ID de Contribution: **40**

Type: **Talk**

Symmetry broken & restored many-body theories in nuclear structure

mardi 29 mai 2018 17:15 (20 minutes)

Methods to solve the N-body Schroedinger equation must cope with two specific attributes of inter-nucleon interactions that are responsible for the non-perturbative character of the nuclear many-body problem. These elements of non-perturbative physics are of ultra-violet and infra-red natures and can be tamed down by pre-processing the nuclear Hamiltonian via Similarity Renormalization Group evolution. Based on the transformed Hamiltonian, dynamical correlations can be treated via standard many-body techniques, such that many-body perturbation theory (MBPT), coupled cluster (CC) or self-consistent green function (SCGF). These methods have been implemented with great success in the last ten years to deal with doubly-closed shell nuclei. Strong, i.e. non-dynamical, correlations induced in singly and doubly open-shell nuclei are of different nature and require specific attention. To proceed one option consists in exploiting the spontaneous breaking of symmetries induced by non-dynamical correlations at the mean-field level. This rationale allows one to incorporate a large part of the non-perturbative physics into a single product state that can serve as a reference for many-body expansions dealing efficiently with dynamical correlations. In practice this is achieved by allowing the reference state to break U(1) global gauge symmetry associated with particle-number conservation and optimized it through the Hartree-Fock-Bogoliubov variational procedure. While traditionally developed within the frame of effective nuclear mean-field (i.e. energy density functional) approaches, this idea has been recently embraced to develop and implement ab initio Bogoliubov MBPT, Bogoliubov CC, Gorkov SCGF to tackle pairing correlations. These methods based on a symmetry breaking reference state are currently allowing a breakthrough in the ab initio description of (singly) open-shell nuclei and are putting state-of-the-art inter-nucleon interactions to the test in medium-mass systems, for which the number of nucleons goes from 20 up to 100.

In this talk, I will motivate the use the symmetry breaking and restoration in many-body theories for nuclear structure. A focus will be made on the breaking of U(1) global gauge symmetry associated with particle-number conservation in order to account for the superfluid character of nuclei. An application of these concepts in the case of the Richardson Hamiltonian will be given.

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Classification de Session: Nuclear Physics - Theory