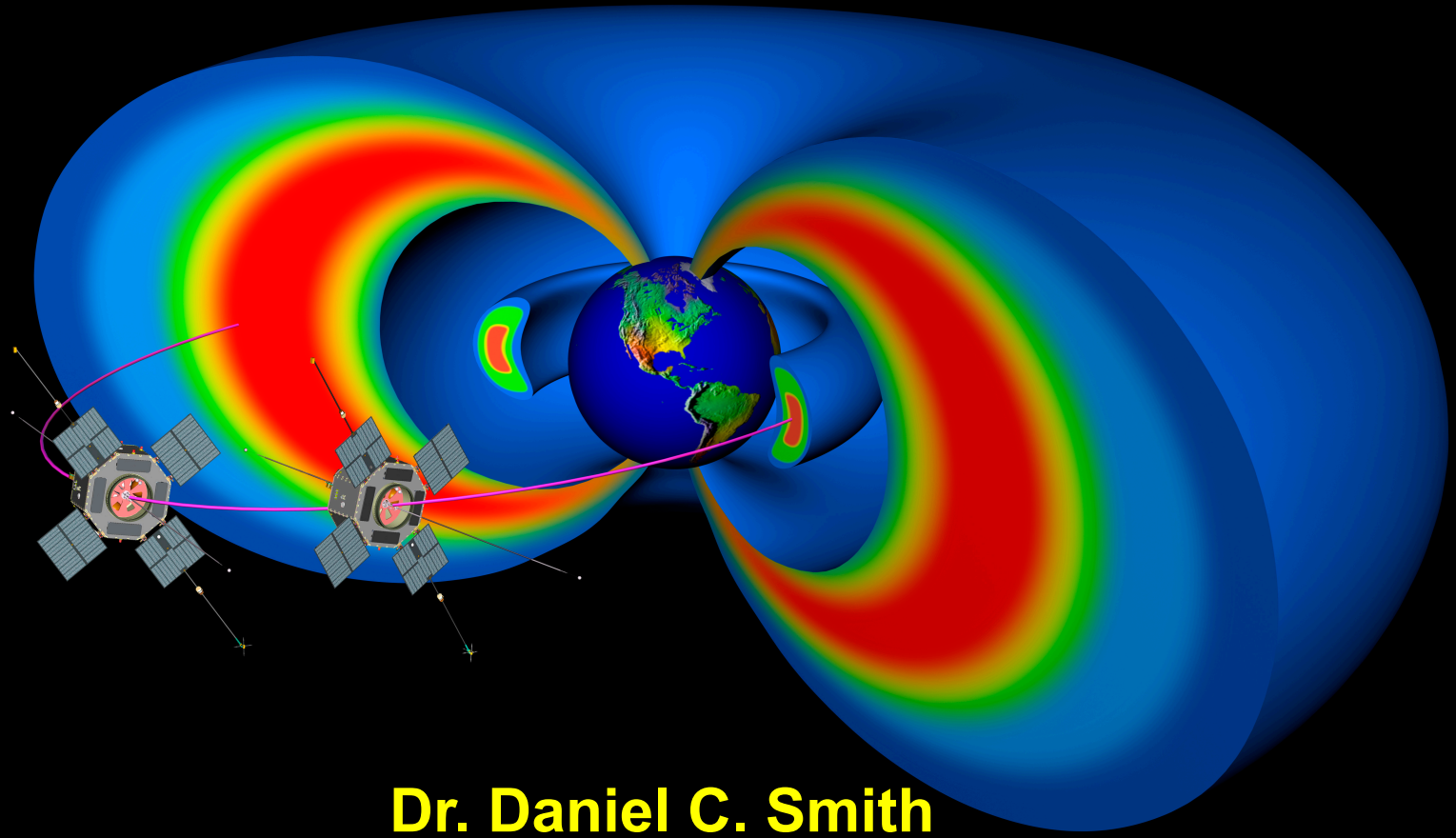
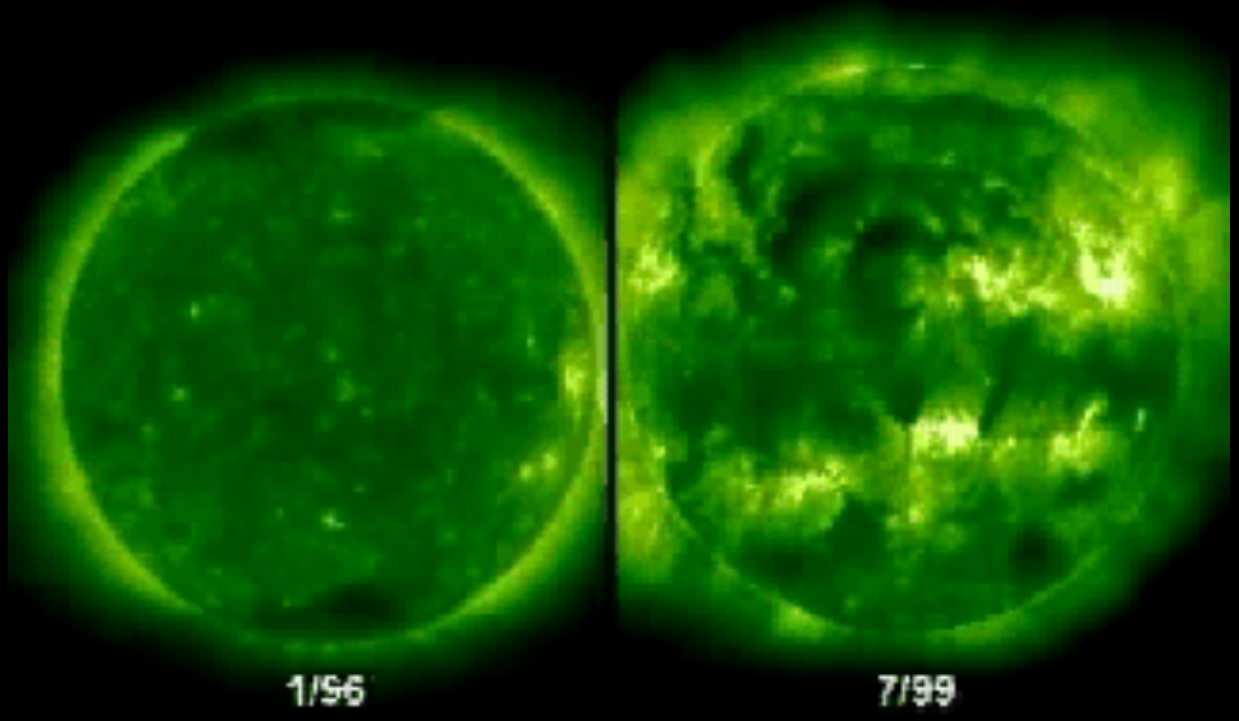
Extreme Exploration: Journey to Earth's Van Allen Radiation Belts



Dr. Daniel C. Smith
Van Allen Probes Project Science Team Member
Johns Hopkins University/Applied Physics Lab

Sun Earth Connections

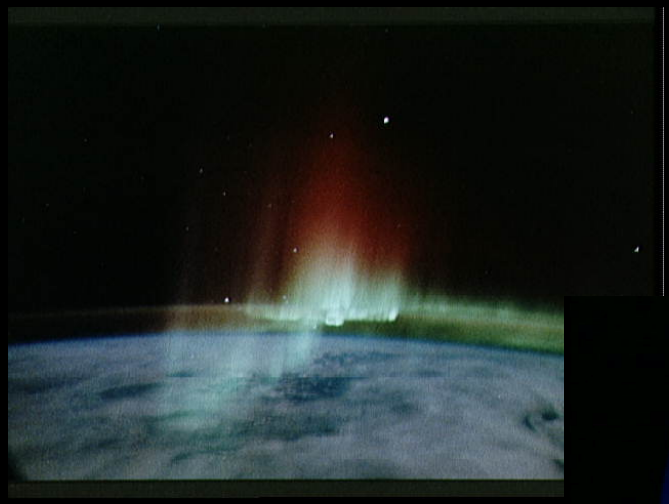
The Sun is a dynamic star



We live in the atmosphere of the Sun

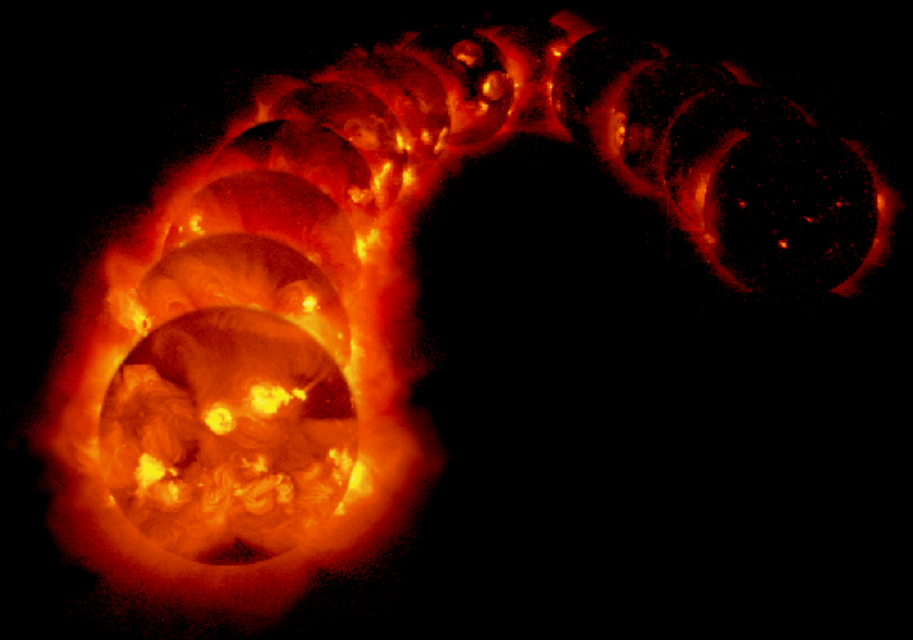
Sun Earth Connections

**Earth responds to the changing Sun,
and this response is known as Space Weather**



The Aurora is a visible, physical sign of this Space Weather

Sun-Earth System -- Driven by 11 Year Solar Cycle

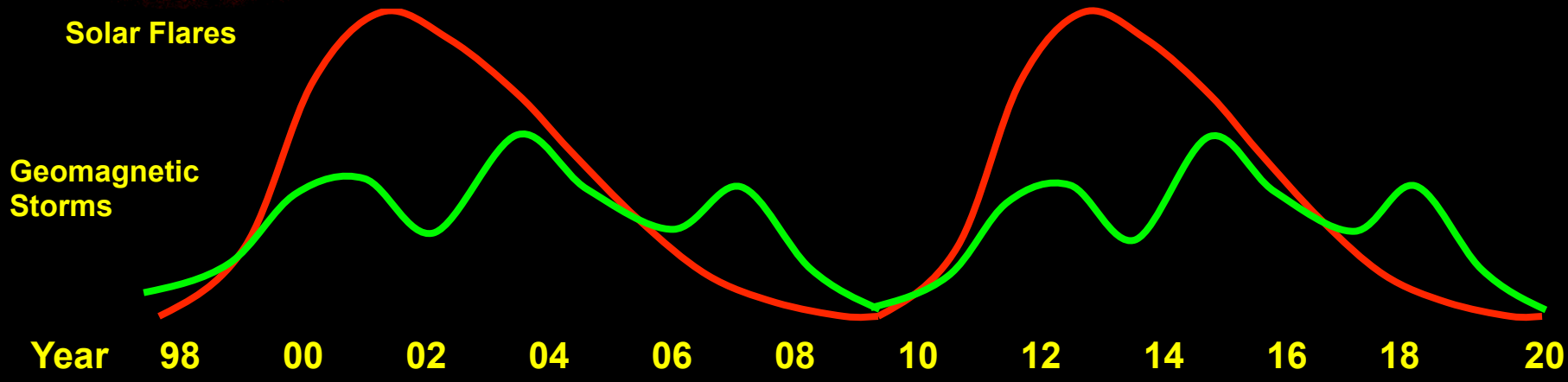


Solar Maximum:

- Increased flares, solar mass ejections, radiation belt enhancements.
- 100 Times Brighter X-ray Emissions 0.1% Brighter in Visible
- Increased heating of Earth's upper atmosphere; solar event induced ionospheric effects.

