NATIONAL ACADEMY OF SCIENCES

PETER MEYER
1920–2002

A Biographical Memoir by

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Biographical Memoirs, VOLUME 83

PUBLISHED 2003 BY
THE NATIONAL ACADEMIES PRESS
WASHINGTON, D.C.

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Peter Meyer

PETER MEYER

January 6, 1920–March 7, 2002

BY EUGENE N. PARKER

PETER MEYER WAS AN experimental physicist who devoted his career to the mysterious origins and behavior of the cosmic rays, contributing substantially to present knowledge of the diverse components of the cosmic rays. He was a friend and colleague whose presence made the day more interesting and the difficulties less onerous. He was a devoted family man. He and his first wife, Luise Meyer-Schützmeister, a prominent nuclear physicist, were enthusiastic skiers, campers, and mountain hikers. Music was a continuing passion. He was an excellent cellist and Luise a pianist. They participated in regular chamber music evenings at their home, for their own pleasure and for the pleasure of those privileged to join in or merely to listen. Luise died in 1981, and Peter married Patricia Spear, a microbiologist, in 1983. Peter and Pat actively pursued their common interest in music and the outdoors and traveled widely, in addition to working intensely on their respective research interests. These many intense activities seemed only to refresh him for his continuing scientific assault on the elusive cosmic rays. Peter had to give up many of his activities during the last few years of his life due to illness, but he did so with grace and style and continued to engage his friends and family with his wit and humor.

Peter Meyer was born in 1920 in Berlin. He studied at the *Technische Hochschule* Berlin with the famous physicist Hans Geiger as one of his teachers. His *Diplom Ingenieur* thesis in 1942 dealt with proportional counters. As the son of a Jewish physician and German mother he was denied the “honor” of fighting for the fatherland, with the result that he survived the war as a factory worker. His father also survived, thanks to the efforts of some of his patients.

After the war Meyer continued his studies in physics at the University of Göttingen. He obtained his Ph.D. in 1948 under the direction of Wolfgang Paul (Nobel Prize in physics in 1989) and Hans Kopfermann with a precise measurement of the binding energy of the deuteron (1949). He continued working in experimental nuclear physics at Göttingen, with a year at the Cavendish Laboratory at Cambridge University (1950). Then from 1950 to 1953 he was a staff scientist at the Max Planck Institute for Physics in Göttingen.

In 1953 Meyer came to the United States and accepted an invitation from John Simpson to work in the pursuit of cosmic rays as a research associate in the Institute for Nuclear Studies at the University of Chicago. His scientific prowess as an experimentalist was soon appreciated at Chicago, and he was appointed assistant professor in the Institute for Nuclear Studies (now the Enrico Fermi Institute) and the Department of Physics in 1956. He was promoted to associate professor (tenure) in 1962 and professor in 1966. Meyer remained at the University of Chicago for the rest of his scientific career, becoming emeritus in 1990.

It was my good fortune to make Meyer’s acquaintance when I arrived in Chicago in 1955 to work with John Simpson on the theoretical implications of the cosmic-ray variations that Simpson and Meyer were observing. Meyer’s two sons, Stephan and Andreas, were born in about the same years as my daughter and son, and the children were soon acquainted through our socializing. It was Peter's performing with his cello that encouraged my daughter to take up the violin and my son the cello. Peter was supportive of their musical activities, even to the extent of locating an excellent old cello in Germany and traveling by plane back to Chicago accompanied by the cello in a monster carrying case. This was but a small sample of his relationships with the younger generation. He was a sympathetic mentor and supportive friend of his many Ph.D. students over the years.

