Three-Body Valence Interactions with the IMSRG

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IMSRG

In-Medium Similarity Renormalization Group

- IMSRG

Perform a unitary transformation on the Hamiltonian

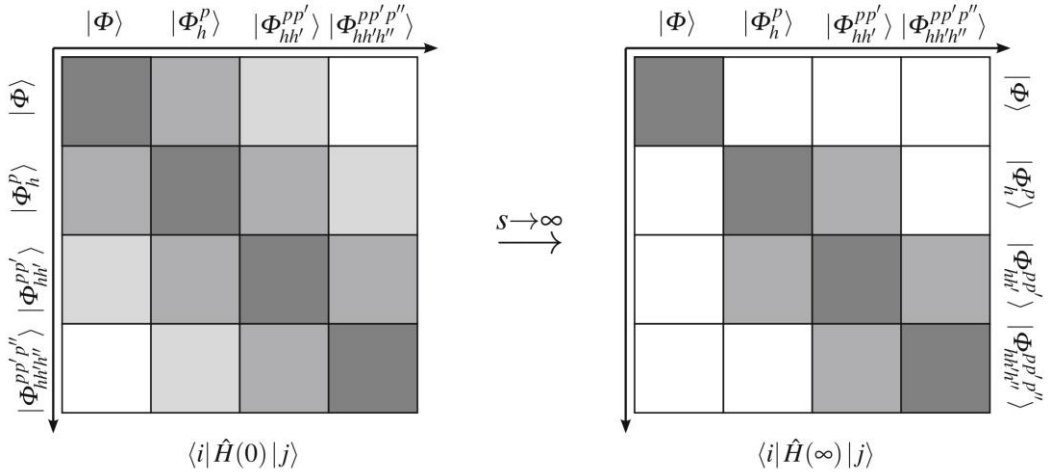
- $H(s) = U(s)HU(s)^{\dagger}$

Split Hamiltonian into diagonal and off-diagonal pieces

- $H = H^{d} + H^{od}$

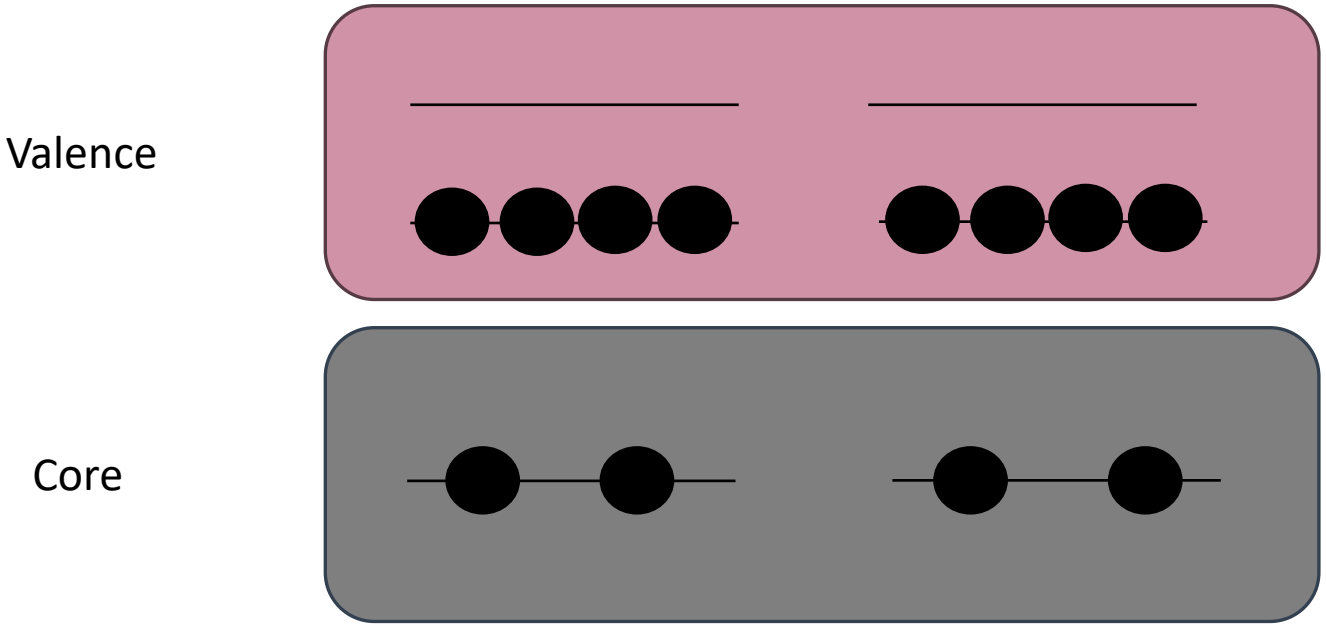
Key truncations for the theory

- IMSRG(2),IMSRG(3f2),IMSRG(3n7),IMSRG(3)



