Nuclear Structure, Nuclear Astrophysics and Mesoscopic Physics

A Proposal to the National Science Foundation

Project Summary

Michigan State University proposes a three-year grant supporting the research of the faculty Professors B. A. Brown, P. Piecuch and V. Zelevinsky at MSU together with M. Horoi at Central Michigan University. The research proposed encompasses a broad range of topics in nuclear structure theory with applications to nuclear astrophysics and with extensions to other mesoscopic systems. The rich experience of the group and the support from MSU and NSCL provide a firm basis for a diverse and topical research program.

Intellectual merit of the proposed activity: The proposed research relates to broad questions in science including: What are the limits of nuclear stability?, How did the chemical evolution of the Universe proceed?, What are the ways of self-organization in interacting many-body systems?, How do the nuclear properties emerge from the underlying nucleon-nucleon interactions?, and How does order coexist with chaos and complexity in quantum mesoscopic systems? Topics include: (i) development of new analytical and computational tools for the description of nuclear structure, especially for the nuclei far from stability and for heavy nuclei; (ii) detailed consideration of specific nuclear phenomena and nuclear processes that shed light on the new features encountered with experimental advances into virgin territory of unstable nuclei; (iii) calculations and modeling of structural and dynamical aspects of nuclear processes of astrophysical interest; (iv) development of the unified description of structure and reactions in open and marginally stable mesoscopic systems, including nuclear reactions, conductance fluctuations and quantum transport; (iv) studies of the nucleus as a mesoscopic system, including many-body quantum chaos and its coexistence with collective and regular features.

Broader impacts resulting from the proposed activity: The suggested program is expected to have appreciable impact on developments in the field of nuclear theory, nuclear astrophysics and the general field of mesoscopic physics. Many of the projects are connected to the experimental programs at the National Superconducting Cyclotron Laboratory (NSCL) and other laboratories. Projects are also closely coupled with the Joint Institute for Nuclear Astrophysics (JINA), and some projects bridge nuclear structure theory with other areas, such as quantum chemistry. In a broader context, successful progress in the program is important for our understanding of the basic constituents of matter and nucleosynthesis in the Universe. The studies of many-body properties, chaos and collectivity in nuclear structure, have a strong interdisciplinary aspect since the nucleus is an exemplary case of a self-sustaining finite Fermi-system with strong interactions. Historically, many ideas first formulated in the context of nuclear theory fertilized other branches of mesoscopic physics. The proposed research is expected to help studies in physics of Bose- and Fermi-condensates, complex molecules, solid state microdevices, signal transmission through mesoscopic systems and quantum computing. The proposal has a considerable educational component being part of the highly ranked nuclear physics program at NSCL/MSU.