Remembering David J Rowe

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December 16, 2022

34th International Colloquium on Group Theoretical Methods in Physics
Strasbourg, 18-22 July 2022
doi:10.21468/SciPostPhysProc.?

David Rowe: Totnes, 4/02/1936 — Toronto, 8/05/2020

David Rowe was a highly respected theoretical physicist who made seminal contributions that improved our understanding of the atomic nucleus, in particular of the collective behaviour of its constituent nucleons—results he often obtained with the use of sophisticated group-theoretical methods. He will also be remembered as the (co-)author of monographs on nuclear physics, written with the scientific rigour that was characteristic of his research.

David Rowe was born in Totnes, United Kingdom, on February 4$^{\text{th}}$ 1936 and went to school in Kingsbridge. He did his undergraduate studies at the Universities of Cambridge and Oxford and graduated at Oxford University with a PhD in nuclear physics.

David's scientific career started with a study in experimental nuclear physics [1] but quickly his attention shifted to theoretical physics, where it stayed for the rest of his life. Three post-doctoral stays turned out to be of crucial importance in the forging of his scientific interests.

The first was in 1962/63 when he was a Ford Foundation fellow at the Niels Bohr Institute in Copenhagen, at the forefront of research in nuclear physics at that time. This post-doctoral stay no doubt must have laid the foundation of his life-long interest in the collective behaviour of nucleons in the nucleus. From 1963 to 1966 David held a post-doctoral position at the Atomic Energy Research Establishment at Harwell in England. There also he thrived in a stimulating intellectual environment where important advances in theoretical physics were made by John Bell, Phill Elliott, Brian (later Lord) Flowers, Tony Skyrme and others; during that period he interacted in particular with Tony Lane. His third post-doctoral stay took place at the University of Rochester in the USA, where he benefitted from the presence of Bruce French who was, among other things, an expert in the application of group theory in physics.

From 1968 onwards he held a permanent position, first as an associate and later as a full professor, at the University of Toronto, where he remained for the rest of his career except for two sabbatical leaves at the University of São Paulo (Brazil) and the University of Canterbury (UK). He was Associate Dean of the School of Graduate Studies in Physical Sciences from 1984 to 1987. For his contributions to theoretical physics he received the Rutherford Memorial Medal and Prize of the Royal Society of Canada in 1983, the CAP/CRM Medal and Prize for Theoretical and Mathematical Physics in 1999 and was elected a Fellow of the Royal Society of Canada in 1986. In 1998 he retired and became emeritus professor at the University of Toronto. Freed from teaching and administrative duties, he could devote more time to research and continued to develop new ideas in theoretical physics until the final days of his life.

A central aim of David's scientific activity at the beginning of his career was to arrive at a microscopic understanding of the collective model of the atomic nucleus. This model, proposed in the 1950s by Aage Bohr and Ben Mottelson, describes nuclear states in terms of vibrations and rotations of a quantised droplet of dense nuclear matter [2]. While this interpretation met with a certain success when confronted with spectroscopic data known at that time, a microscopic understanding of the approach was lacking. That is, its connection with the nuclear shell model, which describes the nucleus in terms of its constituent neutrons and protons, was not well understood. At the time when David began pondering this question (mid-1960s), one important breakthrough had been made by Phil Elliott [3, 4], who had shown that rotational states can be realised in the spherical shell model on the basis of an SU(3) (dynamical) symmetry of the nuclear Hamiltonian. Nevertheless, an embedding of the collective model into the shell model, *i.e.*, the formulation of the collective model as a submodel of the shell model, had not yet been achieved. Inspired by Elliott's earlier work, David realised that group theory would play an essential role in establishing this connection since both the shell model and the collective model have an algebraic structure. He also realised that earlier attempts, where the observables are shape coordinates of the nuclear surface and their associated momenta, cannot lead to a microscopic theory and should be replaced by the monopole and quadrupole moments of the nuclear density. The combination of these two features—the algebraic structure of the shell model and the formulation of collective observables in terms of moments—led in a natural way to the symplectic model based on the algebra $\mathrm{Sp}(3,R)$, as proposed by David and his (then) graduate student George Rosensteel in 1977 [5]. Not only is $\mathrm{Sp}(3,R)$ a subalgebra of the full Lie algebra of shell-model observables (which is infinite dimensional) but it contains itself SU(3) and CM(3) (the algebra of the collective model) as subalgebras. The symplectic model therefore provided the first microscopic understanding of the origins of the rotational dynamics of nuclei, including rigid as well as irrotational flows. It continues to inspire present-day nuclear structure. Recently, $\mathrm{Sp}(3,R)$ was shown to be a symmetry emerging from *ab initio* large-scale shell-model calculations [6].

