Microscopic Description of Bimodal Fission

As has been illustrated many times in all fields of science, with an improved understanding of microworld come applications that benefit society. Fusion and fission are excellent examples. Our description of these fundamental nuclear processes is still very schematic, yet, nuclear fission powers reactors that produce energy for the nation, and fusion, which is responsible for energy production in stars, has the promise to provide a clean alternative source of energy. Additionally, these same nuclear reactions are crucial for our national defense and our ability to provide a more secure Homeland. The theory group at UT/ORNL carries out a programmatic study of the fission process in nuclei, based on self-consistent density functional theory (DFT). We attack the problem of spontaneous fission using modern theoretical methods and state-of-the-art computational tools. Recently, we studied bimodal fission in the Skyrme-DFT approach. This phenomenon is related to the remarkable properties of spontaneous fission observed in several trans-actinide nuclei. In these systems, a sharp transition takes place from an asymmetric mass division in, e.g., ^{256}Fm to a symmetric split in, e.g., ^{258}Fm. In our calculations for fermium isotopes we found three competing fission valleys: (i) a reflection-asymmetric path corresponding to elongated fragments and two reflection-symmetric paths corresponding to (ii) a division into nearly spherical (compact) fragments and (iii) elongated fragments. This pattern of near-lying competing fission pathways explains the phenomenon of bimodal fission.

Fig. 1. Fission is a fundamental many-body phenomenon that possess the ultimate challenge for theory. The figure shows shapes of ^{258}Fm for different values of the total quadrupole moment Q_{20} calculated along the two static fission valleys: (i) asymmetric path leading to asymmetric mass split of fission fragments and (ii) symmetric-compact path corresponding to a division into nearly spherical fragments. The transition from an asymmetric fission path in neutron-deficient fermium isotopes to a compact-symmetric path when getting closer to ^{264}Fm (=^{232}Sn+^{232}Sn) is due to shell effects in the emerging fission fragments approaching the doubly magic ^{132}Sn. In calculations, all possible nuclear shapes, including triaxial and reflection-asymmetric (pear-like) shapes, are allowed. Such calculations require a strong coupling between modern microscopic many-body theory and high-performance computing.