Martin C. Gutzwiller

1925–2014

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
M. V. Berry and D. Baeriswyl

NATIONAL ACADEMY OF SCIENCES

MARTIN CHARLES **GUTZWILLER**

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By M. V. Berry and D. Baeriswyl

Martin Gutzwiller was a leading theoretical and mathematical physicist during the second half of the 20th century, recognized for his contributions to the theory of condensed matter and as one of the creators of quantum chaos theory.

Martin was born into an intellectual family in Basel, Switzerland. His father Max Gutzwiller was a professor of law, and his mother Gisela née Strassmann was educated in the classical humanities. After completing military service, Martin earned undergraduate degrees at the Swiss Federal Institute of Technology, Zürich (ETHZ). He moved to the United States in 1950, received his Ph.D. from the University of Kansas in 1953, and then worked in geophysics at Shell Oil in Houston, TX. Beginning in 1960 he was employed by IBM, first in Zürich and later (from 1963 on) in New York, punctuated by teaching in several places, including Columbia University. Martin was largely a solitary scientist who made his seminal contributions with a deep and scholarly appreciation of the work of his predecessors.

Early years (1925–1945)

Martin's mother Gisela (1896–1942) grew up in Berlin. Deeply involved with literature, art, and music, she also studied ancient languages and philosophy and was knowledgeable in mathematics. Martin's father Max (1889–1989) was born in Basel and studied law at the Universities of Basel, Fribourg, Berlin, and Bonn, where he received his doctoral degree. From 1917 to 1921 he worked as a diplomat for the Swiss government, mostly in Berlin, where he met Gisela. Martin's parents married in 1921, and Max moved into academia as a professor of Roman law at the University of Fribourg. During this period, Martin was born—the fourth child of the couple's two boys and three girls.

In 1926 the family moved to Germany, where Max took up a chair in civil law at the University of Heidelberg. But after the Nazi takeover in 1933, it became increasingly difficult for the Gutzwillers to live in Heidelberg, given Max's uncompromising critical attitude and Gisela's Jewish origin. They returned to Switzerland in April 1936 and settled in Sankt Gallen, a choice largely motivated by the educational needs of the two boys, who were sent to school in the nearby village of Trogen.


Parents: Gisela and Max, about 1940.

Max returned to Fribourg as a full professor of law, moving there in 1938 with Gisela and the three daughters, while the two boys remained at school in Trogen. In April 1942, Gisela died of cancer. Serious problems had appeared at the end of 1941, but the children did not know the truth. Thus Martin's letters to his mother during this time describe amusing details about the daily life at his school and in the village but reflect no special worries about her health.


A musical family: Martin (center) and his brother and sisters, 1939.

During 1942–1944 Martin finished his high-school education at the French-speaking Collège Saint Michel in Fribourg. He excelled not only in mathematics, physics, and chemistry but also in languages, philosophy, and gymnastics. He was less at ease with Catholic apologetics. In 1944, Martin enrolled at the Faculty of Sciences of the University of Fribourg, but mandatory military service prevented him from studying seriously. According to the records of the Swiss Military Department, he did not receive the highest marks at the school for recruits.

In 1939, Klaus Ruedenberg, a relative of Martin's mother, escaped from Germany and found refuge in Fribourg, where he studied chemistry and grew close to the

Gutzwiller family. He was then 19 years old; later, he became an internationally known theoretical chemist and one of Martin's close personal friends. Ruedenberg shares some of the memories of that five-year period:

> *The family treated the penniless teenage refugee with warm sympathy and provided an emotional anchor for me in the foreign country. My respect for Martin's father grew during walks through the countryside or under the high bookshelves in his large study. Through his intrepid and courageous integrity, forthrightness, and high ethical principles, he became a unique role model for me.*
>
> *Martin's mother was a highly intelligent woman, deeply committed to caring with great love for the total well-being of her large family. Her unexpected early death in 1942 was an enormous, profound shock for them.*
>
> *Martin, then in the gymnasium, was the only one whose interests went towards mathematics and the sciences. I remember mentioning to his father that I felt Martin would become very successful in the sciences. Very much later, Martin confided [to] me that the repeated changes, from Heidelberg to the German part of Switzerland—where considerable hostility existed at the time toward speakers of 'German German'—and then to the French-speaking part, had to some degree created in him a feeling of missing a whole social community in his youth.*

