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New progress on microscopic nuclear inputs for astrophysics applications

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One of the major issues in modern astrophysics concerns the analysis and understanding of the present composition of the Universe and its various constituting
objects. Nucleosynthesis models aim to explain the origin of the different nuclei observed in nature by identifying the possible processes able to synthesize them. Though the origin of most of the nuclides lighter than iron through the various hydrostatic and explosive burning stages in stars is now quite well understood, the synthesis of the heavy elements (i.e. heavier than iron) remains obscure in many respects. In particular, the rapid neutron-capture process, or r-process, is known to be of fundamental importance for explaining the origin of approximately half
of the A>60 stable nuclei observed in nature. The r-process was believed for long to develop during the explosion of a star as a type II supernova but recent observations tend to favour the merging of two compact objects. The stellar nucleosynthesis requires a detailed knowledge not only of the astrophysical sites and physical conditions in which the processes take place, but also the nuclear structure and interaction properties for all the nuclei involved.

The need for nuclear data far from the valley of stability, for applications such as nucleosynthesis, challenges the robustness as well as the predictive power of present nuclear models. Most of the nuclear predictions are still performed on the basis of phenomenological nuclear models. For the last decades, important progress has been achieved in fundamental nuclear physics, making it now feasible to use more reliable, but also more complex microscopic or semi-microscopic models in the prediction of nuclear data for practical applications. In the present contribution, the reliability and accuracy of recent nuclear theories are detailed and compared for most of the relevant quantities needed to estimate reaction cross sections and beta-decay rates, namely nuclear masses, nuclear level densities, gamma-ray strength, fission properties and beta-strength functions.

Recent efforts to determine ground-state as well as fission properties within the mean-field approach will be described and compared with more traditional phenomenological models. Recent achievements to determine gamma-ray strength functions in deformed QRPA calculations will also be addressed. The impact of such newly-determined microscopic inputs on nuclear reaction cross sections, but also on the r-process nucleosynthesis will be discussed. A special attention will be paid to such new developments in the light of the recent observation of the binary neutron star merger GW170817 and its corresponding optical kilonova counterpart which suggest that neutron star mergers are the dominant source of r-process production in the Universe.

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