12-2013

James van Allen and his namesake NASA mission

D. N. Baker
University of Colorado Boulder

V. C. Hoxie
University of Colorado Boulder

A. Jaynes
University of Colorado Boulder

A. Kale
University of Alberta

S. G. Kanekal
Goddard Space Flight Center

See next page for additional authors

Recommended Citation

Baker, D.N., Hoxie, V.C., Jaymes, A., Kale, A., Kanekal, S.G., Li, X., Reeves, G.D., Spence, H.E. James van Allen and his namesake NASA mission. (2013) Eos, 94 (49), pp. 469-470. doi:10.1002/2013EO490001

Authors
D. N. Baker, V. C. Hoxie, A. Jaynes, A. Kale, S. G. Kanekal, X. Li, Geoffrey Reeves, and Harlan E. Spence

EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 94 NUMBER 49
3 December 2013
PAGES 469–484

James Van Allen and His Namesake NASA Mission

PAGES 469–470

In many ways, James A. Van Allen defined and "invented" modern space research. His example showed the way for government-university partners to pursue basic research that also served important national and international goals. He was a tireless advocate for space exploration and for the role of space science in the spectrum of national priorities.

Van Allen is best known for his discovery in 1958 of Earth's radiation belts, and his legacy continues as more is being learned about those belts through missions such as NASA's Van Allen Probes. The probes recently found evidence of a third radiation belt that had not been detected or reported before.

James Van Allen and His Research

Van Allen worked and taught for more than half a century at the University of Iowa (see sidebar for more on Van Allen's education, positions, and honors). Prior to his death on 9 August 2006, he had attained immense professional stature because of his clever explorations of the solar system using simple, robust space instrumentation and his insightful analysis methods. His legacy includes leading more than two dozen space flight missions, staunch advocacy of robotic space exploration, and mentoring students for more than 5 decades.

Van Allen was born on 7 September 1914 in Mount Pleasant, Iowa. Biographies show that he had immense talent for gadgetry from his earliest years. He worked extensively in the 1950s on the problem of auroral and cosmic ray particle detection using rockets, balloons, and "rockoons" (rockets sent to great heights (>80 kilometers) by firing them after the rockets had been lofted to altitude (>21 kilometers) by balloons). He and his team of students and postdoctoral researchers developed robust, highly capable sensor systems for particle detection that were fielded from many shipboard excursions in the Pacific [*Van Allen,* 1957].

Van Allen attained preeminence through his strong involvement and leadership in the planning and execution of the International Geophysical Year (IGY) of 1957–1958 [*Van Allen,* 1983]. He was invited to provide instrumentation for the U.S. satellite mission that became Explorer I. This early 1958 mission and subsequent small satellites discovered and delineated the properties of the natural radiation regions around the Earth that are now known as the Van Allen radiation belts [*Ludwig,* 2011].

Van Allen went on to lead many research investigations on missions traversing the solar system. He played a particularly strong role in the Pioneer 10 and 11 missions to the outer solar system. He and the Pioneer team were the first to observe directly the intense radiation around Jupiter [see *Van Allen et al.*, 1974, and references therein] and Saturn, indicating that most magnetized planets probably have radiation belts in their environs. Van Allen continued analysis and interpretation of Pioneer data to the end of his life even as the hardy spacecraft made their way to the very fringes of the solar system.

Many missions subsequent to Van Allen's early explorations have observed parts of the Earth's radiation belts, including the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX), which observed the belts from low altitudes. Other missions such as the joint NASA–U.S. Air Force Combined Release and Radiation Effects Satellite (CRRES) and NASA's Polar spacecraft have also made important contributions. However, the causes of the dynamic variation in the belts have remained a mystery. Indeed, seemingly similar storms from the Sun have at times caused completely different effects in the belts and have sometimes led to no change at all [e.g., *Reeves et al.,* 2003].

