

LETTERS

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wave mechanics (27 January 1926).

The authors say Pauli “beat Schrödinger to the theory of the hydrogen atom.” Although this statement is chronologically not incorrect (Pauli’s paper was sent in 17 January 1926; Schrödinger’s later that same month), it is misleading: Pauli obtained the H-atom spectrum by matrix mechanics, actually beating Heisenberg, who had never tried using his newborn matrix mechanics to solve for the hydrogen spectrum. And Pauli also beat Dirac, who solved the problem again (in two dimensions!) using matrix mechanics, five days later than Pauli. Schrödinger, of course, presented the wave-mechanical solution in a completely independent development.

The authors also say Pauli “discovered nuclear magnetism,” but this is an overstatement. In 1924, Pauli published a paper suggesting that the hyperfine structure in sodium was due to the nuclear spin. People tend to consider Pauli to be the first who suggested that the nuclei should carry spin, but the first calculation of the hyperfine structure (for hydrogen) had to wait until Enrico Fermi’s work (1930).

The article goes on to state, “In papers with Heisenberg and Pascual Jordan, Pauli introduced relativistic quantum field theory.” This sentence is too short to appropriately establish the origins of quantum field theory. Quantum electrodynamics started with Dirac’s 1927 paper on the quantum theory of radiation. In 1928, Jordan and Pauli established the fully relativistic commutation rules for the electric and magnetic fields in vacuum. Incidentally, Jordan is the unsung hero of the quantum theory of fields. But the modern covariant quantum theory of fields truly started with the two papers coauthored by Heisenberg and Pauli in 1929 and 1930.

The respective roles of Heisenberg and Pauli in the crucial years around and after 1925 are still a matter of discussion. I do not agree with the authors’ opinion that “much of Heisenberg’s work was inspired by Pauli’s ideas.” It is clear that Heisenberg sent many of his papers to Pauli prior to publication, in particular the 1925 matrix mechanics one and the uncertainty papers of 1927. But it is equally clear that most of Heisenberg’s ideas were his own.

When the draft earned Pauli’s approval, Heisenberg happily sent it for publication. And when the two men got stuck, as in the naive application of quantum rules to the electromagnetic field, it was Heisenberg who eventually solved the riddle. The same is true with the anomalous Zeeman effect and the helium spectrum, monumental works done essentially by Heisenberg alone (although Jordan collaborated in the Zeeman paper).

I think the statement that Pauli and Heisenberg “were the phenomenologists par excellence” and “felt themselves to be the real physicists” is unfair and vague. True, both were conversant with the latest in theory and phenomenology, but so were others. Also, it is well known (and I have personal testimony) how much Heisenberg appreciated Dirac and Jordan, to mention just two; the same is true of Pauli.

LUIS J. BOYA

(luisjo@posta.unizar.es)

University of Zaragoza

Zaragoza, Spain

SCHUCKING AND VON MEYENN

REPLY: Yes, indeed, it was at the Solvay Conference in 1930 that Bohr reminded Einstein of his elevator. How the wrong date crept into our manuscript baffles us still.

Kurt Gottfried is surprised that Pauli thought of Dirac as a formalist. Dirac was a formalist. He wrote in 1931: “The most powerful method of advance that can be suggested at present is to employ all the resources of pure mathematics in attempts to perfect and generalize the mathematical formalism that forms the existing basis of theoretical physics, and *after* each success in this direction, to try to interpret the new mathematical features in terms of physical entities.”¹

We disagree with Gottfried’s characterization of the Pauli equation for the electron as merely an elegant restatement of a Heisenberg–Jordan paper. Paul Ehrenfest wrote on 25 March 1931 about the Pauli equation: “This work has become very important. It has opened the way to Dirac’s ingenious work on the spin-electrons and probably also to Heisenberg’s famous work about the helium spectrum.”² Pauli introduced *spinors* into quantum mechanics and thus—in hindsight—made the step from two to four components not such a giant leap.

We agree with Gottfried that the golden rule³ is due to Dirac. When

Pauli derived this equation using Dirac’s time-dependent perturbation theory, he analyzed its domain of validity using the uncertainty relation for time and energy that he had first pointed out in a letter to Heisenberg. Apparently, Pauli and Heisenberg⁴ had first thought that Dirac had “gemogelt” (cheated) in its derivation.

We both cherish Dirac’s beautiful physics, but his approach to theory was different from Pauli’s or Heisenberg’s. By praising Galileo, one does not demean Kepler.

On Dirac’s comment about Schrödinger, we stand corrected. Luis Boya also may have a point on vacuum degeneracy. But Pauli’s crucial role in the Heisenberg theory still needs clarification. There are 144 letters from the correspondence between Pauli and Heisenberg in 1957 and 1958, up to 30 pages in length, which still await analysis.

With regard to the early history of quantum field theory, we agree that much more could be said about it, and we refer Boya to Tian Yu Cao.⁵ For the history of nuclear magnetism, we suggest that Boya might consult Hendrik Casimir.⁶

Boya remarks that Heisenberg “never tried using his newborn matrix mechanics to solve for the hydrogen spectrum.” On 3 November 1925 Heisenberg wrote to Pauli: “After your first letter, I had also tried at once the calculation in three dimensions and was busy just this afternoon with the evaluation of the last equations and the elimination of the many possible mistakes in calculation when the postman entered and made my work superfluous.”⁷ The postman had brought Pauli’s three-dimensional calculation for the H-atom. We believe that Boya underestimates the role Pauli played in the dialogue with Heisenberg and that a careful reading of their correspondence supports our view. Freeman Dyson, with his unique insight into physics and the ways of physicists seems to agree with our assessment.

Finally, we thank Gottfried, Boya, and Dyson for their comments.

References

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5. T. Y. Cao, *Conceptual Developments of 20th Century Field Theories*, Cambridge U. Press, New York (1997).
 6. H. Casimir, *Haphazard Reality*, Harper & Row, New York (1983); appendix B, p. 322.
 7. See ref. 4, p. 252.

KARL VON MEYENN

Ulm University

Ulm, Germany

ENGELBERT L. SCHUCKING

(elschucking@msn.com)

New York University

New York City

Ailing Russian Scientist Jailed

As chair of the Committee on the International Freedom of Scientists of the American Physical Society, I am writing to alert our community to the situation of a fellow physicist in Krasnoyarsk, Russia. CIFS is charged by APS with monitoring the rights of physicists and other scientists around the world.

Recently, CIFS learned that Valentin Danilov, head of the Thermo-Physics Center at Krasnoyarsk State Technical University, had been arrested and incarcerated in February and charged in April with selling state secrets to a Chinese company. According to quotes from Russia's Federal Security Service in a Reuters news article, Danilov's relations with this company have "allowed foreign countries to significantly cut the amount of time and money spent on the development and creation of spacecraft."

Danilov was, in fact, the signatory for a legal contract between Krasnoyarsk State Technical University and the Chinese company to create a model to predict the effect of the electromagnetic environment on satellites. Danilov has done significant research in this area, and this work was declassified by the Russian government in 1992. Researchers in the US and Russia with whom Danilov has collaborated indicate that the information provided under this contract has for years been readily available in the scientific literature, including meeting abstracts and materials published by APS. It is difficult for CIFS to understand how Dr. Danilov could be accused of disclosing "state secrets" when our Chinese colleagues have had access to the same information for almost a decade through publicly available scientific literature.