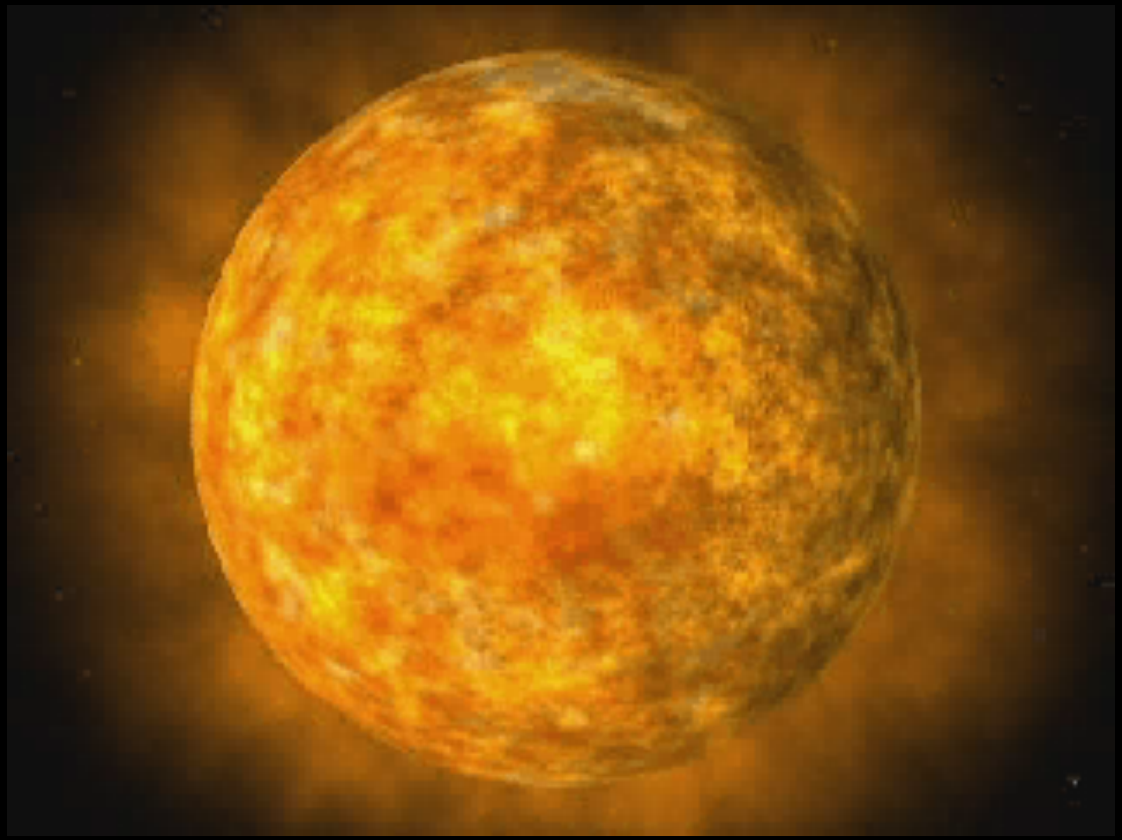
Declining Phase, Solar Minimum:

- High speed solar wind streams, solar mass ejections cause geomagnetic storms.



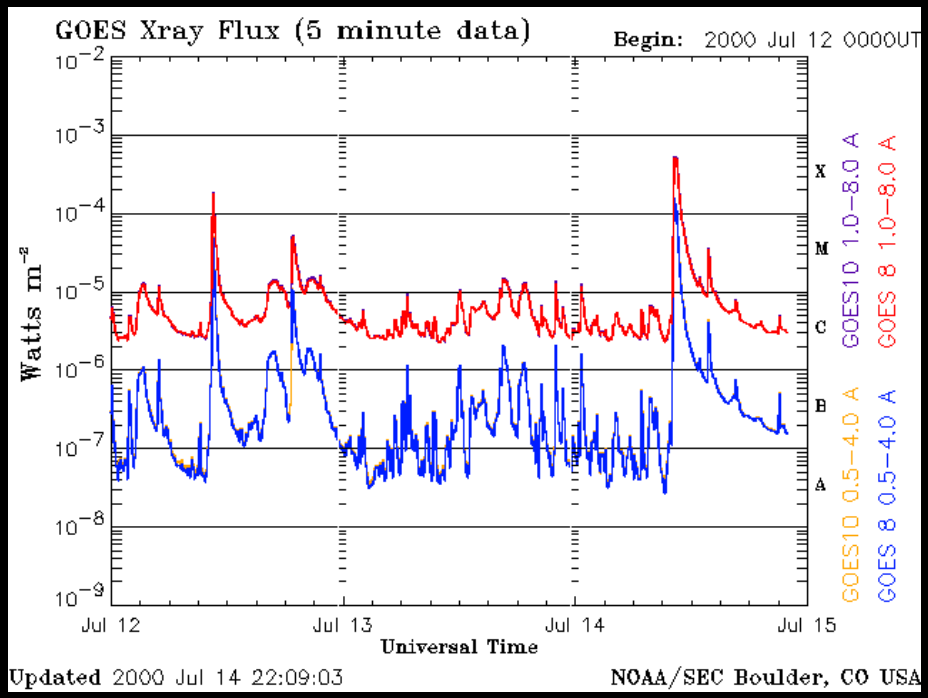
The Violent Sun

Solar flares are violent explosions that occur at the Sun's surface

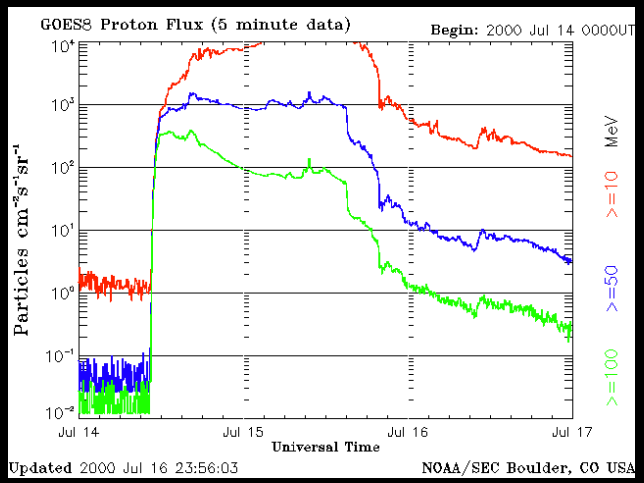


But the Sun is not Vegas; what happens on the Sun does not stay on the Sun!

These solar flares can accelerate huge amounts of very energetic solar protons



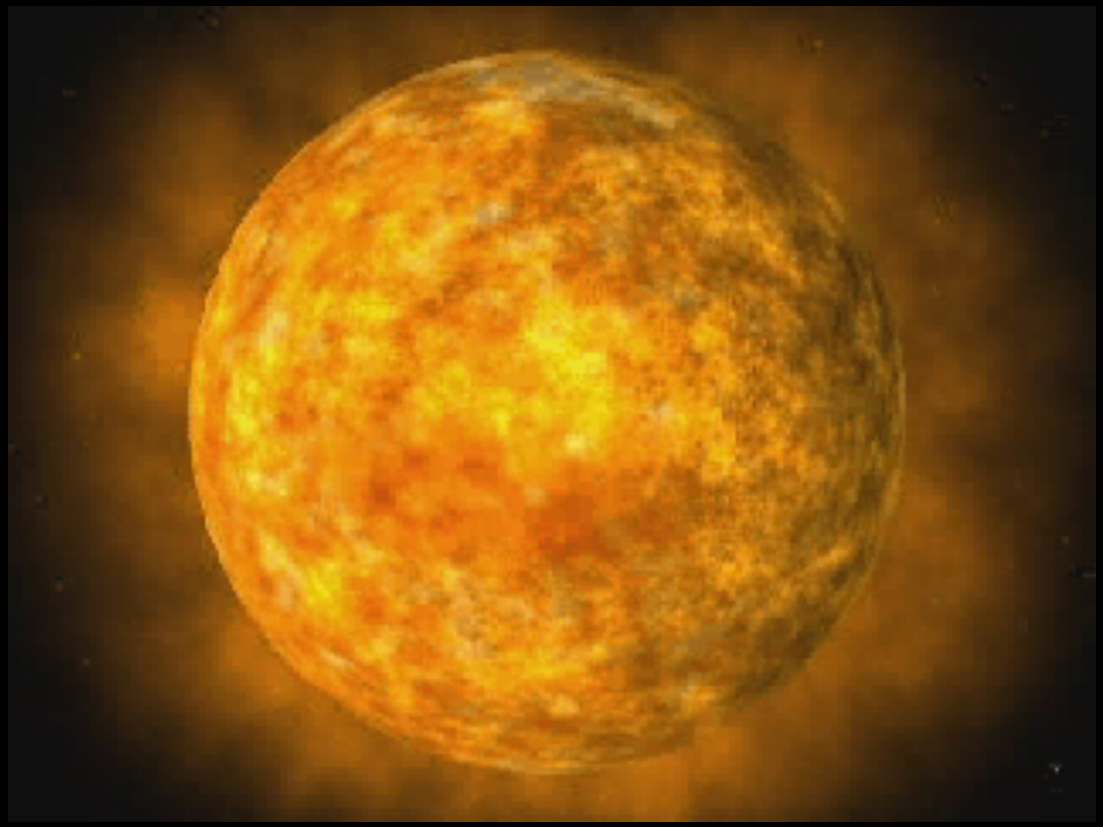
These protons can reach Earth in about 30 minutes



Less than 1 hour after the initial arrival of the protons, the imager becomes saturated & remains so for almost a day

