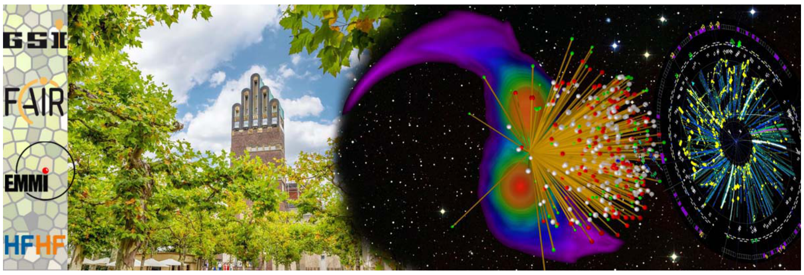

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Nuclear models based on energy density functional for astrophysics applications

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Large-scale models of nuclear structure play an essential role in many astrophysics applications. Nucleosynthesis simulations of heavy elements, through the rapid neutron-capture process (or r-process), for example, require nuclear information inputs across the whole nuclear chart, far beyond the region where experimental data is available. Likewise, describing the extremely dense neutron-rich matter in neutron stars is a challenge for nuclear physics and astrophysics.
The Brussels-Montréal Skyrme (BSk-series) nuclear energy density functionals and associated nuclear mass models have been developed to this end. Based on the Hartree-Fock-Bogoliubov (HFB) method with a Skyrme interaction, their parameters have been fitted to essentially all experimental nuclear masses and constrained to reproduce various infinite nuclear matter (INM) properties (equation of state, effective masses, pairing gaps, …). Recently, the first Brussels-Skyrme-on-a-grid (BSkG) models have been developed. This series focuses on exploiting the powerful concept of symmetry breaking: BSkG1 [1] incorporates for the first time the possibility of triaxial deformation, BSkG2 [2] in addition, allows for the effects of time-reversal symmetry breaking. The latter enables us to access the spin and current densities in the ground states of odd-mass and odd-odd nuclei. These densities contribute to the total energy of such nuclei through the so-called 'time-odd' terms. Moving beyond ground-state properties, BSkG2 also includes information on fission barrier heights of actinide nuclei in the parameter adjustment.
We will present in this contribution the latest BSkG3 nuclear mass model, which brings important improvements. To grasp further collective effects, we now break reflection symmetry, allowing for both triaxial and octupole-deformed ground states simultaneously. Moreover, we add to the description of finite nuclei improvements of relevance to the description of neutron star properties. We focus on rendering the predicted equation of state stiffer along the lines of Ref. [3], ensuring the model can accommodate the existence of heavy pulsars. We also replace the phenomenological pairing interaction of previous models by a more microscopically grounded interaction designed to match the 1S0 pairing gaps in INM deduced from ab-initio calculations. This is particularly important for describing superfluids in neutron stars. Reconciling the complexity of neutron stars with those of atomic nuclei establishes BSkG3 as a tool of choice for applications to nuclear structure, the nuclear equation of state, and nuclear astrophysics in general.

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[2] W. Ryssens et al., Eur. Phys. J. A 58, 246 (2022).
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[4] G. Grams, W. Ryssens, G. Scamps, S. Goriely and N. Chamel, arXiv:2307.14276 [nucl-th] (2023).

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