

# Preface

A great deal of research work has been performed in the field of alpha clustering since the pioneering discovery, by D. A. Bromley and co-workers half a century ago, of molecular resonances in the excitation functions for  $^{12}\text{C} + ^{12}\text{C}$  scattering. The aim of this new series of *Lecture Notes in Physics* entitled **Clusters in Nuclei** is to deepen our knowledge of this field of nuclear molecular physics whose history was so well recounted in 1995 by W. Greiner, J. Y. Park and W. Scheid in their famous book on **Nuclear Molecules** (World Scientific Publishing Co.). Nuclear clustering remains, however, one of the most fruitful domains of nuclear physics, and faces some of the greatest challenges and opportunities in the years ahead.

The conference Cluster '94 as well as the Theoretical Winter School on Clusters in Nuclei were held in Strasbourg in 1994 and 2005, respectively. In recent years, alongside the traditional Cluster Conference series (Cluster '03, held in Nara, Japan, and Cluster '07 held in Stratford-upon-Avon, UK), other more informal workshops have been organised with relatively limited numbers of participants in Rostock (2003, 2004 and 2005), and in Munich and Osaka in 2006. The subjects treated in these recent meetings concentrated mainly on alpha-particle condensates in nuclear systems. But a couple of years ago the Workshop on the **State Of The Art in Nuclear Cluster Physics** (SOTANCP2008) held in Strasbourg, France, was open to more diverse aspects of clustering in nuclei.

The purpose of this volume of *Lecture Notes in Physics*, the first in this new series of lectures, is to promote the exchange of ideas and to discuss new developments in Clustering Phenomena in Nuclear Physics and Nuclear Astrophysics both from a theoretical and from an experimental point of view. It is aimed at retaining the pedagogical nature of our earlier Theoretical Winter School, and should provide a useful resource for young researchers entering the field and wishing to get a feel for contemporary research in a number of areas.

The main topics in this first volume of **Clusters in Nuclei** are divided amongst seven chapters, each highlighting an area where new ideas have emerged over recent years:

- Cluster Radioactivity
- Cluster States and Mean Field Theories
- Alpha Clustering and Alpha Condensates
- Clustering in Neutron-rich Nuclei
- Di-neutron Clustering
- Collective Clusterization in Nuclei
- Giant Nuclear Molecules

The first Chapter entitled **Cluster Radioactivity** by Poenaru and Greiner shows how clustering aspects in nature are so important, as for instance in a new type of natural radioactivity predicted in 1980 by Sandulescu, Poenaru and Greiner. Considerable experimental and theoretical progress has been achieved since the discovery in 1984 of the  $^{14}\text{C}$  decay of  $^{223}\text{Ra}$  by Rose and Jones in Oxford, and further confirmed in Orsay and Argonne. Now, very neutron-rich Ne, Mg and Si isotopes are also known to be emitted through a cluster-radioactivity process that might be considered as super-asymmetric fission.

The second chapter, by Horiuchi, on **Coexistence of Cluster States and Mean-Field-type States** connects the phenomenological aspect of the two-center shell model with cluster-type microscopic dynamics. For the first time, the coexistence of cluster structures and superdeformation found in light alpha-particle nuclei, using large  $\gamma$ -ray multidetector arrays such as Euroball and/or Gammasphere, can be explained within the framework of a single theoretical approach: the Antisymmetrized Molecular Dynamics model (AMD).

**Alpha-cluster Condensations in Nuclei and Experimental Approaches for their Studies** are discussed in Chapter 3 by von Oertzen, who argues that alpha clustering can result in the formation of Bose–Einstein condensates in nuclear physics. While its theoretical background will be reviewed in the second volume, the experimental observation of the decay of such condensed alpha-particle states is proposed here to lead to the coherent emission of several correlated alpha-particles in certain reactions.

Chapter 4 entitled **Cluster Structure of Neutron-rich nuclei studied with Antisymmetrized Molecular Dynamics Model**, and prepared by Kanada-En'yo and Kimura, shows how light, neutron-rich nuclei can be successfully described by the microscopic AMD approach. As the domain of cluster physics has been extended rapidly toward unstable nuclei, the authors propose new perspectives of clustering phenomena and discuss the role of valence neutrons in very light neutron-rich nuclei.

Ikeda and his collaborators attempt in Chapter 5 (**Di-neutron Clustering and Deuteron-like Tensor Correlation in Nuclear Structure focusing on  $^{11}\text{Li}$** ) to reconcile the standard shell model with an effective-interaction approach, using a realistic nucleon–nucleon force. Di-neutron clustering is a new concept found to be a general phenomenon in the neutron-skin and neutron-halo nuclei, that are now experimentally studied more and more, worldwide, exploiting newly-available Radioactive Ion Beams (RIB) facilities.

Chapter 6 is dedicated to **Collective Clusterization in Nuclei and Excited Compound Systems: The Dynamical Cluster-decay Model**. Gupta analyses heavier nuclei with Relativistic Mean Field (RMF) theories. The concept of pre-formed clusters in nuclei is discussed in terms of the dynamical cluster-decay model and is shown to be supported by RMF calculations relying on rigorous basic assumptions.

Finally, the last Chapter **Giant Nuclear Systems of Molecular Type**, presented by Zagrebaev and Greiner, attempts to extend Bromley's nuclear molecule concept for  $^{12}\text{C} + ^{12}\text{C}$  to the superheavy elements (SHE) that might be produced through the decay of giant nuclear molecules created in heavy-ion collisions. Clustering phenomena arising from shell effects play an important role in the low-energy dynamics of heavy nuclear systems, and new experimental perspectives are proposed for the next generation of RIB facilities.

Forthcoming volumes in this series will contain lectures covering a wider range of topics—not only from nuclear cluster theory but also from experiment and applications—that have gained a renewed interest with the availability of RIB facilities and modern detection techniques. We stress that the contributions in this volume and the following ones are not standard review articles. They are not intended to contain all of the latest results or to provide an exhaustive coverage of the field but are written instead in the spirit of graduate lectures having a longer-term usefulness to research groups in this field.

The editing of this book would not have been possible without stimulating discussions with Profs. Greiner, Horiuchi, Schuck, Dufour and Rowley. Our appreciation goes to all of our lecturers for their valuable contributions. We thank also all of the referees for their informative comments on the chapters included in this volume. I would like here to thank, more particularly, Prof. Poenaru for his constant, helpful suggestions throughout. Special thanks go to Dr. Christian Caron and to all the members of his Springer-Verlag team for their help, fruitful collaboration and continued support for this ongoing project.

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