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GERALD MAURICE CLEMENCE
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A Biographical Memoir by

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GERALD MAURICE CLEMENCE

August 16, 1908–November 22, 1974

BY RAYNOR L. DUNCOMBE

GERALD MAURICE CLEMENCE was born near Greenville, Rhode Island, on August 16, 1908, the first child of Richard R. and Lora E. (Oatley) Clemence. He died in Providence, Rhode Island, on November 22, 1974, after an illness of several months. He was one of a small group of dynamical astronomers in this country before the dawn of the space age, and his scientific career spanned the entire period from the lead pencil era of hand computing to the use of the most powerful electronic calculators. Influenced by the career of Simon Newcomb, whose accomplishments he greatly admired, Clemence brought the U.S. Nautical Almanac Office back to the preeminent position in dynamical astronomy it had enjoyed in the later part of the nineteenth century.

YOUTH AND EDUCATION

As a child Gerald lived on an 80-acre farm in northern Rhode Island with a younger sister and three younger brothers, his mother, and an older friend of hers, who was much like a grandmother to them. The farm was mostly woods, with about 10 acres under cultivation. They kept a cow or two, a horse, and hens, and his chief duties were looking after the barn, mowing the lawn, and shoveling snow. His father ran a dairy farm about 10 miles distant, on

which lived his father's parents and two maiden sisters, and was often absent from his own family for days at a time. According to Gerald's own recollections, he attended elementary school only in the third, fifth, and seventh grades. Beyond this, his education was provided at home by his mother, herself a schoolteacher and a most imposing woman both in stature and character. When Gerald completed the eighth grade at the age of 12, his mother thought him too young to enter high school, so he kept the house for one winter while his mother taught school. It was during this early period that he developed his love for good music and literature. His mother had a phonograph with a hundred of the best records of that time and an assorted library of nearly two thousand books. He taught himself to play the piano and violin, and throughout his life he found relaxation in reading and in performing or listening to music. Among his favorite authors was Ambrose Bierce, because of his incisive style and mode of expression, traits that Gerald himself mastered and used. His first acquaintance with astronomy, according to his own recollections, was through a newspaper column "Planets and Stars," which he began to read at the age of eight. An aunt taught him the constellations and how to identify the planets, but he stated later that most of what he learned of astronomy came from reading books and articles.

It has been said that some people are born great, some achieve greatness, and others have greatness thrust upon them. Gerald was of the middle variety and he well exemplified Abraham Lincoln's early motto: "I shall study and prepare myself, and some day my chance will come." After graduation from high school he entered Brown University. Assuming his chief interest to be mathematics, he majored in that subject with an additional year of graduate study and earned the degree of Ph.B. in 1930. "As a recreation,"

he said later, he took a civil service examination for astronomer and upon passing with a high grade (he was first in a field of 50), he accepted an appointment to the U. S. Naval Observatory in Washington, D.C., "attracted by the seemingly high salary of $2,000 per annum." Gerald brought with him his new bride, Edith Melvina (Vail) Clemence, a Canadian girl he had met while visiting his mother Lora at Rhode Island Hospital in June 1927. At the time Edith was head nurse of Ward F at the hospital. They were married at the Vail homestead in Brockway, New Brunswick, on August 17, 1929.

EARLY CAREER AT THE U.S. NAVAL OBSERVATORY

Clemence was assigned at first to the Time Service and later to the Nine-Inch Transit Circle Division under the direction of H. R. Morgan. Morgan was a specialist in star catalogues and fundamental meridian circle observations. Such work is multidisciplinary in the sense that it involves the mechanics of the instrument, the psychology of the observers, the mathematics of practical astronomy, the reduction of vast amounts of observational data, and the gift of intuitive judgment and good sense. Morgan was a superb teacher: patient, meticulous, precise, completely dedicated to his work. And Gerald was an excellent student. After he mastered the fundamentals of such work he decided to take on two ambitious projects concerning the planets Mercury and Mars.