Throughout his life David remained interested in nuclear collective models, steadily improving our understanding of them as well as enlarging their applicability. An example of the latter is his proposal of a computationally tractable version of the collective model [7], which made it much more versatile than in the original numerical implementation. As was so often the case, David's formulation was based on an elegant piece of mathematics, namely the correspondence between SO(5), the rotation algebra in five dimensions, and SU(1,1), the algebra of scale transformations in the radial coordinate. He then exploited the presence of the continuous series of SU(1,1) representations to obtain concrete results in terms of greatly improved numerical convergence properties. In subsequent work, David and collaborators showed that the dual pairing of symmetry and dynamical algebras is a feature common to many physical systems [8], the significance of which therefore largely surpasses that of its application to the collective model.

Since most models can be assigned an algebraic structure, it became important to construct unitary representations of Lie algebras in a systematic way. With this goal in mind, David invented a new mathematical structure, namely vector coherent states [9]. VCS theory can be considered as a physically intuitive version of the mathematical theory of induced representations and can be used in the construction of not-so-simple irreducible representations of a Lie algebra, starting from known irreducible representations of one of its subalgebras. VCS theory provides a powerful technique to derive many concrete results, for example, explicit expressions for vector coupling coefficients.

A common thread in all research activities of David was the use of symmetries, which arise if the Hamiltonian of a quantum-mechanical system commutes with a set of transformations that form a Lie algebra. The concept of symmetry can be further generalised to that of a *dynamical* symmetry when the Hamiltonian leaves invariant the subspaces of the total Hilbert space that carry the irreducible representations of a subalgebra of the dynamical algebra. In fact, the algebraic properties of several 'classical' nuclear physics models, such as Wigner's SU(4) supermultiplet scheme, Racah's seniority model of pairing, Elliott's SU(3) description of rotations and the solvable limits of the interacting boson model (IBM) of Arima and Iachello, can all be understood as arising from a dynamical symmetry. Often a single model may display several incompatible dynamical symmetries. This is well known for the IBM, which has three competing dynamical symmetries (or limits): U(5), SU(3) and SO(6). Competing dynamical symmetries also occur in the nuclear shell model, where the short-range pair-coupling interaction among the nucleons keeps the nucleus spherical and induces an SU(2)-type dynamical symmetry while the long-range quadrupole interaction favours a deformed equilibrium shape, corresponding to an SU(3) limit. The properties of systems with competing symmetries can be elucidated with the notion of quasi-dynamical symmetry: the mixing of different representations of a dynamical symmetry caused by a competing symmetry frequently occurs in a highly coherent manner, creating the illusion that the symmetry is preserved. While this concept can be given a precise formulation in terms of embedded representations [10], the intuitive interpretation is that the dominant symmetry is distorted but not broken. As the competing symmetry increases in strength this distortion becomes more important until it reaches breaking point and the system enters a transition phase from where a quasi-dynamical symmetry of the competing phase may emerge. Over the years David and collaborators investigated several models with competing symmetries [11–13] the properties of which can be in terms of quasi-dynamical symmetries.

We close with some heartfelt memories of David as a friend and colleague, which one of us (JLW) enjoyed for 46 years. David was a private and modest person who loved to think, share stories with friends, walk, and travel. He was a master of bird photography. He was an accomplished pianist. He had an infectious sense of humour. Physics discussion could be very intense, his demand was for logical clarity, often with the sense that only the shadows of his thinking were accessible to lesser souls. He was, at least for us, one of the giants of mathematical physics in the latter part of the twentieth century. But one had to listen very carefully: "when the giants walk by, they do so very silently". Walking by his side was a singular experience and a privilege.

David has left a legacy of ideas that we term the Rowe Legacy. To the limits of our ability, we will see this legacy shared in our role as authors and editors.

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