The Unitary Correlation Operator Method from a Similarity Renormalization Group Perspective

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The Unitary Correlation Operator Method (UCOM) (see [1] and references therein), was devised as a means to describe the correlations induced by the short-range repulsion and the tensor force of modern realistic NN interactions by an explicit unitary transformation. One obtains a phase-shift equivalent correlated interaction $\mathrm{V}_{\mathrm{UCOM}}$ which exhibits a dramatically improved convergence behavior in practical calculations, resulting from a pre-diagonalization of the interaction in momentum space, as shown for the ${}^3S_1$ partial wave in Fig. 1.

This observation provides a first heuristic link to the similarity renormalization group (SRG) approach. Following Wegner's formulation of the SRG [2], one can evolve the many-body Hamiltonian towards a band-diagonal structure by solving the flow equation

$$\frac{d\mathrm{H}_\alpha}{d\alpha} = \big[\eta(\alpha), \mathrm{H}_\alpha\big]\,, \quad \mathrm{H}_0 = \mathrm{H}\,, \tag{1}$$

where α denotes the flow parameter. The generator $\eta(\alpha)$ has to be chosen appropriately for practical applications. Bogner et al. [3] have recently employed $\eta(\alpha) = \big[\frac{\mathrm{q}^2}{2\mu}, \mathrm{H}_\alpha\big]$, which aims to diagonalize the two-body Hamiltonian H_α in a basis of eigenstates of the radial and orbital angular momentum operators. When evaluated for a typical NN interaction at the initial point of the flow, the structure of $\eta(0)$ closely resembles the non-trivial generators used in the UCOM transformation [4]. This result connects the SRG flow picture with a physically intuitive picture of central and tensor correlations in a many-body state. Conversely, the flow equation confirms that the UCOM ansatz contains the important generators, and offers guidance for possible improvements or generalizations of the UCOM scheme.

In Fig. 1, we compare the ${}^3S_1$ matrix elements of AV18 to V_{UCOM} and a SRG-evolved interaction V_α (see [4] for details). The large off-diagonal contributions and strongly repulsive diagonal terms of the parent interaction are dramatically suppressed by the UCOM and SRG transformations, and the attractive low-momentum component is enhanced. The $\mathrm{V}_{\mathrm{UCOM}}$ and V_α matrix elements are very similar, the only noticeable difference being the stronger increase of the SRG matrix elements at high momenta when approaching the diagonal. The same agreement is obtained for the matrix elements in the coupled channel ${}^3S_1 - {}^3D_1$.

This is a numerical confirmation of the close relation of the UCOM and SRG approaches, which offers many interesting prospects for future work, particularly on the optimization of the UCOM correlators via the SRG approach and the application of both approaches to the three-nucleon system.

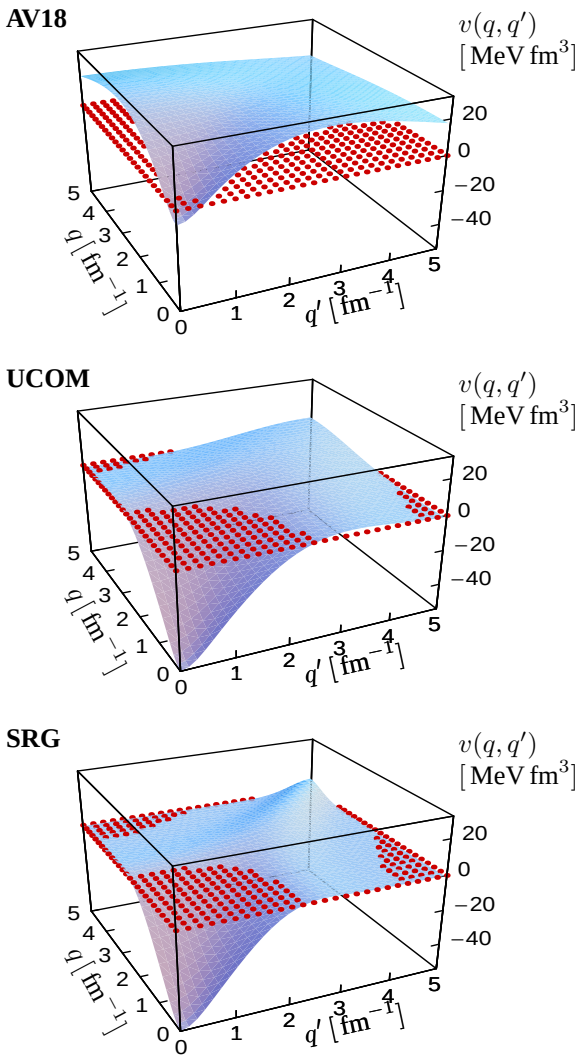

Figure 1: Momentum-space matrix elements in the ${}^3S_1$ partial wave for the AV18 potential (top), $\mathrm{V}_{\mathrm{UCOM}}$ (center), and the SRG-evolved AV18 (bottom).

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References

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