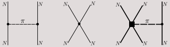
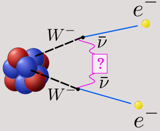
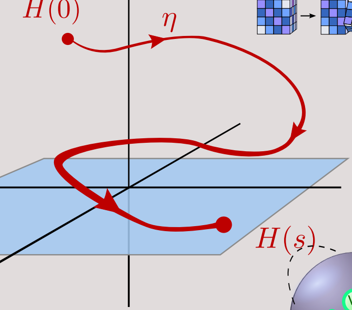
Double beta decay with the valence space IMSRG

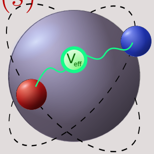
A status update





$$\frac{dH}{ds} = [\eta, H]$$





Ragnar Stroberg

University of Washington

Double Beta Decay
Summer 2019 Collaboration Meeting
UNC Chapel Hill
Sep 6, 2019

Work done by Charlie Payne and Antoine Belley, with help from Javier Menendez

The method

- Valence-space in-medium similarity renormalization group (VS-IMSRG)
- Truncation scheme
- Transformation of operators

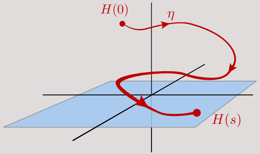
Applications to β decay

- Quenching of g_A in single β decay
- ^{48}Ca $2\nu\beta\beta$ (with 2bc)
- Benchmarking $0\nu\beta\beta$ in light nuclei
- ^{48}Ca $0\nu\beta\beta$ decay (also ^{76}Ge, ^{82}Se)
- $0\nu\beta\beta$ contact in ^{48}Ca

Unitary transformation

Flowing Hamiltonian $\longrightarrow$ $H(s) \equiv U(s) H U^\dagger(s)$

flow parameter



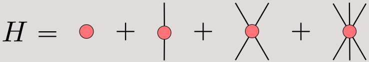
$$\frac{dU(s)}{ds} \equiv \eta(s) U(s)$$

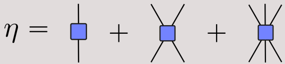
generator, $\eta[H(s)]$

RG flow eq. $\longrightarrow$ $\frac{dH}{ds} = [\eta(s), H(s)]$

Głazek and Wilson 1993; Wegner 1994; Bogner, Furnstahl, and Perry 2007

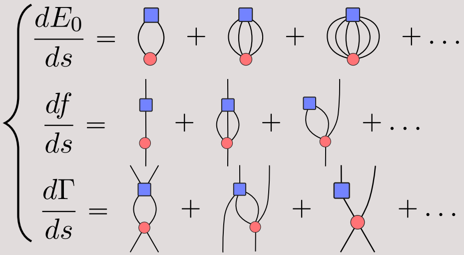
$$H = E_0 + \sum_{ij} f_{ij}\{a_i^\dagger a_j\} + \frac{1}{4}\sum_{ijkl}\Gamma_{ijkl}\{a_i^\dagger a_j^\dagger a_l a_k\} + \frac{1}{36}\sum_{\substack{ijk\\lmn}} W_{ijklmn}\{a_i^\dagger a_j^\dagger a_k^\dagger a_n a_m a_l\}$$

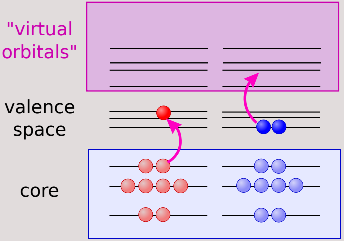




Flow equation:

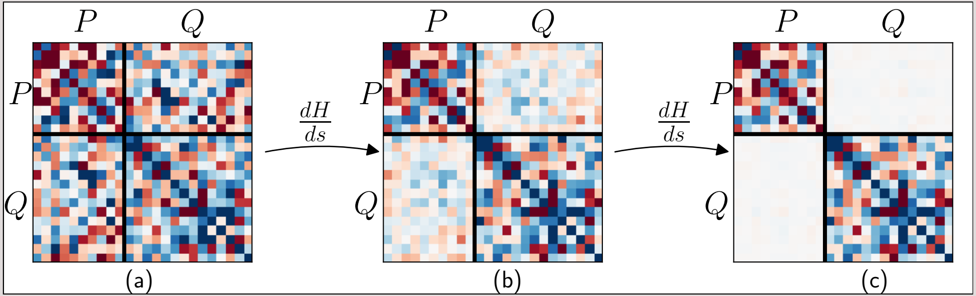
$$\frac{dH}{ds} = [\eta(s), H(s)] \Rightarrow$$





$$\eta \sim H^{\mathrm{od}} \sim QHP \xrightarrow[s\to\infty]{} 0$$

Głazek and Wilson 1993; Wegner 1994; Tsukiyama, Bogner, and Schwenk 2011; Bogner et al. 2014

