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BRYCE SELIGMAN DEWITT
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A Biographical Memoir by

STEVEN WEINBERG

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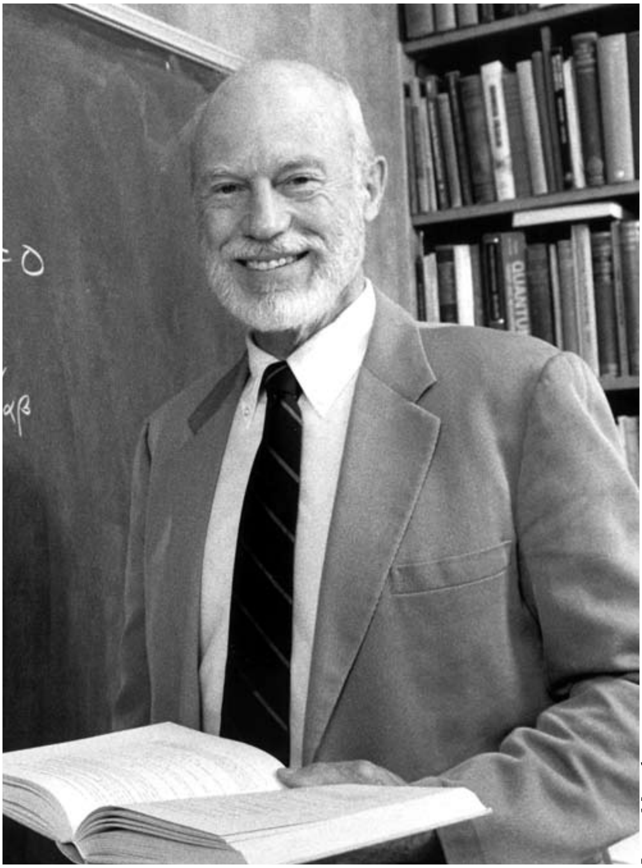

Larry Murphy

Bryce DeWitt

BRYCE SELIGMAN DEWITT

January 8, 1923–September 23, 2004

BY STEVEN WEINBERG

Bryce Seligman DeWitt, professor emeritus in the physics department of the University of Texas at Austin, died on September 23, 2004. His career was marked by major contributions to classical and quantum field theories, in particular, to the theory of gravitation.

DeWitt was born Carl Bryce Seligman on January 8, 1923, in Dinuba, California, the eldest of four boys. His paternal grandfather, Emil Seligman, left Germany around 1875 at the age of 17 and emigrated to California, where he and his brother established a general store in Traver. Emil married Anna Frey, a young woman who had emigrated from Switzerland at about the same time. They had 11 children, whom Anna raised in the Methodist church.

In 1921 DeWitt's father, who had become a country doctor, married the local high school teacher of Latin and mathematics. Her ancestors were French Huguenots and Scottish Presbyterians. DeWitt was raised in the Presbyterian Church, and the only Jewish elements in his early life were the matzos that his grandfather bought around the time of Passover. DeWitt described his early exposure to religion as a boy in California in a moving memoir, "God's Rays," published posthumously in *Physics Today*. His grandmother told him that Armageddon would come in the summer of

1997 and hounded his grandfather to his deathbed, trying to make him give up his belief in Darwinian evolution. Looking back in his memoir, DeWitt came to the conclusion that it was love that gave Christianity its overwhelming impact, but that love "needs no religious framework whatever to exert its power."

DeWitt's mother chafed at her rural surroundings and determined that her sons would live elsewhere. At the age of 12 DeWitt entered Middlesex School in Concord, Massachusetts. The headmaster at Middlesex had initiated a national scholarship program similar to the one at Harvard, and DeWitt had taken (at his mother's insistence) the competitive examination in which he earned his admission.

He graduated from Middlesex at the age of 16, and was admitted to Harvard and Caltech. He chose Harvard because he had become passionate about rowing while at Middlesex, and Harvard had "crew." He eventually stroked the Harvard Varsity. As a physics major he was deferred from military service but always felt guilty about it. Upon graduation in 1943 he went to work on the Calutron at Berkeley, the accelerator used in the Manhattan Project for the final separation of uranium-235 from uranium-238. (This had been recommended to him by Robert Oppenheimer when, because DeWitt wanted to get back to California, he had turned down Oppenheimer's invitation to join a secret research project in an undisclosed location.) He spent seven months at the Berkeley branch of the Manhattan Project and then asked to be released. He reasoned that any bright youngster could do what he was doing (hand soldering, reading meters, general gofer work), and he didn't see that his physics degree was relevant. In January 1944 he enlisted in the navy and became a naval aviator, but World War II ended before he saw combat.