The Van Allen Probes

The dual Radiation Belt Storm Probes (RBSP) satellites (see Figure 1)—renamed the Van Allen Probes mission on 9 November 2012—were launched on 30 August 2012 into

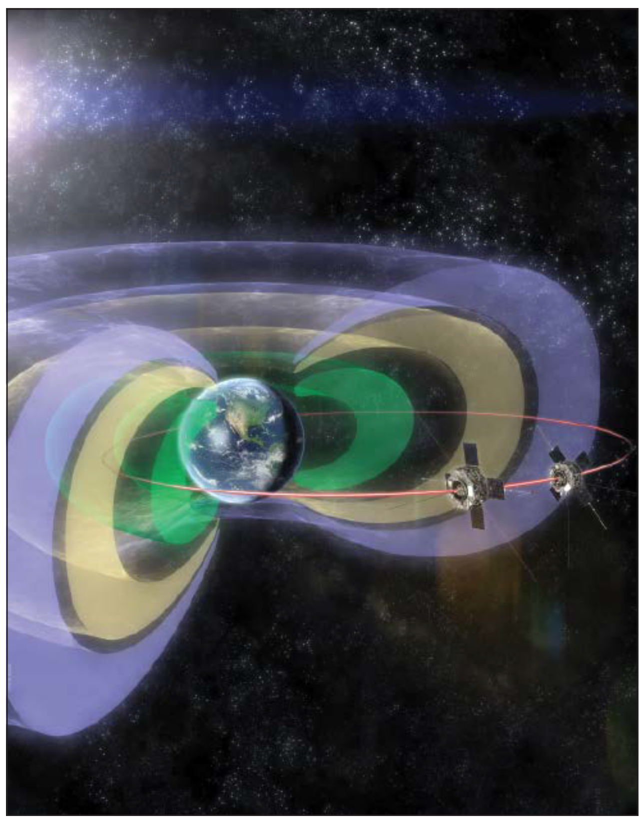

Fig. 1. The twin Radiation Belt Storm Probes, now known as the Van Allen Probes, were launched on 30 August 2012 into elliptical, near-equatorial orbits around the Earth, as illustrated schematically here. Remarkably, rather than seeing just the anticipated two-belt Van Allen zone structure, the new mission found almost immediate evidence of the clear three-belt structure portrayed in this diagram. The third belt (shown in yellow) was dubbed the storage ring feature [see Baker et al., *2013].*

By D. N. Baker, V. C. Hoxie, A. Jaynes, A. Kale, S. G. Kanekal, X. Li, G. D. Reeves, and H. E. Spence

elliptical near-equatorial Earth orbit to study the two known Van Allen belts. The Van Allen Probes include five instrument suites to measure low- to high-energy particles and magnetic and electric fields [see *Mauk et al.*, 2013]. In particular, the Relativistic Electron-Proton Telescope (REPT) measures high-energy electrons and protons. Van Allen also measured these in 1958, but REPT has much greater sensitivity and ability to distinguish particle species. Thus, REPT can detect aspects of energy, flux, and angular distributions that Van Allen and his coworkers could not have observed.

After most NASA spacecraft launches, it can take several months for research instruments on board to be turned on, ramped up to full power, and tested. The REPT research team, however, argued that it would be relatively safe to turn on the REPT instruments early [*Baker et al.*, 2012a]—just 3 days after launch—so that the instruments would overlap with the SAMPEX mission that was soon going to deorbit and reenter Earth's atmosphere [*Baker et al.*, 2012b].

The REPT instruments worked well from the moment they were turned on, on 1 September 2012. REPT made observations of freshly accelerated particles trapped in the belts, recording their high energies as the belts increased in size. Then something happened that no one had ever reported before: The particles settled into a new configuration, showing a third belt extending out into space (see Figure 1). Within mere days of launch, the spacecraft showed something (see Figure 2) that would require rewriting textbooks about how the Van Allen belts can be configured [*Baker et al.*, 2013]: Instead of just an inner and outer Van Allen zone, the data clearly showed three distinct belts. Although hinted at before in low-altitude data such as those from SAMPEX, mentioned above, the temporal, spatial, and energy resolution of the new measurements by the Van Allen Probes has proven crucially important.