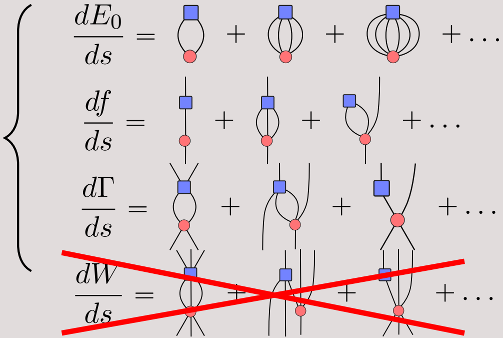


As $s \to \infty$, P space is decoupled from Q space.

Output is a shell model effective interaction
$\to$ diagonalize with NuShellX, Antoine, etc.

Stroberg et al. 2019

$$\frac{dH}{ds} = [\eta(s), H(s)] \Rightarrow$$



Quality of this truncation will depend on

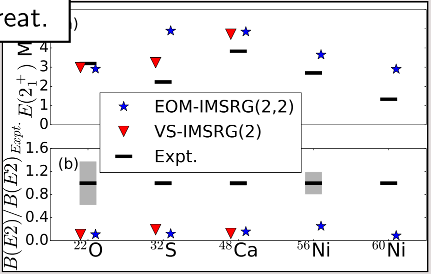
- Softness of potential
- Reference state $|\Phi\rangle$
- The observable in question
- Choice of valence space

IMSRG(3) in progress...

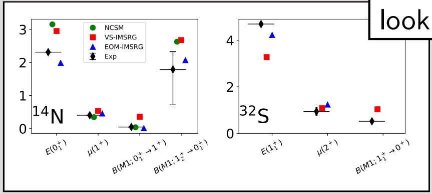
$$H(s) = U(s)HU^\dagger(s) \qquad \longrightarrow \qquad \mathcal{O}(s) = U(s)\mathcal{O}U^\dagger(s)$$

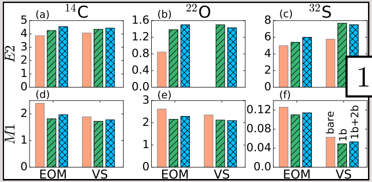
$$\frac{dH}{ds} = [\eta(s), H(s)] \qquad \qquad \frac{d\mathcal{O}}{ds} = [\eta(s), \mathcal{O}(s)]$$

$E2$'s not so great.



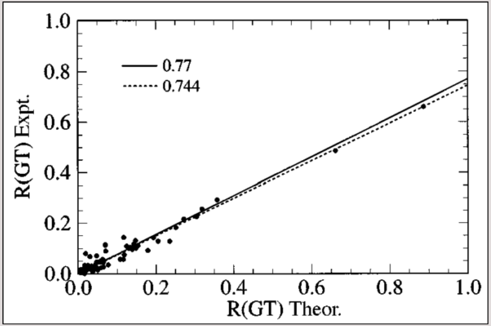
$M1$'s look ok.

