Views of an Octogenarian on a Path to a Nonagenarian: The Field of General Symmetries and its Applications

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Abstract. I am on the path from my eightieth to my ninetieth birthday, or from an octogenarian to a nonagenarian. It is certainly encouraging to have opportunities on this path to talk about personal recollections and my views on my work and activities towards the development of the field—our field—of understanding and applying models in physical and related sciences based on the infinite set of mathematical notions of symmetries in their most general sense and with all their facets. I plan to talk today about the first part of my path in my native city Berlin, followed by the University of Marburg and jointly at the International Centre for Theoretical Physics in Trieste.

1. Part 1
I was born in 1931 at the beginning of a period with a dictatorial national socialist government in Germany with a racist dictator, who occupied, attacked, or tried to dominate neighboring countries, with the consequence that England, Russia, France and the USA built a coalition against Germany to deprive the dictator of his power. World War II resulted and ended in 1945 with the German capitulation and its occupation and partition into four zones, three of them with governments similar to those in western countries—which became later West Germany—and one zone with a socialist government—the GDR (East Germany)—which was much later incorporated into West Germany to form “Germany”.

I mentioned this backdrop because it is obvious that in a given country and at a given time the development and growth of a generation is linked to the living conditions and the political system. These interaction between generations in development and the general life conditions influenced both sides. A world war in this country was a singularity for both evolutions.

For my generation, this singularity produced an unwelcoming and unfriendly atmosphere, full of doubts, which cannot be compared to the situation of the present generation which is living in a peaceful, democratic, and rich country.
However, the influence of the singularity gradually weakened after Western and, with restrictions, Eastern governments were apparently successful in establishing in Germany’s four zones similar democratic structures with living conditions which were not bad.

These developments could be viewed as the instinctive background for the future activities and revival of the sciences in Germany—including physics and mathematics—documented in some curricula of scientists from the mentioned generation.

2. Part 2
In 1948 I finished my secondary education in the British zone of West Berlin. Influenced by my schoolteacher of physics and mathematics, I read books for students in physical chemistry and chemistry. The existence of atoms and their behaviour touched my mind deeply and convinced me to study and work in this field and their mathematical and physical structure.

At that time there were two Universities in West Berlin: the newly founded Free University and the older Technical University.

I applied already in autumn 1948 to both universities but my application was not taken into consideration: a group of German World War II prisoners still in custody in Russia was released that year following an agreement between the German chancellor Adenauer and the Russian government. Former students in this group were directly admitted to continue or to begin their studies after their arrival in Germany. So I had to wait until the next year and worked in the meantime as a kind of assistant in a government Institute for Material Testing where I measured e.g. the detonation velocity of explosive gas mixtures and dust clouds.

I applied again. My applications were accepted, I was asked to write a text to explain why I was interested in studying Physics and was invited for an interview with a Professor from the Department of Physics.

I explained in my text and interview that I wanted to study Physics to learn—among many other things—about three problems:

1. why does our configuration space have 3 dimensions;
2. why is the Newton equation of motion a differential equation of second order;
3. why does the 1/r potential appears in two physically different systems as gravitation and electric force.

I remember the reply of the interviewer: the questions are reasonable and interesting and answers will be discussed in theory classes for Diploma and PhD students, not in classes for beginners. I would have to wait a little. To prepare for a successful start I would have to study first physical experiments and effects together with the mathematical notions used for their modelling. After the Diploma I should look for a PhD thesis contributing to the foundations of physics.

I was a little bit disappointed with his answer. I realized afterwards that obvious and simple physical questions could have complex and counterintuitive answers and that these answers require the necessary knowledge in physics and mathematics. To catch a glimpse of the structure of the universe or introduce new mathematical notions for models in particle physics with observable effects is very difficult and depends on knowledge, vision, ideas, intensive work, and luck.
Please allow me in this talk a short side remark as the last comment could be misunderstood. There are many reasons why communications explaining the complexity of big structures built from many interacting objects are beyond our ability as human beings.

3. Part 3
The Free University accepted me as student of physics. I wrote a diploma thesis at the Institute for Theoretical Physics on nonlocal field theories with Prof. G. Ludwig and continued in 1962 with a PhD thesis on relativistic quantum field theories. I had a position as research and teaching assistant. In 1963 Ludwig moved to the University of Marburg and I followed him with a permanent academic position. The International Centre for Theoretical Physics in Trieste (Italy), director Abdus Salam, offered me in 1964 the status of a guest scientist. The administration proposed a joint position in Marburg and Trieste. I filled this joint position until I accepted in 1970 a call for a chair at the Institute for Theoretical Physics at the Technical University of Clausthal. Since 1999 I have been granted emeritus status.

4. Part 4
During the sixties and seventies, i.e. about 1960–1970, the traditional formulation of compact and non-compact groups, Lie-algebras with their linear representations, were hot topics and of high interest in theoretical and mathematical physics. Experiments e.g. in molecular and solid-state physics, atomic, nuclear, and medium energy particle physics, could be interpreted, understood, and calculated in non-relativistic quantum mechanics with the help of this well-known group theoretical machinery.

A research team in Ludwig’s Institute followed these trends with the awareness of Ludwig’s interest in the foundations of quantum theory.

