Nuclear observables for nucleosynthesis processes

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Abstract:
The heavy elements, beyond ^{56}Fe, are produced in the so-called *rapid neutron capture* nucleosynthesis process (*r-process*) which takes place during cataclysmic events like supernovea explosions or neutron stars collisions. The recent observations by LIGO and VIRGO of the optical *kilonova* signal confirmed that the neutron-star mergers are possible sites for this nucleosynthesis process. Its theoretical simulation remains however challenging and the reproduction of the elemental abundances in the Universe is not yet satisfactory. One of the uncertainties of astrophysical models is the nuclear structure input necessary to describe nucleosynthesis processes, e.g. masses, half-lives, nucleon capture rates, fission barriers.

To describe the r-process the knowledge of e.g. neutron-capture cross section is needed for about 5000 nuclids. The measurements of the neutron-capture cross sections are possible only in stable and long-lived nuclei. Thus astrophysics models and other applications (e.g. reactors physics) rely on theoretical predictions, which are often based on simple phenomenological models of gamma-ray strength functions and level densities, being basic ingredients of statistical calculations of neutron-capture rates. Recently, new microscopic models were developed to describe those quantities. In particular, thanks to the calculations within the Configuration Interaction approach, it was possible to examine structure effects appearing at low energy in the gamma strength functions in different regions of nuclei [1-2] and incorporate those to other models [3] or constrain better the direct neutron-capture reaction rates [4]. Further systematic studies and developments of theoretical tools are however necessary to achieve a fully microscopic description of all the nuclei needed for applications in astrophysics.

The present PhD work will focus on theoretical developments within the Configuration Interaction method. Applications will be done to study the electric dipole transitions and the resonant capture rates on selected exotic nuclei and probe the limits of the statistical Hauser-Feshbach model of the neutron capture. Developments of the CI-inspired mass formulae are also envisaged.

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