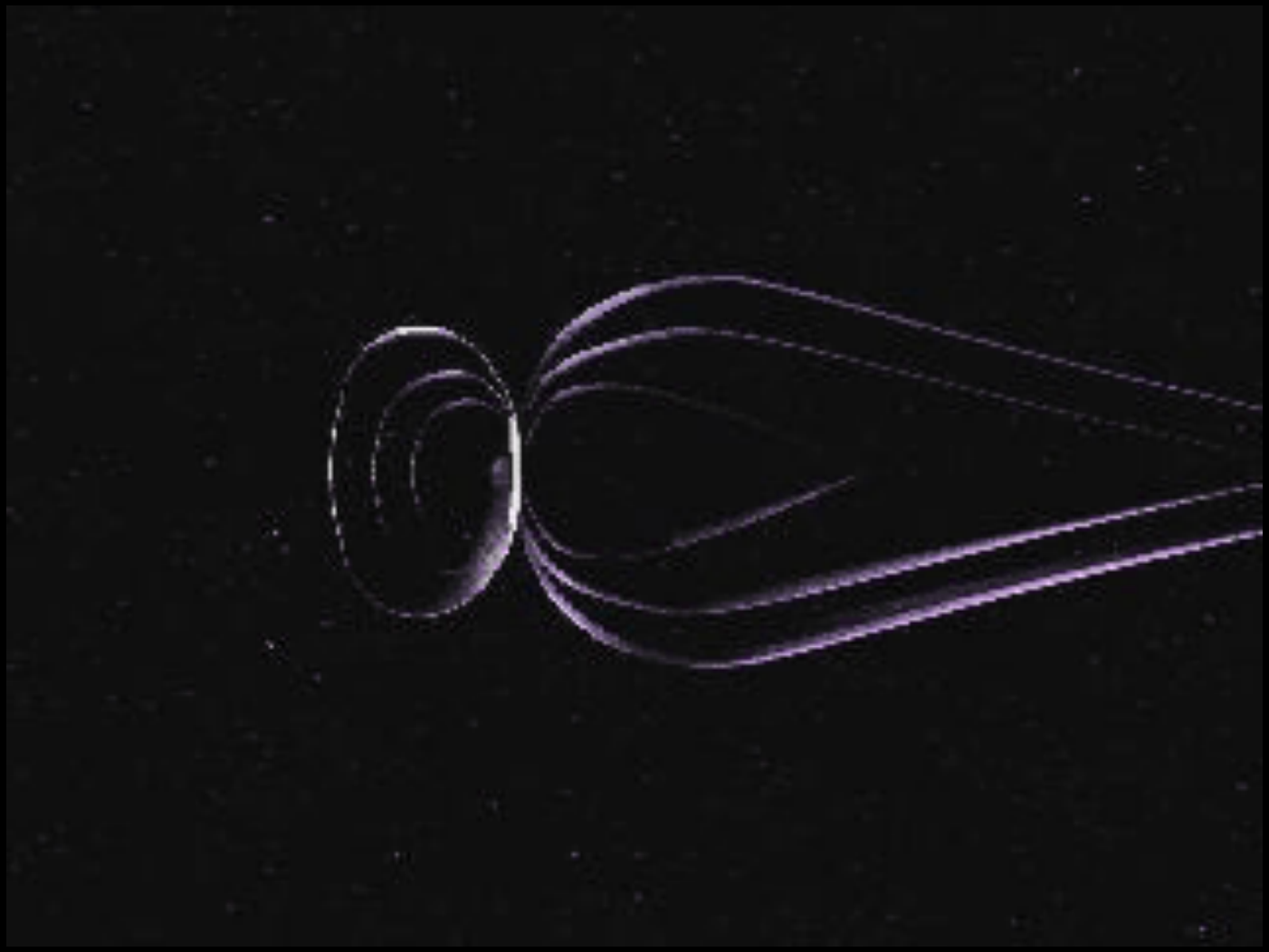
Sun Earth Connections - from there to here

Billions of tons of solar material are hurled from the Sun at millions of miles an hour



When the material reaches the Earth it interacts with our protective magnetic field

The Earth's Magnetosphere



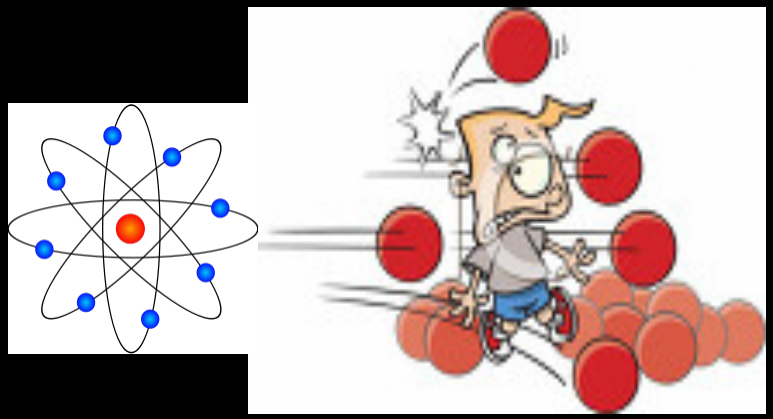
Dangerous electrons and protons are not able to penetrate down to Earth's surface but are forced to move around it by the magnetic field.

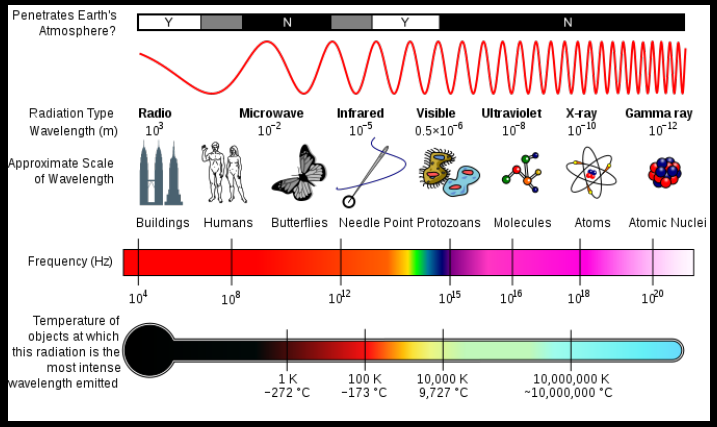
What is Radiation?

Energy moving from one place to another carried by particles or waves

Particle Radiation - A mixture of ions and electrons that have enough energy to knock electrons off of atoms. At times these particles can move close to the speed of light.

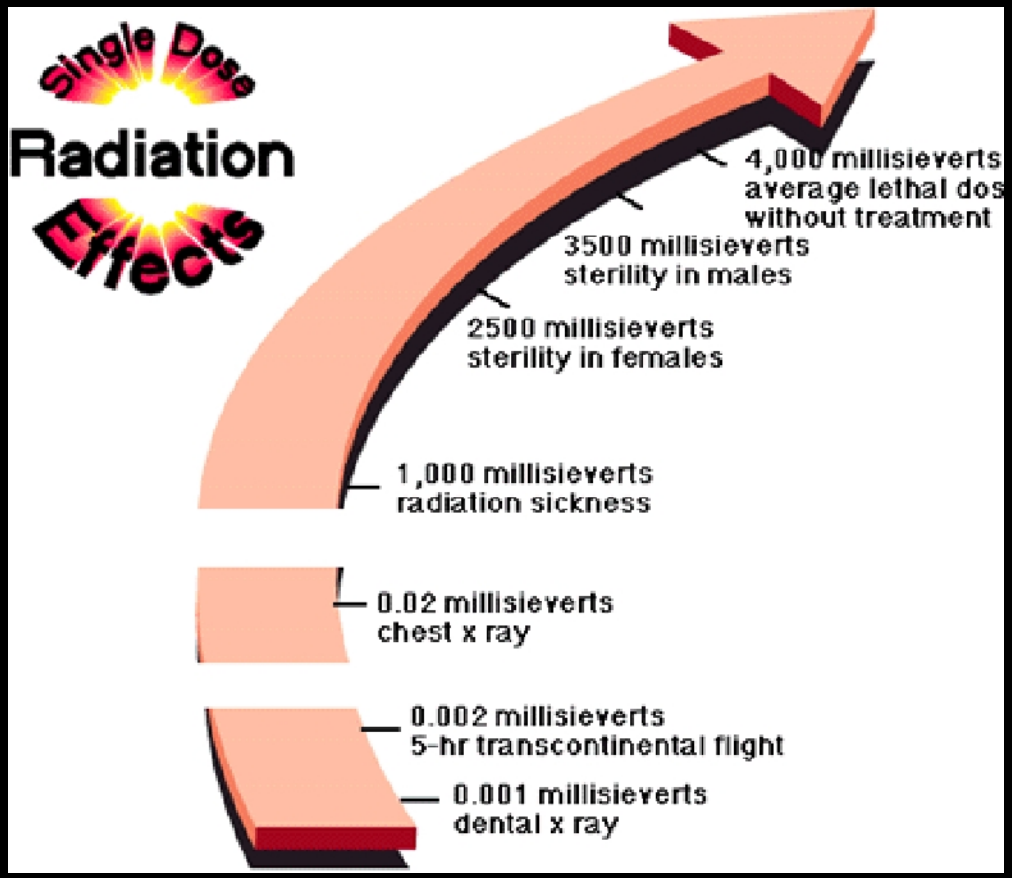
Electromagnetic Wave Radiation - Examples include: *radio waves, microwaves, infrared (heat), visible light, ultraviolet (UV), x-rays, and gamma rays.*





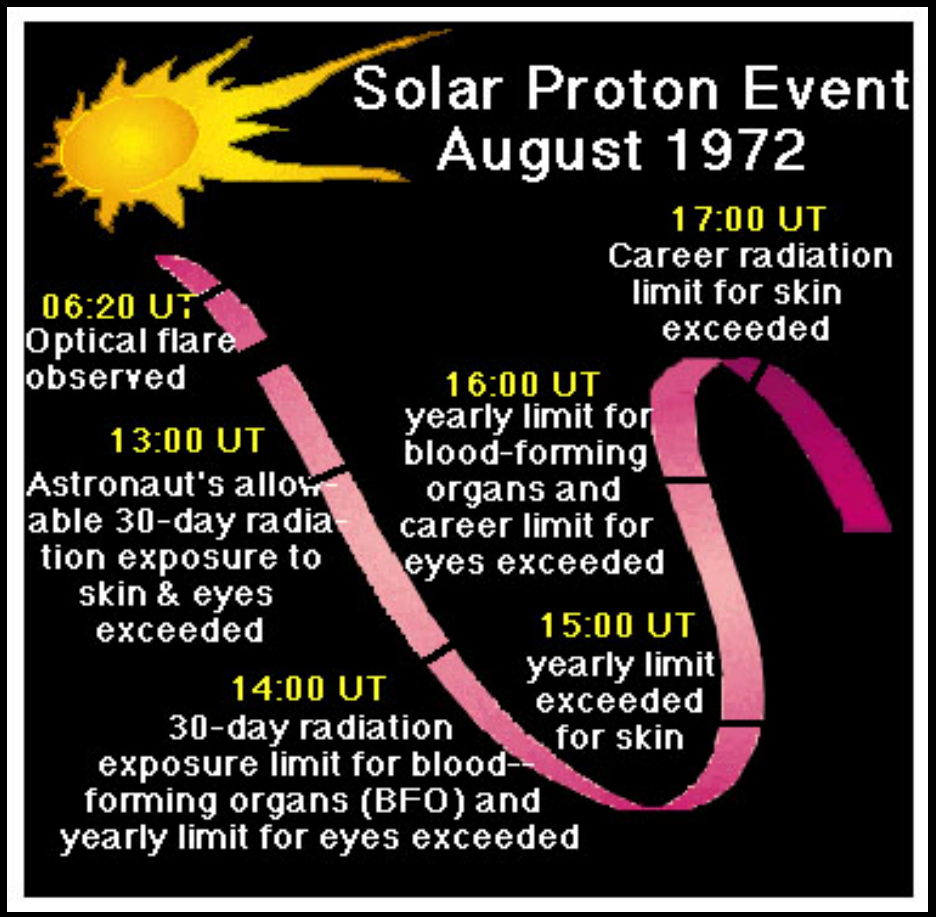
The Van Allen Probes will investigate the first type of radiation, high energy particle radiation.