During their first year in orbit, all the instruments on the Van Allen Probes have worked exceptionally well, and a flood of observations with unprecedented clarity and quality is coming in. This is the first time scientists have been able to gather such a complete set of data about the belts, with the added bonus of watching from two separate spacecraft that can better show how events sweep across the area. Spotting something new in space such as the third radiation belt has more implications than the simple knowledge that a third belt is possible—for instance, it shows that extremely high energy particles can appear and disappear almost in the blink of an eye. In a region of space that remains so mysterious, any observations that link certain causes to certain effects adds another crucial piece of information to the puzzle.

Displaying REPT Data Graphically

It is something of a challenge to take the nearly "invisible" radiation of the Van Allen belts and convert the scientific measurements into an accessible graphical display. The color-coded image in Figure 2 is an example of how scientists have used REPT data to make a picture of the radiation belts come more alive by showing a projection of the three-belt structure in a color-coded magnetic latitude projection.

Figures 3 and 4 show a spatial map of energetic electron (Figure 3) and proton (Figure 4) fluxes in an Earth-centered polar projection. As the spacecraft precess in their elliptical orbits around the Earth, they form a "spirograph" pattern in the geographically fixed, Earth-centered coordinate system. Examining the color-coded fluxes reveals that for the period shown (2 November to 15 December 2012), the energetic electrons had a clear two-belt structure with an obvious inner belt, a "slot" region largely devoid of highly energetic electrons, and a very extensive and stable outer belt region.

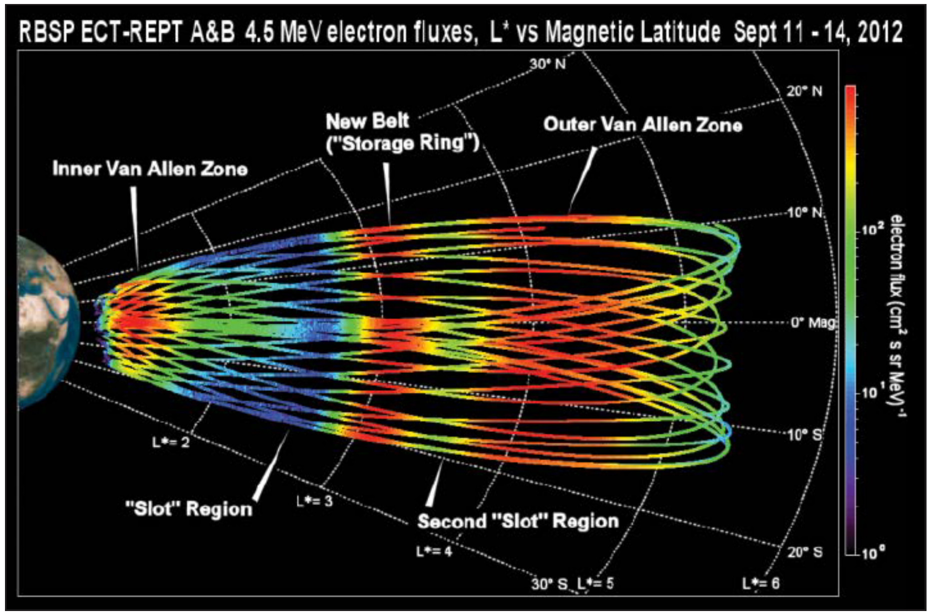

*Fig. 2. This diagram portrays the spatial distribution of highly relativistic electrons (*E = *4.0–5.0 million electron volts (MeV)) confined in the Earth's magnetic field. It shows overlaid magnetic meridional plane projections of the Relativistic Electron-Proton Telescope A (REPT-A) and REPT-B measured electron fluxes plotted according to the logarithmic color scale on the right. This presentation shows these fluxes projected onto the orbital trajectory of each spacecraft in a radial distance-magnetic latitude coordinate system. (*L* *is a measure of where magnetic field lines cross the magnetic equatorial plane). About 3 days' worth of Radiation Belt Storm Probes (RBSP) orbits (11–14 September 2012) are portrayed. This kind of display (adapted from* Baker et al. *[2013]) shows quite clearly the three-belt Van Allen zone structure, as illustrated in Figure 1.*