M. Hjorth-Jensen et al./ An Advanced Course in Computational Nuclear Physics (2017)

Valence Space



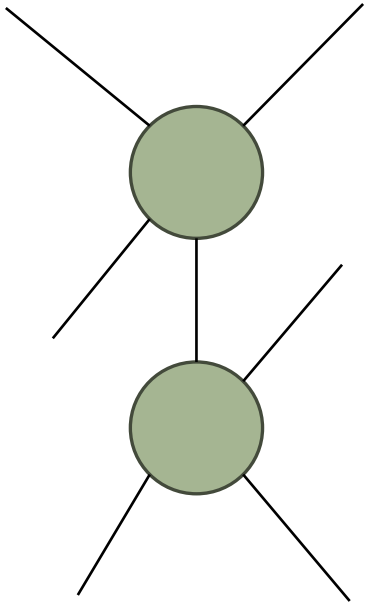
Using Three-Body Operators

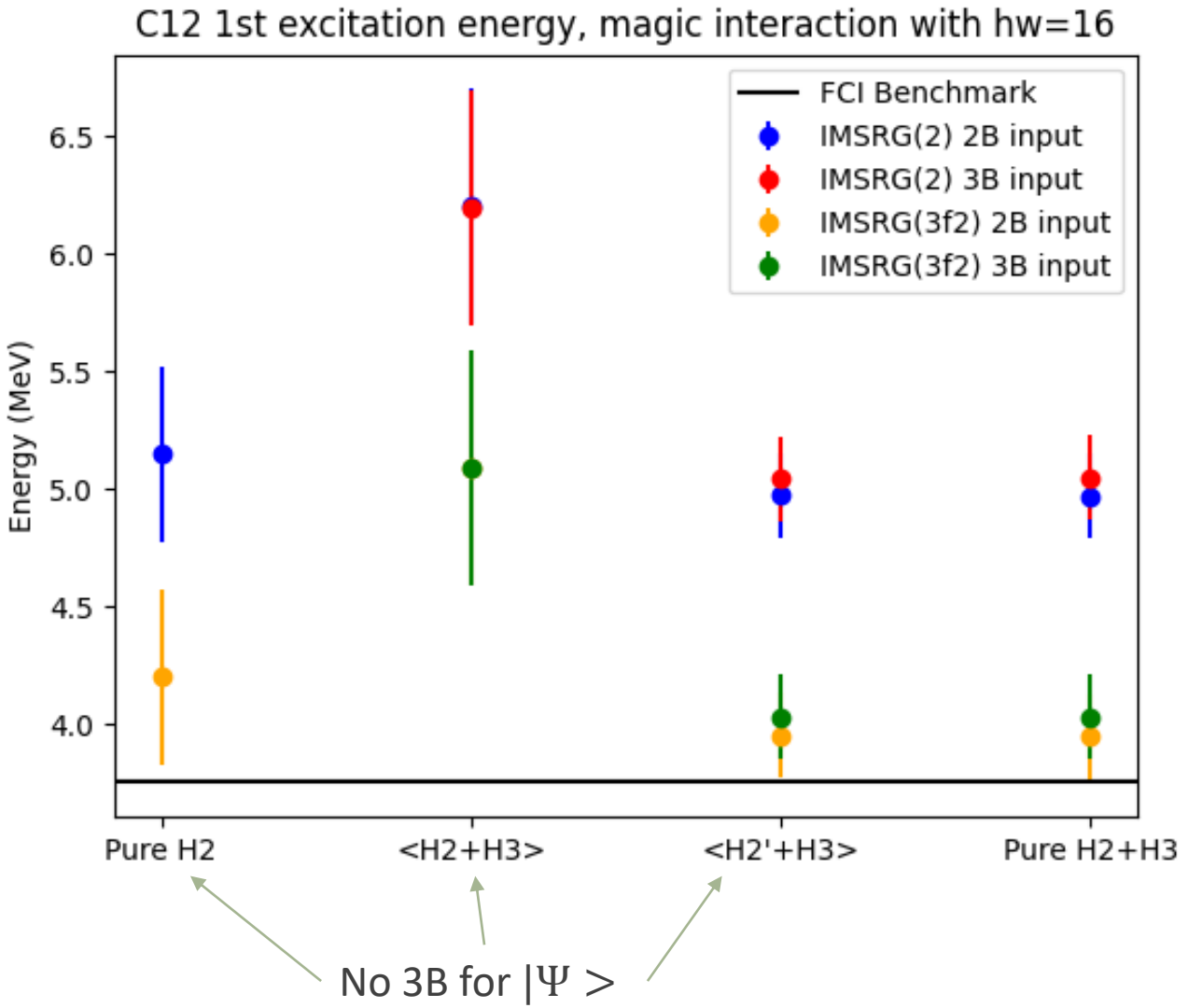
