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Short history of nuclear many-body problem

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Abstract

This is a very short presentation regarding developments in the theory of nuclear many-body problems, as seen and experienced by the author during the past 60 years with particular emphasis on the contributions of Gerry Brown and his research-group. Much of his work was based on Brueckner's formulation of the nuclear many-body problem. It is reviewed briefly together with the Moszkowski–Scott separation method that was an important part of his early work. The core polarisation and his work related to effective interactions in general are also addressed.

Keywords: Nuclear many-body; History

1. Dedication

The main content of this work was presented at the Gerry Brown memorial conference in Stony Brook. I first met Gerry at least 55 years ago while he was with Rudolf Peierls in Birmingham and I was a graduate student in Uppsala and at CERN. I never worked directly with him (although he tried to recruit me for some of his projects). But I did interact with him in various ways over the years. In 1959 he was my opponent at my PhD thesis[1] defense in Uppsala (Sweden). Last time we met was at Eyvind Osnes retirement conference in Oslo in 2008. He told me then, after my talk, that I should have "spruced it up" like he himself does. He was a good friend. Gerry had many collaborators not only among his many students. He was always able to make others interested in problems he considered important. It was one of his strengths. That, together

[1] On optical model with spin–orbit coupling.

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with his enthusiasm, physical insight and intuitive thinking is how he will be remembered. His contributions to the problems of nuclear physics were dominating and will be ever-lasting. It is not possible to cover more than a small fraction of his work on many-body physics in this short talk.

2. Introduction

I find the history of physics (almost) as fascinating as physics itself. A historical perspective shows a scenario of ideas and people behind the ideas often not found in published papers. The real physics is of course found in what experiments reveal to us. The human brain seeks to understand these physical phenomena and that is what theorists are trying. It is a fascinating interaction between us and the world around us. Theory is the subject of this presentation.

When does the history of the nuclear many-body problem start? One of the great discoveries was the nuclear shell-model. Liquid drop, collectivity, was the predominant and successful picture theorists had before that. So how can one explain the success of the seemingly contradictive picture that the shell-model presented? Another problem: nuclear saturation. A possible explanation: NN interactions are repulsive at short distances [1]. But how can one reconcile the strong interactions with a shell-model? How can one deal with the strong and even infinitely repulsive forces computationally? These were some of the nuclear physics problems some 60 years ago.

The stage was set for someone to come up with a many-body theory of nuclear structure. The first successful nuclear many-body theory was that of K.A. Brueckner's. Gerry Brown's (and others) nuclear structure work was based on this theory.

In the theoretical treatment of the nuclear many-body problem, nuclei are in general considered to be composed of nucleons (protons and neutrons) interacting with some specified forces without internal degrees of freedom. The solution of this problem is hampered by two difficulties.

I. The strength and complexity of interaction(s) that are also unknown in details.
II. The mathematics to solve for the physical properties of a many-body system.

The first problem (I) is still being worked on in several ways. A method to overcome the second problem (II) was presented by K.A. Brueckner some 60 years ago. It showed how the strong interaction can be replaced by an 'effective' softer interaction, more manageable to handle. The invention of the shell-model led to a very active research to interpret the experiments on nuclear spectroscopy. A crucial part of this work was of course then the choice of NN-interaction. Gerry Brown, understanding the significance of Brueckner's work, commenced very successful shell-model calculations together with collaborators using the Brueckner 'effective' interaction, the reaction matrix, to do the job.

3. Brueckner theory

Related to the shell-model is the optical model of the 1950s, that pictures nucleons moving in a mean field. It was explained by Francis and Watson as a multiple scattering problem with elementary scatterings being via 'soft' T-matrices rather than 'hard' NN bare interactions [2]. This idea was picked up by Brueckner: Maybe a nuclear many-body theory for bound states could also be built on T-matrices instead of the, at the time, conventional efforts using NN-interactions with slowly converging or diverging results. But the T-matrix is complex