A simple effective interaction for ^{9}He, and Gamow-SRG

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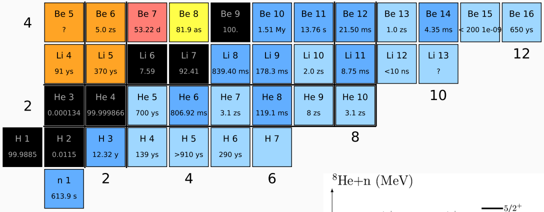
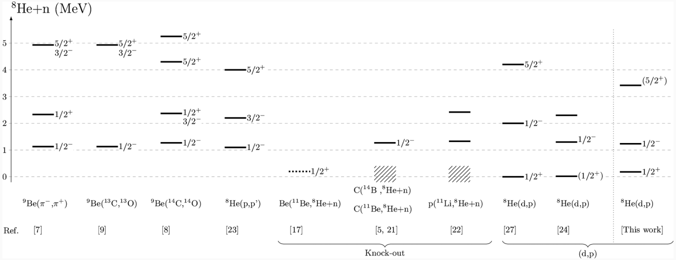
Physics of neutron-rich helium isotopes

Few-body, effective scale separation, continuum couplings, exotic states...



- Two- and four-body halos (^{6,8}He).
- Broad resonances ($1/2^-$ in ^{5,7}He).
- Many th. results, high experimental interest.

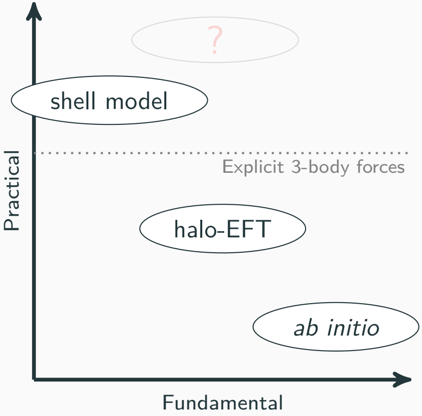
- Uncertain case of ^{9}He.
- Very little known on ^{10}He.



T. Al Kalanee *et al.*, Phys. Rev. C **88**, 034301 (2013)

What are the options to describe ^{9}He?

Practical *vs.* fundamental:



- Well bound core of ^{4}He.

$\rightarrow$ Core approximation justified (SM, EFT).

- Dilute neutron matter above the core.

$\rightarrow$ Residual interaction genuinely residual

- Decent CSM/GSM descriptions of $^{5-10}$He available (small spaces, truncations).

$\rightarrow$ Different phenomenological descriptions are in agreement, it must be a miracle or there is a good reason behind!

Can we find a practical alternative, without explicit 3-body forces, and beyond the SM (with continuum) **for He isotopes?**

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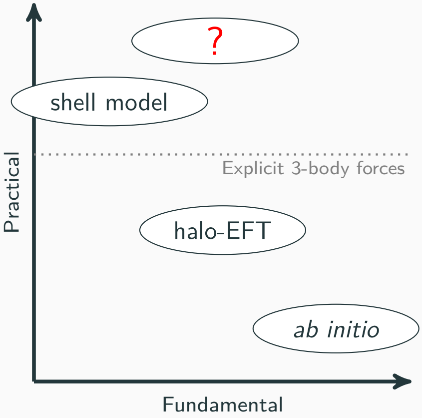

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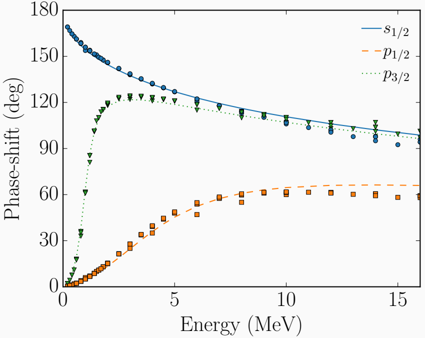
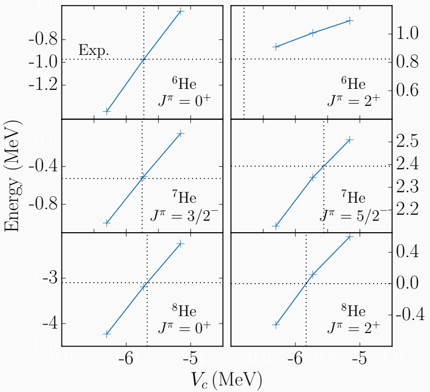
A simple model:

- Core potential fitted on n-^{4}He phase-shifts.
- Contact 2-body central term (3 Gaussian functions) for $(L \text{ even}, S = 0)$ channels.



