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GIULIO RACAH: THE MAN AND HIS WORK

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Abstract

An introduction to the Giulio Racah Centennial Conference. Racah's life and his achievements will be presented. Special attention will be devoted to Racah's contributions to nuclear spectroscopy. Some results induced by and obtained with his methods by I. Talmi and I. Unna will be presented.

This conference celebrates the centennial of Giulio Racah. I am very honored and have the great pleasure to thank the organizers of this conference in this wonderful place. In particular, I want to thank Professor Luis J. Boya and the RAMON ARECES FOUNDATION. By the way, Prof. Boya and I are also celebrating the Jubilee of our first meeting in another beautiful place. In Varenna, 1960, the International summer school "Enrico Fermi" was devoted to "Nuclear Spectroscopy". Racah was the "Direttore del Corso", Nissan Zeldes was the "Secretario Scientifico". Racah gave the course on "Mathematical Techniques", since, as he said in his opening words, "I am more familiar with the mathematics than with the physics of nuclear spectroscopy". My Thesis adviser and Racah's devoted pupil, Igal Talmi, gave "The Nuclear Shell Model". Igal celebrated now his 85th birthday, full of vigour and activity. Unfortunately, he could not come today because he is the organizer of a conference at the Weizmann Institute at exactly the same dates.

The opening of the Hebrew University took place in 1925. At about the same time Quantum Mechanics was born.

For fifteen years, since its opening, the Hebrew University was desperately looking for a good theoretical physicist who was ready to teach and do research in it. Albert Einstein was consulted on an almost daily basis. Several giants were seriously approached and on the verge of agreements, like George Placzek, Felix Bloch, Fritz London and Eugene Wigner. All these efforts failed.

All these fifteen years Quantum Mechanics, with all its successes, was completely impotent in dealing with atoms having more than 2 active electrons, which meant that most atomic spectra could not be explained with the new theory.

Then appeared Racah, a bright young physicist (age 30) from Italy, full of theoretical vigour, and a determined Zionist, and filled the empty position at the Hebrew University as well as the existing void in Quantum Mechanics, like the last missing piece in a jigsaw puzzle completing the picture in all directions. Racah arrived at the Hebrew University in 1940 (after the outbreak of WWII). He had excellent reference letters by his beloved teacher, Enrico Fermi, and also by Wolfgang Pauli, Niels Bohr, Kramers and Fritz London. Fermi wrote:

"Of the cadidates you mentioned I can provide information only on Prof. Racah. I knew him very well... he worked with me for some time in Rome. I could therefore appreciate [his] really outstanding knowledge of physics, and follow very closely his interest in scientific work. His contributions to the quantum theory of radiation are particularly valuable. I have to mention that he arrived independently and almost simultaneously with Bethe and Heitler at the same results concerning the emission of radiation by high-energy electrons. May I be allowed to add, that in my opinion Racah possesses all the personal attributes to lead most effectively young students in scientific work."

(Fermi, 8 September 1939)

In 1951 Racah writes from Princeton to the rector of the Hebrew University:

"I went to visit my Rebbe - Fermi. I did not write so far because I was busy with discussions (and small talk). After all, these were the main purpose of my trip. Doing work I can much better at home in Jerusalem, at least late at night when there are no committee meetings..."

(Racah, 29 January 1951)

Pauli wrote:

"I know him personally, and know his works well. An extraordinary mathematical talent, and in perfect command in any problems and methods of modern theoretical physics (wave mechanics and quantum electrodynamics) .... He succeeded in solving problems which deterred others (the creation of pairs as a result of the collision of fast charged particles with atoms, and also the computation of the radiation of very fast particles ...) problems which are at the core of the most modern theories of cosmic rays . . . and therefore he is qualified also to cooperate with an experimental research institute. He is also extraordinarily conversant with questions of principle .... In conclusion, I do not know a candidate more suitable for a professorship in theoretical physics in Jerusalem than Prof. Racah. As regards [Reinhold] Furth (Prague) [who also was under consideration], he is undoubtedly a good craftsman particularly in the area of Brownian motion, but he is less original, and of weaker attitude to modern physics."

When Racah arrived in Jerusalem in 1940 he had to cope with a new country, new culture, new language, and with complete scientific isolation. Yet, he called the year 1940 "The best year of my life". During this year he learned perfect Hebrew [but even speaking Hebrew he never lost his heavy musical Florentine accent], he married his loving girl Zmira Mani, daughter of a well rooted Jewish-Palestinian family and he wrote his first paper, of the famous four, on the "Theory of Complex Spectra".

The work on these papers was accomplished in complete seclusion from the scientific world. And these papers made his fame. They contain what is now known as the "Racah Algebra". The second paper was included in the "Physical Review Centennial Volume" (1995), which contains the 200 most important articles in a hundred years. Racah's papers were also on the short list of the most cited papers in the 1950s. Hans Bethe in a review of the centennial volume writes:

"The paper by Giulio Racah ["Theory of Complex Spectra"] gives everything the theorist needs to work on the subject."