Where Three-Body Operators come from

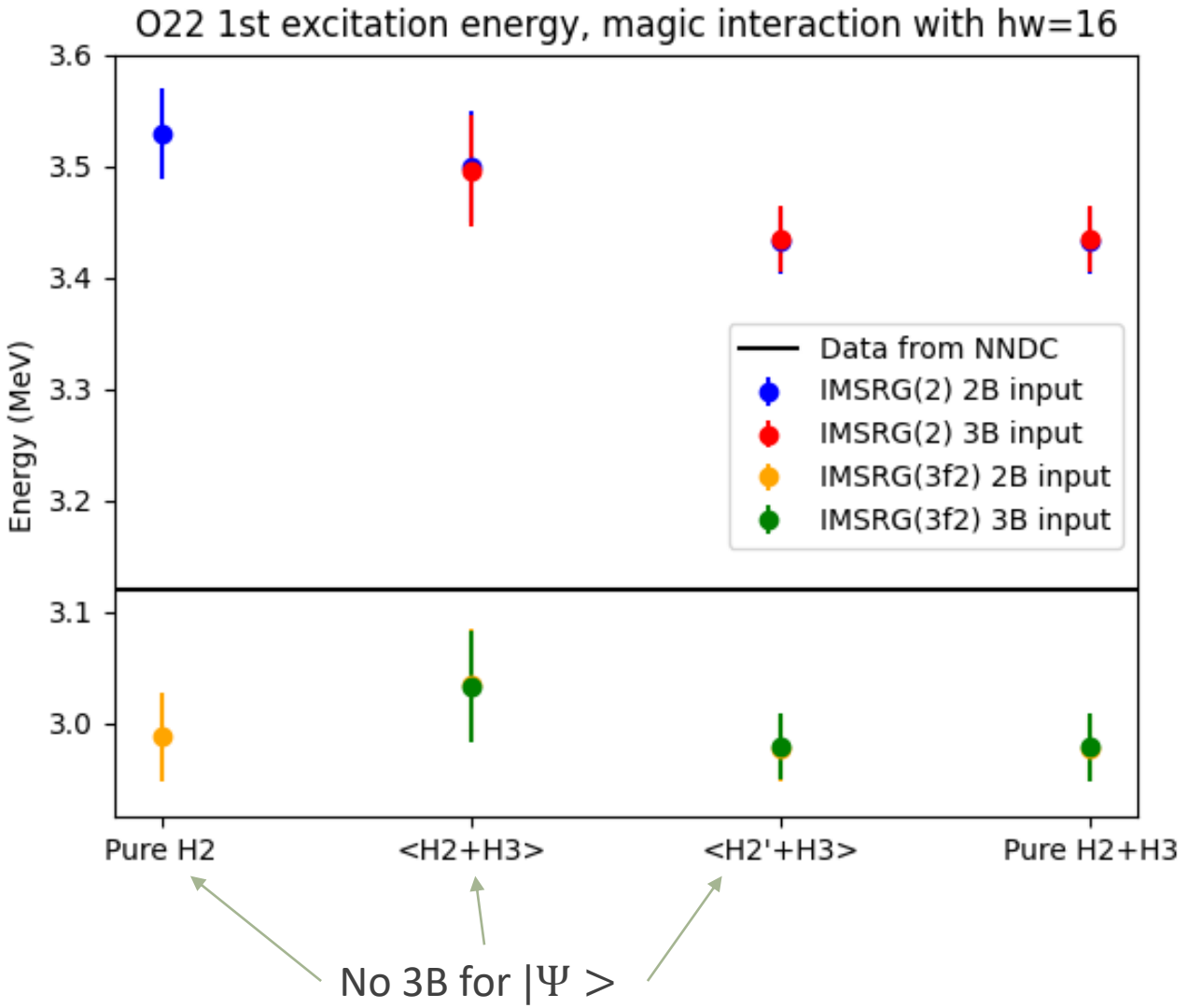
- Perturbative Three-Body
  - $[\Omega_2, H_2]_3 = H_3$
- Input Interaction Three-Body Piece