University studies (1945–1953)

Martin studied physics at the ETHZ. He completed many courses in mathematics, but some key areas of theoretical physics were not offered. As he wrote:

> *There were no lectures in quantum mechanics, let alone in quantum field theory. I decided to learn out of some well-known books (Sommerfeld, Pauli, Dirac, van der Waerden, Wentzel). It was often hard work that required me to be very stubborn. In 1949, I decided to ask Pauli to supervise my 'diploma-thesis,' to be finished in six months. He asked me to figure out the anomalous magnetic moment of the (isospin pair) proton-neutron, supposed[ly] due to the interaction of a charged-vector pi-meson. Pauli assigned his postdoc Villars (later at MIT) to help me. It worked quite well, and I got my diploma with very good grades.*

Already, while in Zürich, Martin acquired a lifelong aversion to purely abstract studies. Klaus Ruedenberg recalls: “We both felt that these—to a large degree, speculative—mathematical developments of our work in meson field theory had led us far away from real-life phenomena, and we both subsequently turned to more concrete physics, he to condensed matter problems, I to theoretical chemistry.”

Ruedenberg had moved to Zürich a little earlier, to work with Wenzel in theoretical physics. He writes:

> *Martin and I overlapped in Zürich for several years, until I left for the U.S. in 1948. Martin always was very lively and entertaining, yet always a thoughtful and noble spirit. The general mood right after the war was still somber, and the memories of both our families were still fresh. Nonetheless, we spent happy hours together. I still have a movie of Martin cheerfully helping my wife and me to harvest melons.*

For a year after his diploma, Martin worked as an engineer at Brown Boveri in Baden, where he helped to install a microwave transmission line between Zürich and Geneva. A grant from ETHZ allowed him to enroll in Ph.D. studies with Max Dresden at the University of Kansas. An elaborated version of Martin’s Ph.D. thesis,“Quantum theory of wave fields in a space of constant curvature,” was published in 1956 in *Helvetica Physica Acta*—his first full scientific paper.

At the University of Kansas, Martin met Ilse Gerecke, another Swiss exchange student, daughter of Eduard Gerecke (1898–1983), a professor of electrical engineering at the ETHZ. Ilse had a degree in French literature from the University of Geneva. They married in 1952, a year after meeting.

Houston, Texas (1953–1960)

Martin accepted a position at the Shell Oil Company’s Exploration and Production Research Laboratory in Houston and moved there with his pregnant wife in late summer 1953. Perhaps he was also attracted by the local presence of some of his mother’s family. That autumn, Ilse gave birth to Patricia. A second daughter, Frances, was born in 1955. Both girls later studied music and became pianists.

At Shell Oil, Martin’s research changed from meson physics and quantum electrodynamics to the more down-to-earth area of solid-state physics, in which he investigated problems relevant to the oil industry: anisotropic elasticity, plastic deformation of rocks under high pressure, and magnetization of sedimentary rocks. He was the only theorist in a group that included experimental physicists, chemists, and biologists.

Although Martin liked his work and had a good salary at Shell, and had a happy family life, roomy apartment, and extended family nearby, Houston was not his final destination. He wanted to return to Switzerland eventually, because he and Ilse were convinced they would be more comfortable there. He also had clear ideas about his preferred scientific activities—theoretical physics or applied mathematics—rather than experimental physics or engineering.

Martin (without a tie) and colleagues at IBM Zürich, about 1960.

