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Towards a Universal Density Functional Theory for nuclei : challenges to overcome[1]

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In the study of medium to heavy mass nuclei, nuclear Density Functional Theory (DFT), based on the self-consistent Hartree-Fock-Bogoliubov (HFB) method and its extensions, is the theoretical tool of choice. As more exotic beams facilities are being built or proposed to be built around the world, DFT is on the edge of becoming a predictive theory for all nuclei but the lightest. This is not only true for ground state properties, such as binding energies, radii or multipoles of the density, but also for low energy excited states of different types and for the calculation of their decay probabilities. These decisive advances are coming to life thanks to the development of better energy functionals and thanks to the increase of computer resources. However, the needed accuracy and predictive power still leaves much to be desired and DFT is facing important challenges in its quest for the truly universal energy density functional which should be able to describe properties of finite nuclei in all possible exotic modes as well as extended asymmetric nucleonic matter. In this talk, I will elaborate on those challenges before discussing the results of two ongoing studies aiming at tackling some of them. The first one is an attempt to construct the pairing part of the nuclear functional starting from the bare nucleon-nucleon interaction. Indeed, and despite its major role, the nature of pairing correlations in nuclei is largely unknown and has mostly relied on pure phenomenology so far. The long-term goal is to identify the in-medium effects at play in the pairing channel and model them via isoscalar and isovector density-dependences and/or gradient corrections. I will describe a way to realize the first step of such a program, that is, to set up a functional which is able to reproduce the pairing properties generated by the full realistic $AV18$ bare nucleon-nucleon force in finite nuclei. The second study deals with the conceptual problem one faces when defining the Particle Number Projected (PNP) HFB method within the context of DFT. Indeed, one manipulates in this case an ill-defined functional presenting divergences and jumps whenever a single particle state crosses the Fermi surface. I will discuss how those divergences and jumps are related to a spurious "self-pairing" interaction between paired nucleons and how one can identify and remove the corresponding spurious contributions to the projected energy.