Where we use the Three-Body Operators

- Use in solving for wavefunction $|\Psi>$
- Use in Operator expectation value, $<\Psi|O|\Psi>$
  - $O = O_1 + O_2 + O_3$




C12 1st excitation energy, magic interaction with hw=16
FCI Benchmark
IMSRG(2) 2B input
IMSRG(2) 3B input
IMSRG(3f2) 2B input
IMSRG(3f2) 3B input
Energy (MeV)
6.5
6.0
5.5
5.0
4.5
4.0
Pure H2
<H2+H3>
<H2'+H3>
Pure H2+H3
No 3B for |Ψ >


O22 1st excitation energy, magic interaction with hw=16
Energy (MeV)
3.6
3.5
3.4
3.3
3.2
3.1
3.0
Data from NNDC
IMSRG(2) 2B input
IMSRG(2) 3B input
IMSRG(3f2) 2B input
IMSRG(3f2) 3B input
Pure H2
<H2+H3>
<H2'+H3>
Pure H2+H3
No 3B for |Ψ >

Summary

1. Can approximate full three-body diagonalization result by including residual one-body and two-body pieces along with three-body piece at the operator level
2. Three-Body versions of input interactions give a small correction(if any) compared to the two-body versions of the same interactions

Thank you!

Ragnar Stroberg

Zhonghao Sun

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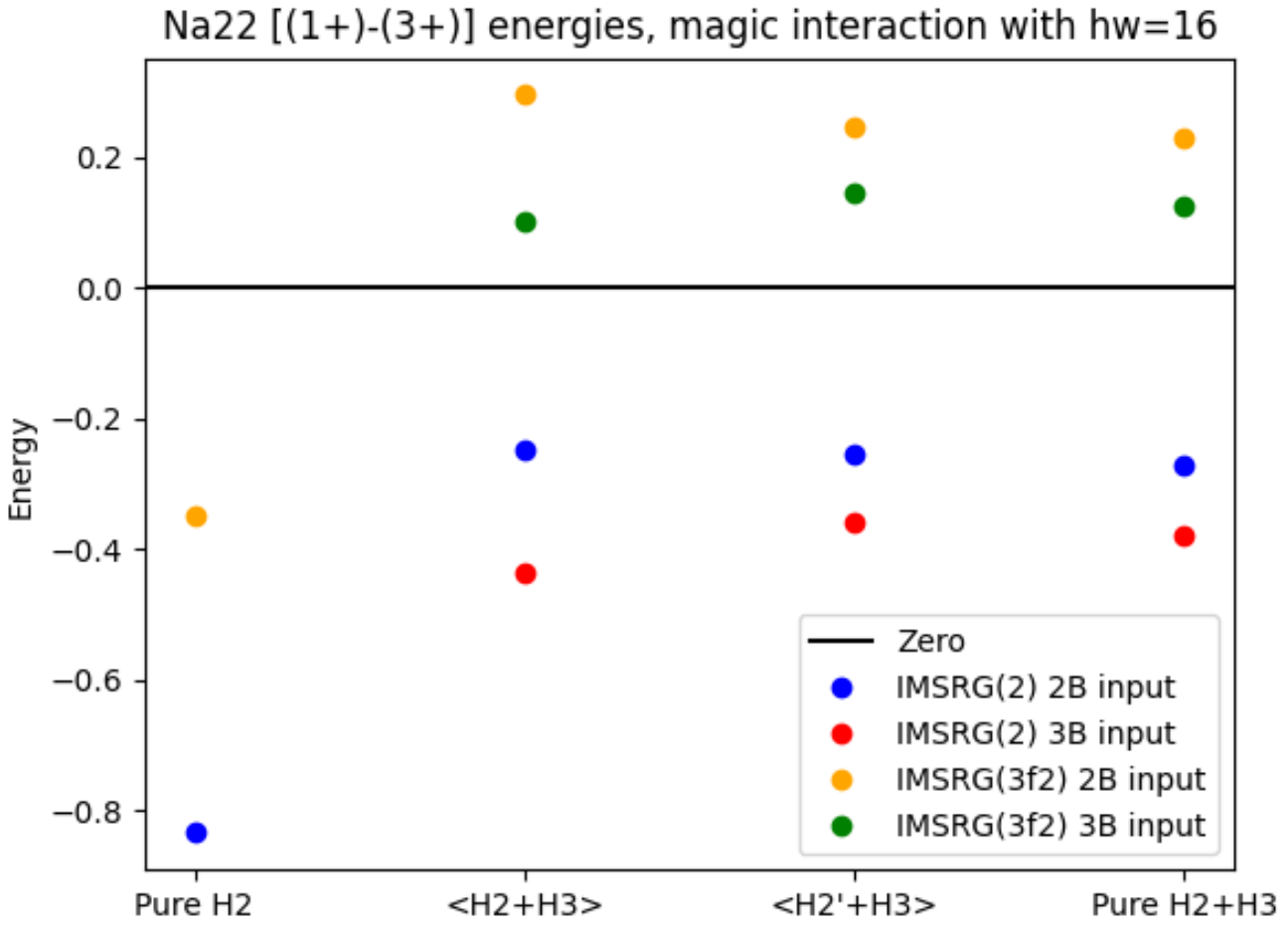
K. Hebeler, S. K. Bogner, R. J. Furnstahl, A. Nogga, and A. Schwenk, Phys. Rev. C 83, 031301(R) (2011).