Lethal Dosages of Radiation



During violent solar events, the Sun can accelerate electrons and protons to almost the speed of light which gives them huge amounts of energy. Protons and electrons at these high energies can be very dangerous to living cells

Radiation Dangers to Astronauts



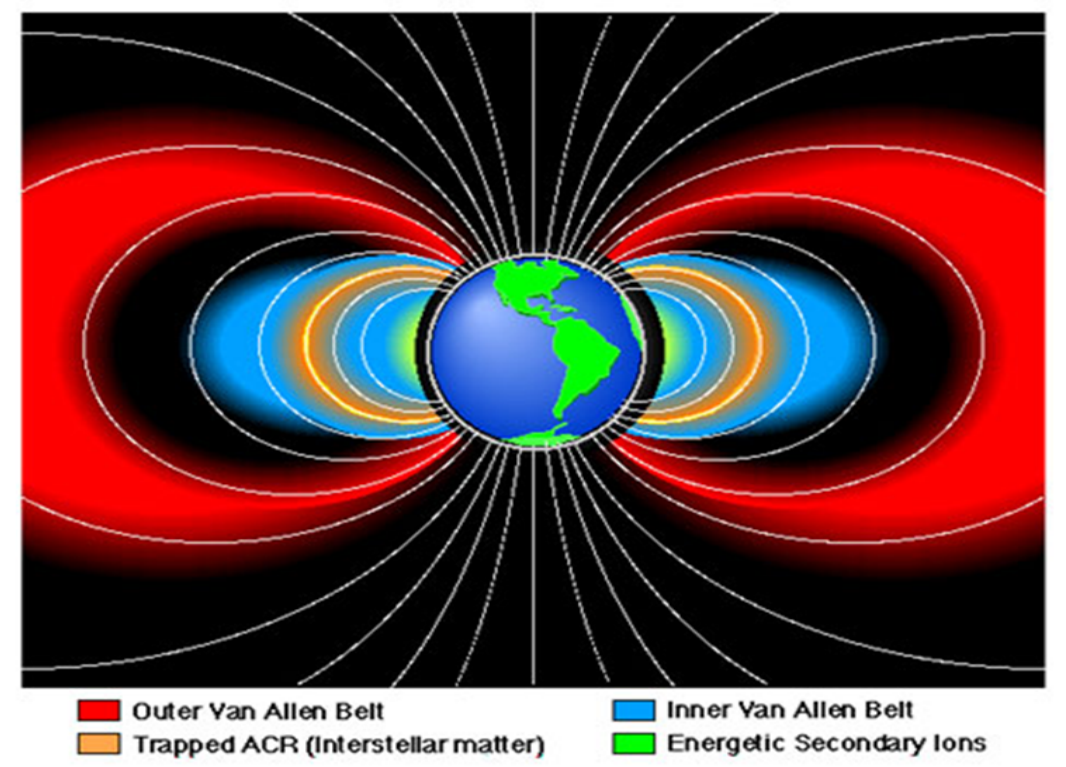
Between Apollo 16 and 17, one of the largest solar proton events ever recorded arrived at Earth. The radiation levels that an astronaut inside a capsule would experience during this event were simulated. Even inside the spacecraft, astronauts would have absorbed lethal doses of radiation within 10 hours after the start of the event (4000 mSv)

The first discovery of the space age

The radiation belts were discovered by James Van Allen In 1958 using data taken on Explorer 1

The radiation belts

High energy particles get trapped by the Earth's magnetic field and forced to circle around the Earth within two large donut-shaped regions.



The belts are different from each other.

- The inner is stable and made of protons,
- The outer changes a lot and is made of electrons and ions.

Where are the radiation belts?

Inner Belt: About 60-6,200 miles up

Outer Belt: About 12,500-39,000 miles up

Image Courtesy of Windows to the Universe, http://www.windows.ucar.edu

To help you imagine it:

60 miles: About the distance it takes to drive 1 hour on the highway

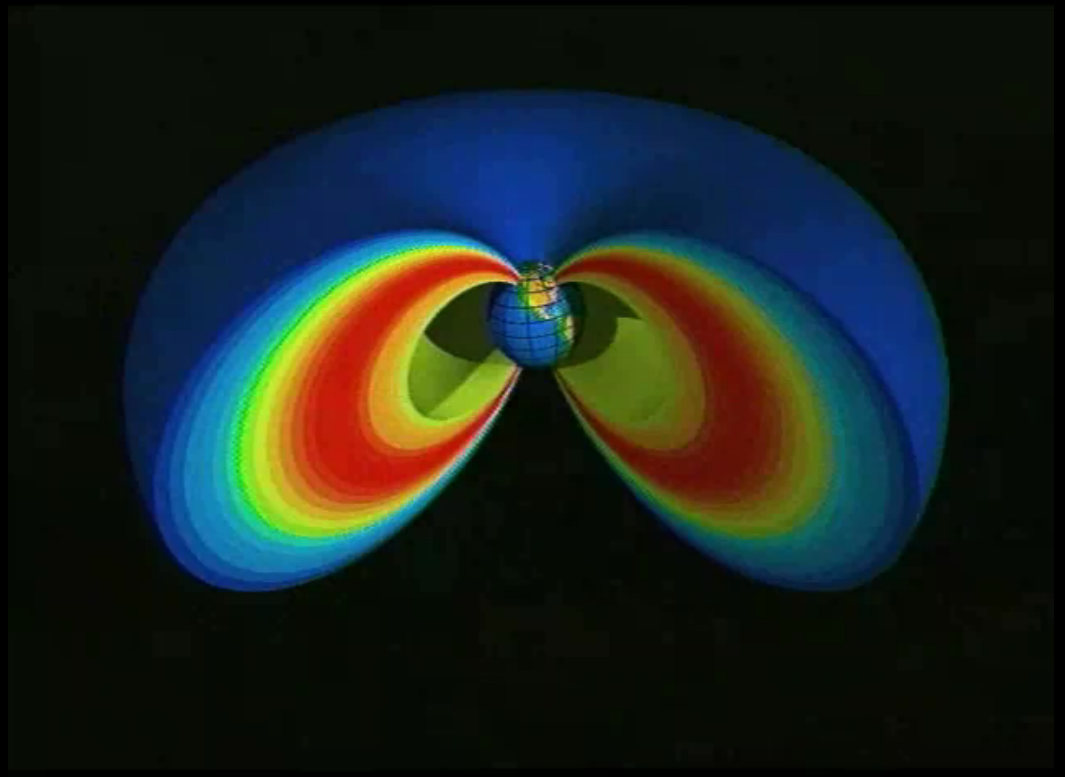
6,200 miles: About the distance to drive from the equator to the north or south pole

12,500 miles: About the distance to drive from the north pole to south pole

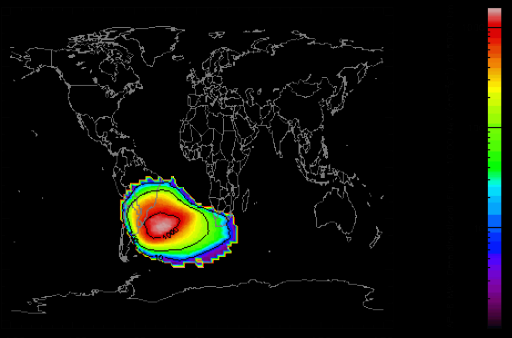
39,000 miles: About 1/6 as far as the moon

Radiation Belt Variability

Instruments aboard spacecraft have monitored the radiation belt activity and have discovered that the belts are highly variable both in intensity and size



The radiation belts – danger, danger!!



South Atlantic Anomaly

- Most spacecraft either avoid these regions of high radiation or turn off sensitive instrumentation while in transit through them
  - Large space weather events can adversely effect spacecraft and operations

- The radiation belts are now part of our technology infrastructure.
  - If we can understand the belts, we can improve our mission planning, and spacecraft operation and system design


P-ANIK!
High-tech chaos as satellites spin out of control
Plug pulled on phones, TV, radio, papers
The New York Times
2 Canadian Space Satellites Are Knocked Out by Storm
OTTAWA, Jan. 22 (Reuters) — An electromagnetic storm knocked out Canada's two communications satellites Thursday, and one of them may be lost for ever, the operating company, Telesat Canada, said Friday.
Telesat executives said an unusual localized storm caused short-circuits in its Anik E-1 and E-2 satellites, disrupting telephone, television and
EOS
Developing Service Promises Accurate Space Weather Forecasts in the Future
Science & Medicine
Weathering the storm in space
The Globe and Mail, Tuesday, January 25, 1994
REPORT ON BUSINESS
Sun gets blame for zapped Aniks
Telesat still trying to fix $300-million satellite, but chance of revival

Image Credit: L. J. Lanzerotti, Bell Laboratories, Lecent Technologies, Inc.

NASA's Van Allen Probes Mission

- On August 30, 2012 NASA launched two identical probes into the radiation belts to provide unprecedented insight into the physical dynamics of near-Earth space.

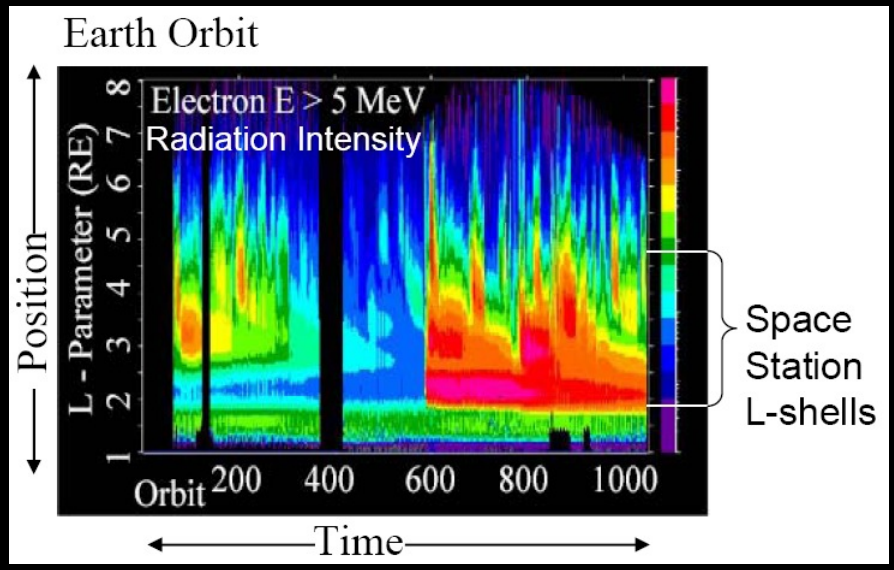
The Van Allen Probes' Mission Objective is important and its Impacts are broad

- Objective:

  Provide understanding, ideally to the point of predictability, of how populations of relativistic electrons and penetrating ions in space form or change in response to variable inputs of energy from the Sun

- Impacts:

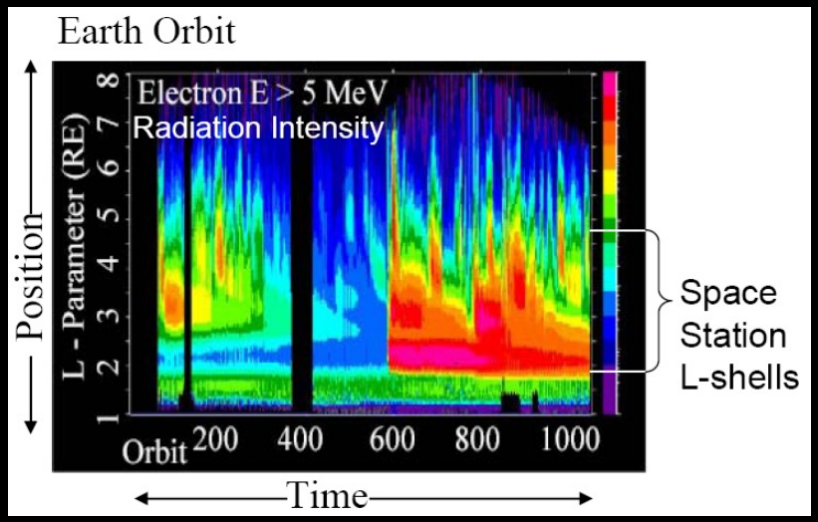
1. Understand fundamental radiation processes operating throughout the universe.
2. Understand Earth's radiation belts and related regions that pose hazards to human and robotic explorers.

