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EDWIN M. McMILLAN, A BIOGRAPHICAL SKETCH

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ABSTRACT. Edwin M. McMillan was one of the great scientists of the middle years of this century. He made notable contributions to nuclear, and particle physics, the chemistry of transuranic elements, and accelerator physics.

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Edwin McMillan was born on September 18, 1907 at Redondo Beach, California. Soon after, the family moved to Pasadena, California where the father practised medicine for many years. The move to Pasadena was a very fortunate one because Caltech was nearby and even in his early school years Ed could take advantage of the excellent public programs and lectures put on there by them. This contact with the world of science as Ed grew from boyhood to a young man was very important, for it nurtured the wide and lasting curiosity and interest that he had in all things natural: rocks and minerals, chemistry, electricity, physics, and botany.

Ed enrolled at Caltech as a physics student in 1924. He also pursued extensive studies in chemistry, which brought him into contact with Linus Pauling. Pauling, then a Research Fellow, became an important influence in Ed's development as a scientist. Ed's first research was on X-ray studies of Lead-Thallium alloys, published with Pauling in 1927. He received a bachelor of science degree in physics from Caltech in 1928 and was awarded a master of science a year later. He then went to Princeton where he did graduate research on molecular beams under the general direction of Professor E. U. Condon. He received his Ph. D. in 1932 and was awarded a prestigious two-year National Research Council Fellowship.

At the invitation of Ernest Lawrence, he elected to spend his Fellowship years at Berkeley. I digress to say something of the Physics Department at Berkeley during those years. A great effort had been started in the late 1920's by Raymond T. Birge and Leonard Loeb to build up and vitalize the Department, which previously had not been first rate. With the coming of Robert Oppenheimer, Ernest Lawrence, Francis Jenkins, Harvey White, and others it was indeed becoming one of the liveliest centers of physics in the United States. Lawrence, who had invented the cyclotron in 1928, established the Radiation Laboratory in 1931, and was embarked on his career of ever larger accelerators. Ed, however, did not at first go to the Radiation Laboratory. He intended to measure the magnetic moment of the proton, but Otto Stern published his result while Ed was completing his apparatus. He changed his efforts to spectroscopy and published several papers on hyperfine structure in 1933-34. Increasingly his interest was drawn to Nuclear Physics and to the intense activity at the Radiation Laboratory. He joined the Laboratory in 1934 and began a lifelong close association with Lawrence.

He quickly established himself as a meticulous and versatile experimenter in nuclear physics with an excellent grasp of theory. During this period he discovered ^{15}O with Stanley Livingston and ^{10}Be with Samuel Ruben. Perhaps his best experiment at that time was the demonstration of electron pair production by the absorption of gamma rays from fluorine bombarded by protons from the cyclotron. [1] He also took a great interest in the operation and development of the cyclotron and helped to rationalize what was then a largely empirical art. He made improvements in magnetic-field shaping, ion sources, beam extraction, and power and control systems.

At this time he also started his teaching career and was steadily advanced, becoming a full professor in 1946. His teaching was recognized by the University with the citation "His teaching is notable for the clarity and simplicity with which he presented even the most complex scientific facts and theories."

Ed McMillan possessed a broad range of capabilities. He was an excellent experimenter in nuclear physics with a good command of theory, and he also was a very competent chemist. He worked well with large complex equipment and groups of people, but most characteristic of his style was to do an experiment that he could carry out by himself with simple equipment and from which he could draw profound conclusions. His discovery of neptunium is an example of this style.

The discovery of fission early in 1939 by Hahn and Meitner created great excitement and stimulated many experiments at Berkeley as it did at many laboratories. McMillan undertook a very simple experiment, a measurement of the range of fission fragments by their penetration of a stack of foils in contact with a thin layer of uranium exposed to neutrons from a cyclotron target. He then examined the uranium layer and found a known 23-minute activity (^{239}U) and a previously unknown 2.3-day beta activity. He immediately suspected that the new activity was a beta-decay product of ^{239}U and therefore an isotope of element 93. Chemical separation of the new activity from uranium proved very difficult. Emilio Segre who offered to try the separation concluded that the activity was from a rare

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earth fission product. Unsatisfied with this identification because there was no evidence of the new activity in the recoil products, Ed returned to the problem a year later. He found increasing evidence that the new activity could not be from a fission product, but conclusive chemical separation still eluded him. Independently Phillip Abelson had started to work on the chemistry of uranium. Combining their talents, they soon established the chemical identity of element 93, and named it Neptunium. [2] The difficulty had been that a second rare-earth sequence started at that point in the table of elements, and the chemistry was not at all as had been expected. McMillan then sought to make and identify the next element, number 94. He did produce samples of an alpha active substance that he conclusively proved was not protoactinium (91), uranium (92) nor neptunium (93), but he did not have time to make the final chemical identification of element 94 because he left the Radiation Laboratory for the first of several wartime activities. Subsequent work on transuranic elements was carried out by a group headed by Glen Seaborg, and after a delay due to wartime restrictions the 1941 discovery of plutonium was published in 1946 by Seaborg, McMillan, Kennedy and Whal. [3]

Edwin M. McMillan and Glenn T. Seaborg shared the Nobel Prize for Chemistry in 1951 "for their discoveries in the chemistry of the transuranium elements."

