Biographical Encyclopedia of Astronomers

Weyl, (Claus Hugo) Hermann

Born Elmshorn, (Schleswig-Holstein), Germany, 9 November 1885

Died Zurich, Switzerland, 8 December 1955

German-Swiss-American mathematician Hermann Weyl appears to have been the first to write the general-relativistic equations of cosmology in a form in which the galaxies could be regarded as staying at fixed coordinate locations (in what are now called commoving coordinates) while the cosmic expansion was carried out by a single function in front of the rest of the equations. He also gave his name to an important mathematical entity called the Weyl tensor

The son of Anna Dieck and Ludwig Weyl, a bank director, Weyl was educated at the Gymnasium in Altona (site of what was then a major observatory), whose headmaster sent him to work at Göttingen with David Hilbert, a relative of the headmaster's. Weyl completed his doctorate and postdoctoral *habilitation* in 1910 with a dissertation on a particular form of differential equations. He remained at Göttingen and continued his mathematical research there until 1913, working on various aspects of functional analysis

That year was marked by three major changes in Weyl's life. He married Helene (Hella) Joseph, a translator of Spanish literature. His first book, *Die Idee der Riemannische Flachen*, dealing with Riemannian surfaces, an area of mathematics he later applied in relativity theory, was published. He was offered an opportunity to remain at Göttingen and assume the chair was being vacated by the retiring Felix Klein, but chose instead to accept an appointment at the Eidgenossische Technische Hochschule [ETH] (Swiss Federal Institute of Technology) in Zurich

At ETH Zurich, Weyl met Albert Einstein, who by then was working on general relativity, and welcomed the opportunity to work with him for approximately a year. In particular, Weyl found himself strongly interested in the application of tensor calculus to the representation of space-time, which served to clarify some of Einstein's concepts. However, as a German citizen, with World War I underway, he was drafted into the German army in 1915. In 1916, at the urgent request of the neutral Swiss government, he was discharged and returned to ETH Zurich.

In 1918, Weyl's second book, *Raum, Zeit, Materie* (Space, Time, Matter), later translated as *Space, Time, Matter*, was published, a comprehensive exposition of relativity theory in terms of differential geometry. It went through five editions in rapid succession, the fifth bearing the date 1923

During 1918/1919, Weyl attempted to derive a unified field theory for electromagnetism and gravitation. Though he abandoned that effort as unsuccessful, his concept of gauge invariance remained fundamental for cosmology. Moreover, Weyl was able to relate gauge invariance to charge conservation

Over the next decade, Weyl alternated his attention and work among basic mathematics, including its philosophical foundations, mathematical cosmology, and the mathematical foundations of quantum theory. In 1926, as the "new" quantum theory emerged, he was in regular communication with Erwin Schrödinger at the ETH and the physicists at the Göttingen school, notably Max Born, Werner Heisenberg, and Pascual Jordan. Weyl's third book, *Group Theory and Quantum Mechanics*, appeared in 1928, followed by an expanded second edition in 1931.

Weyl's contributions to physics are germane to cosmology in a broad contemporary view. In the 1931 edition of the group theory book, he included an analysis of Paul Dirac's relativistic equation for the electron, showing that the positive particle its solutions allowed could not be the proton because the equation constrained its mass to be identical to that of the electron. The positron, thus predicted, was found experimentally by Carl Anderson in 1932

In 1927, Weyl analyzed Wolfgang Pauli's hypothetical neutrino and derived an equation then thought to be inadequate because it lacked the expected symmetry. Only after the experimental discovery in 1957 of the nonconservation of parity by Chien-Shiung Wu and her collaborators was it realized that Weyl's equation had predicted it, decades before the hypothesis published by T. D. Lee and C. N. Wang. The equivalence of mathematical symmetry and physical conservation had been established by Emmy Noether in 1919, but the predictive power of Noether's theorem was not fully realized for many years

Over the same years, Weyl's work on cosmology continued and progressed. In the early 1920s, he showed that the redshifted galactic spectra reported by Vesto Slipher required an expanding Universe rather than the stationary models postulated by Einstein and Willem de Sitter, although de Sitter allowed for redshifts. However, Weyl's postulate on the redshifts led to his model showing all geodesic world lines diverging from a common point as an origin, never intersecting in finite spacetime, and projected back as converging toward negative infinity in the past. He thus postulated that all galaxies had a common origin in the very distant past, and that expansion was therefore required. His postulate also enabled him to define cosmic time. Weyl's paper, "Redshift and Cosmology," appeared in 1930

That year the Weyls and their two sons, Fritz Joachim (also a mathematician) and Michael, moved back to Germany. Weyl had at last accepted an appointment to the faculty at Göttingen, following Hilbert's retirement. However, as the political situation in Germany became increasingly ominous, the Weyls chose to immigrate to the United States in 1934 while it was still possible to do so openly. Weyl was then appointed to the faculty of the Institute for Advanced Study at Princeton University, where Einstein had preceded him. The Weyls were familiar with Princeton since he had spent the year 1928/1929 as a visiting professor at the university.

At the institute, Weyl was able to resume research in several areas of mathematical physics, including spinor theory. His last book, other than revisions and reminiscences, was *The Classical Groups: Their Invariants and Representations*, which was published in 1939

Weyl became an American citizen in 1939. In 1940 he was elected to the US National Academy of Sciences. He was also a foreign member of the Royal Society (London) and a corresponding member of the Paris Académie des sciences. During World War II, Weyl interrupted his research and carried out analyses on fluid dynamics and shock waves pertinent to national needs. This applied work, as well as his basic research, led to papers that appeared throughout the 1940s, including one in 1944 pertinent to relativity theory

In 1948, Hella Weyl died; in 1950, Hermann married Ellen Lohnstein Bär, a sculptor. He retired from the institute in 1951 and marked that occasion with a retrospective book, *Symmetry*, published in 1952. Thereafter, the Weyls divided their time between Princeton and Zurich. The revised and translated version of his first book, *The Concept of a Riemannian Surface,* appeared in 1955. That year, Weyl learned that he had overstayed the time allowed for naturalized American citizens to remain out of the country and was barred from returning to the United States until a legal exception could be arranged. Unfortunately, he died of a heart attack while still in Zurich.

Weyl's contributions to mathematics, physics, cosmology, and philosophy comprise 150 papers and books. Roger Penrose declared him to be "the greatest mathematician of the 20th century."

Frieda A. Stahl

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