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Microscopic Theory of Nuclear Fission

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Since its discovery in the late nineteen thirties, nuclear fission has remained one of the most complex and elusive problems in physics and gaps in our understanding of this phenomena can impact progress in other areas. For example, in basic science accurate knowledge of spontaneous fission half-lives is key to predicting the stability of superheavy elements, and fission fragment charge and mass distributions are also important ingredients in simulations of the formation of elements in nuclear capture processes (fission recycling). In applications of nuclear science for energy production, fuel cycle optimization is also strongly dependent on the characteristics of the fission process in actinides. In all these examples, measurements are either difficult, for technological, financial or safety reasons, or simply impossible. Therefore, most information comes from theoretical predictions. These predictions are often based on powerful semi-phenomenological models that have been developed several decades ago and have been finely tuned on existing data, which limits their predictive power. In an ideal world, a predictive theory of fission should instead be based solely on quantum many-body methods and our best knowledge of nuclear forces. Today, there is a consensus that the nuclear energy density functional theory (DFT) is currently the best framework to achieve a microscopic description of fission. Unfortunately, the proper implementation of nuclear DFT comes at a tremendous computational cost, which explains why progress had been relatively slow in the past. The recent development of leadership computing facilities in the USA, Europe and Asia has, however, introduced a paradigm shift: Calculations that were simply unfeasible only 5 or 10 years ago can now be completed in just a few hours. Such a massive increase in computing power has opened entirely new perspectives and triggered a spectacular renaissance of fission studies. After a historical introduction to fission theory and models, I will give an overview of the DFT approach to nuclear fission and highlight a few selected results.

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