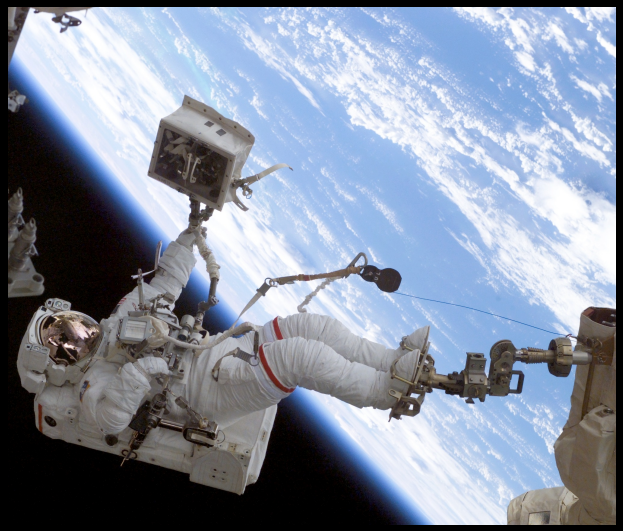


Intensities of Earth's dynamic radiation belts

Van Allen Probes: A Mission to Benefit Life and Society

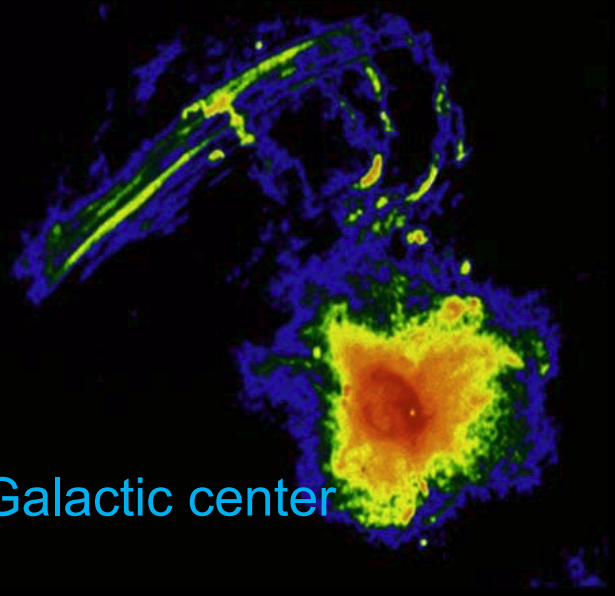
- Data collected by the probes will help researchers develop and improve various radiation belt models that can be used to:
  - design radiation-hardened spacecraft and prevent costly spacecraft over design
  - predict space weather phenomena and alert astronauts and spacecraft operators to potential hazards
  - resolve anomalies
  - improve radiation belt models





Van Allen Probes: A Fundamental Physics Mission

Planetary Radiation Belts are a Universal Phenomenon: ISEE and Voyager results show clear evidence that radiation belts exist at all strongly magnetized planets throughout our solar system



