

Discovery of the Van Allen Radiation Belts

by Carl McIlwain

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*(Images shown during this lecture are in a PDF file
available on the previous web page)*

I would like to join George in expressing my admiration and thanks to Dr. Van Allen. Many people call him Van, but to me he will always be Dr. Van Allen. He not only provided guidance in an accelerated learning experience, but also setup projects for his students which were unusually rewarding and exciting.

I also want to thank George for providing me with images from his personal files, and from the Van Allen archive collection.

The chapter in Berland's book about Dr. Van Allen is entitled, "I'm Sort of a Scoutmaster" Actually, he was far more than a Scoutmaster. He ignited an intense desire in his students to understand what nature was doing at high altitudes. We were very aware we were neophytes, but, Dr. Van Allen always treated us like colleagues. Our ideas and opinions were always carefully considered and thoroughly discussed, even when they were often a little hair-brained.

Even the word 'mentor' does not fully convey Dr. Van Allen's relationships with his students. It is an unusual mentor who takes such a personal interest in each of his students and make sure they are working on projects which require them to expand their range of abilities.

I was lucky, that as an undergraduate music student, my flute teacher, Dr. Morey, also treated me as a colleague. He asked me to help teach the flute students and set me up in a studio adjacent to those of the faculty members teaching cello and clarinet. Knowing my desire to study the science of music as a graduate student, he contacted his Alma Mater, the State University of Iowa, and setup it up for me to teach flute while I took courses in undergraduate physics.

Upon arriving in Iowa City in early 1954, I auditioned for the Chairman of the Music Department, Himie Voxman. He gave me the desired teaching position and a chair in the orchestra. Later, he called, and said apologetically, the previous graduate student in the teaching position had decided to join the faculty, and would continue teaching the flute students. My wife, Mary, had taken a job in the State Water Lab, so I concentrated on my beginning courses in physics, chemistry, and mathematics. I had enrolled as a graduate student in physics having met the only requirement, a bachelors degree.

I was delighted to find that physics students were actually paid to do interesting things in the research labs, and was given a job working in the basement where people were building instruments to be launched on balloon launched rockets, rockoons. One of my first tasks was given to me by Frank McDonald. His rocket payload had a large capacitor which needed a shaped sheet of aluminum to secure it during flight.

In August, Dr. Van Allen returned from a 15 month sabbatical leave at Princeton working on controlled nuclear fusion. He found he had some new graduate students and gathered them in his office to discuss possible masters degree projects. After he had described the various aspects of a list he wrote on a blackboard, it was time to choose a project. Larry Cahill decided to see if the newly invented proton-precession magnetometer could be miniaturized to fit into a three inch rocket. I chose to make a latitude survey using Geiger tubes in balloon launched three inch rockets. It is unlikely Dr. Van Allen knew I was fresh out of music school and had little knowledge of physics.

Dr. Van Allen then wrote a one page proposal to fund my project, requesting \$2000 from NSF. Soon, the machine shop was turning out parts for my rockoon payloads, and about 18 months after auditioning for Voxman, I was on Landing Ship Dock #1 preparing to launch rockoons.

*Joe Kasper holding the insulated ignition circuit.
Joe Kasper, George Ludwig, and our liaison officer, Cmdr Gus Ebel.*

Dr. Van Allen had the idea of placing a three inch rocket on top of a six inch rockoon, so the ex-music student had the machine shop make an adapter to hold them together. Here the igniter is about to be inserted into the three inch rocket and connected to the ignition circuitry inside the adapter.

*Cmdr Ebel and Frank helping insert the adapter.
Frank holding the assembled rockets.
About to cut the balloon tether.*

The first attempt, the differential air-drag did not separate the rockets. The second attempt did achieve separation and the second stage ignited, but within a few seconds, there were loud noises in the telemetry signal, and then no signal. Later, when we told them about it, the JPL people said, "why didn't you tell us what you were going to do. We would have told you that the thin aluminum nose cone would melt" Dr. Van Allen later wrote: "Retrospectively, it appears likely that this inexpensive technique, given a heat-resistant nose cone, would have resulted in discovery of the geomagnetically trapped radiation."

We continued to launch rockoons until the launch preparations for the ninth 3 inch rocket ended in near disaster when it ignited while still on the sawhorse. Cmdr Ebel was badly burned, but made a complete recovery. The tenth and last 3 inch rocket was tossed overboard, Commander Ebel was taken to the nearest port, and we sailed home.

That winter, on the morning of February 26, 1956, a call was received from the University of Chicago, saying that a gigantic solar storm was bombarding the Earth with cosmic rays, and that we should launch something if at all possible. The only thing that could be found was the unlaunched tenth payload brought back from the expedition. We hurriedly took it to the Iowa football field and launched it with a cluster of rubber balloons. Dr. Van Allen wrote a paper about our solar cosmic ray observations resulting in my first published paper.