IBM Zürich (1960–1963)

The IBM Zürich laboratory, founded in 1956, was initially aimed at improving computer hardware. However, as its first director Ambros Speiser recalled, “the subject of electronic digital circuits was not a good choice” because the small Zürich group could not compete with IBM’s large U.S. laboratories. Therefore a new vision was developed, namely to transform IBM Zürich to “a physics laboratory strongly rooted in the basic sciences, with emphasis on solid-state physics" and also theoretical physics. Martin was the second theorist to be hired there.

At IBM Zürich, Martin had to deal with electronic and magnetic properties of metals and superconductors. With his scientific flexibility he soon adapted to this new work, and came up with original ideas, especially in the field of correlated electrons, as described below.

Despite its name, the IBM Zürich laboratories were located eight kilometers from the city, in the small town of Adliswil. After spending three years in this peaceful environment, Martin and his family moved back to the United States—to New York City. Klaus Ruedenberg remembers "Martin mentioning that Seymour H. Koenig of the IBM Watson Laboratory at Columbia University (Director of that Laboratory, 1967-1970) was instrumental in persuading him to join that Laboratory". According to Martin the combination of research at IBM with teaching at Columbia University was his major motivation for the move, but the marvelous cultural life of New York certainly offered an additional attraction.

From IBM Watson Laboratory to Yorktown Heights (1963–1993)

New York became the place where Martin spent most of his life, almost 50 years. He worked first at the IBM Watson Laboratory at Columbia, where he found himself among a colorful group of scientists who, he wrote, "shared a broad range of scientific and other interests, keenly enjoyed interdisciplinary discussion and collaboration, and had the flexibility—to an extraordinary degree—to move easily from one scientific area to another."

In 1970, the Watson Laboratory was closed and its staff transferred to the Thomas J. Watson Center at Yorktown Heights, NY, some 45 miles north of the city. Martin soon became director of General Sciences, which he regarded as the smallest but most interesting department, as it included biophysicists and astrophysicists as well as social and environmental scientists.

A few months after first arriving in New York, he and his family settled in a spacious apartment in Riverdale, overlooking the Hudson River. Patricia and Frances went to elementary school, and later to high school and university, nearby. Ilse also returned to university, earning a second master's degree, in social work. Then, for almost 30 years, she was employed as a social worker at the Jewish Home and Hospital for the Aged in Manhattan. She died in New York in 2011.

First wife Ilse, and daughters Patricia and Frances, about 1970.

Martin and Ilse divorced in 1974. Martin remarried in 1991, to Marilyn Frankfurt, a psychotherapist. Martin's daughter Patricia recalls that Marilyn was "a lovely, very sociable, elegant woman, and very family-oriented." Marilyn died of cancer in 2004.

Late years (1993–2014)

After he retired from IBM, Martin remained active in physics and the history of science, and he became an adjunct professor at Yale University. During this period he published review articles and book reviews, introductory texts, an annotated bibliography, and public letters on research and education. He could also now indulge his hobbies: travel to Europe, mountain hiking, opera in New York City, playing music, and enjoying his grandson.

Martin's relationships with his daughters became closer in the late years, especially during his final four-year illness. Patricia spent endless hours with him in New York; and when he moved to New Mexico, Frances visited him many times and managed his medical care until he died.

Correlated electrons

Martin's work on correlated electrons was largely conveyed in three papers written between 1962 and 1964. In this research, his primary motivation was to understand the nature of itinerant ferromagnetism in transition metals, such as iron, cobalt, and nickel.

For ferromagnetic insulators, Werner Heisenberg had already developed a first quantum theory, in 1928, wherein electrons in localized orbitals interact with each other as a result of the interplay of Coulomb repulsion and Pauli exclusion. For ferromagnetic metals, a theory involving extended Bloch functions, rather than localized orbitals, had been developed in the 1930s, notably by Edmund Stoner. It was based on the fact that a pair of electrons, one with spin up, the other with spin down, feels a strong on-site repulsion when the electrons occupy the same energy band—in contrast to the case of parallel spins, where this repulsion is absent. An unbalanced occupation of spin-up and spin-down states can therefore reduce the interaction energy and lead to a finite magnetization. In this effective single-particle theory, the magnetized state is compared to the nonmagnetic state of the filled Fermi sea.