Galactic center

Particle acceleration to high energies is observed in other space plasma systems

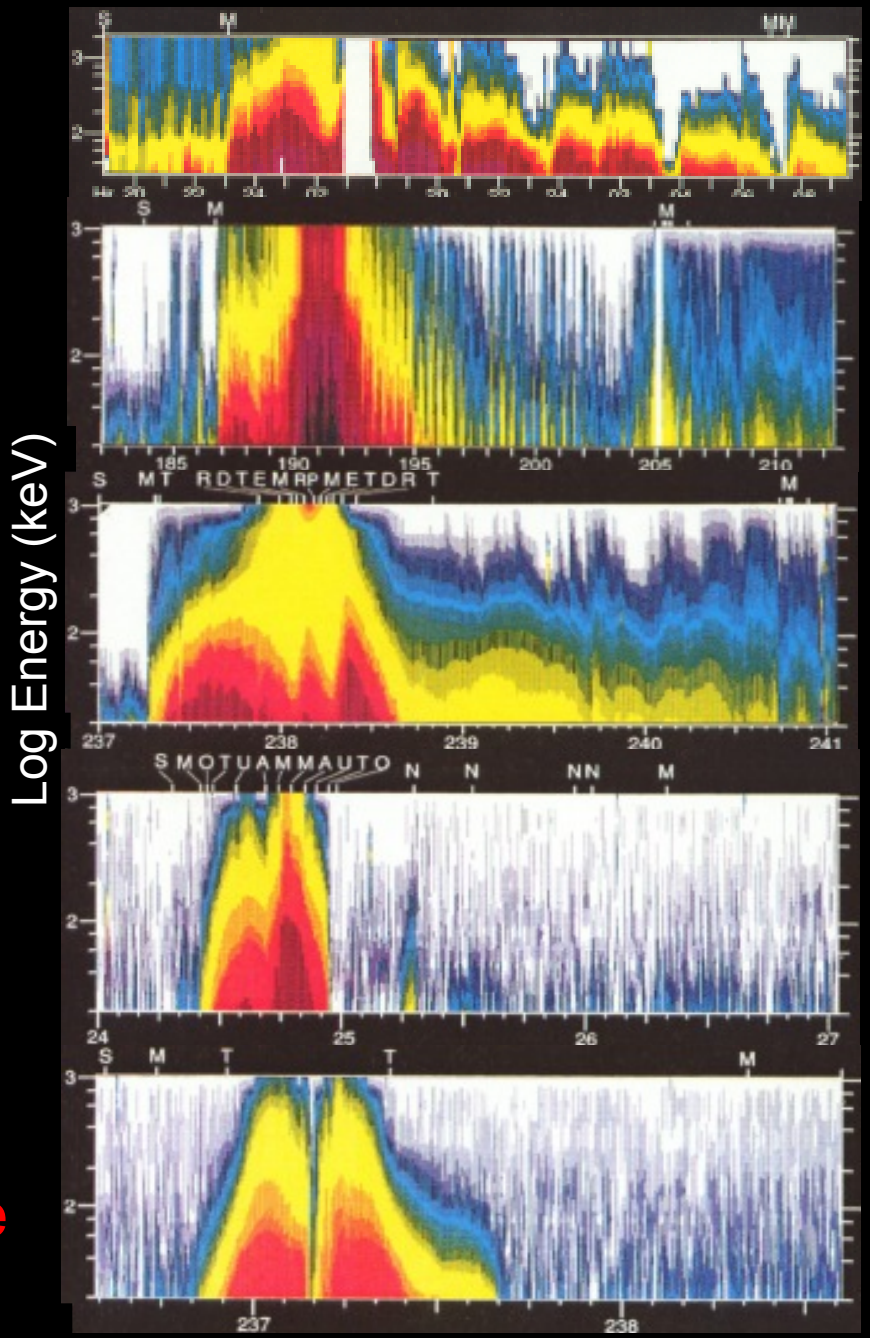
Earth

Jupiter

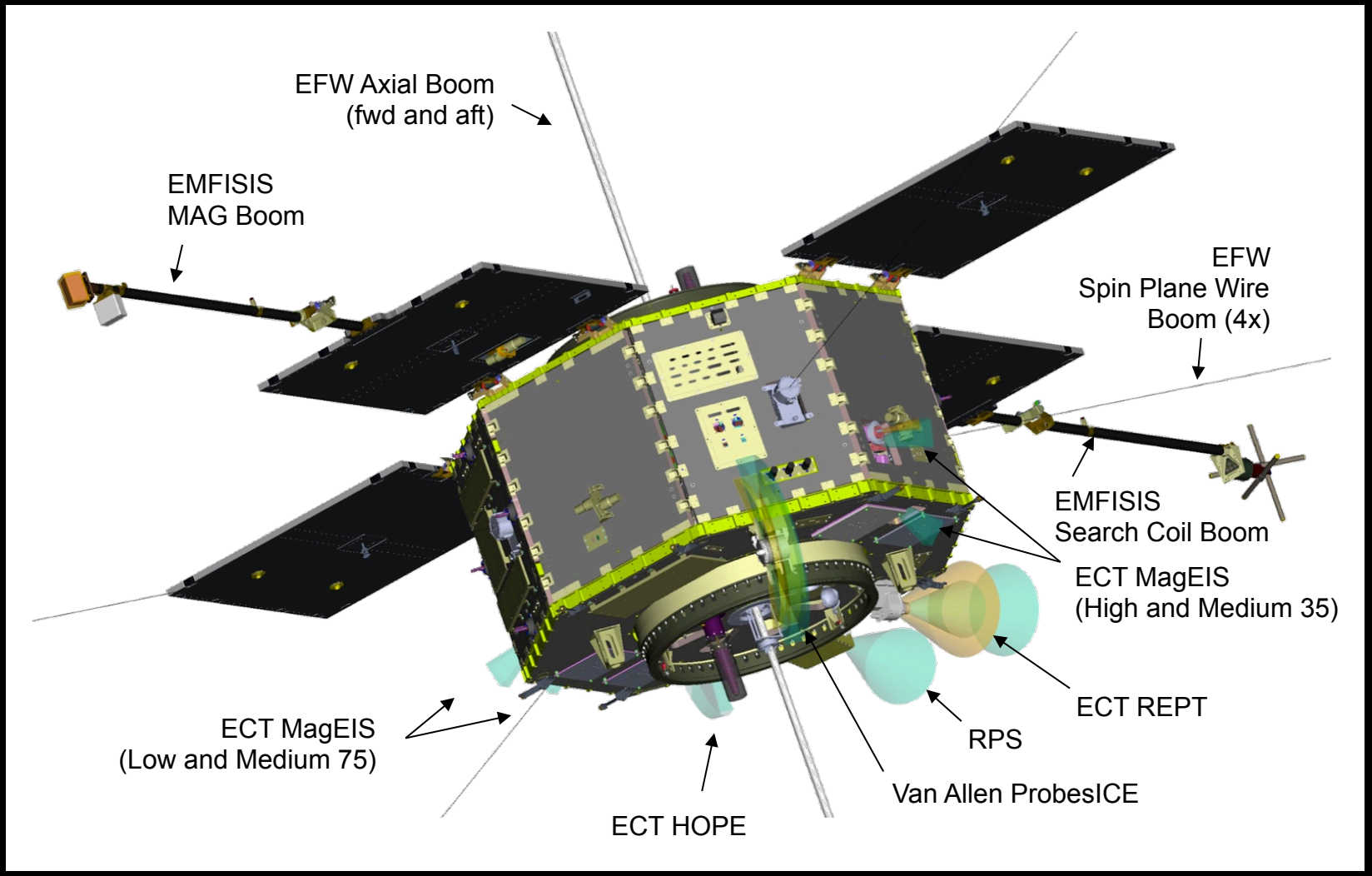
Saturn

Uranus

Neptune



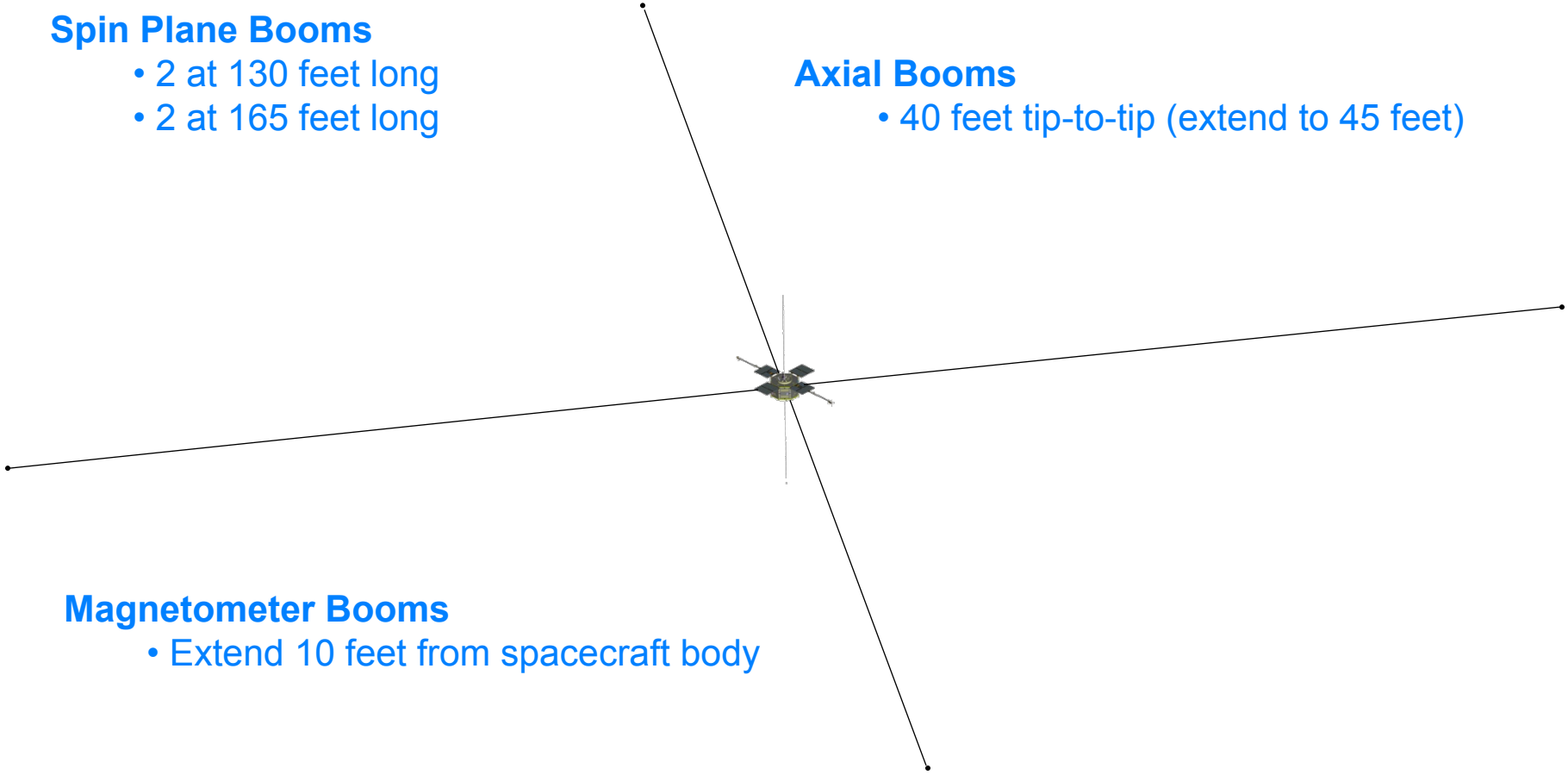
Van Allen Probes Observatories



Deployed Spacecraft

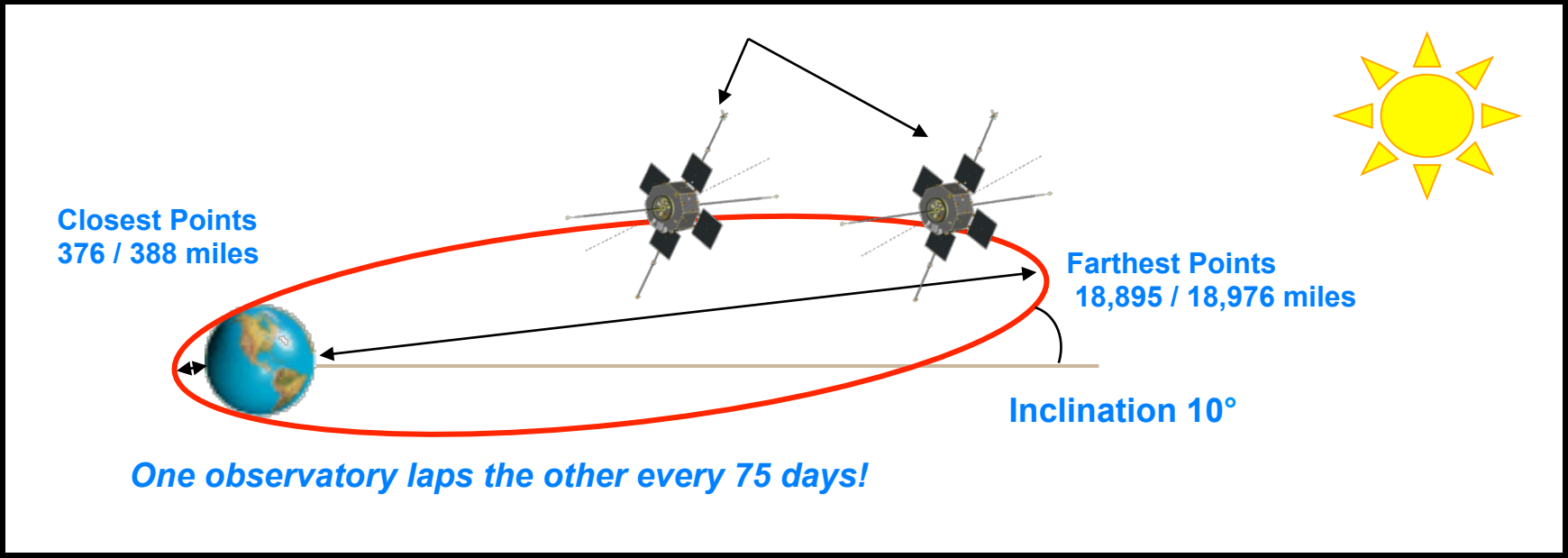
Spin Plane Booms
- 2 at 130 feet long
- 2 at 165 feet long

Axial Booms
- 40 feet tip-to-tip (extend to 45 feet)



Magnetometer Booms
- Extend 10 feet from spacecraft body

Orbit

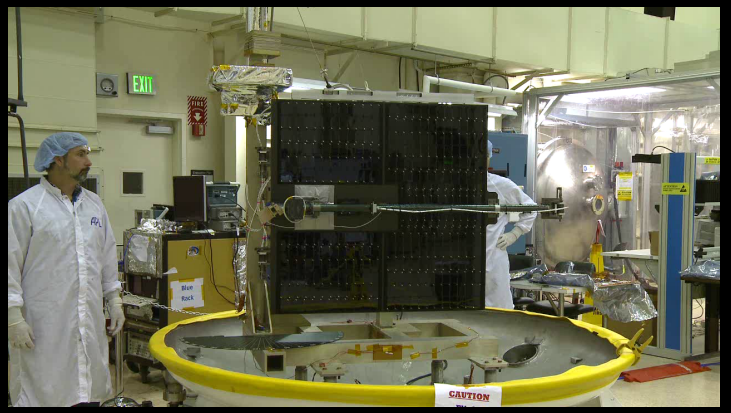


The twin Van Allen Probes observatories . . .

- **stay stable by spinning (5 times per minute)**
- **get an ‘attitude adjustment’ every 3 weeks**
- **are designed to operate for 2 years**

