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# ON GIULIO RACAH

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Giulio RACAH (Firenze, Italy, 9-II-1909; Firenze, 28-VIII-1965) was a remarkable italo-israeli theoretical physicist. He graduated in Physics in Firenze in 1930, studied after under Enrico Fermi in Roma, being nominated Professor of Physics in Pisa in 1937. But in 1939, due to the racial laws imposed upon Mussolini by Hitler, he had to emigrate to Palestine, at the time under British mandate, but after 1948 the actual state of Israel (Fermi himself, after receiving the Noble Prize, settled in the United States).

In Jerusalem he was professor of physics, and eventually Dean of the Faculty of Science and later became Rector of the Hebrew University (founded in the 1920s, Albert Einstein himself was involved in the creation), and acting President. He was instrumental in converting the Hebrew University in a first class institution for modern science, as it is still today.

Giulio Racah was rather active politically, and fought very much for the cause of Israel state: from 1942 until 1948 he belonged to the Haganah (Defense), a paramilitary organization which was instrumental in abolishing the British mandate and establishing the actual state of Israel en 1948. Racah also participated as a soldier in the 1948 and 1956 wars against the arabs. He did frequent visits to the US, and in several of them he stayed at Princeton.

In 1958 he received the Israel Prize in exact sciences for his ever-lasting contributions to Physics, mainly in the domain of atomic and nuclear spectroscopy. In 1965, in a trip from Jerusalem to Amsterdam, he stopped in his family home in Firenze and unfortunately died in a domestic gas-escape accident.

The great transcendence of his research was the clarification of complex atomic spectra, for what he developed some techniques which are used very much even today; he started first with "open shell" atoms (incompletely filled last electronic shell in complex atoms, starting with 3d (Fe) row): the techniques that Racah introduced to study these complex atomic spectra are standard today. Then, he was the first to attack the very complex spectroscopy of lanthanides, those atoms with the 4f shell filling (14 elements). His four papers in Physical Review, covering

the period 1942-49 are landmarks: they are reproduced, for example, in the Reprint volume by Biederharn [1]. In a way, the so-called "Racah algebra" is a continuation of the Wigner coefficients (ca. 1930) to combine angular momenta. Group theory was first employed in Quantum Mechanics by H. Weyl and E.P. Wigner in the "heroic" period around 1926. Three books (a third one by B. L. van der Waerden) testify this, and run through several editions.

Racah introduced also generalizations like "coefficients of fractional parentage", the seniority quantum number (vethek), very much used ever after both in atomic and in nuclear spectroscopy. In 1960, the Italian Physical Society, which organized annual summer schools in Varenna (in the shores of the Como lake), organized a course: Racah was the director of the summer course on "Nuclear Spectroscopy", in June, 1960 (that I attended), and I still remember his lectures, with a strong German accent, by Racah himself: "neutrons" he pronounced "noitrons", similar to German; the proceedings were published by the Italian Physical Society [2]. Racah was settling the with his whole family, including his beautiful daughter Erella, who unfortunately also died pretty young.

His spectroscopic techniques were later published as a book which became a classic, entitled Irreducible Tensorial Sets, with his collaborator Ugo Fano [3].

In 1952 G. Racah gave some lectures on Lie groups in Princeton, published later as a CERN yellow report [4]: it is a fact that these lectures introduced the average theoretical physicist to the importance of Lie group theory for physics. When in the following decade (60) Murray Gell-Mann developed the SU(3)-flavour model group for strong interactions, physicist were convinced that a knowledge of this particular branch of modern mathematics have to be included in the curricula of the average theoretical physicist... and that is the case nowadays... Historically these studies were preceded by the very important work of E. P. Wigner (1939) on the unitary representations of the Poincar group to classify the elementary quantum system (elementary particles), which to day it is incorporated as a first chapter on books on Quantum Field Theory (e.g. S. Schweber [5], S. Weinberg [6], etc.).

The scientific contributions of G. Racah were not exhausted with spectroscopy; back in the 30s, working with the group of Enrico Fermi in Rome, Racah also made contributions to the operator C, for Charge conjugation (particle-antiparticle) ... in relation with spinors and in general fermions. In the fifties, Schwinger, Pauli, Lüders and others applied the results of Racah to prove the all-important "CPT" theorem, which says: from the continuous Lorentz invariance (Poincaré invariance, really), with locality and other plausible assumptions, one has CPT invariance, predicting particle-antiparticle would have equal masses and lifetimes; this has been checked so far successfully many times (see, e.g., the Tables of Particle Properties, published in Phys. Rev. and in Phys. Lett. every two years [7]). Racah also attempted to understand renormalization in a paper of 1946, which however was somewhat controversial.

Perhaps the most ever-lasting contribution of G. Racah to physics was the foundation of the Israeli school of Theoretical Physics, still flourishing today, with people like H. Lipkin, U. Fano, I. Talmi, Issachar Unna and others. One of most brilliant successors is Nathan Seiberg, actually

Professor in Tel Aviv University, which with E. Witten has revolutionized string theory. Today, the department of Physics of the Hebrew University holds the Racah Institute for Theoretical Physics.

To celebrate the Centenary of his birth in 1909, several Conferences were organized. We refer here only to two of them. In February 22-24, 2010, The "Academia de Ciencias de Zaragoza" sponsored one, with Luis J. Boya (University of Zaragoza) and Rutwig Campoamor-Stursberg (U. Complutense, Madrid) as organizers; we had the support of the "Fundación Ramón Areces" from Madrid. Among the foreign invited people we cite: I. Unna and S. Elitzur from Jerusalem, the latter being now the Director of the Racah Institute in the Hebrew University; P. van Isacker from the GANIL in Caen, France, M. Kibler from Lyon, France, F. Iachello from Yale University, USA, and H. de Guise from Lakehead, Canada. The cited "Academia de Ciencias de Zaragoza" is currently processing the Proceedings.

A second Conference was organized by the Hebrew University, Jerusalem itself, in June 6-8, 2010, under the title " Symmetry in Physics Research", and it took place in the "Maison de France" on the Safra Campus at Givat Ram, Jerusalem; LJB participated also in this Workshop; among the notorious speakers we must mention F. Iachello, I. Unna, again, N. Zeldes, Nathan Seiberg, Alain Aspect, etc. Also, a joint meeting in the Literary University at Mount Sion took place, attended by some of Racah's sons, and it was very profitable.

## References


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