- Only a prefactor V_c in the interaction to fit!
- (New: just $(L = 0, S = 0)$ works too)



Effective interactions inspired from EFT (preliminary)

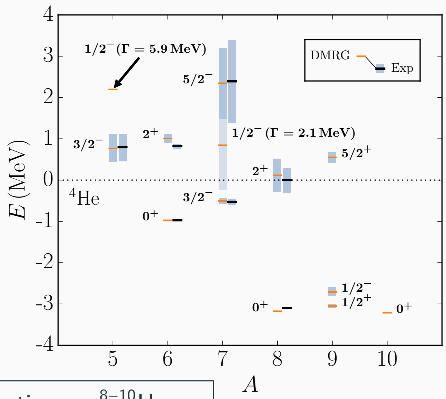
UQ beyond a sensitivity analysis:

- $V_c^{(\text{opt})}$ (mean), σ (standard deviation).
- The uncertainty on the energy is given by:

$$\Delta E = \frac{1}{2}\left|E(V_c^{(\text{opt})} + \sigma) - E(V_c^{(\text{opt})} - \sigma)\right|.$$

Questions:

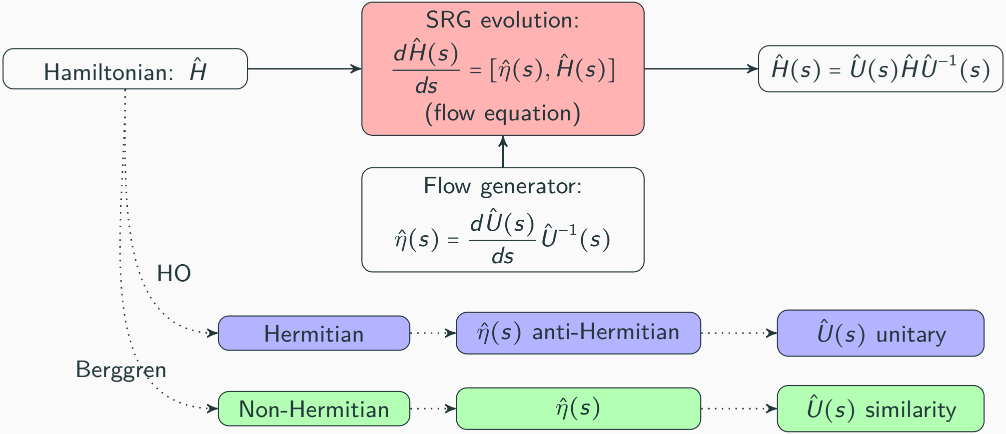
- Why does the core need to be fitted on phase-shifts?
- Is there a proper EFT for all He isotopes behind this simple scheme?
- Can it be generalized to other isotopic chains?



→ Parity inversion in ^{9}He, structure information on $^{8-10}$He.
→ Powerful approach with full continuum couplings, tens of keV uncertainties.

Gamow-SRG

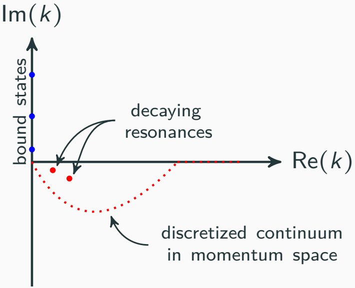
Similarity renormalization group:



Gamow-SRG

The Berggren basis:

- Single particle basis including bound states, decaying resonances and scattering states.