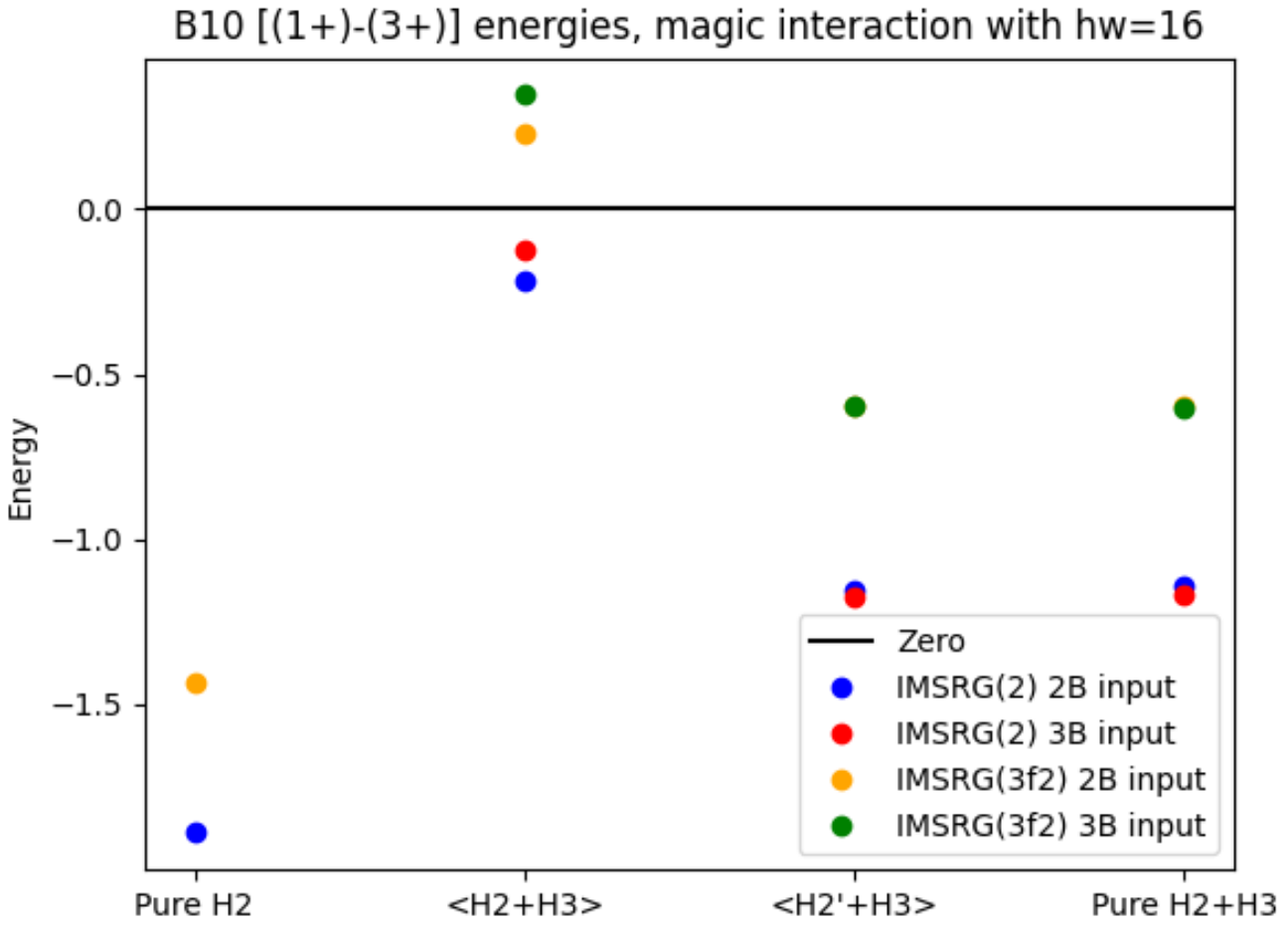
Backup

Approximate Three-Body Density

$$\rho_{ijklmn} \approx A\{\lambda_{il}\lambda_{jm}\lambda_{kn}\} + A\{\lambda_{il}\lambda_{jkmn}\}$$

$$\lambda_{ijkl} = \rho_{ijkl} - A\{\lambda_{ik}\lambda_{jl}\}$$


Na22 [(1+)-(3+)] energies, magic interaction with hw=16
Energy
0.2
0.0
−0.2
−0.4
−0.6
−0.8
Pure H2
<H2+H3>
<H2'+H3>
Pure H2+H3
Zero
IMSRG(2) 2B input
IMSRG(2) 3B input
IMSRG(3f2) 2B input
IMSRG(3f2) 3B input


B10 [(1+)-(3+)] energies, magic interaction with hw=16
Energy
0.0
−0.5
−1.0
−1.5
Pure H2
<H2+H3>
<H2'+H3>
Pure H2+H3
Zero
IMSRG(2) 2B input
IMSRG(2) 3B input
IMSRG(3f2) 2B input
IMSRG(3f2) 3B input

IMSRG -> OSM

IMSRG decouples the interaction

- We extract the zero-body energy

OSM takes decoupled interaction as input

- Along with target nuclei
- Produces the energy spectra for target nuclei

We combine zero-body energy with energy spectra to get binding energy

BCH

Baker-Campbell-Hausdorff (BCH) formula

- $\frac{d}{ds}\Omega(s) = \sum_{k=0}^{\infty} \frac{B_k}{k!} [\Omega(s), \eta(s)]^{(k)}$

What we do

In-Medium Similarity Renormalization Group

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Perform a unitary transformation on the Hamiltonian

- $H(s) = U(s)HU(s)^{\dagger}$

Magnus Formulation

- $U(s) = e^{\Omega(s)}$, $\Omega(s)$ is anti-Hermitian

Using Baker-Campbell-Hausdorff (BCH) formula

- $H(s) = e^{\Omega(s)}H(0)e^{-\Omega(s)} = \sum_{k=0}^{\infty} \frac{1}{k!}[\Omega(s), H(0)]^{(k)}$

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Dependence of $U(s)$ on flow parameter s

- $\frac{d}{ds}U(s) = \eta(s)U(s)$, $\eta(s)$ is our generator

SRG flow equation

- $\frac{d}{ds}H(s) = [\eta(s), H(s)]$

Reference and modelspace

Reference is what we normal order with respect to

- In this case, Sn132

Modelspace is what we define our allowed transitions

- Nuclei with Z<50 would need a different modelspace compared to nuclei with Z>50
- Ex: ‘jj45’ for Z<50, and ‘jj55’ for Z>50