DeWitt came back to Harvard in January 1946. In 1947 he began his thesis work under the nominal supervision of Julian Schwinger. The topic he chose, the quantization of the gravitational field, became his life's work. In 1949 he began his first postdoctoral year at the Institute for Advanced Study. When Wolfgang Pauli, in November of that year, learned what he was working on, he remained silent for several seconds, alternately nodding and shaking his head (a well-known Pauli trademark), and then said, "That is a very important problem. But it will take somebody really smart!"

In 1950 two major but totally unrelated developments occurred in his life. First, he became engaged to be married to Cecile Morette, a young French physicist who was in her second postdoctoral year at the institute. Second, at the urging of their father, he and his three brothers began the legal procedures for changing their surname to a name from their mother's side of the family. The younger boys were, or had been, at school in the eastern United States, and all had encountered repeated misunderstandings and false assumptions based solely on their surname, something that had seldom occurred in California.

From June to December 1950 DeWitt was with Pauli at the ETH in Zürich, and afterward he went to Bombay to spend a postdoctoral year at the Tata Institute of Fundamental Research. This sojourn did not make good professional sense, but it suited his roving spirit. Unfortunately it ended in an abrupt and serious illness, which forced his return to Europe. In May 1951 he and Cecile were married in Paris, and in July they were in Les Houches, where the famous l'École d'Été de Physique Théorique was starting its first year. This school had been created by Cecile as a penance for marrying a foreigner, but she also saw it as something potentially valuable in its own right. It was certainly valuable to DeWitt, who during the summers he was there, was exposed to a very broad range of topics in theoretical physics. That the school was also valuable to others is attested by the fact that at its jubilee in 2001 it numbered among its past students and lecturers 26 who later became Nobel laureates and two who became Fields medalists.

In September 1951 DeWitt, this time accompanied by Cecile, returned to the Tata Institute, determined to complete his postdoctoral year. Their eldest daughter was born in Bombay in April 1952. Three other daughters were born during the following decade. In the summer of 1952 Cecile was back at Les Houches while DeWitt was looking for a job in the United States. His years abroad had kept him out of the market for academic appointments, so he accepted a job at the nuclear weapons laboratory at Livermore, where he remained for three and a half years. During his stay at Livermore, in addition to writing a treatise on "The Operator Formalism in Quantum Perturbation Theory," he became the lab's expert on (2+1)-dimensional hydrodynamical computations (impelled by NATO's desire to possess nuclear artillery shells). This expertise was applied by him years later in computations of the behavior of colliding black holes, and by his students in a variety of astrophysical problems.

Through the efforts of John Wheeler, who had become aware of his work on quantum gravity, DeWitt was offered and accepted the directorship of the Institute of Field Physics at the University of North Carolina in Chapel Hill. His initial title at UNC was visiting research professor, which enabled him to teach, or not, as he chose, and to have students. With his very first student, and with the aid of the book of Jacques Hadamard on the Cauchy problem, he discovered the basic properties of Green's functions in curved spacetime. He was also led to the beginnings of a manifestly covariant quantum theory of gravity in which, unlike the usual approach to quantum mechanics, the Hamiltonian has no role to play.

In quantum mechanics the commutator AB-BA of any two quantities A and B is inferred from a quantity known as the Poisson bracket, which is calculated on the basis of classical mechanics. DeWitt came upon the 1952 paper of Rudolf Peierls, which gave a global definition of the Poisson bracket in terms of these Green's functions. Peierls's definition yields a completely unambiguous Poisson bracket for any pair of quantities, whose definition does not depend on the choice of coordinate system. The problem now addressed by DeWitt was to extend these classical results to the quantum theory with all its infinities.

In January 1957 Cecile, who had also been given the title of visiting research professor, organized the first of the general relativity and gravitation (GRG) conferences: "On the Role of Gravitation in Physics." The participants included Christian Møller, Leon Rosenfeld, Andre Lichnerowicz, Hermann Bondi, Thomas Gold, Dennis Sciama, Peter Bergman, John Wheeler, and Richard Feynman. Samuel Goudsmit had recently threatened to ban all papers on gravitation from *Physical Review* and *Physical Review Letters* because he and most American physicists felt that gravity research was a waste of time. The conference aimed to point out the shallowness of this view. In those early years, arguments were often put forward that gravity should not be quantized. Feynman vigorously disagreed and became interested in the problem while visiting Chapel Hill. Four years later, at the GRG conference in Warsaw, Feynman gave the first correct statement of how to quantize gravity (and also the non-Abelian gauge field) in the one-loop order of perturbation theory. He was the inventor of what are known as "ghosts" in non-Abelian gauge theories. These theories, invented in 1954 by Chen-Ning Yang and Robert Mills, became the subject of much of DeWitt's future work, and later turned out to furnish the basis of successful theories of all of the observed interactions of elementary particles except gravitation.

