UCOM Correlators Constructed from SRG Evolved Interactions*

S. Reinhardt, R. Roth, and H. Hergert
Institut für Kernphysik, Technische Univeristät Darmstadt, Germany

The Unitary Correlation Operator Method (UCOM) and the Similarity Renormalization Group (SRG) are two modern methods to derive universal effective interactions suitable for nuclear structure calculations in different many-body methods. Both approaches employ phase-shift conserving unitary transformations to tame an initial realistic interaction such that the transformed interaction induces less correlations and exhibits a superior convergence behavior.

In UCOM the unitary transformation is formulated via explicit correlation operators whose structure is motivated by the physics of short-range central and tensor correlations [1]. The UCOM transformation is characterized by correlation functions $R_+(r)$ and $\vartheta(r)$ which describe the radial dependence of the central and tensor correlations. For the first-generation of UCOM-transformed interactions, these functions were determined from an energy minimization in the two-body system [1]. In SRG a more generic idea is used. The unitary transformation is formulated in terms of a renormalization-group flow equation with a dynamical generator that drives the matrix elements of the Hamiltonian to a band-diagonal structure with respect to an uncorrelated basis. Solving the flow equations for momentum-space matrix elements leads to a transformed interaction that is band-diagonal in momentum space—similar to the matrix elements of the UCOM-transformed interaction.

Since both methods address the same physics of short-range correlations, we can connect them and use the SRG-evolution to construct correlation functions for UCOM [2]. For this we first construct an SRG-evolved interaction and solve the two-body problem in the different spin-isospin-channels. The lowest resulting two-body eigenstate is then used to define SRG-generated UCOM correlation functions by requiring, that the UCOM transformation should map the evolved two-body state onto the corresponding two-body eigenstate for the initial interaction. The resulting central and tensor correlation functions for the $(S,T) = (1,0)$ channel are depicted in Fig. 1 together with the first-generation variational correlation functions. The short-range behavior of the two sets of correlators is very similar, however, at intermediate ranges the SRG-generated UCOM correlators show a negative contribution which was not considered before.

Figure 2 summarizes the Hartree-Fock ground-state energies and charge radii obtained with the two types of UCOM interactions (variational and SRG-generated correlators, resp.) and a pure SRG interaction. Whereas the systematics of the binding energies is similar for the two UCOM interactions, the SRG interaction develops a severe overbinding for heavier nuclei. This systematic difference between UCOM and SRG interactions shows that three-body interaction play a very different role in the two approaches. This is also confirmed by the charge radii, which are significantly too small for the SRG interaction and best with the second-generation UCOM potential.

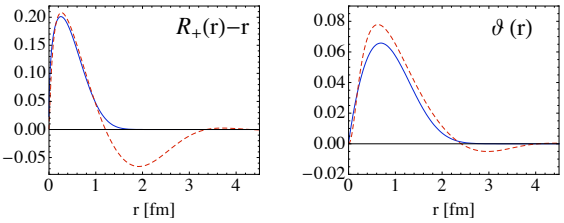

Figure 1: Variationally optimized (——) and SRG-evolved (– – –) central and tensor correlation functions $R_+(r) - r$ and $\vartheta(r)$ for $(S,T) = (1,0)$.

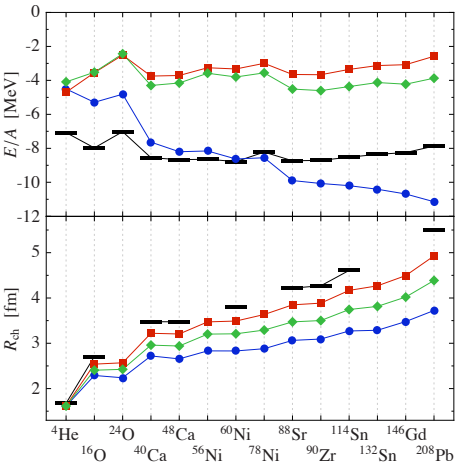

Figure 2: Hartree-Fock results for the SRG interaction for $\bar{\alpha} = 0.03$ fm^4 (●), the UCOM potential with $I_\vartheta = 0.09$ fm^3 (◆) and the SRG-generated UCOM potential with $\bar{\alpha} = 0.04$ fm^4 (■).

References

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[3] R.Roth *et al.*, Phys. Rev. C 77, 064003 (2008)

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