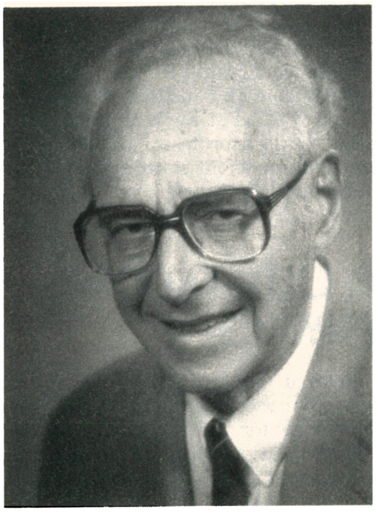
# WOLF PRIZES RECOGNIZE WORK ON NUCLEAR AND PARTICLE PHYSICS AND NMR

Maurice Goldhaber of Brookhaven National Laboratory and Valentine L. Telegdi of the Swiss Federal Institute of Technology (ETH) in Zurich have been named corecipients of the 1991 Wolf Prize in Physics. Richard R. Ernst, also of ETH, and Alexander Pines of the University of California, Berkeley, shared the Wolf Prize in Chemistry.

The four scientists, along with the prizewinners in medicine, the arts and agriculture, received their certificates and prize money at a ceremony held on 5 May in the chamber of the Israeli Parliament. President Chaim Herzog of Israel presented the winners in each discipline with $100 000, to be divided equally between corecipients.

The Wolf Foundation, the Israel-based organization that confers the Wolf Prizes, cited Goldhaber and Telegdi for "their separate seminal contributions to nuclear and particle physics, particularly those concerning the weak interactions involving leptons." Goldhaber's and Telegdi's independent experiments supplied evidence that was crucial to the eventual unraveling of the universal structure of the weak interactions. Ernst and Pines were recognized for their "revolutionary contributions" to nuclear magnetic resonance spectroscopy—Ernst for Fourier-transform and two-dimensional nmr, and Pines for multiple-quantum and high-spin nmr.

Maurice Goldhaber

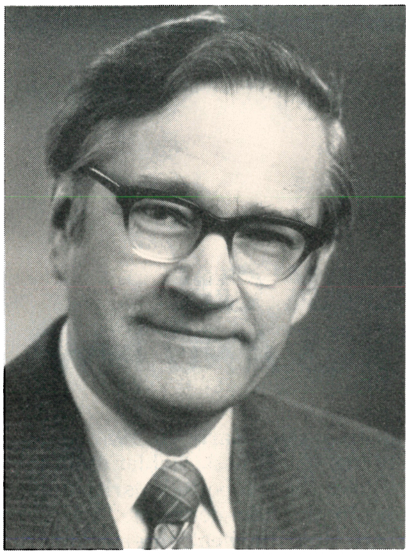


Early in his career Goldhaber, with James Chadwick, investigated the photodisintegration of the deuteron and the disintegration of light nuclei ($^{6}$Li, $^{10}$B and $^{14}$N) by slow neutrons. In 1948 he and Edward Teller gave the first explanation of one of the collective motions of nuclei—the large electric dipole resonance. Three years later Goldhaber and Andrew Sunyar classified nuclear isomers by gamma multiplicity and elucidated their structure using the shell model of the nucleus. In a 1958 experiment with Lee Grodzins and Sunyar, Goldhaber measured the helicity of the electron neutrino by relating the helicity of the neutrino emitted in forming the excited state of $^{152}$Sm to that of the photon emitted in its subsequent decay. This measurement demonstrated unequivocally the "handedness" of the weak interactions in nuclei. Goldhaber has long been interested in testing the conservation laws, in particular the stability of the proton. For the last decade he has been a member of the Irvine–Michigan–Brookhaven collaboration, which has set a lower limit of $5.5\times10^{32}$ years on the mean lifetime of the proton with respect to its decay into $e^{+}\pi^{0}$.

Goldhaber received his PhD in physics from the University of Cambridge in 1936. In 1938 he joined the physics faculty at the University of Illinois, Urbana–Champaign. In 1950 he moved to Brookhaven. He was director of the lab from 1961 to 1973, and is now Associated Universities Inc Distinguished Scientist Emeritus there. AUI operates Brookhaven National Laboratory for the Department of Energy.

Telegdi began his career studying the photoexcitation and photodisintegration of light nuclei, but muon physics soon became the main focus of his research. Early in 1957 Chien-Shiung Wu, Ernest Ambler and their collaborators reported parity violation in the beta decay of $^{60}$Co. Evidence that the weak interactions responsible for the decay sequence $\pi$-$\mu$-e violate parity was found by Telegdi and Jerome I. Friedman, essentially simultaneously with Richard L. Garwin, Leon M. Lederman and Marcel Weinrich at Columbia University. Also in 1957, collaborating with physicists at Argonne National Laboratory, Telegdi initiated a series of experiments on the beta decay of polarized neutrons that largely established the V − A form of that interaction. This result, coupled with his extensive work on muon capture by nuclei, enabled Telegdi to show that the interactions underlying the reaction $\mu^{-} + p \rightarrow n + \nu_{\mu}$ have the same form as those describing $e^{-} + p \rightarrow n + \nu_{e}$. For two decades Telegdi focused his research on the muon, studying its weak and electromagnetic properties. With Garwin and a group of young CERN physicists, Telegdi performed the first precise measurement of the gyromagnetic ratio $g$ of the muon, which gave the best evidence yet