DeWitt, who had followed Feynman's work closely, extended it to two-loop order in 1964. In the meantime he had pushed forward on several other fronts. On three occasions he had presented courses of lectures at Les Houches. In 1963 he gave his most famous course, "The Dynamical Theory of Groups and Fields," which was published as a book the following year. In it he introduced a condensed notation applicable to all field theories, extended Schwinger's heat kernel methods to curved spacetime and other nonconstant backgrounds, and gave the first (and now standard) nonperturbative definition of the effective action as a Legendre transform of the logarithm of the vacuum persistence amplitude.

By the end of 1965 he had found the rules for quantizing the gravitational and non-Abelian gauge fields to all orders. But this work did not get published until late 1967 for two reasons. First, his Air Force grant was terminated and he could not pay the page charges that *Physical Review* had begun levying. Second, there seemed to be no rush. The standard model of electroweak interactions had not yet been worked out and the fundamental importance of the non-Abelian gauge field was not fully understood. Dimensional regularization, which would make renormalization easy, had not yet been invented. And he was momentarily sidetracked by John Wheeler's eagerness to develop a canonical approach to quantum gravity based on Dirac's theory of constraints. The application of Dirac's methods to gravity had some interesting features of its own. DeWitt was led to what subsequently became known as the Wheeler-DeWitt equation, which has since been applied many times to problems in quantum cosmology.

DeWitt's paper on the non-Abelian Feynman rules finally appeared two weeks before a paper by Fad'deev and Popov deriving the same rules. These rules were seized upon by 't Hooft and Veltmann who, apparently unaware of DeWitt's contributions, proceeded to call Feynman's ghosts "Fad'deev-Popov ghosts," a name that has stuck.

In the summer of 1968 DeWitt was visited by Max Jammer, who was thinking of writing a book on the interpretation of quantum mechanics and its history. DeWitt was astonished to learn that Jammer had never heard of Hugh Everett III, who had published a paper on this topic in the same issue of *Reviews of Modern Physics* in which contributions from the 1957 Chapel Hill conference had appeared. In fact Everett's paper, which proposed that one should regard the formalism of quantum mechanics as providing a representation of reality in exactly the same sense as the formalism of classical mechanics was once thought to do, had been totally ignored by the physics community during the intervening years. DeWitt resolved to correct this situation and in 1970 wrote a popular article in *Physics Today* expounding Everett's views. These views, although almost totally rejected at first, have little by little gained increasing numbers of adherents. The assumption that the formalism of quantum mechanics provides a direct representation of reality implies the existence of what from the point of view of classical physics would appear as many "realities." Everett's interpretation consequently became known as the "many-worlds" interpretation. DeWitt, who found Everett's ideas liberating in the sense that they lead one to ask questions that might not occur to one otherwise, became regarded as one of the foremost champions of the many-worlds interpretation, although it was always peripheral to his main interests.

By 1970 the DeWitts had begun to think of leaving Chapel Hill. Several years earlier Bryce's title had been changed to professor while Cecile had been demoted to lecturer. In addition, upon the death of Agnew Bahnson Jr., the Winston-Salem industrialist who had founded and provided financial security for the Institute of Field Physics and upon his widow's transfer of its backup funds to the university, the status of the institute underwent an abrupt change. No longer was it possible to offer postdoctoral positions with the assurance that funds would be available even if grant money failed to materialize. The postdocs of earlier years had included Felix Pirani, Ryoyu Utiyama, Peter Higgs, and Heinz Pagels. This stream of talented people had now come to an end.

In the fall of 1971 DeWitt accepted a visiting professorship at Stanford. The physics department was looking for a replacement for Leonard Schiff, who had died the year before. Stanford indeed looked promising, not least because the mathematics department expressed an interest in hiring Cecile. The members of the physics department were sufficiently pleased by Bryce's visit that they made preparations to offer him a professorship. This, however, was vetoed by Felix Bloch, who upon learning that Bryce had changed his surname 20 years earlier, refused to allow the offer to proceed.