McMillan's wartime service began November 1940 with work on airborne microwave radar at the newly established Radiation Laboratory at the Massachusetts Institute of Technology. About this time he married Elsie Blumer, the sister of Ernest Lawrence's wife, Molly (Figure 1). A year later he went to the Navy Radio and Sound Laboratory in San Diego where he worked on the development of sonar devices. In November 1942 the uranium bomb project had advanced to the point that a weapons laboratory was needed to develop and build the device and Robert Oppenheimer was chosen to head the laboratory. Oppenheimer's first recruit was Ed McMillan, whose first job was to help find the site, Los Alamos, and to help organize that laboratory. At Los Alamos, Ed had major responsibilities for development of the gun assembly method used in the uranium bomb and for diagnostic tests for the implosion method used in the plutonium bomb.

That Ed's mastery of physics was such that he could work effectively in a wide variety of fields was amply demonstrated by this succession of wartime jobs. His discovery of the Principle of Phase Stability and his return to

Figure 1. Edwin and Elsie McMillan. ca. 1950.

peacetime physics in the immediate postwar years is recounted in the accompanying paper on The Principle of Phase Stability and the Accelerator Program at Berkeley, 1945-1954, and is not repeated here.

Through the exchange of letters and visits Vladimir Veksler and Edwin McMillan came to know each other and became quite good friends. In 1963 they were jointly awarded the Atoms for Peace Award. The citation said, in part: "Working independently in widely separated laboratories, Drs. Veksler and McMillan proposed ... a basis for designing more effective devices to explore the nucleus. From their insights have come ... the synchrotrons, which have introduced us to the finer structure of the nucleus..."

From the day he joined the Radiation Laboratory in 1934, Ed had been a scientific leader. In the 1950's as the Laboratory grew in size and complexity he was asked by Lawrence to also assume increasing administrative responsibilities. In 1958 a colitis that Lawrence had suffered from for years became worse and to lessen his burden he appointed Ed to the position of deputy director. In August 1958 Ernest Lawrence died and Edwin McMillan was appointed by the Regents of the University to be Director of the Laboratory which was renamed The Ernest O. Lawrence Radiation Laboratory (later Lawrence Berkeley Laboratory).

The position of Director at this time was a very difficult one. There was intense competition for the use of the unrivaled accelerators and other resources of the Laboratory. New programs and organizations were introduced into the Laboratory in response to concerns about the environment and the supply of energy. The grasp of bureaucracy on science began to increase. All these things made the job of Director a great burden on a man who was first of all a great scientist and a scholar. However, his wide knowledge, his innate fairness, his approachability and modesty enabled him successfully to lead the Laboratory until the time of his retirement in 1973. He was universally liked, even by persons with whom he had substantial disagreements.

After his retirement McMillan spent a rewarding year, 1974-5 at CERN, participating actively in the running and analysis of the "g-2" experiment to measure the magnetic moment of the muon. His modesty and fine sense of humor enabled him easily to integrate into a group of young physicists. By a detailed analysis of an unexplained loss of muons from their orbits he was able to trace the cause to the tiny grooves made in the magnet pole faces by the milling machine. This was another example of his style, described in connection with his discovery of neptunium. On returning to Berkeley, he wrote several papers and notes on topics in the history of accelerators, and maintained an active interest in physics and the Laboratory. In 1990 he was awarded the National Medal of Science by President Bush.

In 1984 he suffered the first of a series debilitating strokes. He died on September 7, 1991, just eleven days short of 84 years of age.

Edwin McMillan is remembered as a great man by the people who knew him. He had a range of knowledge and curiosity that can only be described by saying that he was a natural scientist. He contributed to many fields of science in addition to physics and chemistry: mathematics, biology and medicine, and astrophysics. His quiet sense of humor and appreciation of the absurd lay just below his serious surface (Figure 2). His demeanor was relaxed, but in matters of principle firm.

Figure 2. Ed. McMillan contemplates "AJAX, combination atom smasher and cigarette lighter" ca. 1970. [4]

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