The team refreshed and improved their group theoretical knowledge, e.g. based on the information available in many lecture notes and in informative reviews which were on the market. I published with my student G.C. Hegerfeld a first contribution of this team in 1964 on the application of group theory to particle physics, ‘Remarks on omega-phi and octet-octet mixing,’ followed by contributions in different group theoretical topics together with my PhD students; I mention Arno Böhm, Olaf Melsheimer, J.-D. Hennig and W. Lücke among others and publications on embeddings and extensions of external and internal symmetry groups, group contractions, dynamical groups and their limits, domain questions for integrable and non-integrable Lie algebra representation, and properties of linear representation.

5. Part 5
During this time the Centre for Theoretical Physics was a maximal accumulation point for research on a group theoretical approach to the quantum theory of relativistic particles with an orientation on nonrelativistic systems and its group theoretical machinery.

As a German Guest Scientist with a joint position in Marburg and Trieste, I was fascinated by the spirit and aim "to push the frontiers of knowledge forward" (as Salam said) using intuition and hard work and on the successful and systematic cooperation with colleagues from different countries. At that time we felt that we understood at least parts of a path into “unknown territories”.

However, after many experimental and theoretical studies, it became obvious that a traditional group theoretical approach can cover only a small part of the reality of particles.
In the seventies and the early eighties, the interest e.g. in \( \text{su}(n) \) and \( \text{U}''(12) \) slowly cooled down and quantum field theory took for some time the leadership in theoretical particle physics with other mathematical notions and methods.

6. Part 6

Some fellows in Trieste, coworkers in Marburg and later in Clausthal, including myself, thought that groups, with its strict rules, are not flexible enough to model the physical behaviour of particles. There was (and is) an interest in constructing models with elements ‘beyond’ groups that have some properties which are observable and behave ‘similar’ to groups and algebras while other properties need new physical interpretations and corresponding quantization schemes to control the numerical results of measurements of all observables. The model has ‘generalized symmetries’ and represents a notion ‘beyond groups’ (and quantization).

There are many candidates for such models. I mention three algebraic attempts:

I. Superalgebras are obviously notions ‘beyond groups’. They have linear representations in a reasonable function space with a particle structure as physical property.

II. Kinematical algebras on n-dimensional smooth manifolds, as well as diffeomorphism groups of n-particle systems in \( \mathbb{R}^3 \) are infinite-dimensional objects that can be catalogued as notions ‘beyond groups’. Both structures admit linear representations, up to unitary equivalence, through a new quantum number which enforces and parameterizes the nonlinear evolution of systems as a physical property.

III. Non-integrable representations of Lie algebras on a dense domain in a Hilbert space are by definition objects ‘beyond groups’ and lead to domain dependent evolutions as a physical property.

In this context, quantum groups should also be mentioned as a special case of notions beyond Lie-groups and -algebras, their deformations and noncommutative co-multiplications with e.g. applications to additive quantities in quantum mechanics.

Another attempt is the Wigner quantization from 1950 which starts with relations between formal position and momentum operators on function spaces over an unspecified environment—not the Heisenberg relations in local coordinates in \( \mathbb{R}^3 \)—and generate (through the mentioned relation) an explicit form of position operators and a realization of the originally unspecified environment. Wigner quantization is therefore a method ‘beyond groups’. Together with T. Asselmeyer-Maluga a formulation of Wigner’s method is in preparation.

7. Part 7

Examples I.–III. show the disadvantage of our efforts to introduce flexibility in partly successful theories. A physically motivated and convincing model for a theory ‘beyond groups’ for a big class of systems has been—up to now—only successful in special cases.

I regret this fact from a physical viewpoint, but from a mathematical one I like the ideas and results of model building. I remember mathematical notions, e.g. quantum groups, which were at first sight convenient for a reasonable model, but it took time and motivation to become familiar with their elaborated details and it is not apparent how to apply them to a physical problem. Certainly, on the one hand it is inspiring to realize a kind of harmony between a mathematical model and the real properties of a successful physical model but on the other any disharmony is a little disappointment.
With presumably not yet known mathematical notions and a new vision to formulate observable quantities our field will develop successfully. Maybe these notions will belong to the generalized symmetries which I mentioned in the beginning of my talk.

This is the end of the first part of my scientific path.

For further accomplishments of Professor Doebner see also:
Festschrift on the occasion of his 60th birthday: J.D. Hennig, W. Lücke, J. Tolar (Eds.) Differential Geometry, Group Representations and Quantisation, Lecture Notes in Physics, vol 379 (1991) with contributions of E Binz, J.J. Slavianowki, J. Sniatycki, U. Uhlmann, G.C. Hegerfeld, J. Kijowski, L. O’Raifeatairgh, R.Razka, I.E.Segal, S. Twareque Ali and G. A. Goldin, J. Tolar, L.C. Biedenharn, A. Bohm, V.K. Dobrev, A.O. Barut, Y. Ne’eman, Th. Görnitz and C.F. v. Weisäcker.
L.L. Boyle Physics of Atomic Nuclei, 71, 777 – 779.
Contributions Journal of Physics, Conf Ser. 343 (2012) of L.L. Boyle in 012002, J.P. Gazeau in 012003, Reidun Twarock in 012004, S. Twareque Ali in 012005, G. A. Goldin in 012006, A. Aizawa, V.K. Dobrev in 012997.