Fission barriers of r-process nuclei using the BCPM energy density functional*

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The nuclear fission process plays a crucial role during the r-process nucleosynthesis in neutron star mergers (see e.g. [1] for a recent review). In this specific astrophysical site the fission process determines how matter is recycled during the neutron irradiation and the production of superheavy nuclei. The theoretical description of the nuclear fission process is nowadays one of the most challenging and fascinating problems in nuclear physics. In the last years several studies based on the Energy Density Functional (EDF) theory were devoted to this topic. However, despite of the great efforts made to reduce its theoretical uncertainties, the fission process is still far from been satisfactorily described [2].

Here we want to report on the fission properties of the Barcelona-Catania-Paris-Madrid (BCPM) EDF [3, 4]. The fission properties of 330 even-even nuclei in the superheavy region ($92 \leq Z \leq 120$ and $160 \leq N \leq 202$) were computed following the standard Hartree-Fock-Bogoliubov (HFB) theory based in the Self-Consistent Mean-Field Approach. The spontaneous fission lifetimes $t_{\rm sf}$ were computed using the semiclassical approach given by the Wentzel-Kramers-Brillouin (WKB) formalism. Within this formalism, the fission probability can be written in terms of the action integral computed along the fission path. The collective inertias were calculated using the Gaussian Overloap approximation to the Generator Coordinate Method (GOA-GCM). The fission path is obtained by minimization of the HFB energy (static approximation) and constraining the quadrupole moment operator assuming axial symmetry.

Using these prescriptions the BCPM functional predicts an enhanced stability against the spontaneous fission process around the neutron magic number $N = 184$ for the lightest nuclei ($Z \leq 100$). In this region the fission barriers can increase up to 12 MeV leading to long-live nuclei [5]. This general enhancement of the fission barriers is consistent with the predictions obtained in other studies computed using the Thomas-Fermi semiclassical model [6], the microscopic-macroscopic model of Ref.[7] and the HFB14 parametrization of the Skyrme interaction [8].

The competition between the neutron capture process and the neutron-induced fission is driven by the difference between the fission barrier height B_f and the neutron separation energy S_n [9]. In Fig.1 the $R_{BS} = B_f - 0.5 \times S_{2n}$ value is depicted in the (N, Z) plane. As rough estimation is usually considered that nuclei with a $R_{BS} \leq 2$ MeV would fission immediately after capturing a neutron. As a consequence of this estimation, we can conclude that after the magic shell $N = 184$ the production of heavier nuclei is inhibited by the neutron-induced fission. This results agree with the predictions made in Ref.[10] using a combination of the TF barriers and FRDM masses.

For a complete nucleosynthesis modeling, fission yields computations are required. A work in this direction is already in progress.

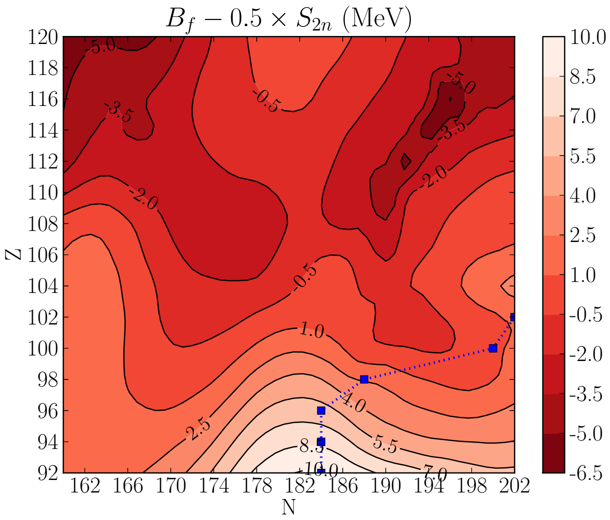

Figure 1: Contour plot of the quantity $R_{BS} \equiv B_f - 0.5 \times S_{2n}$ in MeV computed with the BCPM interaction. Squares represent the heaviest isotope for each nuclei with $Z \leq 102$ and $S_{2n} \geq 4.0$ MeV.

* The work of SAG and GMP was supported by the Helmholtz Association through the Nuclear Astrophysics Virtual Institute (VH–VI–417) and the BMBF–Verbundforschungsprojekt number 06DA7047I. The work of LMR was supported by the Spanish MICINN Grants No. FPA2012–4694 and No. FIS2012–34479 and by the Consolider–Ingenio 2010 MULTIDARK CSD2009-00064.
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DOI:10.15120/GR-2015-1-MU-THEORY-12