In transition metals, the d-electrons, responsible for the magnetic properties, are neither completely localized nor fully itinerant. Therefore adequate descriptions of ferromagnetism in iron-group elements cannot be derived either from the Heisenberg picture or the Stoner theory. Gutzwiller's entry into the subject was stimulated by J. H. Van Vleck, who in 1953 proposed modifying Stoner's theory by reducing the large charge fluctuations of a filled Fermi sea (principle of "minimum polarity"). Similarly, John Slater pointed out that a satisfactory theory of itinerant ferromagnetism should include correlation effects: the ground state should be a superposition of (Slater) determinants—rather than a single determinant, as in the case of a filled Fermi sea.

According to Patrik Fazekas, "it was the outstanding achievement of Gutzwiller to develop a formalism which turned Van Vleck's ideas into a calculational tool." Indeed, Martin's first paper on the subject, published in *Physical Review Letters* in March 1963, introduced a variational ansatz for the ground state, where charge fluctuations are reduced. In his words, "the correlated wave function is obtained from the antisymmetrized product of Bloch functions by simply eliminating those parts in which two electrons of opposite spin happen to be at the same lattice site."

The model Hamiltonian, introduced after defining the trial ground state, consists of two parts, one describing electrons of a single band and the other representing "the repulsion between two electrons with opposite spin which happen to be in the same orbit around a particular lattice site."

Quantum chemists had already used a similar model for π-electrons in conjugated polymers. The crucial role of the on-site repulsion between electrons in transition-metal oxides had been recognized in the 1950s, in particular by Philip Anderson.

Shortly after Martin's first paper on the subject, two papers appeared in which the same Hamiltonian was studied—one by John Hubbard, the other by Junjiro Kanamori—but without citing Martin's work. These papers were submitted in April and May 1963, respectively—i.e., after Martin's first contribution had been published—with the same aim: understanding correlation effects for ferromagnetism in systems with narrow bands. It is notable that in his third paper, Martin gave full credit to Hubbard and Kanamori, but they seem never to have cited him. The Hamiltonian introduced by Gutzwiller, Hubbard, and Kanamori was baptized “the Hubbard model” around 1968. It became the central model for the study of correlated electrons. In Elliott Lieb’s words, “the Hubbard model is to the problem of electron correlations as the Ising model is to the problem of spin-spin interactions.”

In his first paper on itinerant ferromagnetism, Martin used a low-density expansion of his variational ansatz, for which he found that a ferromagnetic ground state could potentially exist only for very large on-site coupling and a high density of (band) states. He even conjectured that the exact ground state of his model—i.e., of the Hubbard Hamiltonian—is never ferromagnetic. Many sophisticated calculations during the last 50 years have supported this conjecture. Indeed, a ferromagnetic ground state exists only under very special circumstances, such as for extremely large coupling strength near half-filling, or for special flat-band structures.

In his second paper, Martin studied a generalized model with two bands, which was thought to yield a better representation for the d-electrons of transition metals. He found conditions for ferromagnetism less stringent than in the nondegenerate case considered earlier.

The third paper, published in 1965, dealt again with the single-band Hubbard model and with the Gutzwiller wave function, and the paper succeeded in overcoming the limitations of low densities. Martin treated the innumerable terms contributing to the energy expectation value by means of an averaging technique, thereby reducing the task of summing them to a combinatorial problem. In a final step, he replaced the sum over double occupancies by its largest term. The resulting expression for the ground state energy was deceptively simple and could be represented, on the one hand, by a reduced hopping amplitude, corresponding to an enhanced effective mass; and on the other hand by a reduced double occupancy. Both effects increased as a function of the on-site interaction strength. Unfortunately, some of Martin’s arguments leading to what is now called the “Gutzwiller approximation” were somewhat obscure. Perhaps this is why his paper at first was not widely cited.

