 Ebins, 6 polar, 4 azimuth, 2 min
  - 14 Ebins, 6 polar, 18 azimuth, 2 min
- **Low proton energy: TOF vs. MCP pulse height**
  - 10 Ebins, 6 polar, 18 azimuth, 12 sec
  - 18 Ebins, 6 polar, 4 azimuth, 2 min
- **Ion energy with composition**
  - 14 Ebins, 6 polar, 18 azimuth, 12 sec for H
  - 10 Ebins, 6 polar, 12 azimuth, 12 sec for He
  - 6 Ebins, 6 polar, 12 azimuth, 12 sec for O

- **Real-time Space Weather Data**
  - 50 – 300 keV (proton): 4 Ebins, 1 polar, 18 azimuth, 12 sec
  - 1 – 10 MeV (ions): 2 Ebins, 1 polar, 4 azimuth, 2 min

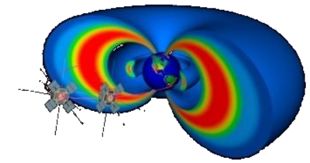
Summary: The RBSPICE instrument

- RBSPICE's statement of task is to investigate the ring current ion plasma pressure and pitch angle distributions which change dramatically during geomagnetic storms.
- RBSPICE is a TOF x Energy particle detector with substantial heritage with previous flight instruments such as Galileo EPD and New Horizons PEPSSI.
- RBSPICE is designed to make clean measurements in a harsh radiation environment that includes Earth's ring current.





Summary: RBSPICE science



Topic/Objective	Conditions
Structure of the pressure-driven ring current	SYMH < -100 nT
Structure and dynamics of the storm-time ring current ion distribution	SYMH < -100 nT
A dawn-side source of energetic O^+ ions on low L-shells	SYMH < -100 nT with injections
Role of injections and pressure enhancements in the inner magnetosphere	SYMH < -100 nT with injections
Spectral dynamics of ring current ions and implications for global E-field variability	SYMH < -50 nT with variable IMF
Spatial and temporal scales of ion temperature anisotropies and EMIC wave coherence scales	Storm/injections in post-midnight sector
Relation between pressure and field inflation and stretching	SYMH < -50 nT

Thank you!!