Ab initio Hamiltonian approach to light nuclei and quantum field theory

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Nuclear structure physics is on the threshold of confronting several long-standing problems such as the origin of shell structure from basic nucleon-nucleon and three-nucleon interactions. At the same time those interactions are being developed with increasing contact to the underlying theory of the strong interactions, QCD using effective field theory. The motivation is clear - QCD offers the promise of great predictive power spanning phenomena on multiple scales from quarks and gluons to nuclear structure. However, new tools that involve non-pertrubative methods are required to build bridges from one scale to the next. I will provide an overview of recent theoretical and computational progress with a Hamiltonian approach to build these bridges and provide illustrative results for nuclear structure of light nuclei and quantum field theory.

Here I present a basis-function approach that has proven successful for solving the non-relativistic strongly interacting nuclear many-body problem [1] and appears promising for solving relativistic field theory in a light-front Hamiltonian framework [2]. Both conventional nuclear many-body theory and light-front field theory face common issues within the Hamiltonian approach - i.e. how to

(1) define the Hamiltonian;
(2) renormalize to a finite space;
(3) solve for non-perturbative observables, preserving as many symmetries as possible; and,
(4) take the continuum limit.

Each of these challenges requires a substantial undertaking but appears solvable.

Advances in computational physics, both algorithms and parallel computers, have proven essential to the recent progress. I will present results that illustrate the recent advances and indicate the path forward to ever more realistic applications.

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References

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