A few years later, when Martin had already left the field of correlated electrons, the Gutzwiller approximation was presented by others in more transparent ways than in his third paper: in terms of a configuration-independence of hopping processes, as a low-order cluster expansion, or as a saddle-point approximation of slave-boson theory. It was also shown that the Gutzwiller approximation represents the exact solution for the

Gutzwiller ansatz in the limit of infinite dimensions. This observation heralded a new era in the theory of correlated electrons, that of dynamical mean-field theory.

The Gutzwiller ansatz became very popular in the 1980s and ’90s, due to the enormous interest in materials with strong electronic correlations—for example, the heavy-fermion compounds and the cuprate high-temperature superconductors. It was shown that the ansatz could be handled exactly in one dimension. In two dimensions, relevant for layered cuprates, variational Monte Carlo methods were introduced in order to treat the Gutzwiller wave function to high numerical precision for relatively large systems. Extensions of the ansatz, incorporating long-wavelength collective density fluctuations, were also proposed.

One of us (D. B.) proposed “inverting” the ansatz by starting from the localized limit, where there are no doubly occupied sites, and then using the hopping term to delocalize the electrons. The resulting ansatz would be more appropriate in the strong-coupling limit, but unfortunately it can only be dealt with in rather exotic situations. This drawback did not prevent Martin from praising the (rather obvious) idea in a letter dated March 3, 2001: “Warum ist mir dieser Gedanke nie gekommen? Mangel an Fantasie! Gratulationen!” “(Why has this idea never crossed my mind? Lack of imagination! Congratulations!).” This statement, from a man who actually had a fertile imagination, exemplifies Martin’s generous and supportive attitude toward the work of others.

The Gutzwiller approximation was successfully applied to systems other than the (fermionic) Hubbard model—for instance, to the Anderson Hamiltonian involving both *s* and *d* electrons, to the Bose-Hubbard model (relevant for cold atoms in optical lattices), and to liquid helium-3. And a great number of phenomena were studied using Martin’s variational ansatz. They included Mott localization due to electron-electron interactions, antiferromagnetism, bond alternation in π-conjugated polymers, and high-temperature superconductivity. It was also used for establishing an explicit link between a microscopic theory and Landau’s phenomenological theory of the Fermi liquid.

Periodic orbits

Martin made seminal contributions to our understanding of the connection between classical and quantum mechanics. This is ‘semiclassical mechanics’, whose aim is to analyze the behavior of quantum phenomena in regimes where Planck’s constant can be regarded as small (in comparison with classical quantities with the same dimensions). He began with four papers, written between 1967 and 1971, that focused on the spectra of discrete energy levels of isolated and bound quantum systems—atoms and molecules, for example. He wanted to understand how such spectra, in particular their highly excited levels, were related to the trajectories of the corresponding classical systems.

The first three of these papers were virtuoso elaborations of ideas already in circulation, and the fourth broke fundamentally new ground. In those days, classical chaos theory had yet to emerge as an important area of study. But one phenomenon was already appreciated: dynamical systems in which the coordinates could not be separated and no conserved quantities other than the energy was known. Quantum counterparts included the hydrogen atom in a strong magnetic field; and molecules with more than two anharmonically bound atoms. It was impossible to treat such systems with existing "Bohr-Sommerfeld" semiclassical approximations, because (as Einstein had realized as early as 1917) these tools depended on the existence of a full set of constants of motion, which corresponded to a complete set of quantum numbers.

Martin's innovations were in realizing that the energy spectrum depends on the subset of classical trajectories that close on themselves—the periodic orbits—and in understanding that in nonseparable systems these trajectories are often unstable. The fourth paper included his tricky derivation of the contribution of an individual unstable periodic orbit to the energy spectrum. This was a central ingredient in the celebrated "Gutzwiller trace formula"—a quantum-classical relation that can be written symbolically in the form

Sum over quantum energy levels = Sum over classical periodic orbits.