An alternative then appeared at the University of Texas at Austin. A few years earlier Alfred Schild had secured the university's agreement to establish a well-funded Center for Relativity. Schild, as its director, brought to Austin such people as Roy Kerr, Robert Geroch, and Roger Penrose. In a short time these gifted young people were snapped up by other more prestigious institutions. There was always a vacancy at the Center for Relativity, and Schild was determined to get the not-so-young DeWitts. He arranged that they would both be offered full professorships, Cecile half-time at first in the astronomy department and then later full-time in the physics department.

Mixing astronomy and relativity, the DeWitts became co-leaders of a National Science Foundation-funded eclipse expedition to Mauritania in 1973. The aim of the expedition was to repeat, with modern technology, the light-deflection observations of bygone years. This effort would not have been possible without warm cooperation between the astronomy department and the Center for Relativity.

The DeWitts were instrumental in attracting to Austin John Wheeler, who was facing compulsory retirement at Princeton. Texas gave him a center of his own to which he invited people such as David Deutsch and Philip Candelas, with whom DeWitt had become acquainted during a Guggenheim year as visiting fellow at All Souls College, Oxford, in 1975-1976.

DeWitt's early years at Texas were devoted to the colliding black hole problem and to the problems of quantum field theory in curved spacetime, including the problem of the conformal or Weyl anomaly and the description of Hawking radiation. He also continued to develop his Hamiltonian-free approach to quantum field theory. By 1983 when he again lectured at Les Houches, he was able to set the theory of conservation laws, tree theorems, and dimensional and zeta-function regularizations completely within this framework.

In the 1980s he wrote his book *Supermanifolds*. Supermanifolds are spaces that have coordinates that anticommute (in the sense that xy=-yx), as well as having the ordinary sort of commuting coordinates (for which xy=yx). The book brought together in a systematic way a number of related but never before united topics, such as supertraces, superdeterminants, Berezin integration, super Lie groups, and path-integral derivation of index theorems. A useful topology that he introduced for integration on supermanifolds is now known by mathematicians as the DeWitt topology. A second edition of *Supermanifolds* appeared in 1991.

In 1992 DeWitt and his associates completed a lattice quantum field theory study of the O(1,2) nonlinear sigma model in four dimensions. This model, which bears some similarities to quantum gravity, proved to be trivial in the continuum limit.

DeWitt's last book, *The Global Approach to Quantum Field Theory* (1042 pages), was published in 2003, when he was 80 years old. It effectively sets forth his special viewpoint on theoretical physics and includes the following unique contents:

- A derivation of the Feynman functional integral from the Schwinger variational principle and a derivation of the latter from the Peierls bracket;
- Proofs of the classical and quantum tree theorems;
- A careful statement of the many-worlds interpretation of quantum mechanics in the context of both measurement theory and the localization-decoherence of macroscopic systems, which leads to the emergence of the classical world;
- A display of the many roles of the measure functional in the Feynman integral, from its relation to the Van Vleck-Morette determinant in semiclassical approximations to its justification of the Wick rotation procedure in renormalization theory;
- Repeated use of the heat kernel in a wide variety of contexts, including a zeta-function computation of the chiral anomaly in curved spacetime;
- An exhaustive analysis of linear systems, both bosonic and fermionic, and their behavior as described through Bogoliubov coefficients;
- A novel approach to ghosts in non-Abelian gauge theories: use of the Vilkovisky connection to *eliminate* the ghosts in the closed-time-path formalism that is used to calculate "in-in" expectation values; and
- A proof of the integrability of the Batalin-Vilkovisky "master" equation.

DeWitt's obituary in *Physics Today* notes that:

> as a scientist, Bryce was bold and extraordinarily clear thinking. He eschewed bandwagons and the common trend of trying to maximize one's publication

list. Most of his papers are long masterpieces of thought and exposition. Indeed, Bryce had a rare, perfect combination of physical and mathematical intuition and raw intellectual power that was very rarely surpassed.

To this I would add that he was a fount of wisdom about theoretical physics for his colleagues at the University of Texas. His death has left a gap in our working lives that time does not seem to cure.

For his many contributions to physics DeWitt received the Dirac Medal of the Abdus Salam International Centre for Theoretical Physics (Trieste), the Pomeranchuk Prize of the Institute of Theoretical and Experimental Physics (Moscow), and the Marcel Grossmann Prize (with Cecile). Shortly before his death he was named the recipient of the American Physical Society's Einstein Prize for 2005. He was elected to membership in the National Academy of Sciences in 1990; he was also a member of the American Academy of Arts and Sciences. DeWitt was an indefatigable trekker and mountain climber, traveled widely, and lectured in many parts of the world. He is survived by his wife, Cecile, and four daughters.

THIS MEMOIR INCORPORATES materials provided to me by Bryce DeWitt before his death.

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