Meyer worked with John Simpson in pursuit of the mysterious time variations of the cosmic-ray intensity. It must be understood that the term "cosmic rays" is a generic term for the ionizing radiation coming down through the atmosphere of Earth. When Meyer began his professional career in 1948, it had just been established that the top of the atmosphere is continually bombarded from space by energetic protons, accompanied by a smaller number of heavier nuclei with speeds up to that of light. The impact of these energetic protons on the nuclei of the air atoms near the top of the atmosphere produces π mesons (quickly decaying to μ mesons) and gamma rays and leading to electrons, positrons, antiprotons, neutrons, and more secondary protons, which all come showering down through the atmosphere. These particles ionize ambient air atoms along the way. Indeed, it was the discovery of the slight but ubiquitous ionization of the air in the laboratory a century ago that led to the recognition of the cosmic rays. In 1912 the Austrian physicist Victor Hess ascended in a balloon to a height of several thousand feet to find that the ionization increases dramatically with altitude, thereby demonstrating that the ionization is caused by something from outside the atmosphere. The alternative explanation had been the recently discovered natural radioactivity of the rocks and soil, whose effects would diminish rapidly upward from ground level. With the external origin of the ionization the term *cosmic rays* was coined to refer to whatever was responsible. And after many years of speculation as to the precise nature of cosmic rays, they turned out to be mostly energetic protons. Over the last half century it has been established that the protons are accompanied by small numbers of heavier nuclei and by a few electrons, positrons, and antiprotons. Protons are not rays, of course, but the terminology "cosmic rays" survives nonetheless. We are, after all, creatures of habit.

The studies of cosmic rays moved forward rapidly after World War II with the advance of technology (e.g., high resolution nuclear emulsions and sophisticated electronic detectors). Over the course of his career Meyer designed many innovative instruments to explore the energy distributions of both the major and minor components among the cosmic-ray particles.

Simpson recognized that time variations of the cosmic-ray intensity, often correlating with solar activity, were somehow a consequence of conditions in space. Lacking spacecraft in those days to carry instruments into space for a direct look, he sought to use the cosmic-ray variations as a probe of those conditions. The idea was to obtain quantitative measurements of the dependence of the time variations on the energy of the protons, so that various speculations on electric fields in space or modifications of the geomagnetic field or, whatever, could be tested and confirmed or ruled out. Thus, besides the five neutron monitor stations set up by Simpson at geomagnetic latitudes from 0° to 60°, Simpson and Meyer exploited the magnetic field of Earth as a spectrometer with extensive north-south flights with neutron monitors, etc., in aircraft supplied by the U.S. Air Force. They also launched many balloon-borne instruments to the upper atmosphere (~100,000 ft) to connect the ground measurements of the cosmic-ray intensity to the intensity at the top of the atmosphere. The gigantic cosmic-ray flare on the Sun on February 23, 1956, was a lucky event in this respect, showing the direct arrival of energetic protons from the Sun, followed by a slow decline, indicating that the inner Solar System is open out to about the orbit of Mars and enclosed by magnetic fields beyond (1956). Together with the energy dependence of the day-by-day time variations inferred from the neutron monitor stations, it became clear that the variations of the cosmic rays could be a consequence only of time-varying magnetic fields in interplanetary space, implying that space was filled with plasma (ionized gas) strongly influenced by solar activity (1959).

They showed that the occasional abrupt Forbush decrease in the cosmic-ray intensity, discovered by Forbush with ionization chambers some years earlier, extended to energies of 20-30 GeV and could be understood only in terms of broad domains of magnetic field in interplanetary space. These revelations set the intellectual stage for the construction of the theoretical solar wind concept in 1958.

The space age was beginning at about this time, and Meyer collaborated with Simpson in studies of the outer Van Allen radiation belt. The outer belt is fed by fast particles from the Sun and by the decay of neutrons produced by the cosmic-ray proton bombardment of the terrestrial atmosphere. The distribution of the trapped particles is continually modified by diffusive losses and by azimuthal drift of the particles in the active geomagnetic field. The structure and behavior of the outer radiation belt was a challenge to experimentalists and theoreticians alike. The studies carried out by Simpson and Meyer (1961) showed that electrons were sometimes accelerated in place, and, during times of large variations in the outer magnetosphere, the particles were carried with the displaced magnetic field.

