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Bogoliubov Many-Body Perturbation Theory

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The last few decades in nuclear structure theory have seen a rapid expansion of ab initio theories, aiming at describing the properties of nuclei starting from the inter-nucleonic interaction. Limited for a long time to very light nuclei, they are now able to access nuclei with up to A ˜ 100 particles. Such an expansion relied both on the tremendous growth of computing power and novel formal developments, with methods scaling polynomially with the number of particles.
The recently proposed Bogoliubov Many-Body Perturbation Theory [1] makes use of a particle-number-breaking reference state to tackle singly open-shell nuclei and capture pairing correlations, while dynamical correlations are accounted for perturbatively through quasiparticle excitations truncated in a systematic way. While BMBPT is presently used as a stand-alone approach, it eventually provides the first step towards the implementation of the particle-number projected BMBPT (PNP-BMBPT) which exactly restores good particle number at any truncation order.
As the number of contributions to be considered grows very rapidly with the perturbative order, the development of the present diagrammatic formalism has been associated to the production of an open-source software [2] generating and evaluating contributions at arbitrary truncation orders, with implications possibly extending to quantum chemistry and condensed matter communities.
Systematic ground-state energies along complete isotopic chains from oxygen up to tin have been computed using a standard chiral effective field theory Hamiltonian. Low-order BMBPT calculations performed on the basis of a soft interaction were found to agree at the 2% level with state-of-the-art non-perturbative many-body methods at a small fraction of the computational cost [3]. They establish BMBPT as a method of interest for large-scale computations of isotopic or isotonic chains in the mid-mass sector of the nuclear chart, be it for the systematic pre- or post-diction of nuclear properties or the test of newly developed Hamiltonians.
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Author: Dr ARTHUIS, Pierre (University of Surrey)

Co-authors: Dr TICHAI, Alexander; Prof. DUGUET, Thomas

Presenter: Dr ARTHUIS, Pierre (University of Surrey)

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