Valentine L. Telegdi



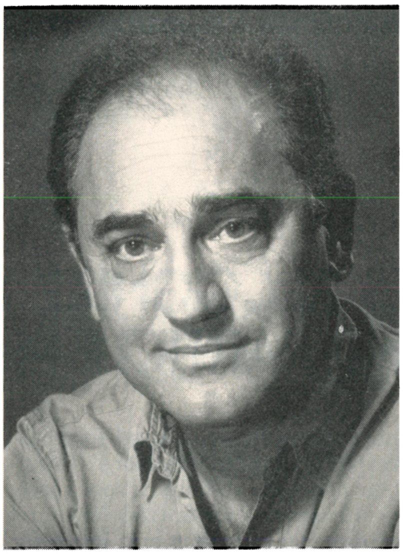
Richard R. Ernst

obtained that the muon is a heavy electron.

Telegdi also produced a precise value of the fine-structure constant by measuring the hyperfine structure of "muonium" (the bound muon–electron system). Through a series of experiments on neutral kaons, he clarified many aspects of the $K_S$-$K_L$ complex. In a 1981 experiment analogous to Goldhaber's electron-neutrino experiment, Telegdi, with Laszlo Grenacs and others, measured the helicity of the $\nu_\mu$. Telegdi also established an upper limit on the magnitude of the hypothetical "second class" currents in beta decay.

Telegdi received his PhD in physics from ETH in 1950. From 1951 to 1976 he was on the physics faculty at the University of Chicago; for the last four years of that period he held the title of Enrico Fermi Distinguished Service Professor. After leaving Chicago, Telegdi became a physics professor at ETH. In 1980 he accepted an additional appointment as a visiting professor at Caltech. He retired from ETH in 1989.

Ernst dramatically increased the usefulness of nmr in 1965, when he developed, with Weston A. Anderson, the technique of Fourier-transform nmr spectroscopy. Ernst and Anderson suggested that rather than wasting time sweeping through the entire spectrum of frequencies, most of which produced no signal, one could apply a single magnetic pulse to a sample and subject the resulting data to a Fourier transform to convert them from the time domain into the frequency domain. This technique made possible nmr studies of biomolecules and low-sensitivity nuclei in liquid solutions. In the 1970s, following up on a suggestion by Jean Jeener,



Alexander Pines

Ernst and his research group developed two-dimensional Fourier spectroscopy, which opened up new possibilities in molecular biology, chemistry and materials science. Kurt Wüthrich and others have applied this technique to create three-dimensional models of biomolecules in solution. Two- and three-dimensional nmr are now standard techniques for structural studies of biological macromolecules. Also in the 1970s, Ernst introduced nmr Fourier tomography, an imaging technique that became the basis for much of the magnetic resonance imaging used for medical applications.

Ernst received his PhD in physical chemistry from ETH in 1962. He worked at Varian Associates in Palo Alto, California, until 1968, when he returned to ETH as a member of the faculty. He has been a professor of physical chemistry there since 1972.

Pines, while still a graduate student at MIT with John Waugh, helped introduce high-resolution nmr of dilute spins in solids using Hartmann–Hahn cross-polarization and spin decoupling. By most accounts, the spectra of adamantane and benzene Pines and Waugh produced marked the beginning of high-resolution solid-state nmr of carbon-13 in chemistry. Today the technology they developed is widely used in commercial instrumentation for the study of spin-$\frac{1}{2}$ systems, including carbon-13, nitrogen-15, silicon-29 and phosphorus-31. In the 1970s Pines devised the theory of, and the experimental means to observe, high-multiple quantum transitions in liquid crystals and solids. According to the Wolf Foundation, this work "has led to a truly coherent picture of nuclear spin dynamics, and has opened up new exciting possibilities for studying the structures of molecules and molecular clusters in solids." In multiple-quantum nmr, the molecules in the sample coherently absorb the rf pulses in groups of up to a hundred quanta, rather than one quantum at a time. In developing the technique, Pines and his students demonstrated the selective excitation of $n$-quantum transitions, creating coherent superpositions of "$n$ spins up and $n$ spins down."

In the last few years Pines has worked on topics including iterative maps, topology and geometric phase, zero-field nmr, time reversal of spin interactions, molecular dynamics in constrained geometries, magnetic-isotope effects, optical pumping, quantum tunneling and the development of superconducting detectors. Most recently, Pines and his coworkers came up with a technique that aims to erase not only inhomogeneities in nmr due to nuclear magnetic dipole moments and anisotropic chemical shifts, but also those due to quadrupole moments. Double-rotation and dynamic-angle spinning (based on icosahedral symmetry) have made possible the use of high-resolution solid-state nmr on nonspherical nuclei, including the important isotopes oxygen-17 and aluminum-27, thereby extending the application of nmr to a wide class of materials including catalysts, minerals, semiconductors, superconductors and polymers.

Pines earned his PhD in chemical physics from MIT in 1972. Since then he has worked at Berkeley, where he is currently a professor of chemistry and a senior scientist at the Lawrence Berkeley Laboratory.

# APS AWARDS HONOR OUTSTANDING CONTRIBUTIONS TO PHYSICS

At its April meeting held in Washington, DC, The American Physical Society presented awards to several individuals in recognition of their contributions to physics research, physics and society, and other areas.

Peter J. Twin of the University of Liverpool received the Tom W. Bonner Prize for, in the words of the award citation, "the discovery and characterization of superdeformed nuclear states at very high spin. His