Van Allen's Education, Positions, and Awards

Education

- Iowa Wesleyan College in Mount Pleasant (bachelor's degree, 1935)
- State University of Iowa (now the University of Iowa; Ph.D., physics, 1939)

Positions

- Research Fellow, Carnegie Institution of Washington, Department of Terrestrial Magnetism (1939–1941)
- Staff physicist, Carnegie Institution, Department of Terrestrial Magnetism (1941–1942)
- Johns Hopkins University Applied Physics Laboratory (1942)
- Ordnance and Gunnery Officer, United States Navy (1942–1946)
- Johns Hopkins University Applied Physics Laboratory (1946–1950)
- Guggenheim Fellow at Brookhaven National Laboratory (1951)
- Princeton University (1953–1954)

Selected Awards and Honors

- Member of the National Academy of Sciences
- AGU William Bowie Medal (1977)
- Gold Medal of the Royal Astronomical Society (1978)
- Crafoord Prize of the Swedish Academy of Sciences in 1989 (often regarded as the equivalent of the Nobel Prize in the space sciences and geosciences)

The protons (Figure 4), on the other hand, are seen only in the inner Van Allen zone and are confined to the region quite close to Earth. Both the electron and proton plots in this format show the clear belt structure and show longitudinal asymmetries in particle fluxes associated with the Earth's offset, tilted dipole magnetic field. This leads to a reduced intensity of measured particle fluxes over the American sector due to Earth's distorted field.

Legacy of Van Allen and the NASA Mission

James Van Allen was accorded countless accolades and awards, but through all of his recognitions and commendations he remained a modest, unassuming researcher and teacher. He always had time to counsel students and protégés and to dispense sound, commonsense advice.

At his 90th birthday celebration in 2004, more than 200 of his colleagues, former students, and friends gathered in Iowa City to honor Van Allen. There, as throughout his life, he graciously and unassumingly thanked family and colleagues for their roles in his success. Indeed, it is Van Allen who should be thanked and remembered for all that he provided to modern science. The spacecraft mission named after Van Allen is expected to continue to shed new light on the fascinating regions he discovered so many decades ago.

References

Baker, D. N., et al. (2012a), The Relativistic Electron-Proton Telescope (REPT) instrument on board the Radiation Belt Storm Probes (RBSP) spacecraft: Characterization of Earth's radiation belt high-energy particle populations, *Space Sci. Rev., 179,* 337–381, doi:10.1007/s11214-012-9950-9.

Baker, D. N., G. M. Mason, and J. E. Mazur (2012b), SAMPEX to reenter atmosphere: Twenty-year mission will end, *Space Weather, 10,* SO5006, doi:10.1029/2012SW000804.

Baker, D. N., et al. (2013), A long-lived relativistic electron storage ring embedded in Earth's outer Van Allen belt, *Science, 340*(6129), 186–190, doi:10.1126/science.1233518.

Ludwig, G. H. (2011), *Opening Space Research: Dreams, Technology, and Scientific Discovery,* 478 pp., AGU, Washington, D. C.

Mauk, B. H., et al. (2013), Science objectives and rationale for the Radiation Belt Storm Probes mission, *Space Sci. Rev., 179*(1–4), 3–27, doi:10.1007/s11214-012-9908-y.

Reeves, G. D., K. L. McAdams, R. H. W. Friedel, and T. P. O'Brien (2003), Acceleration and loss of relativistic electrons during geomagnetic storms, *Geophys. Res. Lett., 30*(10), 1529, doi:10.1029/2002GL016513.

Van Allen, J. A. (1957), Direct detection of auroral radiation with rocket equipment, *Proc. Natl. Acad. Sci. U. S. A., 43*(1), 57–62.

Van Allen, J. A. (1983), *Origins of Magnetospheric Physics,* Smithson. Inst. Press, Washington, D. C.

Van Allen, J. A., D. N. Baker, B. A. Randall, and D. D. Sentman (1974), The magnetosphere of Jupiter as observed with Pioneer 10: 1. Instrument and principal findings, *J. Geophys. Res., 79*(25), 3559–3577, doi:10.1029/JA079i025p03559.

