Summaries of the manuscripts of Chief Assist. Prof. Stoyan Raykov Mishev, PhD

for participation in a competition for the academic position "Associate Professor" of the area of higher education: 4. Natural Science, Mathematics and Computer Science in professional field 4.6. Informatics and Computer Science announced in State gazette volume 26 from 21.03.2023

To participate in the competition Stoyan Mishev presents three titles of scientific papers as habilitation thesis and eight scientific papers while none of them is used previously to gain the academic position "Chief Assistant" or the Educational and Scientific Degree "Doctor"(PhD). Below are summaries of the scientific papers, grouped by topic.

Struture of the phonon vacuum state
On this topic the following papers are presented:

1. S. Mishev, Structure of the phonon vacuum state, Physical Review C 87 (6), 064310 (2013), Q1
2. S. Mishev, The phonon vacuum state in a Lipkin model, J.Phys.Conf.Ser. 533 (2014) 012013, SJR 0.21

In the presented papers on this topic a variational approach for determining the properties of ground states of fermionic systems with a small even number of particles is developed. These are mixed quantum states contributed by configurations composed of $4n$ different particle states ($n = 1, 2, 3, ...$). An estimate of the accuracy of the obtained result for the energy of the ground state in performed using an exact result by diagonalizing the Lipkin-Meshkov-Glick (LMG) model Hamiltonian. Further comparisons are established with other well-known methods based on the Random Phase Approximation (RPA). The inherent problem with the collapse of the RPA energy at a critical value of the interaction strength is shown to be removed in our approach as a non-trivial solution can be found for any value of the interaction strengths. Moreover the evolution of the weights of different configurations is evaluated with the increase of the interaction strength between the particles. In addition, analytical expressions for the Hamiltonian matrix elements used to calculate the energies of the one-particle-one-hole states in the LMG model are derived.

For accomplishing the results above computer codes were created in order to perform both numerical and analytical computations. The main software packages used incorporate realizations of numerical methods for solving nonlinear algebraic equations, eigensolvers as well as algorithms for symbolic expansions and reductions of expressions using the Clifford algebra.

Exciting Pygmy Dipole Resonances in atomic nuclei via beta decay of neighbouring nuclei
On this topic the following papers are presented:

3. M Scheck, S Mishev, V. Y Ponomarev, R Chapman, et al, Investigating the Pygmy Dipole Resonance Using Beta Decay, Physical Review Letters 116 (13), 132501 (2016) Q1
4. Marcus Scheck, S Mishev, V Ponomarev, et al, β decay as a new probe for the low-energy e1 strength, Acta Physica Polonica B, 2017, Vol. 48 Issue 3, p547-552 Q4

In the presented papers on this topic the possiblity to excite relatively low-lying (with energies of about 5-6 MeV) dipole resonances in even nuclei via beta decay from neighbouring odd-odd nuclei is explored and theoretically evaluated. These are the so-called Pygmy Dipole Resonances. The created model and the symbolic and numerical calculations are performed based on the quasiparticle-phonon nuclear model which incorporates up to three charge-exchange interacting phonons. This process is investigated for the first time and the predicted transition probabilities and the corresponding population intensities were vindicated against experimental data over the β decay from ^{136}I to ^{136}Xe.

This research was aided by computer systems for symbolic calculations which are able to partially calculate expressions based on the expressions for commutators between quasiparticle and phonon operators. In addition, numerical libraries were used to solve the so-called secular algebraic equation.

Корелации в основни състояния и структура на нисколежащи състояния в нечетно-четни атомни ядра
On this topic the following papers are presented:

- S. Mishev, V. V. Voronov, Ground-State Correlations and Structure of the Low-Lying States in Odd-Even Spherical and Transitional Nuclei, Romanian Journal of Physics, v 57, 380-398 (2012), Q3
- S. Mishev, V. V. Voronov, The interacting quasiparticle–phonon picture and odd–even nuclei. Overview and perspectives, Physics of Atomic Nuclei, volume 79, pages 851–857 (2016), SJR 0.25
- S. Mishev, V. V. Voronov, Magnetic moments in odd-A Cd isotopes and coupling of particles with zero-point vibrations, Physical Review C 92 (4), 044329 (2015), Q2
- S. Mishev, V.V. Voronov, Matter Density in a Simple Core-Plus-Particle Model, Bulletin of the Russian Academy of Sciences, 2020, SJR 0.23

In the presented papers on this topic a model for describing low-lying states in odd-even spherical and transitional nuclei including correlation between nucleons in the ground states of the respective even-even nuclei ("cores") is systematically developed. This models is an extension of the "classical" version of the quasiparticle–phonon model with additional terms in the wave function of the odd-even nucleus which take into account the non-zero probability for annihilating particular configurations in the ground states of the core. A series of original results including a characteristic description in the energies of the low-lying states in odd-even nuclei with same angular momenta and spins, improved description of the magnetic moments in cadmium isotopes etc. An important outcome of these studies is the derivation of new analytical expressions for the transition charge densities between states in odd-even nuclei, which allow to calculate radii of odd-A nuclei.
The quasiparticle–phonon model introduces particular concepts which can be expressed using the object-oriented approach for building software. In this way a software framework including a hierarchy of classes for modeling quantum states built upon other states of this same hierarchy and modifiable computational objects for evaluating the properties of the states was built. For flexibility in using the code some of the classes were implemented as template classes.

Equation of state of infinite nuclear matter
On this topic the following papers are presented:

- S. Mishev, M. Savova, "Towards a microscopic theory of neutron star matter", AIP Conference Proceedings 2302, 100006 (2020), SJR 0.19
- S. Mishev, M. Savova, "Coupled-cluster method for nucleonic matter using GPU tensor cores", AIP Conference proceedings, 2522, 090007 (2022), SJR 0.19
- Stoyan Mishev, Coupled-cluster calculation of neutron matter equation of state, Journal of Physics: Conference Series 2255 (2022) 012006, SJR 0.21

In the presented paper we solve a simplified model for the equation of state of neutron matter of out about a thousand neutrons using a microscopic Hamiltonian. For that we used the coupled-cluster method for obtaining the composition of the wave function of the system. For that purpose we used the Minnesota potential to perform first calculations of the matrix elements between complex configurations of the interaction.

This task involves solving a system of many coupled equations which include contractions of tensors of fourth or higher rank. The new generations of the graphical processing units (GPU) with their streaming architecture and vectorized operations prove very good in accelerating such operations. Оиr practical calculations on NVIDIA GPU of generation VOLTA showed a tenfold acceleration in performance as compared to similar calculations on CPU.

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