While this work was going on, Meyer was thinking about the still undetected electron component of the cosmic rays, estimated to make up perhaps one in a hundred of the cosmic-ray particles at any given particle energy. The detection of these rare relativistic electrons among the numerous protons was quite a challenge to the ingenuity of the experimentalist for two reasons. First, an occasional proton produces a signal in the detector that mimics the signature of an electron, and second, it must be ascertained that a detected electron comes from somewhere out in space and is not produced as a secondary particle in the upper atmosphere. Thus, a sophisticated detector system is required and must be flown at high altitude on stratospheric balloons.

The successful electron detection was reported by two teams just a couple of weeks apart. First, James Earl of the University of Minnesota succeeded by visualizing the characteristic showers generated by electrons in a multiplate cloud chamber flown on balloons. Peter Meyer with his graduate student Rochus Vogt developed a purely electronic detector system. The range of the electron shower, and hence the electron energy, was measured in a sandwich of alternating layers of lead and plastic scintillators; backward-moving particles, or interacting protons that could simulate shower signals, were excluded by analyzing the signals in two NaI scintillators above and below the sandwich. The contribution of secondary electrons generated in the atmosphere could be determined as the instrument ascended toward the top of the atmosphere. One would expect that the intensity of downward-moving secondary electrons would decline in proportion to the declining air mass overhead. However, the measured electron intensity reached a constant value before the balloon approached its maximum altitude, with only 3-5 g/cm^2 of air left overhead. This clearly indicated a flux of cosmic-ray electrons arriving from space.

Meyer and Vogt measured 4 × 10^{-3} incoming electrons/ cm^2sec sr in the energy range 100-1000 MeV (1961), to be compared with about 300 × 10^{-3} protons/cm^2 sec sr in the same energy range. So there was indeed an electron component of the cosmic rays, of the same general magnitude as estimated from the observed nonthermal synchrotron radio emission from the Galaxy.

Meyer and Vogt were able to show how the electrons varied through a Forbush decrease (1961), receiving the same modulation as the cosmic-ray protons, thereby showing that the electrons originated outside the Solar System. They were soon able to identify the temporary increases of energetic electrons produced by solar flares (1962).

The next step after the measurements of the cosmic-ray electrons was the question of the cosmic-ray positrons (the anti-electrons) among the cosmic rays. Cosmic-ray electrons and positrons must be produced throughout the Galaxy in about equal numbers by the occasional collision of high-energy protons with the nuclei of atoms in interstellar space. In fact, for positrons this secondary process must be the predominant production mechanism, while electrons might also be accelerated from a sample of "ordinary matter," just like the protons and other nuclei. Thus it would be interesting to measure the abundance of positrons relative to electrons. Again the experimental difficulties are that the positron intensity is much smaller than the protons, and positrons are produced in great numbers by the proton collisions with the nuclei of the atmosphere and collisions with the instrument itself. After the electron studies were well in hand Roger Hildebrand related how Meyer asked him one day what he thought it might take to distinguish the positrons. Hildebrand replied that it would require a whole physics laboratory to go up with a balloon to the top of the atmosphere. Meyer smiled and said, “Why don’t we give it a try?”

Positrons differ from electrons in their opposite electric charge, of course, so the electron-positron separation could be accomplished with a suitable magnetic field. Meyer and Hildebrand developed a sophisticated instrument much along the lines of the electron detector but with a strong magnetic field between the poles of a permanent magnet, through which the particles had to pass if they were to be recorded. The electrons were deflected one way by the magnetic field and the positrons the other. They used spark chambers instead of NaI scintillators, and the system was again enclosed in guard counters so as to be sensitive only to particles from above. The Meyer-Hildebrand collaboration led to a clean separation and measurement of the positrons and electrons as a function of energy (1965). Very roughly, they found that there were far fewer positrons ($\sim 10^{-1}$) than electrons over the energy range 40-3000 MeV. As the positrons are produced by collisions of cosmic-ray protons with the nuclei of the ambient interstellar gas, their relative number provides a measure of the amount of matter through which the cosmic-ray protons have passed while being accelerated in their sources and subsequently in their passage through interstellar space before arriving at the Solar System. The surplus of electrons over positrons shows that there must be cosmic accelerators that produce the electrons directly, perhaps together with the protons and nuclei that constitute the majority of the cosmic rays.

