DYNAMICAL AND PARTICAL DYNAMICAL SYMMETRIES IN NUCLEI AND THEIR BREAKING

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There are two general perspectives from which to consider the structure of atomic nuclei – one that focuses on the motions of the individual nucleons and their interactions, and one that views the nucleus as an integral many-body system as a whole with its own overall structure, shape, symmetries, quantum numbers, selection rules, and other predictions. The former is sometimes called a microscopic viewpoint and the latter macroscopic but one should realize, of course, that both labels refer to a femtometer size scale.

In this talk, the focus will be on the macroscopic perspective and, specifically, will look at descriptions of the low-lying collective structure of nuclei from the standpoint of symmetries of the system. In this context, such symmetries are called dynamical symmetries (DS) when the Hamiltonian can be written in a certain kind of group theoretical language. For nuclei with even numbers of protons and of neutrons, the Interacting Boson Model (IBM) has long provided the most used set of DS, denoted (after their group theoretic descriptions) by the labels, U(5), SU(3), and O(6). The first refers to nuclei that are spherical and can vibrate, the second to a special subset of ellipsoidal, axially symmetric, nuclei that can both rotate and vibrate, and the third to a shape similar to the second but without axial symmetry.

While these DS are very elegant constructions, they are seldom, if ever, realized in pure form in real nuclei. Therefore, most studies of such nuclei involve introducing symmetry-breaking and the numerical solution of simple Hamiltonians. This has, over the last decades, resulted in accounting for a remarkably diverse phenomenological description of many collective nuclei. Of course, such models cannot, a priori, predict nuclear properties: they must be "fed" by choosing the values of certain Hamiltonian parameters, usually to reproduce a couple of key observables. They then provide powerful tools to develop substantial arrays of detailed testable predictions. Justification of the parameter values lies in the complementary domain of microscopic nuclear theory.

In recent years, the limitation in the applicability of pure DS has been tempered by the development of the concept of Partial DS (PDS) in which some of the properties of a symmetry are maintained but others are (often severely) broken. The study of PDS, in turn, has given fresh insights into the study of symmetry-breaking in collective nuclei in general and of the role of the finite number of nucleons in determining nuclear structure.

In this talk, these ideas will be presented and an overview of the status of simple symmetry-based descriptions and of the need for symmetry-breaking will be offered.

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