The content of these papers is now part and parcel of every advanced textbook in Quantum Theory. Racah was a prominent figure, very dynamic and full of vigour. Each of his classes, or even an eventual conversation in the corridor (never gossip or nonesense) was an unforgettable experience. He was an excellent teacher. I had the great privilege to aquire the whole base of physics – classic and modern – from him in his courses. Beginning with classical mechanics and electrodynamics, ending with QED, atomic spectroscopy and nuclear physics. The most devoted pupil and assistant of Racah was Nissan Zeldes, who was invited to give this talk, but was, unfotunately, unable to come. He published recently a big article in the "Archive for the History of Exact Sciences" [63, 289-323, (2009)]: "Giulio Racah and Theoretical Physics in Jerusalem" [I helped with the final editing of it]. Another relevant reference is my paper in "Physics in Perspective" [2, 336-380, (2000)] : "The Genesis of Physics at the Hebrew University of Jerusalem".

My thesis advisers were Igal Talmi and the late Amos de-Shalit, his world known pupils. But they were at the Weizmann Institute, Rehovoth, and I was still studying in Jerusalem. So I went to get advise from Racah whenever I got stuck with my calculations in nuclear shell theory. Later I learned that my questions motivated Racah to further developments of his theory in nuclear spectroscopy.

I shall not forget our excitement as students before each of his lectures. We were fighting for good seats in the lecture hall. Indeed, the lectures were masterpieces of clarity in content and presentation. With typical stubbornness he insisted on carrying out each calculation from start all through to the final results. The complicated expressions were written in perfect order, line after line, on the big blackboard. It could be the form of a hanging chain in classical mechanics, the detailed solution of a differential equation in quantum mechanics or calculating the refraction coefficients of light directly from Maxwell's equations. He did not omit any stage of the calculation. It was never "it easy to see" or "you can easily verify"

When he published his book together with his cousin Hugo Fano, "Irreducible Tensorial Sets", he told me that he and Fano had lots of fights over the book. I asked him why. He answered that "The reason was that we had a common grandmother who was very stubborn"

Indeed, stubbornness was a typical virtue of Racah, in the good sense of it. When he decided to carry out a calculation - nothing could stop him, even if it turned out to be very lengthy and extremely complicated. That is how he succeeded in calculating his coefficients and developing his algebra during long lonely nights.

Racah was a good friend with us, students, and showed his friendliness in so many ways. I remember, in particular, traveling with him, in his car from Jerusalem to seminars in Rehovoth. He invited us to join him and we felt honored and excited. During the trip we had lengthy talks, usually on scientific subjects. When he got excited during a discussion he would talk with both his hands in the air, and we trembled till his hands returned to hold the steering wheel. He showed high involvement in our students' life. He joined us in parties and volunteered with us in going to the country to build fortifications around isolated settlements. He arrived in a labourer's shirt, shorts and a big sun hat and was amongst the best workers out there. From time to time we could hear talks on better angular momenta coupling modes or new checks of matrix diagonalization programs coming out from one of the deep ditches, accompanied by the sounds of digging ploughs and spades.

A few years before his untimely death he had a car accident on his way to Eilath. Talking about it, he said he has an accident once every 20 years. He is glad he survived this one unhurt. Next time he will be old so he has nothing to be afraid of. It seems, this was his greatest mistake. At the age of 56 an accident of a different kind took his life when he was still full of vigour and abounding with plans.

Five years after his death the "Racah Institute of Physics" was established at the Hebrew University. In the same year a crater on the moon was officially named after him. In 1993 the State of Israel issued a post stamp with his portrait. Streets in Jerusalem and Beer-Sheva carry his name.

Racah is also remembered for many public activities at the Hebrew University,as well as nation-wide and international. Let me mention a few. He was member of commissions on standards and spectra by the International Astronomical Union, and IUPAP (later also IUPAC). The Joint Commission for Spectroscopy set Jerusalem as the clearing house for angular wave functions, giving all the information on the related calculations carried out worldwide so as to prevent overlapping activities. Thus, the theoretical physics department in Jerusalem became a world center for atomic spectroscopy. In his last years (1961-1965) Racah served as Rector and President of the Hebrew University. In this position he promoted the teaching of courses for students from African and Asian countries. He had the privilege to convocate a honorary degree on Haim Weizmann, the big Zionist leader, founder of the Hebrew University and the first Peresident of the State of Israel. Later he honored Felix Bloch with the Honorary Degree of the University.

He was amongst the founders of the Israel Academy of Sciences (1959). He served as member of the Scientific Council to the Prime Minister (later - the National Counsil for Research and Development) and was a member of Israel's Atomic Energy Commission. As such, he served as delegate to the Geneva International Conferences on the peaceful uses of atomic energy.

In 1961 he was convocated Doctor Honoris of Manchester University. The ceremony took place at the Rutherford Jubilee International Conference (celebrating 50 years to Rutherford's discovery).

I was fortunate to attend it. Many of the greatest physicists were there. Niels Bohr, Dirac, Peierls, Aage Bohr, Mottelson etc. I remember Niels Bohr, dressed with big blue garter of the "Order of the Elephant" dancing at the evening party. Racah received many honors and prizes during his academic life including the prestigious Israel Prize.

