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Assessment Letter
of the habilitation Thesis by František Knapp

I have read with interest and pleasure the habilitation thesis by František Knapp.

The author has been able to provide a unified view of a diversity of approaches to the nuclear many-body problem. Nuclear structure is a complex, highly specialised sub-domain of theoretical physics in which different techniques have been developed in order to understand the rich experimental phenomenology. Nuclei are aggregates of fermions that, in certain cases, behave in a quasi-independent manner like quasi-particles in different orbitals - whereas in other cases they display a highly collective behaviour. In the thesis, both aspects are treated: as for the former aspect, a treatment of the nuclear shell model is present, while for the latter aspect the interacting boson model (IBM) is alluded to but, most notably, a clear introduction to Random Phase Approximation (RPA) is reported. Within RPA, the nuclear states are described as coherent superpositions of particle-hole (p-h) excitations, starting from the independent single-particle orbitals. The p-h pairs are described, to some extent, as quasi-boson and give rise to collective behaviours like in the case of the famous nuclear Giant Resonances. These, as well as other states in which the nucleus behaves as a whole, are often called “phonons”.

Although these methods have been already described in textbooks, the thesis has been developed in a fully independent manner, along a personal and quite appreciable logic. In my opinion, this testifies to the maturity of the candidate and his ability to transfer these concepts to fresh students in an effective way.

The most original aspect of the habilitation thesis is related to the discussion of the so-called Equation of Motion Phonon Method (EMPM). In many of the calculations that are available on the market, the aforementioned “phonons” are calculated at the RPA level. In a few cases, coupling between one- and two-phonon states are taken into consideration. The EMPM is a unique model, in which states of 1, 2 … n phonons are included in the Hilbert states, and their mutual coupling is considered in order to describe the physical states. It is an original development stemming from the collaborations between the groups in Prague and Naples, and the candidate, František Knapp, has played a pivotal role in its development.

In particular, a direct diagonalization of the n-phonon problem is shown to be not feasible. The candidate discusses, however, how to obtain equations in an iterative manner, that is, how to discuss the mixing of n phonon-type states once the mixing has been calculated using $(n-1)$ phonon-type states. František Knapp has introduced these ideas, together with co-workers, and applied the method first to magic even-even nuclei, then to open-shell and odd nuclei, with remarkable successes. These results are described in

the central part of the habilitation thesis, that reports what has been already published, yet in a very clear manner which is very readable.

Once again, this part testifies to the pedagogical skills of the candidate and, in my opinion, there are potential applications of the EMPM method even for other Fermi systems.

Although the EMPM was primarily introduced as a way to understand the fragmentation of the nuclear spectra, František Knapp has made, and included in the manuscript, many others interesting aspects. He has performed calculations using realistic, *ab initio* potentials and investigated the pros and cons of these state-of-the-art Hamiltonians. He has investigated the role of three-body forces. He has applied the method to calculations of the dipole spectra, that are also relevant for astrophysical processes like the nucleosynthesis. Last but not least, he has applied the method to the cases (open-shell and odd nuclei) in which the spectra are really complex. Fig. 1.9 in the thesis shows how the method he has developed, although not perfect, is very powerful and among the best in terms of comparison with spectroscopic data.

The thesis discusses details of the EMPM, also in the case of open-shell systems and odd systems, that show the competence and technical skills of the candidate. The section on the elimination of spurious states is an example that shows the skills of the candidate as far as the technical details are concerned. I have also appreciated the part related to the shell-model, although the no-core shell model with SU(3) basis is more demanding and less developments have been, or are expected to be, pursued.

Throughout the manuscript, the comparison with experimental data is emphasised. I have personally appreciated the fact that the thesis starts with an introduction to general concepts that are common between theory and experiment and pertain to basic, important observables (electromagnetic transition probabilities and cross sections, for instance). This initial part shows that František Knapp masters the general ideas of nuclear structure physics in the way we expect from those who should direct the research by others.

The thesis is well written. The plagiarism check did not find any significant element pointing to issues. The thesis includes reprints but the part written by the candidate is definitely original.

Milano, March 20th, 2023

Gianluca` Colò