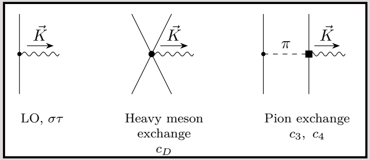


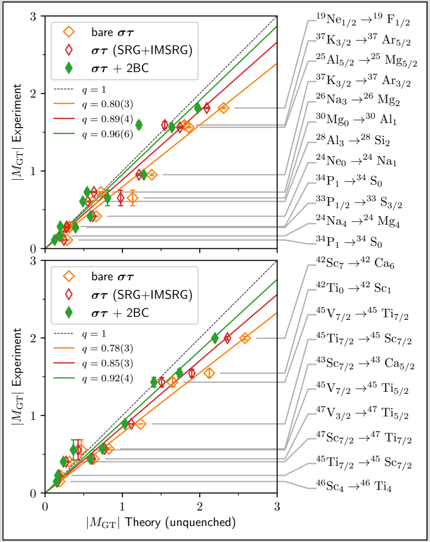


$1b > 2b$

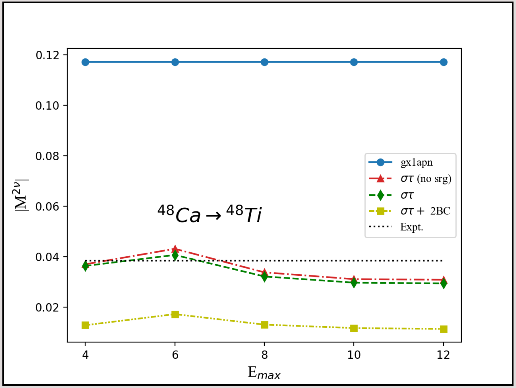
Parzuchowski et al. 2017

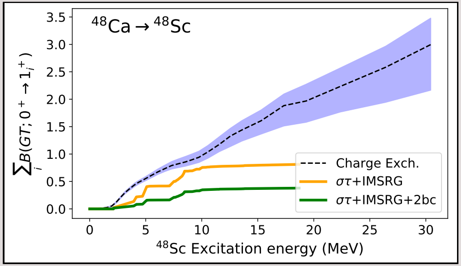


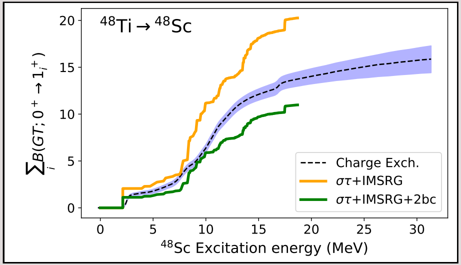




Gysbers et al. 2019

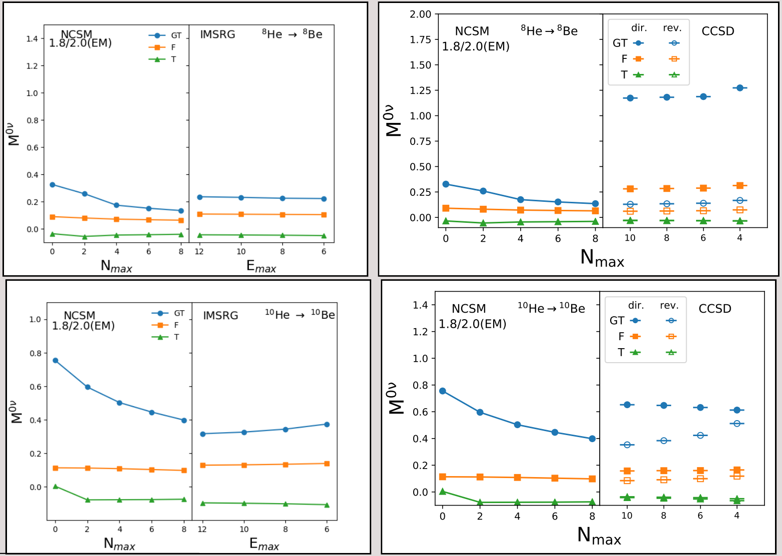






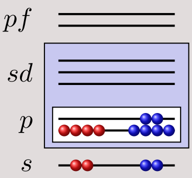
Caveat: application of weak 2bc to hadronic process is dubious

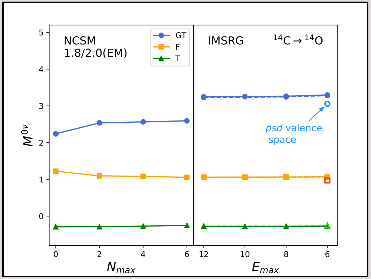
Yako et al. 2009

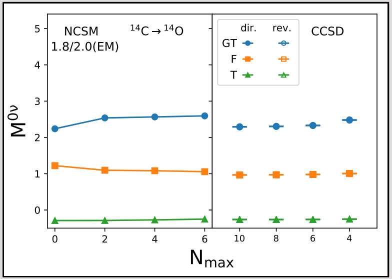


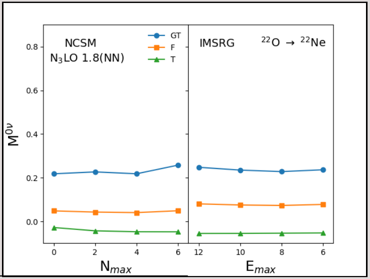
A. Belley, P. Navrátil, S. Novario (private comm.)

