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HERMAN FESHBACH
1917—2000

A Biographical Memoir by
EARLE LOMON

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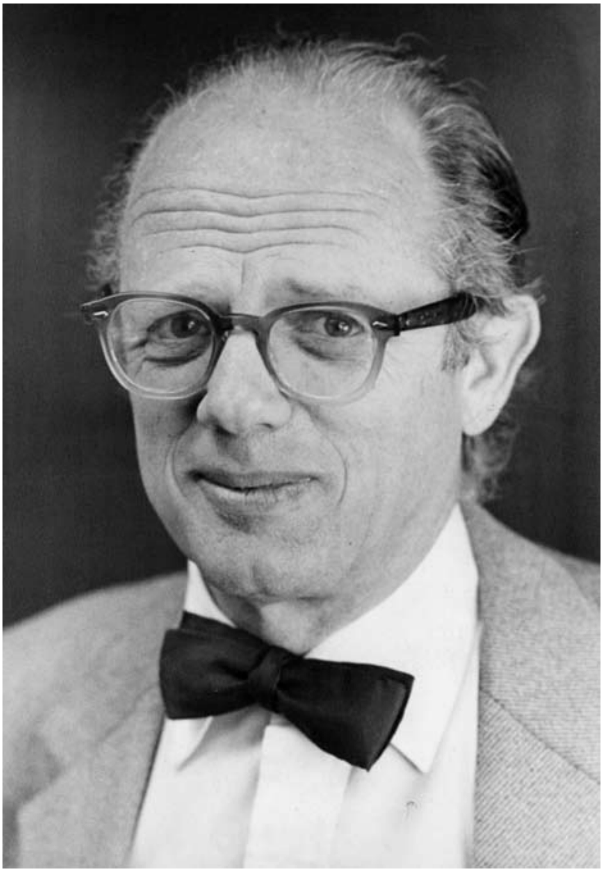
Biographical Memoir



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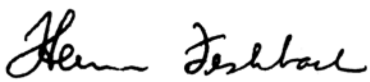

HERMAN FESHBACH

February 2, 1917–December 20, 2000

BY EARLE LOMON

HERMAN FESHBACH WAS BORN IN NEW YORK CITY. His parents were immigrants from Russia, and he had one sister and two brothers. As a teenager he was adept at athletics and in his father's business, but he transferred his interest to academics. He married Sylvia Harris in 1939 and they parented a daughter and two sons.

Herman was awarded an S.B. in 1937 by City College, New York, and a Ph.D. from the Massachusetts Institute of Technology in 1942. He remained at MIT as an instructor until 1947 when he became a lifelong faculty member. Apart from extensive travels for meetings and lectures Herman indulged in only one sabbatical that took him and his family away from home, to CERN in 1962-1963. The only other sabbatical, in the mid-1950s, was spent at Harvard University, which was closer to his Cambridge home than MIT.

Until his death he had an outstanding career, both as a theoretical nuclear physics researcher and as a teacher. Herman held important administrative positions at MIT, served on national and international physics committees, actively supported civil and human rights, and was devoted to his wife and children. He was a warm and gentle person but often fierce in his devotion to science and humane causes.

His interest in physics matured alongside that of his lifelong friend Julian Schwinger. They attended City College together and later, when on the MIT and Harvard faculties, respectively, collaborated on a numerical investigation of the strong and electromagnetic properties of the deuteron, using phenomenological potentials (1951,1).

Some of his early publications were about acoustic and electromagnetic scattering, but his 1942 Ph.D. thesis (under the supervision of Philip Morse) related the properties of tritium to nuclear forces, research that he extended later (1949; 1951,2). He published (with Laszlo Tisza) a paper on electroproduction of pion pairs in 1945.

In the years 1946-1954 Herman in collaboration with Victor Weisskopf and others developed the theory of neutron elastic and inelastic scattering from nuclei, averaging over the excitations of the compound nuclear levels (1947, 1953,1). This culminated in the Cloudy Crystal Ball model of nuclei, authored with Weisskopf and C. E. Porter (1954). This model relates the neutron resonance widths to the compound level spacing and reproduces the neutron total cross-sections and angular distributions over several MeV. The model's characterization of the nucleus as a complex "optical" potential combines the independent nucleon aspect embodied in the shell model with the excitation of dense compound nuclear levels, postulated by Niels Bohr, to explain many aspects of nuclear reactions. This was the first of Herman's series of seminal contributions to nuclear reaction theory.

Herman's subsequent development of a general nuclear reaction theory (1958; 1962; 1964,1) based on the projection of the nuclear state into direct and compound channels (1964,2) quantitatively connected the statistical aspects of the compound nucleus excitations to the reactions in which an incoming projectile directly knocks out a cluster from the nucleus and may excite a single-particle or collective state of the residual nucleus. This is accomplished by a partitioning formalism based on the definition of two complementary projectors P and Q. The subspaces, onto which P and Q project, are sets of states obeying the continuum and the bound-state boundary conditions respectively, interpreted as the projectors on the background and the resonant subspaces.