The next few years were devoted to improving the systems detecting the electrons and positrons, with an eye to obtaining the combined energy spectrum of electrons and positrons up to several hundred GeV. Gas Cerenkov counters and time-of-flight measurement techniques were introduced to reject background protons and were combined with massive shower counters to analyze the electron cascade in detail. The instruments were calibrated at laboratory accelerators (e.g., at the Stanford Linear Accelerator Center) (1968, 1972, 1973, 1974, 1976).

Meyer advanced the particle detection technology to do a number of other measurements. One interesting episode was the detection of the electrons from the Jupiter electron beacon. Simpson et al. and Teegarten et al. had found, from particle detectors carried on spacecraft out to the general vicinity of Jupiter, that Jupiter emits a powerful burst of relativistic electrons once each 10-hour rotation period. These electrons can be detected at distances up to 1 AU or more and can be identified by their precise period of recurrence. Jupiter orbits the Sun at a distance of 5 AU, and the electrons dash from Jupiter along the spiral magnetic field in interplanetary space. Working with Jacques L'Heureux and using the electron detector on the OGO-5 spacecraft, they found that when Earth was passing through the spiral magnetic lines of force connecting out to Jupiter, Earth was bathed in the electrons from the Jupiter beacon, no longer clearly pulsing but occurring only when the field connects Earth to Jupiter.

At the same time Meyer and Dietrich Müller became interested in the composition of cosmic-ray nuclei at high energies. With graduate student E. Juliusson they designed a new detector system to measure the abundances of heavy nuclei at energies above 10 GeV/nucleon (1972, 1974, 1975, 1978). The essential point is that cosmic rays presumably consist of ordinary matter in an ionized state when the matter is caught up in the acceleration process and the individual particles are hurled away at nearly the speed of light. Thus, determining the precise relative abundances of the different elements among the cosmic rays tells us something about where the cosmic rays were accelerated. As had already been observed at lower energy, they found the relative abundances of the nuclei to be more or less along the lines of the standard cosmic abundances determined from meteorites, etc, except for such nuclei as Li, Be, and B. These nuclei are rare in the general cosmos because they are burned up quickly in stellar interiors.

Most of the matter in the Galaxy (including ourselves) has been processed through one or more massive stars, as indicated by the general presence of the heavier nuclei C, N, O et al. synthesized in the late stages of evolution of the individual massive star. Thus when the matter is dispersed by the supernova explosion at the end of the short life of the massive star, the matter is sent on its way with C, N, O, etc., but very little if any ^{2}H, ^{3}He, Li, Be, and B. On the other hand it was found that cosmic rays contain substantial amounts of these otherwise rare nuclei. The explanation is that these nuclei are spallation products (i.e., chunks of heavier nuclei C, N, etc., among the cosmic rays knocked off by a collision with the nucleus of an atom or ion of the interstellar gas). On this basis one could determine that the cosmic rays have passed through about 7 gm/cm^2 of interstellar matter. The discovery by Meyer and colleagues was that the Li, Be, and B became less abundant with increasing energy above about 10 GeV/nucleon. This indicates a shorter path length and consequently shorter life in the Galaxy with increasing energy of the heavy cosmic-ray nuclei. It shows that the cosmic rays are not gradually accelerated by reflections from the magnetic fields of moving interstellar gas clouds. The gradual acceleration was originally suggested by Fermi as a possible origin of the cosmic rays. The gradual acceleration predicts that the particle energy increases with the time spent in the Galaxy. Instead the measurements require that the cosmic rays be accelerated to their final energies in some initial short-lived event (e.g., a supernova explosion or supernova remnant). The more energetic cosmic-ray particles seem to be able to escape sooner from the magnetic fields of the Galaxy, so they generate fewer spallation nuclei.