Spacecraft Development

Integration and Test



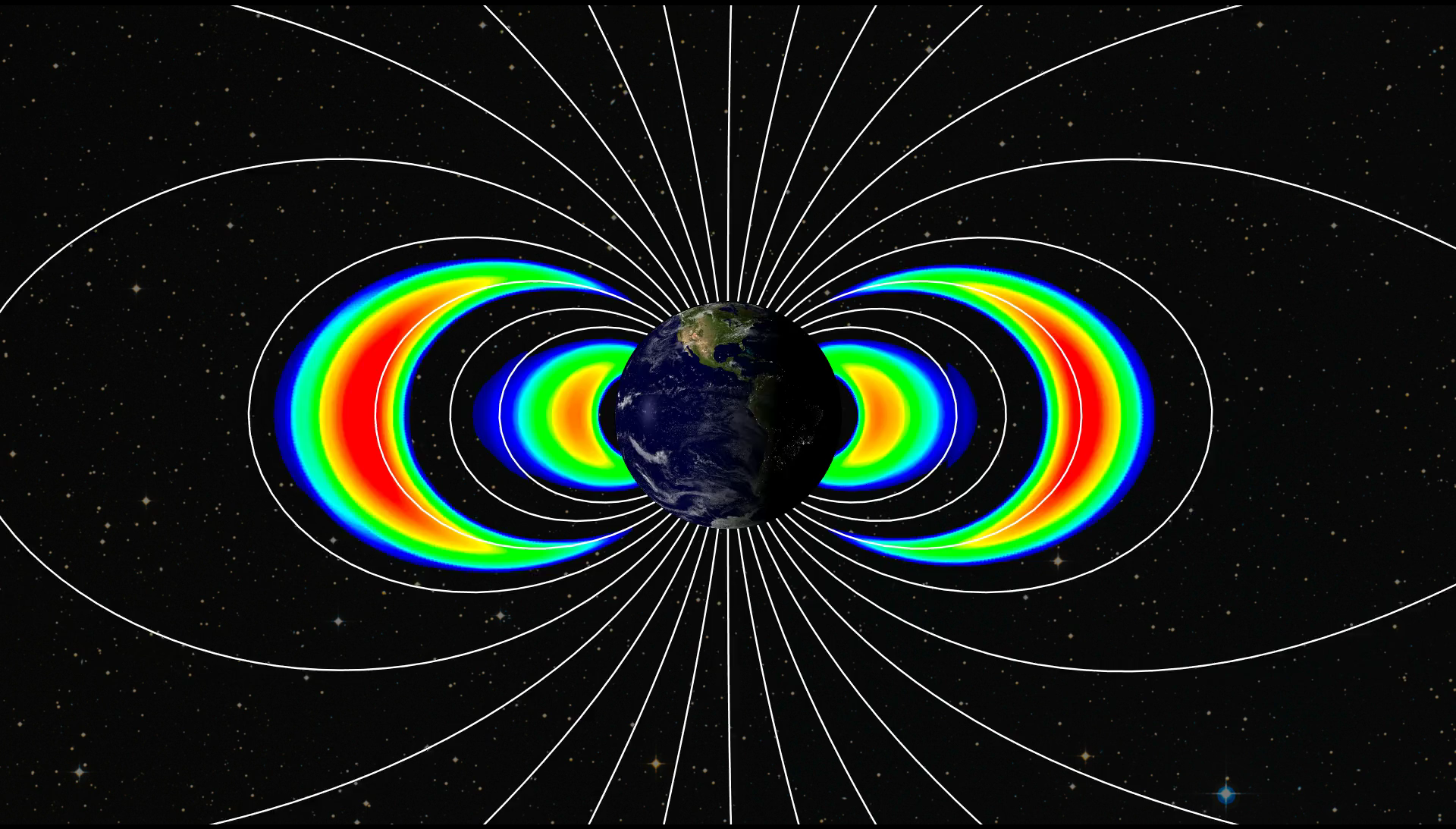
Acoustic and Vibration Testing

Thermal Vacuum Testing

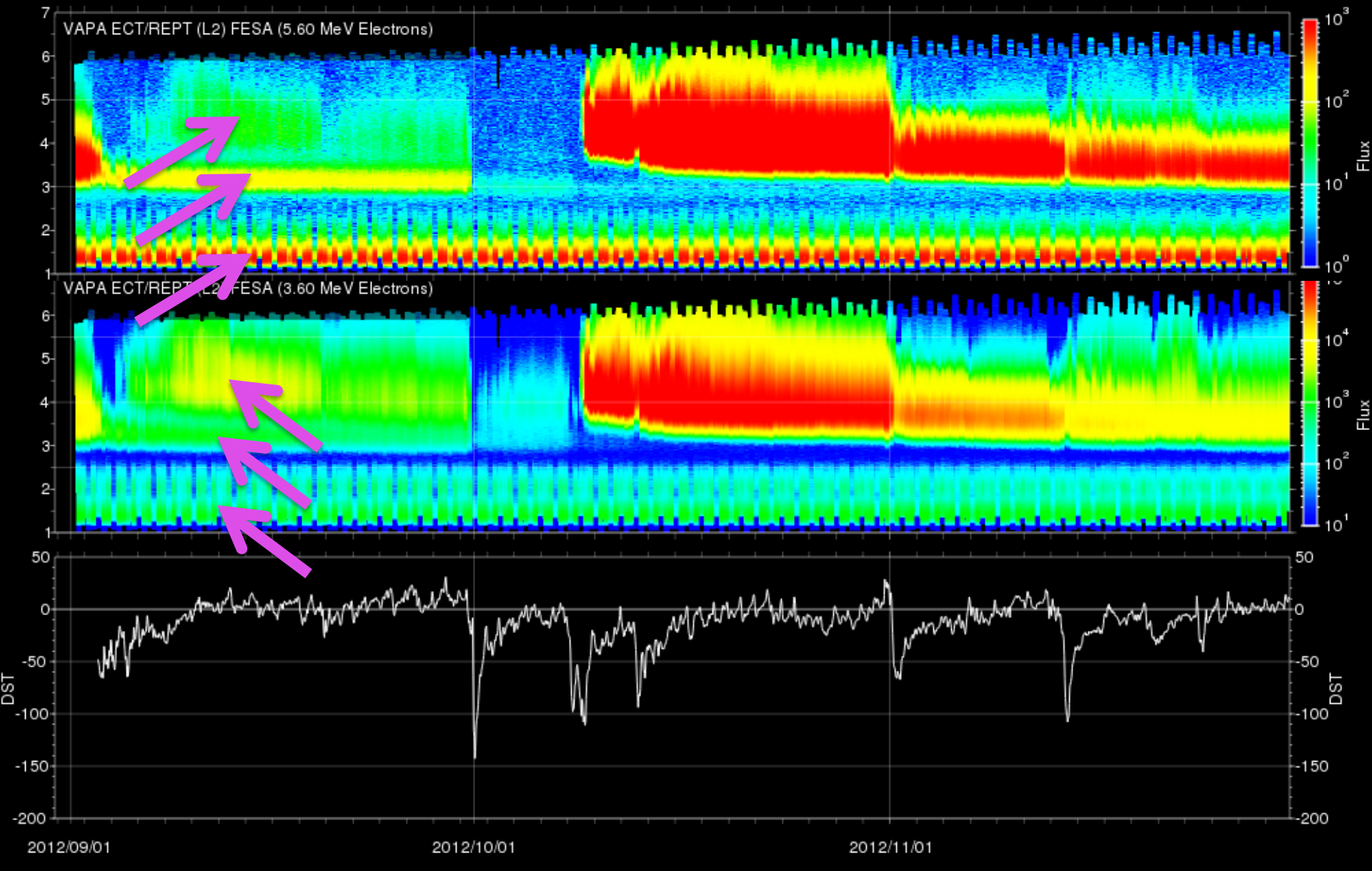
Van Allen Probes launched on August 30, 2012 at 4:05 AM EDT

http://youtu.be/9mlaQothGWA

First month into the mission…

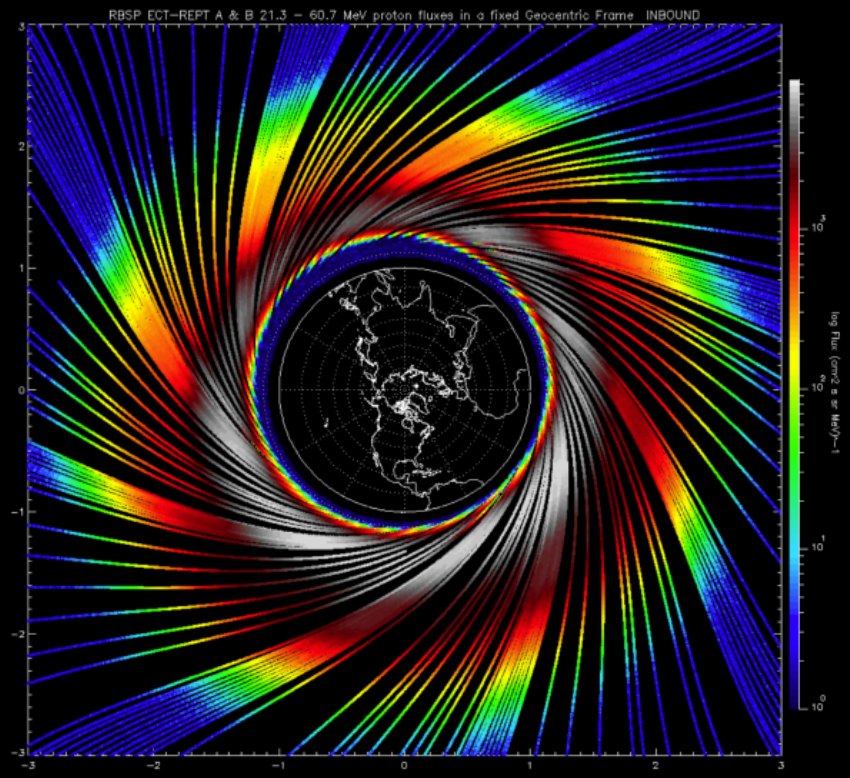


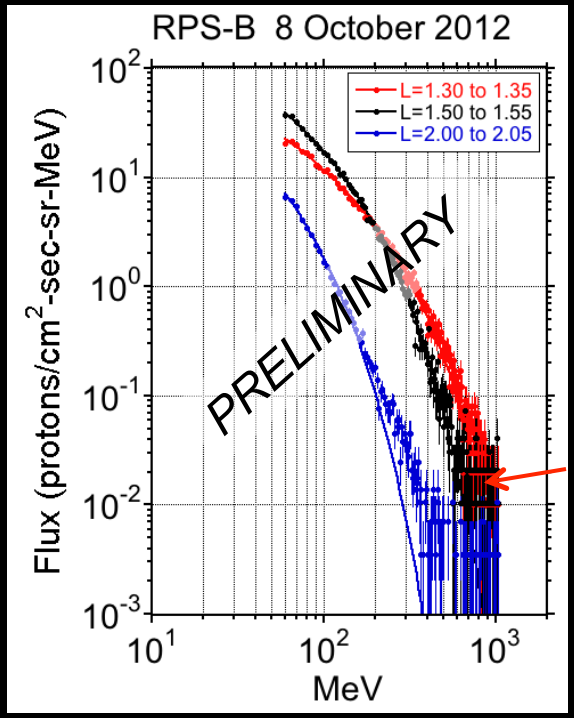
Third Belt Discovery



A few months into the mission…

We can now map out spatial distributions of the inner (and outer) belts with high fidelity