As mentioned, Racah applied most of his mathematical methods to atomic spectra. He felt that there were not enough nuclear spectroscopic data available for reliable calculations. But his interest and theoretical ideas were gradually shifting to the nuclear regime. The establishment of the nuclear shell model was a crucial step and motivated his ideas. His students Zeldes, de-Shalit, Talmi and others took over the torch into the nuclear spectroscopy. Zeldes specialized in nuclear masses. He and the others took shell model calculations to their real great sucesses. This was the time when I entered the scene (1958).

In the year 1944 Racah gave the major talk at the Israel Chemists Organisation. The title was: "Introduction to Nuclear Theory". At the end of his talk he said: " If it is true that new neutrons are emitted upon the explosion of Uranium induced by neutrons then we might obtain a chain reaction. If this was achieved I do not know, since from the beginning of the war this kind of information is kept secret" . He then spoke about the difference between slow and fast neutrons and the possible necessity of separating the U235 component. "But", he ended, "we shall have to wait till the end of the war to know where the nuclear science stands."

On the 18th December 1945 he gave again a talk at the same forum: "New Developments in Nuclear Theory". This talk was post Hiroshima and it dealt with the new knowledge attained ("although, a lot is still kept secret", as he said). Ten years later I attended the course on Nuclear Theory given by Racah for a whole semester. But his mathematical methods I learned in his course on Atomic Spectroscopy as well as by attending his seminar on Selected Topics in Atomic Spectroscopy. Here I discovered how much we can achieve in analysing spectra without making detailed assumptions on the form of the interaction. Actually, this is exactly what the Racah Algebra helps us do. In his atomic calculations the few Radial integrals are kept as parameters and the quantum predictions are made purely by applying Racah's algebraic and group theoretic methods to the angular parts of the wave functions.

These methods become even more important in nuclear spectroscopy where the basic interaction is unknown a priori. The assumptions we make in our caculations are minimal. All we assume is that the nuclear interaction is a two body interaction, and that it does not change with the addition of nucleons so long as we are confined to a single nuclear shell. Thus, we could use the two particle spectra, applying Racah's methods to calculate the spectra of n particles in the same open shell.

Some of Racah's inventions for efficient atomic calculations are even more spectacular in the nuclear context. In paticular, the concept of the seniority quantum number and the use of sophisticated Lie groups for the analysis of nuclear spectra. The seniority is first introduced in his TCS III paper (1943). Explicit use of group theory appears first in TCS IV (1949), where Racah caculated f^n configurations. In this paper he also proves a very useful lemma. A much more systematic exposition of Lie groups and their application to spectroscopy was given in a set of lectures delivered in 1951 at the Institute for Advanced Study in Princeton. [here, Racah also met Albert Einstein for the first time.]. These important lectures were written as notes by Eugen Merzbacher and David Pank. For years these notes were so hard to get that they almost became collectors' items. Ten years later, by a lucky chance, a copy was uncovered in CERN. With Racah's permission they mimeographed it for the benefit of a wider audience. Later the notes appeared as a book in the Springer Lecture Notes series.

In a small and quite unknown paper [L.Farkas Memorial Volume, Research Council of Israel, 1, 294-304 (1952)] Racah transferes his methods specifically to nuclear jj-coupling spectra. Here, as it turns out one has to use the Symplectic group instead of the Orthogonal group. This group was first introduced by Herman Weyl in his Classical Groups (Princeton, 1938). This group leaves a skew- symmetric bilinear form invariant. This is necessary because the scalar two-body wave function, the $j^2 \quad (J = 0)$ is antisymmetric contrary to the $l^2 \quad (L = 0)$ case. This group gave a very efficient tool in calculating j^n spectra. We (Igal Talmi and myself) were able to obtain some excellent fits with experimental data. The first good case was the binding energies of nuclei with $1f_{7/2^n}$ configurations (neutrons or protons) [I. Talmi, Phys. Rev. 107, 326 (1957)]. Even more exciting was a result we obtained for ^{11}Be. Using the the simplest Racah methods we confirmed its positive parity ground state, which was contrary to what everyone believed [I. Talmi and I. Unna, Phys. Rev. Letters, 4, 469 (1960)]. In spite of its apparent simplicity, this was an exact shell model calculation. Good reviews of the methods and of our results can be found in: I. Talmi and I. Unna, Annual Rev. Nuclear Sci., 10, 353 (1960) and I. Talmi, Revs. Mod. Phys., 34, 704 (1962). The latter summarizes many of my early works on nuclear spectroscopy.

Later, I did some basic work on applying BCS , RPA, second RPA and HF to nuclei and dealing with the eliminations of spurious states [see, for example, Spectroscopic and Group Theoretical Methods in Physics, Racah Memorial Volume, edited by F.Bloch / S. G. Cohen / A. De-Shalit / S. Sambursky / I. Talmi (Notrth Holland 1968), p. 403]. Now, I do history – mainly working with the huge editorial project of editing the writings of Einstein, the EPP, Caltech, Pasadena, and, believe me, working on Einstein's correspondence and unpublished material we make a lot of exciting discoveries.

Thank you!.