Meyer and Juliusson subsequently extended the measurements beyond Fe, covering atomic numbers up to 36, the very heavy nuclei (1975). They found the relative abundances among the very heavy cosmic-ray nuclei to parallel the normal cosmic abundances, further supporting the idea that the cosmic rays originated from ordinary cosmic matter that just happened to be hit by an exploding supernova or other catastrophe.

One of the more exciting results in the next few years was the direct observation of the particles accelerated by shocks in interplanetary space created by an outburst associated with a solar flare. (We would recognize the shock today as the result of a coronal mass ejection at about the same time as the flare.) A flare often produces a burst of fast particles, sometimes called solar cosmic rays, although their numbers diminish more rapidly with increasing energy than the true galactic cosmic-ray particles, and the relative abundances of the nuclei show a strong enhancement of elements with low first ionization potential. Meyer, assisted by Paul Evenson and S. Yanagita, found a population of nuclei accelerated in interplanetary space within the shock wave from an explosive event on the Sun (1982). A little later accelerated electrons were found as well (1985). The measurements demonstrated again the remarkable efficiency of nature to accelerate nuclei to high energy. Nothing more than the common shock front is needed. Indeed it is now believed that the shock front is probably the universal particle acceleration mechanism, because little else shows promise for converting so large a fraction of the bulk kinetic energy into fast particles.

Another result was the detection of the energetic protons produced by the decay of neutrons created by flares on the Sun. The vigorous acceleration of nuclei (mostly protons) to high energy in flares bombards the Sun and provides many nuclear reactions in the solar atmosphere below the flare, emitting gamma rays and neutrons, etc. The gamma rays can be observed directly, of course. The neutrons, equally free to escape from the magnetic fields of the flare, do not get as far as Earth (8 light minutes from the Sun) because their speeds are only about a tenth of the speed of light and they enjoy only a 15-minute half-life. They decay into protons of the same kinetic energy, which then channel along the spiral interplanetary magnetic field and can be detected whenever a suitable particle detector meets that spiral. Detection at Earth requires only that the neutron have a direct spiral line of communication to Earth at the time it decays, perhaps having come from a flare on the back side of the Sun (1983, 1984, 1990).

Inasmuch as cosmic rays are observed to extend up to energies above 10^{20} eV/nucleon (from unknown sources) it was clearly desirable to extend the work on the relative abundances of the cosmic-ray nuclei to above the 100 GeV/nucleon region achieved in the work already cited. However that extension required new technology. The number of cosmic-ray particles in a given energy interval declines with increasing particle energy E approximately as E^{-n} with n lying somewhere in the interval 2.7 to about 3, depending upon E. It is obvious then that to go to higher energies means far fewer particles among the general background of cosmic rays. That is to say, the background "noise" becomes deafening. Meyer with Müller and others came up with the idea of looking for very energetic nuclei using the transition radiation produced as the nuclei pass from air into a transparent solid and from the solid into air. The transition radiation is very weak but increases rapidly as the speed of the particle approaches the speed of light. Thus an instrument detecting the passage of energetic nuclei by their transition radiation fades out for particles below about 100 GeV/nucleon (traveling at a speed of 0.99995c, where c is the speed of light). That is to say, a transition radiation detector would be deaf to most of the background noise, but it would begin to respond to nuclei of 100 GeV/nucleon or more. Even so, the instrument would have to be large, to intercept enough of the very-high-energy particles and then to pass the particles through enough air-plastic interfaces to get a detectable signal.