This resulted in such intuitive and important concepts as doorway states and multistep reactions (1967). These methods are the backbone of complex nuclear reaction calculations today. Another specific application of this theory is the multichannel Feshbach Resonance (and related shape resonance). Feshbach resonances have become a crucial tool in the study of atomic quantum gases (Bose-Einstein condensates and ultracold Fermi gases). A pair of atoms (at very low temperatures) coupled to a molecular state is the analog of nucleon-nuclear coupling to states of the combined nucleus. The Feshbach Resonance occurs when the energy of a bound state of an interatomic potential is equal to the kinetic energy of a colliding pair of atoms, which is essentially zero at ultracold temperatures. By tuning across the Feshbach Resonance with an external magnetic field, Bose-Einstein condensates (BEC) with adjustable repulsive and attractive interactions could be studied, and for fermions the BCS-BEC crossover was realized.

The compound nucleus channels require a statistical description of the level distribution, a subject to which Herman gave much attention. With Arthur Kerman and Steven Koonin he developed from 1977 to 1980 a statistical treatment of multistep compound and direct reactions (1980). In the years just preceding his death this research was extended with Alfredo Molinari and others to the properties of nuclear matter by developing a statistical theory of the mean field (1998).

Herman, with Kerman in 1966, noted that recoilless (K^-, π^-) reactions would efficiently produce heavy hypernuclei. As a result of this finding Harry Palevsky and Robert Chrien initiated experimental programs.

Eugene Wigner's R-matrix theory is frequently used to express the effect of the degrees of freedom appropriate within the nuclear radius on the longer range wave function. Herman realized that this separation into two regions connected by a boundary condition was relevant to the interactions of hadrons. He successfully interpreted, with the author, the interactions between nucleons up to intermediate energies in this way (1964,3; 1968). Because of the simple properties of quantum chromodynamics at short distances, the R-matrix method can incorporate the quark and gluon degrees of freedom in hadron reactions.

Herman, together with Francesco Iachello, initiated another, very different approach to nuclear structure and reactions in the Interacting Boson model in which the large number of single fermion degrees of freedom are approximated by a few bosonic degrees of freedom (1973). Since the formulation of this approach, there have been extensions to nuclei with an odd atomic number and the powerful use of dynamic symmetries. Herman expected the model to be more limited in scope; he watched its later successes bemusedly from the sidelines.

The role of symmetries in nuclei always intrigued Herman. Beyond the many well-known applications of rotational and isotopic symmetry, Herman considered the effect of SU(3) symmetry in hypernuclei (1986). In particular, he showed with Carl Dover that the symmetry could lead to observable widths of Σ hyper-nuclei despite the expected rapid transition to a Λ hyper-nucleus (1987). In the last year of his life he applied his reaction theory, together with Mahir Hussein, and Kerman, to understanding the large parity violations seen in thermal neutron reactions in heavy nuclei as being due to the coherent effects of the doorway states, and predicting

Feshbach (on left) with (from left to right) Igal Talmi, Francesco Iachello, and Akito Arima in Erice, Sicily in 1978. *Photo courtesy of F. Iachello.*

the effects of time-reversal symmetry breaking (1995).

Francesco Iachello contributed the picture included above. It has an historic value as it represents four of the persons who have contributed most to nuclear physics in the second part of the 20th century.

Herman's great service to physics was not limited to research. Many of his students are well known and respected in the field. I can attest to the care, consideration, and friendship he extended to his graduate students. He gave them ideas and technical help while allowing them to develop their own approach to the research. Francesco Iachello, whose thesis for Herman led to an important career in theoretical physics, expresses the views of many of his students.

To his students, especially to me, he was the "father" figure. He contributed tremendously to the development of my scientific career. I remember working out all the problems in Morse and Feshbach (I was his teaching assistant for Methods of Mathematical Physics) and learning a lot from those. He was also interested in music, especially opera, and we went several times to the opera together He was also interested in good food and wine. One time, while at a conference in Aix-en-Provence, we drove 50 miles to a three star restaurant in Les-Baux-de Provence to eat bouillabaisse.

Herman's leadership in the MIT physics department (as director of the Center for Theoretical Physics [1967-1973] and head of the Department of Physics [1973-1983]) extended to national and international physics. In the 1960s he, Allan Bromley, and Heinz Barschall organized the American Physical Society's division of nuclear physics, which he chaired from 1970 to 1971. In 1969 Herman was elected to membership in the National Academy of Sciences. He was a consultant to the White House Office of Science Policy in the early 1970s. He was an initiator of the Nuclear Science Advisory Committee to the U.S. Department of Energy and the National Science Foundation and its first chair (1979-1982). He was president of the American Physical Society in 1980-1981 and president of the American Academy of Arts and Sciences from 1982 to 1986.