The orbits of the major planets of the Solar System, which had been adopted for international use by most major nations, had been computed in the later part of the nineteenth century. G. W. Hill spent seven years of his life computing the orbits of Jupiter and Saturn. The others were computed under the direction of Simon Newcomb, director of the Nautical Almanac Office (1877-97). By the mid-1930s

there existed nearly half a century of observations of even better quality than those made previously, which had never been used in establishing the basic elements for each planet.

In addition to his required duties in the Nine-Inch Transit Circle Division Gerald decided to undertake the extra work of comparing all of the observations of Mercury with Newcomb's orbit in order to derive more accurate orbital elements and to render more reliable the predictions and other uses of these elements. This effort evolved into a Works Progress Administration project with three technicians working under his supervision over several years and resulted in a vastly improved set of elements that clearly demarked the excess motion of the perihelion predicted by general relativity. These results appeared in the *Astronomical Papers of the American Ephemeris* (1943), the series of publications started by Simon Newcomb to document his research, which Gerald reactivated and continued.

The situation with respect to Mars was even worse. As Gerald recounted later, "While inspecting a 20-year-old graph showing the discrepancies between the observed positions of Mars and the theory of its motion, I was struck by the systematic character of the deviations and in a flash of insight surmised that the theory was at fault." It became obvious to him from the periodic character of the residuals that the Fourier series that represented the motion were either inadequate or actually contained some errors. Gerald decided to derive an entirely new theory, completely independent of any previous work on Mars and following Hansen's method as Hill had used it. The fortitude of such a decision must be judged in the context of the computing facilities at his disposal at the time. They consisted of a lead pencil, large sheets of computing paper, a hand-operated "Millionaire" desk calculator, and considerable manual dexterity. Eventually this project, which took over 12 years, was completed

by means of punched-card machines and then electronic calculators. It proved to be the greatest single accomplishment of Clemence's entire scientific career. The first order theory of Mars was documented in the *Astronomical Papers of the American Ephemeris* (1949).

TRANSFER TO THE NAUTICAL ALMANAC OFFICE

The year 1940 brought some changes that crucially affected the course of Gerald's career. Wallace J. Eckert had just been appointed director of the Nautical Almanac Office, and Dirk Brouwer became the director of the Yale University Observatory. They had been colleagues and collaborators for the previous 10 years at Columbia and Yale, respectively. Eckert's notable forte at that point was the use of punched-card machines for scientific computation, and almost immediately he revolutionized the Nautical Almanac Office and celestial navigation by the automatic production of the new *Air Almanac*. He offered Gerald an appointment in the office only one position below the assistant director, and thus Gerald left the Transit Circle Division (with a wealth of experience that was later to stand him in good stead).

Gerald quickly adapted the punched-card equipment to the problems of the Almanac Office and to his own work on the theory of Mars. In 1942 he was promoted to the position of assistant director, and Paul Herget of the University of Cincinnati joined the staff. The routine work of the Nautical Almanac Office and other war work commanded the highest priorities during these years, and Gerald and Paul cooperated on many projects for the armed forces. They also developed the principle in the construction and use of mathematical tables known as the optimum-interval method (1944). In 1945, at the end of the war, Eckert resigned to become director of IBM's Watson Scientific Computing Laboratory at Columbia University, Herget returned to

Cincinnati as director of the Cincinnati Observatory, and Gerald was promoted to the post of director of the Nautical Almanac Office. This was probably the proudest moment of his life, because he had attained the post once held by Simon Newcomb, whom he greatly admired and respected. He was deeply concerned with the responsibilities of his new position, and his astuteness, good judgment, and administrative skills came to the fore.

