Two-year Post-Doc Proposal

Bridging nuclear ab-initio and energy-density-functional theories

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This project aims to connect modern and microscopic analyses performed through ab-initio methods with the nuclear EDF theory, with the goal of rendering EDF approaches less empirical and of relating EDF ingredients to properties of underlying quarks and hadrons. Such a bridge is particularly challenging and promising first investigations along this direction have been recently initiated. This connection will contribute to reduce uncertainties in the construction of a nuclear density functional for finite nuclei and for nuclear systems of interest in nuclear astrophysics and will offer a practical tool for describing nuclear systems with many-body techniques in both structure and reaction applications.
Nuclear physics has strongly progressed during the last years with significant achievements in the understanding of the nuclear interaction and in the development of sophisticated many-body models. Recently, with important advances in EFTs, especially in the low-energy QCD non-perturbative sector, new interactions have been designed that are appropriate for solving the nuclear many-body problem. This has opened new opportunities in particular to perform so-called exact ab-initio calculations. The applicability of ab-initio methods is however restricted in a rather narrow region (relatively small masses and, mostly, closed-shell nuclei) and many areas of nuclear physics cannot yet take advantage of these achievements.
On the other hand, the nuclear EDF theory is a powerful and versatile approach for the nuclear many-body problem. It allows for a unified description of static and thermodynamic properties of nuclei all along the nuclear chart. EDF may also be applied to very extended systems like neutron stars giving insight in selected astrophysical observations. Its time-dependent version provides a microscopic description of a variety of dynamical phenomena. It is however clear that the empirical ingredients used to build the nuclear EDF reduce its predictive power.
In recent years, attempts have been made to bridge modern aspects of nuclear physics and nuclear EDF with the goal to render less empirical the latter approach and to directly link the EDF ingredients with properties of the underlying quarks and hadrons. This bridge would remove part of the uncertainties in the construction of a nuclear EDF. Such a timely project is still at its early stage and many aspects need to be clarified in the next few years.
The candidate will work along this direction and the following major results are foreseen:

1) Validating a **strategy for designing *ab-initio*-type EDF functionals**, based on completely microscopic ingredients and benchmarked on *ab-initio* EFT-based results.
2) Progressing on the definition of a **power counting for EDF** to unambiguously associate functionals to each order of the perturbative many-body Dyson expansion (for instance for mean-field and beyond mean-field models).
3) **Using microscopic functionals for systematic predictions** in applications to study for example low-lying modes and giant resonances.
4) Using also properties of **Fermi gases at the unitary limit** to further reduce (or eliminate) the parameters dependence of the new-generation EDF functionals.

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