The Unitary Correlation Operator Method from a Similarity Renormalization Group Perspective

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Summary
- construct phase-shift equivalent effective nucleon-nucleon interactions with the SRG [1;2]
- SRG evolution leads to generators with the same structure as used in the UCOM
- momentum-space matrix elements confirm the similarities of both approaches
- construct UCOM correlation functions by using SRG evolved interactions [3]
- no-core shell model calculations show good convergence for light nuclei
- realistic systematics of binding energies of heavier nuclei on the Hartree-Fock level

Unitary Correlation Operator Method (UCOM)
- define unitary operators to describe the effect of short-range correlations [4-6]
  \[ C_0 C_r = \exp \left\{ -i \sum_{\nu<\lambda} g_{\nu,\lambda} \right\} \exp \left\{ -i \sum_{\nu<\lambda} g_{\lambda,\nu} \right\} \]
- central correlator \( C_r \): radial distance-dependent shift of two nucleons
  \[ g_r = \frac{1}{2} \vartheta(r) q_r + q_s s(r) \]
- tensor correlator \( C_{\sigma} \): angular shift depending on spin-orientation of two nucleons
  \[ g_{\sigma,\sigma'} = \frac{1}{2} \vartheta(r) \left[ \sigma_1 \cdot q_0 (\sigma_2 \cdot r) + (\sigma_2 \cdot r) (\sigma_1 \cdot q_0) \right] \]
- parameters to determine: \( R_r \approx r + s(r) \) and \( \vartheta(r) \) describe strenght and distance dependence of the transformations

Extracting UCOM Correlation Functions from SRG Calculations
- SRG confirms that all relevant generators are included in UCOM scheme
- derive UCOM correlators \( \vartheta(r) \) and \( R_r \) from SRG calculations
- mapping of the SRG-evolved states onto the initial states
  1. Solve SRG flow equation for an initial interaction with a certain value of the flow parameter → matrix elements for each partial wave
  2. Solve two-body problem with these
  3. Map two-body eigenstates of SRG-evolved interaction onto corresponding states of initial interaction → UCOM correlation functions
- UCOM (SRG opt.): \( R_r \) → \( r \) changes sign, correlators have negative part

Momentum-Space Matrix Elements for \(^1S_0\) Partial Wave
- strong reduction of off-diagonal matrix elements
- narrow band-diagonal structure for SRG

Hartree-Fock Calculations
- \( V_{\text{UCOM}}(\text{SRG}) \) and \( V_{\text{UCOM}}(\text{var.}) \): realistic trend of binding energies
- \( V_{\text{SRC}} \): strong overbinding for heavier nuclei → needs three-body interaction

No-Core Shell Model Calculations for \(^4\text{He}\)
- \( V_{\text{UCOM}}(\text{SRG}) \) and \( V_{\text{SRC}} \): good convergence behavior, better than \( V_{\text{UCOM}}(\text{var.}) \)