THE GOLDEN YEARS FOR CELESTIAL MECHANICS

In 1947 the Office of Naval Research began a sustained period of support for research in celestial mechanics through a contract involving Yale, the Nautical Almanac Office, and the Watson Scientific Computing Laboratory. The Cincinnati Observatory joined in the effort and the congenial and constructive relationships that existed among Clemence, Brouwer, Eckert, and Herget was terminated only by the deaths of Brouwer (in 1966) and then Eckert (in 1971). The preliminary agenda for this research involved (1) a revision of the motions of the principal planets; (2) work on the secular perturbations of Pluto; (3) work on a new mathematical theory of the motions of Saturn and Jupiter; (4) calculations to develop the theory of the motions of the first four minor planets; (5) completion of the development of the theory of the motion of Mars by Hansen's method; and (6) measurement of photographic plates of Saturn's satellites to allow evaluating the mass of the system.

The research output of this coalition was prodigious and in the period between 1949 and 1970 resulted in 22 contributions to the *Papers of the American Ephemeris* and *Nautical Almanac*, as well as many shorter articles in scientific journals. In addition, over 25 Ph.D. dissertations were based on research carried out in this project. Gerald was a prolific contributor, individually and in concert with others. Gerald's

paper on the system of astronomical constants (1948) formed the basis for the later introduction of the idea of ephemeris time at the 1950 Paris conference. He played a primary role in the simultaneous numerical integration of the orbits of the five outer planets (1951) and subsequently produced the tables for the computation of the perturbations of the five outer planets by the four inner ones (1954). He also produced tables for the coordinates of the center of mass of the Sun and the five outer planets (1953). By this time, several comparisons of numerical integrations of the orbit of Mars with his first-order theory had indicated that some second- and higher-order terms were of significance. He amended his theory to account for these omissions and produced the theory of Mars completion in 1961. This magnificent piece of work, the most accurate and the only one of its kind that had been done since the turn of the century, stands as a monument to Gerald's perseverance and genius. A geocentric ephemeris based on his theory for 1950-2000 was published in 1960.

In 1958 another turn in his career occurred when he was appointed to the newly created position of scientific director of the U.S. Naval Observatory. In this post the administration of the scientific programs of the whole observatory became his responsibility. He assumed his new duties with the same foresight, good planning, scientific insight, and administrative ability he had exercised as director of the Nautical Almanac Office. The high regard in which he was held by the national and international scientific communities enhanced the standing of the observatory. As his administrative duties increased the volume of his scientific research diminished, although there was still a steady flow of articles on relativity, astronomical constants, and time. It was during this period that he collaborated with Brouwer in the production of the excellent text *Methods of Celestial*

Mechanics (1961) and began his work with Woolard on the equally important text *Spherical Astronomy* (1966).

Dismayed by the lack of time to carry out his ambitious program of research on the motions of the Sun and planets, he retired at the age of 55, hoping to find an academic position that would allow him more time. In 1963 Brouwer offered him the position of senior research associate at Yale, and Gerald was able to continue his work on the general perturbation theory of the motion of Earth. Upon the sudden death of Brouwer in 1966 Gerald was promoted to full professor and was given the scientific and administrative responsibility for the astronomy department until such time as a new director could be found. These new duties impinged on his research, and the work on the theory of the Earth was not finished at the time of his death.

In the area of astronomical navigation Gerald made many contributions. He produced many technical reports on subjects such as bubble sextant errors, refraction, dip, irradiation, and time. Because of the high regard in which he was held internationally and with the full cooperation of D. H. Sadler, superintendent of H.M. Nautical Almanac Office, he was able to convince the naval administration that it was to everyone's benefit to unify the British and American air almanacs. This unification was later extended to all tables for navigation in the United States and the United Kingdom and led to their use in numerous other countries. Ultimately it became possible to unify the astronomical ephemerides, which were then published jointly in both countries.

A farsighted report "The Need for Training Students in Celestial Mechanics" (1947) anticipated the future need for scientists trained in the fundamentals of orbital mechanics. With the onset of the space age and the launch of *Sputnik* in 1957 Gerald cooperated with Brouwer in launching the

series of Yale Summer Institutes in Dynamical Astronomy aimed at meeting the burgeoning requirement for scientists trained in this subject. He presented lectures in the early institutes and provided other help to the program. Otherwise his role in the space age was mostly supervisory, although U.S. Naval Observatory personnel were involved in many aspects of the Earth satellite programs.