The trace formula is a relationship of mutual collectivity: the totality of *quantum* energy levels depends on the totality of classical periodic orbits. Nevertheless, and as Martin realized, the trace formula can sometimes be approximated by taking just one periodic orbit and its repetitions. This led him to a quantization formula that gave good results when applied to some low-lying states of an electron in a semiconductor whose mass depends on direction—a system later called the anisotropic Kepler problem. For a few years, this approximate calculation was widely misinterpreted as implying a relationship between the individual energy levels and individual periodic orbits of chaotic systems. This assumption works for one-dimensional systems—for the hydrogen atom, and for some multidimensional harmonic oscillators—but in general it fails. And when applied to particles in a bounded domain within which they move freely ("quantum billiards"), the fallacy can give rise to a totally false set of singularities in the density of states.

Misunderstandings apart, the importance of Martin's fourth paper was immediately appreciated. A 1972 review by one of us (M. B.) concluded:

> *Finally, the difficulties raised by Gutzwiller's (1971) theory of quantization, which is perhaps the most exciting recent development in semiclassical mechanics, should be studied deeply in order to provide insight into the properties of quantum states in those systems, previously almost intractable, where no separation of variables is possible.*

Martin's papers quickly inspired others. In 1974, it was shown that the trace formula could be operated in reverse, so that a sum over energy levels generated a function whose singularities were the actions of periodic orbits. This was exact, not semiclassical, and led to what is now called "inverse quantum chaology" and "quantum recurrence spectroscopy," in which classical periodic orbits are identified by measurements of the spectrum. In 1975, some of Martin's 1960s results were generalized—to get the trace formula for systems where the periodic orbits are not isolated and not unstable—so there is a full set of quantum numbers. And a puzzle was resolved about the application of the trace formula for a stable orbit. By properly quantizing transverse to the orbit, the missing quantum numbers were restored. As a result, Martin's single-orbit quantization rule made sense as a limiting case of the old Bohr-Sommerfeld quantization.

Classical and quantum chaos

In the early 1970s, physicists gradually became aware of Russian mathematicians' major discoveries in classical mechanics. These discoveries complemented Western scientists' insights from computer explorations and would lead to chaos theory. That is, classical trajectories can be unpredictable, even if they are deterministic. It soon became clear that chaos theory needed to be incorporated into the semiclassical mechanics of quantum systems, though this inclusion would be unrelated to the familiar quantum indeterminacy.

The subject of quantum chaos began with energy-level statistics. It was soon conjectured, with support from computer simulations and some experiments, that the energies of highly excited quantum states in classically regular systems were distributed differently from those in classically chaotic systems. In the latter case, nuclear physicists discovered that the level statistics were the same as eigenvalues of random matrices. But these insights gave no clue as to why random-matrix universality applied, and in particular how it was connected with classical chaos.

In the 1980s, it became clear that the answers to these questions lay in several insights in Martin's 1971 paper. First came the understanding that random-matrix universality was inherited from a classical universality in the Gutzwiller trace formula's distribution of long periodic orbits. These orbits determined the correlations between nearby energy levels. A consequence, soon confirmed, was that correlations between distant levels—a function of the short periodic orbits that differ from system to system—are not those of random-matrix theory. This characterization of the origin and limitations of random-matrix theory in quantum chaos was far from mathematically rigorous; making it so required understanding, still being pursued today, of the subtle correlations between periodic orbits.

The second insight came from the realization that the series of periodic orbits in the trace formula did not converge—a consequence of the exponential proliferation of unstable isolated periodic orbits. As Martin put it in 1971: "Even more serious is the fact that there is usually more than a countable number of orbits in a mechanical system, whereas the bound states of a Hamiltonian are countable."