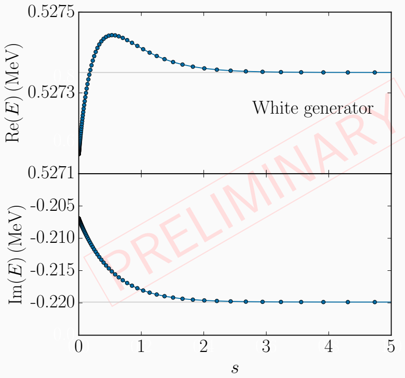
$$\boxed{\sum_{n\in(b,d)} |u_\ell(k_n)\rangle\langle\tilde{u}_\ell(k_n)| + \sum_i |u_\ell(k_i)\rangle\langle\tilde{u}_\ell(k_i)|\, w_{k_i} \approx \hat{\mathbb{1}}_{\ell,j}.}$$

- Discretization:

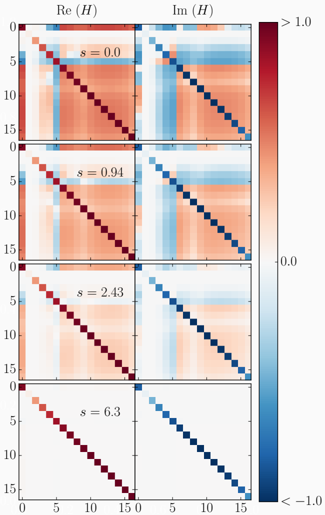
$$|u_\ell(k_i)\rangle \equiv \sqrt{w_{k_i}}\,|u_\ell(k_i)\rangle,$$

$$\sum_{n\in(b,d,i)} |u_\ell(k_n)\rangle\langle\tilde{u}_\ell(k_n)| \approx \hat{\mathbb{1}}_{\ell,j}.$$

Proof of principle:



- Various generator tested.
- Consistent with observations on Hermitian matrices.
- It works best for a Berggren basis with selected scattering states.



→ Promising for IM-SRG in the Berggren basis.

Gamow-SRG

Some technical observations:

- Non-Hermitian Hamiltonian:

$$\hat{H} = \hat{H}_{\mathrm{h}} + \hat{H}_{\mathrm{ah}} = \frac{1}{2}(\hat{H} + \hat{H}^{\dagger}) + \frac{1}{2}(\hat{H} - \hat{H}^{\dagger})$$

- Wegner flow generator for a non-Hermitian Hamiltonian:

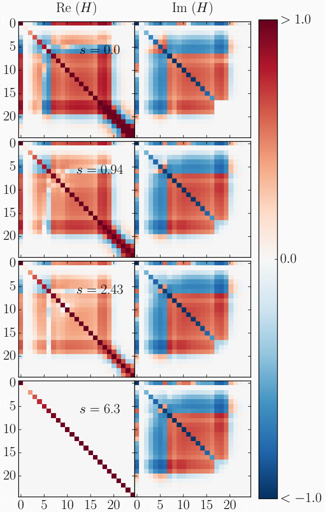
$$\hat{\eta}_{\mathrm{W,cx}} = \left[\hat{H}_{\mathrm{h,d}} + \hat{H}_{\mathrm{ah,d}}, \hat{H}_{\mathrm{h,od}} + \hat{H}_{\mathrm{ah,od}}\right]_{-} \ \text{(unstable)}$$
$$\Rightarrow \hat{\eta}_{G} = \left[\hat{H}_{\mathrm{h,d}}, \hat{H}_{\mathrm{od}}\right]_{-} = \left[\hat{H}_{\mathrm{h,d}}, \hat{H}_{\mathrm{h,od}} + \hat{H}_{\mathrm{ah,od}}\right]_{-}$$

- Wegner flow generator for the real part only:

$$\hat{\eta}_{G,\mathrm{h}} = \left[\hat{H}_{\mathrm{h,d}}, \hat{H}_{\mathrm{h,od}}\right]_{-}$$

→ Not yet clear how to extract the anti-Hermitian part (key for continuum).

$$\hat{\eta}_{G,\mathrm{h}} = \left[\hat{H}_{\mathrm{h,d}}, \hat{H}_{\mathrm{ah,od}}\right]_{-} \ \text{(not similarity)}$$



Thank you for your attention!

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(NC)GSM vs DMRG