In the 1990s Herman was persuaded by Bromley to chair the nuclear physics commission of the International Union of Pure and Applied Physics. As chair he organized an international meeting on nuclear physics in Amsterdam with the goal of improving international cooperation for nuclear facilities. It was a politically difficult meeting; Bromley, who was the keynote speaker, remembers that Herman, with his usual diplomacy and flair (including a display of temper that only his close friends recognized to be totally simulated), brought the meeting to a peaceful and constructive close. Herman also served on the boards of governors of the Weizmann Institute of Science (1978-1995) and Tel Aviv University (1987-1990).

Herman's publications affected physics. Generations of physicists and engineers fueled their mathematical toolkits from Morse and Feshbach's *Methods of Theoretical Physics* (1953,2). In two large volumes it is extremely detailed, and a joking remark attributed to Julian Schwinger asserts that it is "an atlas of theoretical physics on a scale of one to one." In his last years he put much of his energy into modernizing these volumes, including adding a chapter on group theory and its applications. Unfortunately, he did not complete this task before his death. His book with Amos de Shalit, *Theoretical Nuclear Physics* (1974), is one of the classics in the field; Following de Shalit's early death, Herman wrote the sequel, *Theoretical Nuclear Physics: Nuclear Reactions* (1992), which is of similar importance. Herman's impact on the physics literature went beyond his own writings. In 1957 he and Morse, in reaction to the splitting of *Physical Review* into subfields and the publication's constraints on lengthy articles, founded *Annals of Physics* to publish a range and depth of material. Herman succeeded Morse as chief editor.

Passionate about human welfare and rights and about the folly of war, Herman put his energy and talents into rectifying wrongs. His strong feelings about these issues are indicated by Leo Sartori's account of Werner Heisenberg's first visit to MIT after the war: "Viki [Weisskopf] introduced him; he apparently bore no animus toward Heisenberg for his work on the German nuclear program. But Herman pointedly did not attend. When asked about it, he replied, 'I do not want to shake the hand that shook the hand of Hitler.'"

Herman played a critical role in the founding of the Union of Concerned Scientists, served as its first chair, and continued to support it, especially on nuclear arms control. He pursued similar goals as chair of the American Physical Society panel on public affairs (1976-1978). In 1980, as APS president, he established a human rights committee to intervene in support of oppressed physicists in the Soviet bloc, Argentina, and Chile and made major personal efforts on behalf of the dissidents and *refuseniks.* Of special interest was his fight for the freedom of Andrei Sakharov. On another front, he was instrumental in improving the position of women and minorities in physics and academia.

Herman's energetic leadership style in the above activities, as well as in his MIT administrative roles, is well described by the following remarks of Kurt Gottfried:

I had a lot of interactions with Herman during the time he was APS president, as well as with other presidents that followed him. Herman was far more decisive than some others, less concerned with being controversial. On several occasions Herman suggested potentially controversial decisions, which I thought he might first vet with the Council, to which he immediately replied, "they can always fire me!" He was also busy on many other fronts, so when I called him one mid-morning I was astonished to learn that he was out playing tennis. When I reached him later that day I asked how he could possibly find time for tennis, and he replied "I give it my highest priority or I would never play."

Another aspect of Herman's leadership style is well described by this episode remembered by his MIT colleague Heather Lechtman.

Years after Herman had retired as Head of the Physics department I asked him how it was that all his colleagues in the department loved him so much as department head. All the physics faculty—men and women, those who fought with him, those who held markedly different opinions from his—they all loved him. I asked him how that happened. Herman did not hesitate in responding. He said, "It's because I never said no to anyone. When colleagues came to see me about plans they wanted to put into action I never said no to them. We talked through their ideas so that it became clear what a yes answer would entail.

Herman's fervor for physics and people endeared him to his colleagues, even if his fierceness on behalf of his causes may have sometimes distressed them. He is sorely missed by the physics community and his many friends.

I am grateful to George Trilling and Paul Martin for giving me this opportunity to chronicle the tremendous accomplishments and humane character of my mentor, friend, and hero Herman Feshbach. Beyond that, they carefully scrutinized my drafts and provided many helpful comments. I apologize to George and Paul for taking so many years to produce this result. In addition, I received much helpful information and comments from Kurt Gottfried. The reminiscences of Herman I received from Kurt, from Leo Sartori, Heather Lechtman, and Francesco Iachello illuminated Herman's humanity beyond my own ability to do so. I thank Herman's sister Florence Nadelman and brother Bernard Feshbach for providing background on his family and early years, and Wolfgang Ketterle for clarifying the importance of the Feshbach Resonance.

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