Eventually these concerns about convergence led naturally to the study of zeta functions, which in quantum physics are functions where the energy levels are zeros, rather than steps or spikes. Its grandparent was Riemann's zeta function in pure mathematics. Again it is amazing that Martin anticipated this connection in his 1971 paper. He had written: "This response function is remarkably similar to the so-called zeta functions, which mathematicians have invented in order to survey and classify the periodic orbits of abstract mechanical systems."

And in 1982, Martin explicitly wrote a semiclassical zeta function of the kind we consider today; he used it, in conjunction with some tricks from statistical mechanics, to sum the periodic orbits for the anisotropic Kepler system. Eventually this led to approximate representations of spectra as convergent sums over periodic orbits.

A third Gutzwiller innovation was "cycle expansions"—which made use of "symbolic dynamics," or codes that represent periodic orbits as strings of symbols—to speed the convergence of Martin's original sum over orbits. This application of coding to semiclassical mechanics was also originally his idea; he used it in the 1970s and early '80s to classify and then estimate the sum over orbits in the anisotropic Kepler problem.

Further extensions of Martin's ideas came in the mid-'80s, with the discovery that for some chaotic systems, the wave functions of individual states are scarred by individual short-period orbits in ways that depend on how unstable they are. From this came new sorts of spectral series of periodic orbits, not involving traces, for the morphologies of quantum states both in phase space and configuration space.

In spite of all this progress, the central question Martin posed in 1971 remains: "What is the relation between the periodic orbits in the classical system and the energy levels of the corresponding quantum system?"

Of course, the trace formula itself is one such relation. But what Martin meant was: how can periodic orbits be used for effective calculations of individual levels? For the lowest levels, there is no problem. But—again from Martin's 1971 paper—"the semiclassical approach to quantum mechanics is supposed to be better, the larger the quantum number." And for high levels, even the convergent versions of the trace formula now available require exponentially many orbits to reproduce the spectrum. This is a gross degree of redundancy, unacceptable to anybody who recognizes the spectacular power of asymptotics elsewhere. That it remains a live issue demonstrates the continuing vitality of Martin's ideas.

Martin was well aware that some of the ideas in periodic-orbit theory were extensions of concepts anticipated by mathematicians. For example, his trace formula generalized the "Selberg trace formula" of number theory from special dynamics on surfaces of constant negative curvature to much wider classes of chaotic motion.

Personality and scientific style

Far from denying partial anticipations of some of his ideas, Martin revered his predecessors. His approach, rare today, was deeply scholarly, as he often delved into the remote scientific past—into literature that others might deem obscure or irrelevant. In 1989 he wrote: "A practicing physicist can find inspiration and interesting ideas from looking at the original publications, even going back several centuries."

Consistent with this interest in scientific history was Martin's passion for old books. The book dealer Jonathan Hill said:

> *"Martin was one of the rare science book collectors who actually understood what was in the books he collected. He was clearly a man of enormous intelligence and knowledge, which he wore very lightly. His rare*

His solitary approach led to slowly maturing ideas and not many papers, almost all with him as sole author. But every one was a gem.

book library [was] a testament to his knowledge, and the enormous success [that] his library enjoyed when sold at auction reflect[ed] his considerable taste."

Throughout his life Martin maintained his enthusiasm for literature, art, and music, absorbed from his parents as a child. He read books in several languages, and fulfilled a lifelong dream by turning to the violin at the age of 63.

Martin ignored the scientific fashions of his day, but his contributions have themselves become fashionable: Google searches report 34,000 hits for "Gutzwiller wave function," and 24,000 for "Gutzwiller trace formula," and his achievements were recognized by more traditional honors, including the Dannie Heineman Prize, the Max Planck Medal, membership in the U.S. National Academy of Sciences, and four honorary doctorates.

Another way in which Martin's science ignored common practice was that he almost always worked alone. He was not a conference-chaser, and his talks were rare events, with delivery understated; we never heard him raise his voice. His solitary approach led to slowly maturing ideas and not many papers, almost all with him as sole author. But every one was a gem. Martin's written output exemplified the motto of the mathematician Carl Friedrich Gauss: "Few, but ripe."

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