Nuclear observables for astrophysical processes

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Elements heavier than iron (Z=26) are created in various astrophysical environements, either during the normal life of a large star or its explosive conclusion. The vast majority of the isotopes of the heavy elements are created in processes (s and r process) where neutron-capture reactions compete against the beta-decay and therefore accurate knowledge of both is necessary. Direct measurements of neutron cross sections are limited to stable nuclei and those with the long half-lives. Beta half-lives are unknown experimentally for many of neutron rich nuclei of interest for the r-process. Therefore, most applications resort to large sets of theoretical predictions of such nuclear observables, often based on simple global models instead of more precise miscroscopic theories.

The modern large-scale shell-model is currently the most precise tool available for microscopic studies of nuclear properties [1]. The energies and wave functions in this approach are obtained by diagonalization of the Hamiltonian matrix in the many-body basis consistng of Slater determinants representing different configurations which can mix via the residual nuclear interaction. Due to developments of shell-model codes and effective Hamiltonians for such calculations carried in the Strasbourg group, more and more aspects of nuclear structure over the whole nuclear chart can be adressed within this method, including those of interest for stellar evolution and nucleosynthesis models. We have applied it successfully, e.g. to the studies of beta half- lives of the r-process waiting point nuclei [2]. Recently, we have also undertaken studies of low energy radiative strength functions [3], which are basic ingredients in evaluations of neutron capture cross sections.

The objective of the thesis are further studies of radiative strength functions at low energies within the large-scale shell-model approach and the build up of new global models of such strength functions. Investigations to be carried are of interest for nuclear structure and will lead to providing new theoretical predictions for various astrophysical applications.

The present subject is a part of a collaborative project involving other theory groups (CEA-DAM and University of Brussels) and experimentalists (University of Oslo, IThemba LABS).

[1] E. Caurier et al., "Shell model as unified view of nuclear structure", Rev. Mod. Phys. 77 (2005) 427.
[2] Q. Zhi et al., "Shell model half-lives including first-forbidden contributions for r-process wating point nuclei", Phys. Rev. C87 (2013) 025803.
[3] K. Sieja, accepted in Eur. Phys. J A.