Long before Sputnik, Dr. Van Allen had proposed a satellite in a pole-to-pole orbit for studying auroral particles. He suggested that I study the auroral soft radiation by flying Nike-Cajun rockets from Fort Churchill, Canada. Thus, in the fall of 1957, Don Enemark, Don Stillwell, and I arrived at the launch site with two payloads. The first launch attempt failed, and the second rocket rotated and pointed the instruments downward. On the second trip that winter we had much better luck. Our last rocket went into a bright aurora and measured electrons with an energy spectrum indicating they had just fallen through and electric potential. At the time, theorists knew that plasmas instantly short out such electric fields. It has taken almost a half century, but now most theorist agree that these electric fields are a prime driver of auroral processes.

In the meantime, Sputnik had been launched. George has told about his work preparing the Explorer I payload. When I got back from my Churchill expedition, Explorer I was in orbit and George and Dr. Van Allen were busy looking at the data, and scratching their heads. "Here is the normal cosmic ray counting rate, but here it is zero. Are there periods when something is not working properly?" I pointed out that another possibility was that the flux might sometimes be very high, driving the Geiger tube into such hard saturation that it did not count at all. Whether it was failure or high fluxes could be answered by seeing the transition from normal to zero rates. Did it just drop suddenly as in a failure, or did it smoothly rise to higher rates, go into saturation, and finally give only zeros? To find out, we had to wait for the launch of Explorer III with George's tape recorder.

Dr. Van Allen was in Washington, DC when the first recording was received. He picked up a copy at the Vanguard data center, went to his hotel room, jotted down the pulse pattern, and plotted the implied counting rates. At 3:00 AM, he turned in for the night "with the conviction that our instruments on both Explorers I and III were working reliably and giving reproducible results but that we were encountering a mysterious physical effect of a real nature"

This letter George found in the archives probably accompanied the copy of the film sent to Iowa City. Joe Kasper, Ernie Ray, Herb Sauer and I put it in a film reader and began searching for a transition. **AND THERE IT WAS**, with its immediate implication of high fluxes. I grabbed the prototype Geiger tube system, put it in front of the X-ray machine Dr. Van Allen had let me buy for calibrating my auroral instrumentation. Yes, the apparent counting **COULD** be driven to zero by trying to make it count higher than 35,000 per second.

As the senior member, Professor Ernie Ray wrote the note for Dr. Van Allen to read upon his return to Iowa City.

Upon seeing my graph of X-ray data, Dr. Van Allen instantly agreed with our interpretation that there were high fluxes out there.

On May 1, 1958, Dr. Van Allen announced the discovery at the National Academy of Science. He had already deduced that the particles jamming the Geiger tubes were in trapped orbits.

People everywhere were closely following space activities, and the space race was in full swing. The discovery was given a large amount of publicity.

It was clear that a spacecraft was needed to go up and study this new phenomenon. The preceding fall, Nicholas Christofilos had asked "What would happen if we set a high-altitude atomic bomb off; would it inject many trapped particles? Of course it would. So let's try it and measure what happens". Project Argus was conceived to do just this, and was now put in motion. Van Allen proposed to launch a satellite with better detectors to measure, without saturation, the trapped radiation that was already up there, and to detect the electrons injected by the atomic bomb blasts. An explicit requirement was to launch in time to beat the moratorium on high-altitude nuclear explosions. This was because the United States wanted to somehow set off high-altitude nuclear explosions in the time period before the moratorium, but after the spacecraft was up. Van Allen's proposal was accepted in part because most people felt the required schedule was impossible and refused to propose.

George Ludwig working on Exp IV

We found that working longer than 16 hours a day tended to produce more negative than positive results

*Exp IV ready to be buttoned up
Exp IV in shipping box*

During an Explorer IV press conference, George and I received little attention compared to that given to Wernher von Braun. Later, when von Braun and I were having lunch at a roadside cafe, he told me "You are the important ones. I'm just the trucker"

*Explorer IV was successfully launched 77 days after conception.
Paper about Exp IV observations
Christofilos, Argus
Argus ignition and launch from ship in S Atlantic
Argus shell encounters
Exp IV telemetry*

Annabelle Hudmon hired a cadre of students to measure the switching times of the scalers off the long strip charts and pencil their measurements in standard MIT lab notebooks. We had to edit the notebooks and quickly erase data that looked as if it had anything to do with the bomb blasts. Explorer IV proceeded to measure a great deal of what was to be known about the radiation belts for some time.

In February 1959, there was a classified workshop at the Lawrence Livermore Laboratory. Earlier, Edward Teller had asked Ted Northrop to "see if you can find out how particles drift in longitude". Nobody knew. We knew that particles spiraling around the magnetic field lines would bounce and be trapped, but did not know how they would drift around the Earth. Ted Northrop found the key: the Rosenbluth longitudinal invariant. At the workshop, he gave an impromptu seminar on the invariant to Dr. Van Allen, me, and other interested people.

Integral invariant, longitudinal drifting. This invariant formed the basis for devising a way of mapping trapped radiation, the B,L coordinate system.

Don Gurnett and Brian O'Brien

It is now recognized that radiation belts are an important and common aspect in many parts of our universe. We at the State University of Iowa who were involved with the early spacecraft were exceedingly lucky to be there to help produce mankind's first view's of this wondrous new phenomenon.

Dr. Van Allen cannot be thanked too much for providing the many opportunities for research and personal development, and for his continued support over the years.

Van Allen, Time 5/30/59