Research interests

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2016

Background

I am a theoretical physicist with a strong interest in computational physics and many-body theory in general, and the nuclear many-body problem and nuclear structure problems in particular. This means that I study various methods for solving either Schrödinger's equation or Dirac's equation for many interacting particles, spanning from algorithmic aspects to the mathematical properties of such methods. The latter also leads to a strong interest in computational physics as well as computational aspects of quantum mechanical methods. A large fraction of my work, in close collaboration with colleagues at Michigan State University, the University of Oslo, Oak Ridge National Laboratory as well as many other institutions worldwide, is devoted to a better understanding of various quantum mechanical algorithms. This activity leads to strong overlaps with other scientific fields. Although the main focus has been and is on many-body methods for nuclear structure problems, I have also done, and continue to do, research on solid state physics systems in addition to studies of the mathematical properties of various many-body methods.

The applications to many-body problems in nuclear physics lead also to many interactions with experimentalists and various experimental programs. The theories I participate in developing, have as final aims to be able to explain correlations in complicated many-body systems like nuclei and dense nuclear matter.

Why the nuclear many-body problem, you may ask. Well, for me, to understand why matter is stable, and thereby shed light on the limits of nuclear stability, is one of the overarching aims and intellectual challenges of basic research in nuclear physics and science. To relate the stability of matter to the underlying fundamental forces and particles of nature as manifested in nuclear matter is central to present and planned rare isotope facilities.

Examples of important properties of nuclear systems that can reveal information about these topics are masses (and thereby binding energies), and density distributions of nuclei. These are quantities that convey important information on the shell structure of nuclei with their pertinent magic numbers and shell closures, or the eventual disappearance of the latter away from the valley of stability.

Neutron-rich nuclei are particularly interesting. As a particular chain of isotopes becomes more and more neutron rich, one reaches finally the limit of stability, the so-called dripline, where one additional neutron makes the next isotopes unstable with respect to the previous ones. In a recent article published in Phys. Rev. Lett. 109, 032502 (2012) we computed several properties of calcium isotopes, including three-body forces, a much debated and studied issue in nuclear many-body theory. Our calculations predict the dripline of the calcium isotopes at mass 60, partly in conflict with present results from mean-field and mass models used in astrophysical calculations. To understand the limits of stability of the calcium isotopes is one of the benchmarks experiments of the coming Facility for Rare Isotope Beams at Michigan State University. The computed first excited 2+ state for calcium-54 was later observed in an experiment published in Nature in 2013, confirming our theoretical predictions.

A promising recent development involves a proper parametrization of the strong force, resulting in better Hamiltonian for nuclear physics studies. Combining very powerful effective field theory derivations of the nuclear interaction and multidimensional optimization techniques, we were able to generate a very precise two-body interaction that reproduces experimental data in neutron rich oxygen and calcium isotopes.