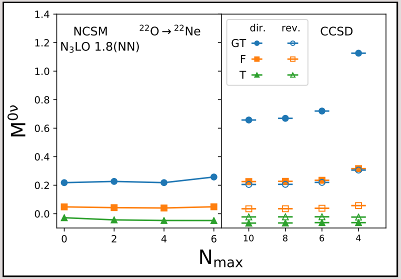
Benchmarking in light nuclei











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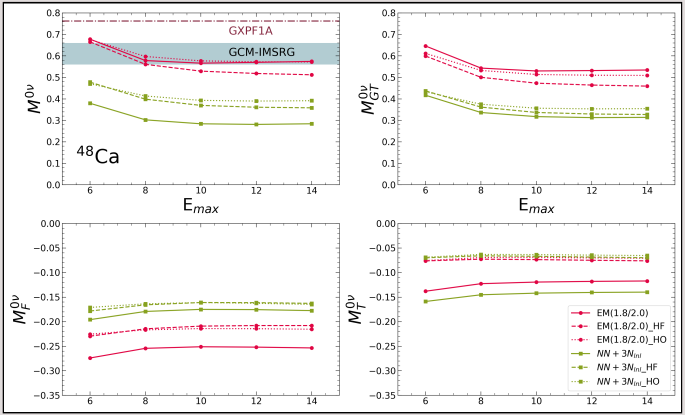
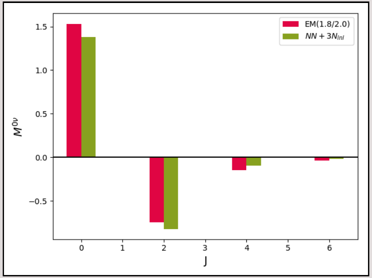


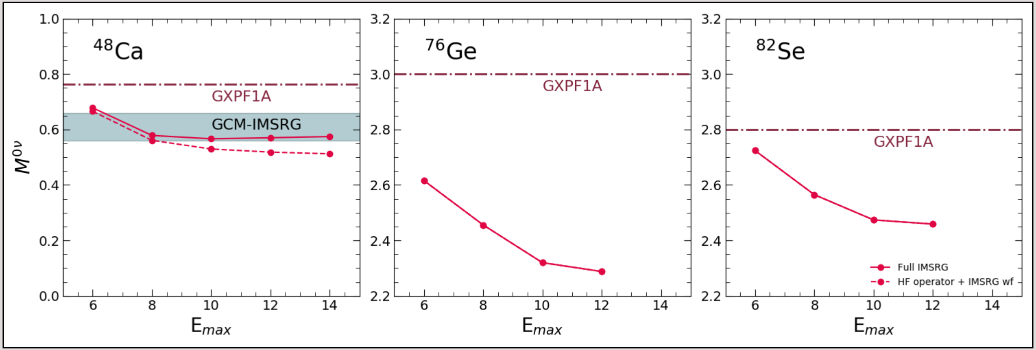


Angular momentum of decaying pair

Interactions: 1.8/2.0 EM

N^{3}LO NN + N^{2}LO 3N (loc/non-loc)

Payne 2018



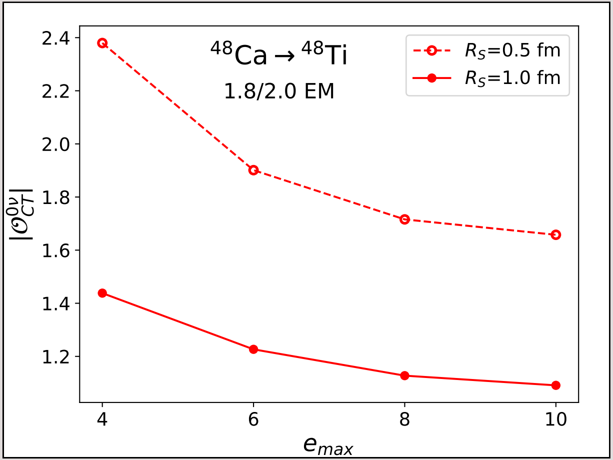
1.8/2.0 EM, $\hbar\omega$=16 MeV

Payne 2018

$$\mathcal{O}^{0\nu}_{CT} = -2 \underbrace{\hat{g}^{NN}_{\nu}}_{=1} \frac{1.2A^{1/3}}{f_\pi^2} \delta^3_{R_S}(\vec{r})\tau_1\tau_2$$

$$\delta^3_{R_S}(\vec{r}) \equiv \frac{1}{(\pi R_S^2)^{3/2}} e^{\frac{|\vec{r_1}-\vec{r_2}|^2}{R_S^2}}$$

$$f_\pi = 92.2 \text{ MeV} = 2.14 \text{ fm}^{-1}$$



Cirigliano et al. 2018

Summary

- 2b currents appear to over-quench $2\nu\beta\beta$ in ^{48}Ca
- Benchmark $0\nu\beta\beta$ calculations show encouranging agreement
- Significant interaction dependence in $0\nu\beta\beta$ decay of ^{48}Ca
- $0\nu\beta\beta$ strength also reduced in ^{76}Ge,^{82}Se relative to phenomenology
- Confirm that $0\nu\beta\beta$ contact has $\mathcal{O}(1)$ contribution to NME in ^{48}Ca

Collaborators:

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