Report on
MERIT Long Term Overseas Dispatch

Sota Yoshida
5th, Department of Physics D2
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Overview

I visited Professor Achim Schwenk in Technische Universität Darmstadt, Institut für Kernphysik for three month. Darmstadt is now one of the central places in the nuclear physics community and there are many excellent researchers in the group of Prof. Achim Schwenk. Their research subjects cover a wide range of topics from light nuclei by means of ab initio calculations to infinite nuclear matters and neutron stars.

In this report, I summarize what I have done during the stay. This stay is supported by JSPS Overseas Challenge Program for Young Researchers, No. 201880031.

Research

In many research fields of modern physics, theoretical estimates rely on highly sophisticated theoretical models and computational techniques to solve the problems of interest. That is especially true for modern nuclear physics due to the fact that the fundamental interaction among nucleons, the nuclear force, cannot be written down in a closed form because of its highly non-perturbative character at low-energy regime. Nuclear theories have been developed by iterative cycles of forward modeling and inverse modeling processes. In the latter processes, one modifies the parameters in a model so as to reproduce experimental data more and more accurately. However, if one uses a model with so-called point estimation of the optimal input parameters, there is a risk of the overfitting to the given observations and of lacking the generalization ability to the data not taken into the optimization process. Therefore, it is desired that any theoretical models properly accompany with uncertainty quantifications, which is stressed in the Editorial on Physical Review A [1].

The valence shell model, which is generally called as configuration interaction method, is one of the most important and promising theoretical models in nuclear structure physics. Shell-model calculations have been providing successful and systematic descriptions of a wide variety of properties of light to medium-mass nuclei. Moreover, owing to the recent developments in the description of nuclear forces based on chiral effective field theory and many-body methods to derive shell-model effective Hamiltonians for a physically motivated valence space, shell model is important not only from phenomenological viewpoints but also from microscopic perspectives.

However, quantifications of uncertainties in shell-model calculations have been unsatisfactory so far. Under these circumstances, I thought it is an urgent task to quantify the uncertainties in shell-model calculations to make more meaningful comparison with data or predictions for experimentally unknown nuclei. I invented the novel methodology in shell-model calculations to quantify the uncertainties coming from its input parameters, effective interactions, using Bayesian inference and various sampling methods. This also enables us to quantify, in a statistical manner, which states likely to be described within a given model space, i.e. active orbitals for valence particles, and indicate exotic structures like clustering or intruder configurations in the states of interest. I hope this will open the new era for phenomenological calculations in nuclear structure physics. This kind of uncertainty estimates is also important for microscopic studies. There is a possibility to provide important constraints on modern nuclear potentials or to indicate higher order terms in many-body methods which are not to be omitted.

I have almost completed writing a paper for this study and we are in the final phase before submitting the paper.

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References

[1] The Editors, Phys. Rev. A **83**, 040001 (2011).