Author Information

D. N. Baker, V. C. Hoxie, and A. Jaynes, Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder; email: daniel.baker@lasp.colorado.edu; A. Kale, Department of Physics, University of Alberta, Edmonton, Canada; S. G. Kanekal, Goddard Space Flight Center, NASA, Greenbelt, Md.; X. Li, LASP; G. D. Reeves, Space Science and Applications Group, Los Alamos National Laboratory, Los Alamos, N. M.; and H. E. Spence, University of New Hampshire, Durham

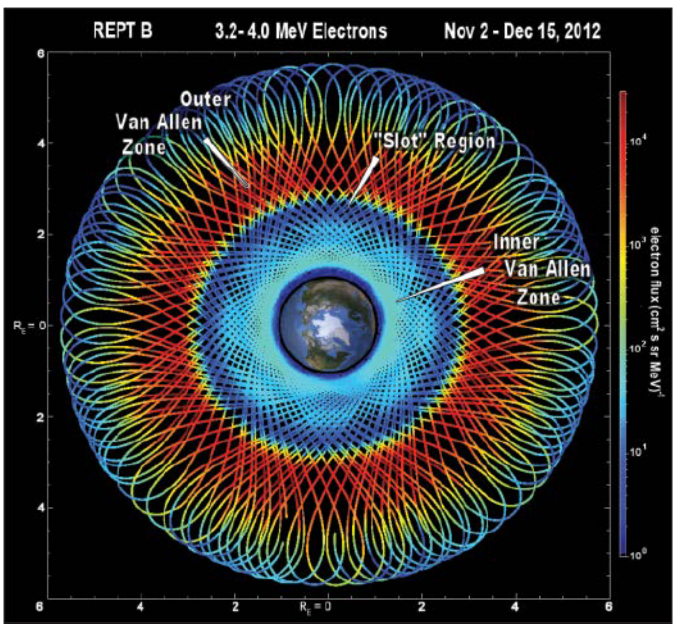

Fig. 3. A color-coded representation of energetic electron (3.2 MeV ≤ E ≤ 4.0 MeV) fluxes measured by REPT sensors from 2 November 2012 to 15 December 2012. The orbital traces of the Van Allen Probes B spacecraft are projected onto the geographical equatorial plane. The coordinate system is a geographically fixed, Earth-centered frame. The resulting orbital pattern is like a "spirograph," showing in the colored bands the relatively weak inner Van Allen zone population of electrons, the slot region, and the stable (during this quiet 6-week interval) outer Van Allen zone.

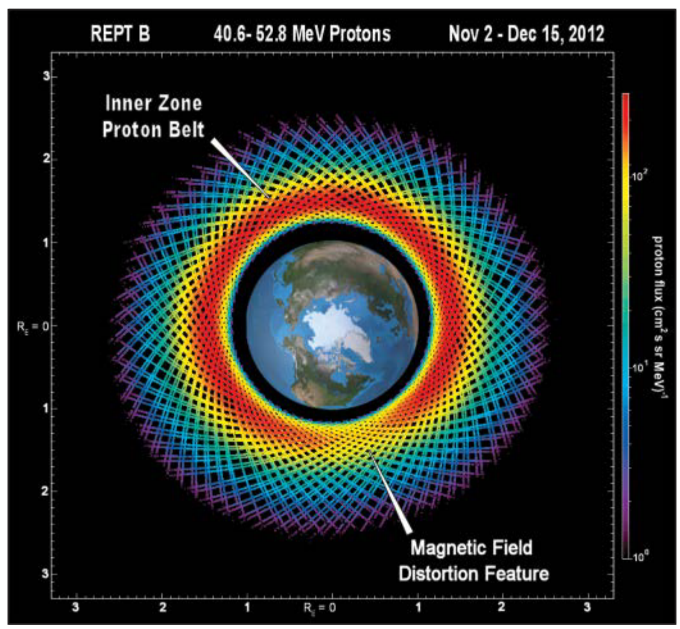

Fig. 4. Analogous in concept to Figure 3 but showing a more expanded radial scale for 40- to 53-MeV protons measured by REPT in the Earth's inner Van Allen zone. Note the lower flux levels over the American sector due to the magnetic field discussed in the text.