The result was the “Chicago Egg,” which was flown on Spacelab 2 on the space shuttle. Designed and built by Meyer and Müller, the Egg was 9 feet in diameter and 12 feet high. The instrument was enclosed in a welded aluminum tank: the shell of the egg. Inside the shell the instrument consisted of scintillation counters, to define and delimit the paths of the cosmic rays that it recorded. The heart of the instrument was the large volume of commercial polyolefin fiber forming the transition radiation generator. The essential aspect of the generator was that the individual high-energy cosmic-ray particle should pass through many air-plastic interfaces, producing transition radiation at each interface, and that the transition radiation not be absorbed by the plastic fibers. The transition radiation was soft X rays and was detected in xenon-filled proportional chambers interspersed between layers of fiber material. The whole thing weighed 2.5 tons and cost about $10 million. The size was limited by the cargo bay of the shuttle, and the Chicago Egg flew on the *Challenger* in 1985 for several days’ exposure to the cosmic rays. During that time it acquired the most detailed data ever obtained on the composition of cosmic rays at extreme energies (1988, 1991).

Briefly, the Chicago Egg recorded the atomic number and energy of nuclei above 150 GeV/nucleon based on their transition radiation. The measurements faded out at high energies of several thousand GeV because of the declining number of cosmic rays at increasing energies. Nuclei in the lower energy range 40-400 GeV/nucleon were detected and sized with gas Cerenkov counters. The results of this investigation showed that the relative abundances of the secondary nuclei (e.g., the abundance ratio B/C) continually decreases up to very high energies. This can be understood with the assumption of an energy spectrum $E^{-2.1}$ produced in the unknown cosmic-ray source, as is predicted for shock acceleration processes, followed by more rapid escape from the Galaxy with increasing E. As was already known at lower energies, the data indicate the enhanced abundance of nuclei with low first ionization potential, much as one finds for energetic nuclei from solar flares, etc. Detailed comparisons with the relative abundances of cosmic-ray nuclei at lower energies begins to give a picture of the conditions under which cosmic rays are created in their various sources.

There are numerous other investigations that Meyer accomplished along with the major achievements summarized here. In addition to the ambitious scientific program that marked his career he took on many responsibilities at the University of Chicago and in national and international scientific organizations. For instance, he was chair of the Cosmic Ray Physics Division of the American Physical Society, 1972-73. He was a member of the Space Science Board of the National Academy of Sciences, 1975-78 and served as chair of the Committee on Astronomy and Astrophysics of the Space Science Board, 1975-77. He served as director of the Enrico Fermi Institute at the University of Chicago, 1978-82. He was then chair of the Department of Physics, 1986-89. These responsibilities all involve considerable time and energy, but he handled them in some of his scientifically most productive years. His commitment to undergraduate teaching was recognized in 1971 by the Llewellyn John and Harriet Manchester Quantrell Award for Excellence in Undergraduate Teaching.

Meyer's scientific productivity was also recognized in the land of his birth, where he became a foreign member of Germany's Max Planck Society and the Max Planck Institute for Physics and Astrophysics in München in 1973. In 1984 he was a recipient of the Alexander Von Humboldt Award for Senior United States Scientists.

He was elected a member of the National Academy of Sciences in 1989 in recognition of his many fundamental contributions to present understanding of the fast particles (cosmic rays) that come from everywhere, near and far, in the active universe. He leaves behind a scientific legacy and the fond memories of his many colleagues. He is survived by his second wife, the renowned microbiologist Patricia Spear, who is chair of microbiology-microimmunology at the Northwestern University Medical School; by his two sons, Stephan Meyer, professor of astronomy and astrophysics at the University of Chicago, and Andreas Meyer of Portsmouth, New Hampshire; and by two grandchildren, Samantha Meyer and Niels Meyer of Chicago.

THE AUTHOR RECEIVED important comments and suggestions in the construction of this biographical memoir from Rochus Vogt, Dietrich Müller, and Patricia Spear.

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