The Interacting Boson Model

Interacting Bose-Fermi Systems in Nuclei. Proceedings of a seminar, Erice, Italy, June 1980. F. IACHELLO, Ed. Plenum, New York, 1981. x, 406 pp., illus. $49.50. Ettore Majorana International Science Series, vol. 10.

There are two major models utilized in the study of nuclear structure, the shell model and the collective model. The concepts of the former, considered the more fundamental, were borrowed largely from atomic physics. Though there have been impressive gains in power of implementation, no fundamental changes in concept have occurred since the adaptation was carried through.

By contrast, the collective model, in the version elucidated in the early '50's by A. Bohr and B. Mottelson (BMM), has, since 1975, faced an increasingly formidable challenge from the interacting boson model (IBM). Within the context of nuclear physics the boson is a construct that describes correlated pairs of protons and neutrons, introduced to simplify the mathematical description of a wide range of phenomena occurring in all but the very lightest nuclei. Since the BMM also utilizes bosons, one must seek elsewhere to understand the impressive surge of the new ideas.

The explanation for this revolution in the making lies first in the intrinsic merit of its concepts, second in the unfailing energy and intelligence with which one set of authors of the model, A. Arima and F. Iachello, with the aid of a growing army of collaborators, have elaborated and promoted their ideas, and last in the stimulus it offers to nuclear spectroscopy to produce new and more accurate data against which to test the model.

Much of this development can be gleaned from the volume under review, which results from a workshop that was the second of what may well be a continuing series. This volume thus serves as a companion to *Interacting Bosons in Nuclear Physics*, which commemorates the first workshop, held in 1978. Since bosons alone can at best describe systems with even numbers of neutrons and protons, in order to include (the usually more complex) odd nuclei, one must mix boson ideas with some residuum of the description in terms of individual neutrons and protons (fermions). This recent development has provided the title for the new volume, even though only the last third of the book is devoted to it. (Of course, the BMM model also has its versions for odd nuclei.)

To assess where the subject stands requires that we address at least three questions: Does the IBM model work? How new is it, and, in particular, what is its relationship to the BMM, which has reigned for more than a quarter of a century? To what extent has success crowned efforts to derive the model or models from the next deeper level of theory—the shell model?

To give a sensible answer to the first question one must distinguish between model as a toolbox of ideas (boson and fermion constructs) and model as narrowly defined by the particular tools that have been utilized so far. Even with the narrow definition, the overall agreement of model and experiment is hugely impressive at low excitation energies. On the other hand, clear discrepancies have emerged at higher excitation energies, for which remedies exist, such as the addition of "g" bosons to the s and d bosons currently utilized. Such conclusions emerge quite clearly from a reading of this volume.

Important contributions both to the first volume and to the present volume address the problem of establishing the relationship between the boson variables of the IBM and the bosons that occur in the BMM. The reviewer has also written on this subject, more recently, in agreement largely with views found in the earlier volume, but not developed further in the current one. The major conclusion is that there is only one concept in the new toolbox that is absent from the old: In the IBM the total number of bosons, N, is fixed for each nucleus, since it is related to the number of neutrons and protons in the nucleus. On the other hand, for the (physically different) bosons of the original BMM the number is both variable and unbounded. However, by changing unbounded to bounded by N, there emerges a mathematical theorem of equivalence of the IBM framework to the BMM framework thus altered. This is to say that for every analysis of experiment by means of the IBM there is a corresponding analysis within the framework of the altered BMM that yields exactly the same concordance with experiment.

No such alternative analyses were presented at the workshop. That is because any experimental group requesting it has been furnished with an IBM program for analyzing its data, but no such gifts have even been forthcoming from the proponents of the BMM.

There is more to the IBM, however, than its impressive achievements in spreading the faith. Of paramount importance, the IBM lends itself in a natural way, precluded for the BMM, to group theoretical or symmetry arguments for the classification of spectra and other properties, which have resulted in important new discoveries, most recently for odd nuclei.

Another important distinction is that because of the different physical meaning of the variables in the two frameworks there is an implication that there have to be technical differences, perhaps major ones, in deriving each from the shell model. The task of deriving the BMM from the shell model, a topic outside the proper framework of the workshop, has been a serious but restricted occupation for over 15 years. Increasing success has been reported. The task of deriving the IBM from the shell model, moderately clear in its outlines, is a young subject, discussed in both volumes. It is a reasonable but not yet ineluctable conclusion that the IBM is more closely related to the shell model than the BMM and is therefore the more natural way to go.

We are currently on the exponential rise of the curve measuring work done on or stimulated by the IBM. We may have even greater need in the near future for such workshops and their reports.

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Stellar Physics

Physical Processes in Red Giants. Proceedings of a workshop, Erice, Italy, Sept. 1980. ICKO IBEN, JR., and ALVIO RENZINI, Eds. Reidel, Boston, 1981 (distributor, Kluwer Boston, Hingham, Mass.). xvi, 492 pp., illus. $66. Astrophysics and Space Science Library, vol. 88.

After spending most of their lifetimes as dwarfs, stars exhaust the hydrogen supply in their cores and become red giants for a relatively short period of time. But it is during this brief evolutionary phase that stars exhibit the most dramatic density contrast between their cores and their enormous convective envelope, dredge up to their surfaces material previously processed by nuclear re-