About Wolfgang Pauli

Among the handful of names that appears across the canvas of twentieth century theoretical physics, that of Wolfgang Pauli is one of the most prominent. The century had begun with Max Planck's discovery of his radiation law and quantum of action in October 1900; it was also the year of Pauli's birth. The adjustment of the fabric of physics to accommodate the new constant of nature occupied the next quarter century. It resulted in the new quantum mechanics which, unlike the relativity theories, was the work of many hands. The years 1901 and 1902 saw the birth of many of those destined to give shape to the new physics: Heisenberg and Fermi in 1901, Wigner and Dirac in 1902. The other principal characters – Einstein (1879), Max Born (1882), Niels Bohr (1885), Erwin Schrödinger (1887) and Louis de Broglie (1892) – all belonged more or less to an earlier generation.

Wolfgang Pauli (jr) was born on April 25, 1900 in Vienna. His father Wolfgang Josef Pauli, a medical doctor and later a University Professor of biology, had converted from the Jewish to the Catholic faith. His mother Berta Camilla Schutz was a Catholic, his sister Hertha was nine years younger. He was baptized in the Catholic church, his godfather being the physicist – philosopher Ernst Mach. Pauli learnt an incredible amount of physics and mathematics in the school years, graduating from the Dobling Gymnasium in Vienna in 1918.

He then joined Arnold Sommerfeld as a student in Munich, and obtained his Ph.D in 1921 for a thesis showing the failure of Bohr's atomic model for the ionized hydrogen molecule. On the way, barely 21, at Sommerfeld's invitation he completed a masterly encyclopedia article on relativity, to replace one that Einstein had agreed to but did not write.

Pauli spent winter 1921–22 with Max Born at Göttingen, and spring 1922 with Wilhelm Lenz at Hamburg. In summer 1922 he met Niels Bohr at the latter's lectures at Göttingen; this led to his spending 1922–23 at Copenhagen. In early 1924 he became an Assistant Professor at Hamburg. The period 1924–27 saw many extended visits to Copenhagen – this was when quantum mechanics was discovered and its orthodox or Copenhagen interpretation created by Bohr, Heisenberg and Pauli. In April 1928 Pauli moved as Professor to the Swiss Federal Polytechnic Institute (ETH) in Zurich. He stayed there for the rest of his career, except for the war years 1940-46 spent at the Institute for Advanced Study at Princeton. The 1945 Physics Nobel Prize was awarded to Pauli 'for the discovery of the Exclusion Principle, also called the Pauli Principle'.

In 1929 Pauli renounced the Catholic faith. His first marriage in 1930 failed after just a year, leading to deep depression during 1931–32. He then married Franciska Bertram on April 4, 1934.

Pauli's landmark achievements in physics are many. Both the exclusion principle and the discovery of a new two-valued variable for the electron date from late 1924 – early 1925. The latter came from a penetrating analysis of the anomalous Zeeman effect. Years later he recalled:

> *"A colleague who met me strolling rather aimlessly in the beautiful streets of Copenhagen said to me in a friendly manner, 'You look very unhappy'; whereupon I answered fiercely 'How can one look happy when he is thinking about the anomalous Zeeman effect?"*

His description of the new variable associated with the electron reads:

"According to this point of view the doublet structure of alkali spectra as well as the deviation from Larmor's theorem is due to a particular two-valuedness of the quantum theoretic properties of the electron, which cannot be described from the classical point of view."

In late 1925 he applied Heisenberg's new matrix mechanics to the hydrogen atom, beating Dirac by a few days, and showed that it worked. In 1927 he showed how to extend the (nonrelativistic) quantum mechanics to accommodate the spin of the electron. Along with Heisenberg, and following upon Dirac's earlier work, he created quantum field theory in 1928. In 1930 he conceived of the neutrino as a new hitherto unknown particle in nature, as a means of saving the principle of energy conservation in beta decay. His famous letter containing this idea appears elsewhere in this issue. As Leon Lederman said decades later: "Obviously, a particle that reacted with nothing could never be detected. It would be a fiction. The neutrino is just barely a fact."

Pauli's 1927 work on the paramagnetism of an electron gas inaugurated solid state physics, though he said: *"I don't like this solid state physics ... I initiated it though"*. In 1930 with Weisskopf he showed how to make sense of the Klein–Gordon equation in quantum field theory, and in 1940 came the spin-statistics theorem. In the 1940's at Princeton he worked on the strong coupling theory, and in 1955 came the CPT theorem.

Pauli was a severe critic, not least of himself, and an exceedingly sharp mind. Quoting Heisenberg: *"Pauli had a very strong influence on me. I mean Pauli was simply a very strong personality ... He was extremely critical. I don't know how frequently he told me, 'You are a complete fool', and so on. That helped a lot."* His sharp criticisms stopped many from pursuing or publishing speculative ideas – Kronig on electron spin, de Broglie on alternative interpretations of quantum mechanics, Salam on the two-component neutrino, to mention a few. He once said about a manuscript: "It is not even wrong". He was however completely honest when he said: *"I have indeed mistakenly held something right to be wrong, but never considered something wrong to be right"*.

In time, Pauli became the *"conscience of physics"*, playing successor to Einstein in this role. In a 1960 tribute, no less a person than Niels Bohr wrote: "*At the same time as the anecdotes about his personality grew into a veritable legend, he more and more became the very conscience of the community of theoretical physicists.*" His critical nature helped him foresee difficulties exceedingly quickly, and probably held back his own creativity. Tomonaga has characterised the situation thus: " ... *Pauli's perfectionism was phenomenal. He not only wanted to be perfect himself, but was well known for applying this standard to other people, sometimes arguing harshly against other people's work. For this reason when people asked his opinion of their work and he gave his assent, they called it Pauli's sanction*".

Pauli ventured to express his philosophical views on physics – a long standing and deep interest – late in life, in an extensive correspondence with Markus Fierz. These letters, kept at CERN in Geneva, are even now being studied and assessed. In the interpretation of quantum mechanics he was Bohr's closest pupil, and he had the courage to carry this interpretation to its logical end.

During a lecture at Zurich in early December 1958 he suddenly took ill due to intensive pains, and died ten days later on 15 December 1958.

N Mukunda