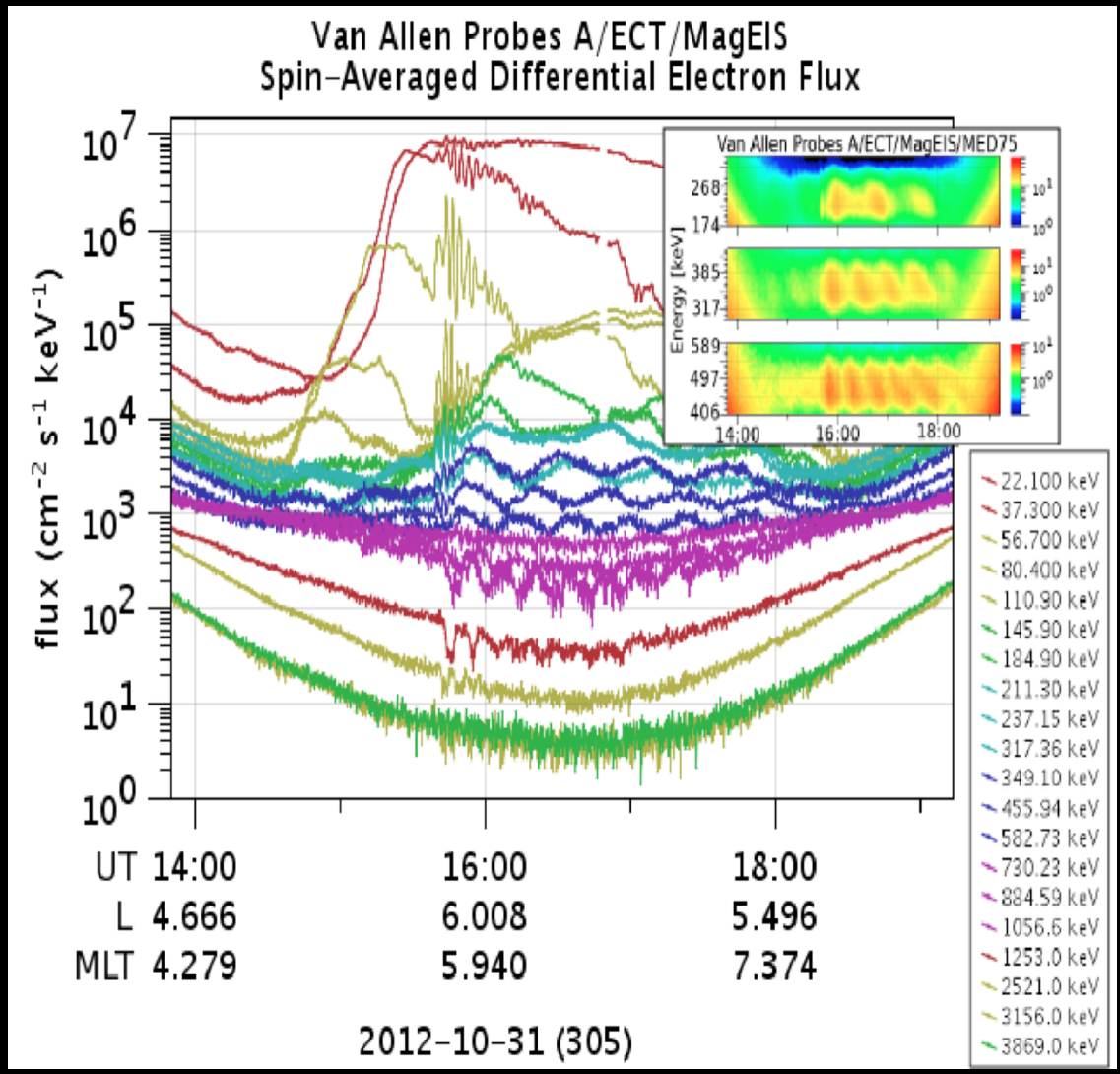




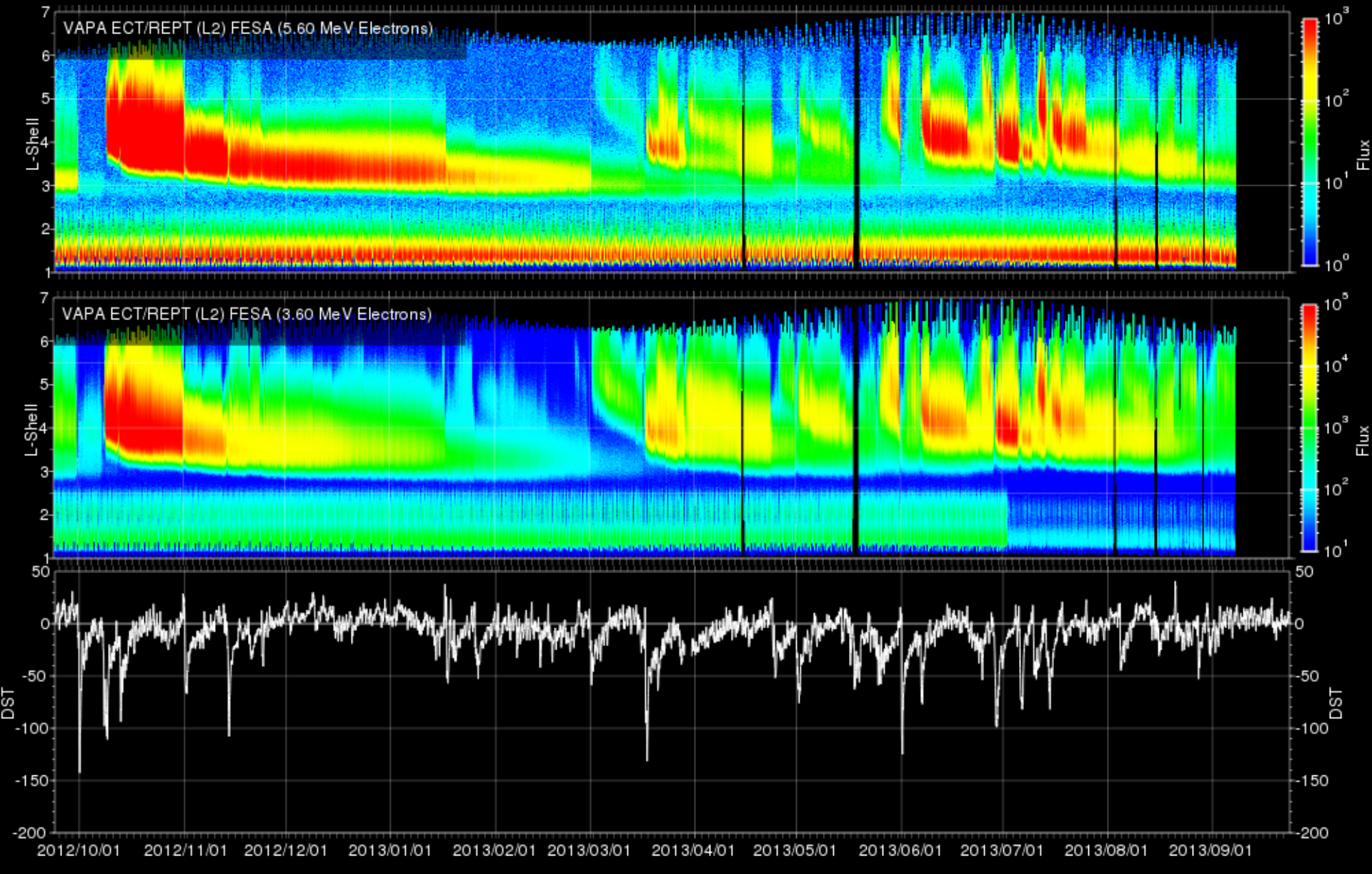
We have now measured damaging protons in the heart of Earth's inner belt to one billion electron volt energies; it is not possible in practical systems to shield against such high energy particles

A few months into the mission…

- Electron responses to Interplanetary Shock-driven Ultra Low Frequency (ULF) waves were captured by the Van Allen Probes ECT instruments. Fast oscillations extend from 22 to 520 keV energies.
- >145 keV electrons show “electron drift echoes” where electrons are “phase-bunched” as they drift all the way around the Earth, with drift structures that persists for hours.
- ECT measures these echoes with unprecedented energy resolution (inset) providing new insights that have not before been available



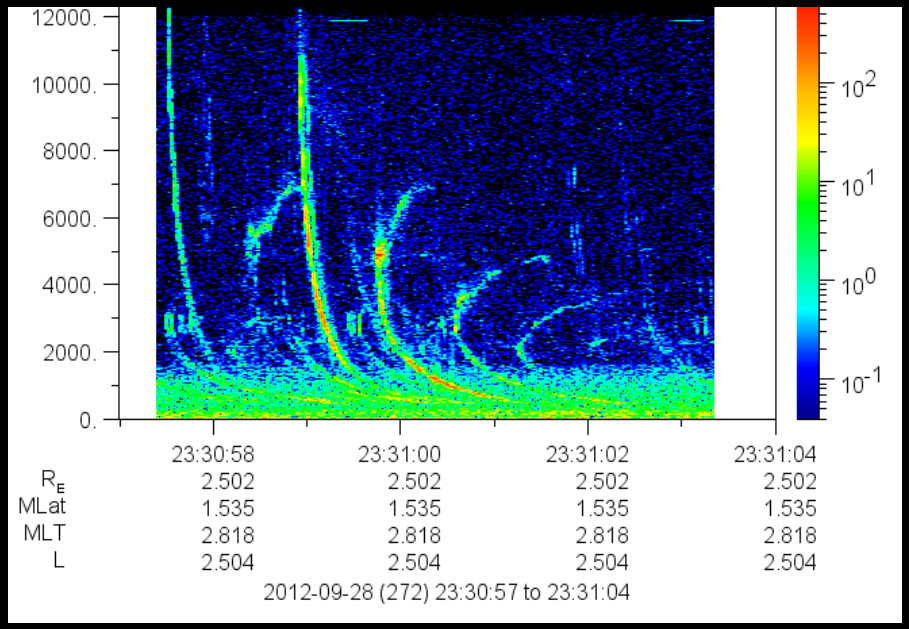
A year into the mission…

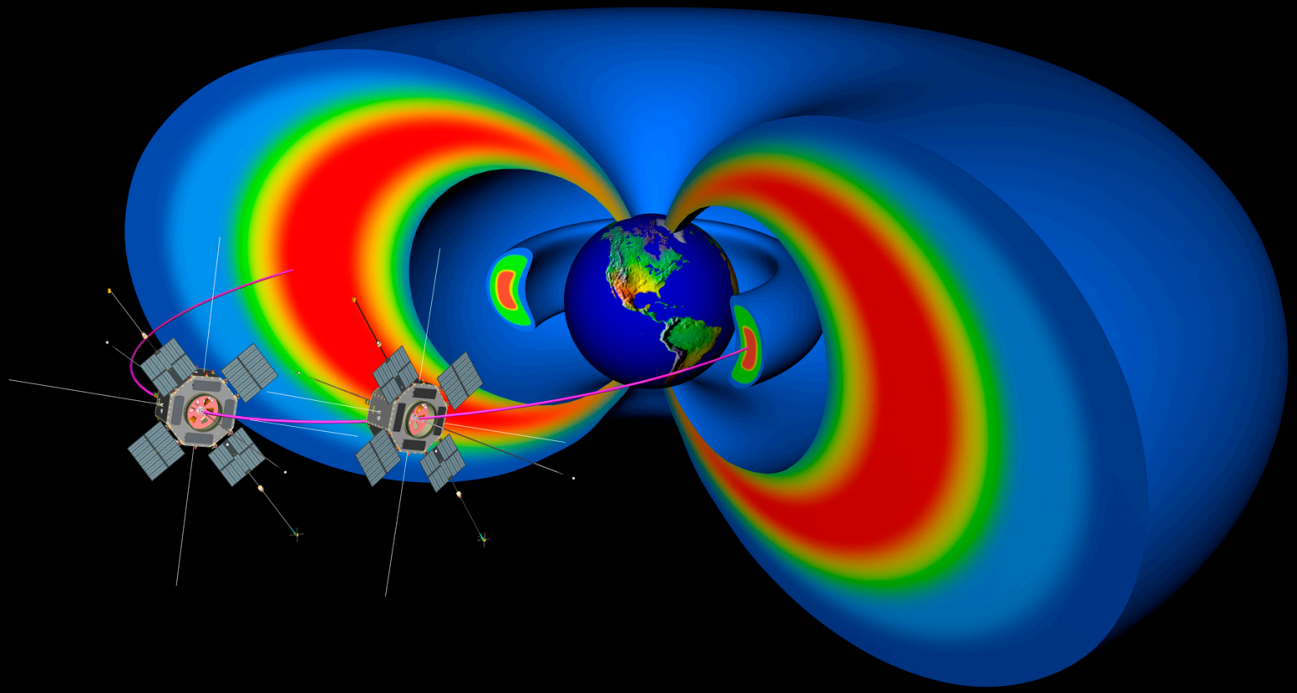


The Sounds of Space

The EMFISIS/Waves tri-axial search coil magnetometer and receiver captured several notable peak radio wave events in Earth's magnetosphere. The radio waves, which are at frequencies that are audible to the human ear, are emitted by the energetic particles in the magnetosphere.

People have known about chorus for decades. Radio receivers are used to pick it up, and it sounds a lot like birds chirping. It was often more easily picked up in the mornings, which along with the chirping sound is why it's sometimes referred to as 'dawn chorus.





Van Allen Probes: Exploring Earth's Radiation Belts and the Extremes of Space Weather

Find out more:

http://VanAllenProbes.jhuapl.edu/

Acknowledgements

Most of the slides in this presentation are slight modifications of slides created by Dr. Nicky Fox, the Deputy Project Scientist for the Van Allen Probes mission, for previous talks.

The Van Allen Probes team is vast and is comprised of talented people from many fine institutions. See the following websites for information on the project and instrument teams:
http://vanallenprobes.jhuapl.edu/mission/team.php
http://rbsp-ect.sr.unh.edu/team.shtml
http://emfisis.physics.uiowa.edu/about/team
http://rbspice.ftecs.com/Team.html
http://rbsp.space.umn.edu/team.html