OFFICES, AWARDS, AND HONORS

Gerald's reputation as a scientist and as an administrator was well recognized in the United States and abroad, and he was drafted to serve in many roles. From 1949 to 1966 he served as associate editor of the *Astronomical Journal* and from 1969 to 1974 as editor. He oversaw the expansion of the journal resulting from the resurgence of interest in classical and fundamental astronomy as large high-speed calculators appeared and the requirements of the space age arose. The American Astronomical Society called upon his talents over the course of his career, and he served as president from 1958 to 1960. In 1952 he was elected to membership in the National Academy of Sciences. He became chairman of the Board of Directors of the B. A. Gould Fund from 1953 to 1969. In 1955 he was elected a fellow of the American Academy of Arts and Sciences. From 1962 to 1965 he was chairman of the Division of Physical Sciences of the National Research Council. In 1946 he was elected a fellow of the Royal Astronomical Society of Great Britain and in 1952 an associate.

Gerald was an active participant in the activities of the International Astronomical Union, serving as president of Commission 7 (Celestial Mechanics) from 1948 to 1955 and of Commission 4 (Ephemerides) from 1964 to 1967. He received the U.S. Navy Award for Distinguished Achievement in 1963 and for Superior Achievement in 1964. He

was elected an honorary member of the Royal Astronomical Society of Canada in 1946. In 1965 he was awarded the Gold Medal of the Royal Astronomical Society of Great Britain "in recognition of his application of celestial mechanics to motions in the Solar System and his fundamental contributions to the study of time and the system of astronomical constants." Sir Richard Woolley, president of the society, noted the many similarities between Gerald's accomplishments and those of his famous predecessor Simon Newcomb. Gerald greatly appreciated this comparison. Later in 1965 Gerald presented the George Darwin Lecture on "Inertial Frames of Reference." In 1975 he was posthumously awarded the J. C. Watson Medal of the National Academy of Sciences.

THE SCIENTIST AND THE FAMILY MAN

As a scientist Gerald presented a reserved appearance, was conservatively dressed, and maintained a dignified composure. When speaking, he thoughtfully considered his remarks and gave them with an economy of words. His scientific papers were similarly concise: to the point and without excess verbiage. In speaking and in writing he chose his words carefully and they meant exactly what he intended them to convey. As a person, Gerald was a sincere, forthright individual who was guided by an ethical code absorbed at an early age from his parents. Throughout his life he maintained close contact with his three brothers and his sister. He was a devoted husband and father (of two sons) and took great delight in their accomplishments. His principal hobby was good music: He was self-taught and accomplished on the violin, the piano, and the organ. On occasion he played the organ in several churches, including the Washington Cathedral, and was a member of the Organists Guild. A secondary hobby was watching trains (sometimes in the company of Paul Herget). When time permitted they would

go to the famous horseshoe curve on the Pennsylvania Railroad, carefully noting each type of locomotive observed, especially in the age of steam engines. In his travels he went by train whenever feasible.

Gerald was a patient mentor, a kind friend, and a steadfast colleague. He has given his students and associates a target to strive for in their own careers. In his final illness he was taken to a Providence nursing home near Brown University, while Edith took an apartment nearby in the area where they had lived as newlyweds 45 years before. After an illness of several months he died in Roger Williams Hospital.

He was survived by his widow, Edith, and two married sons, Gerald Vail Clemence and Theodore Grinell Clemence.

THIS MEMOIR was derived from Gerald Clemence's published papers; his autobiographical sketch on file at the National Academy of Sciences; from data received earlier from Paul Herget and D. H. Sadler; and from the recollection of the writer, who was fortunate enough to be Gerald's student, colleague, and friend for a number of years at the Nautical Almanac Office. Editorial review by Gerald Vail Clemence and his wife, Barbara, and by Donald Osterbrock is gratefully acknowledged.

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