LOUISIANA STATE UNIVERSITY

Monopole, dipole, and quadrupole excitations in nuclei from the *ab initio* Symmetry-Adapted No-Core Shell Model (coupled with the Lorentz Integral Transform Method)

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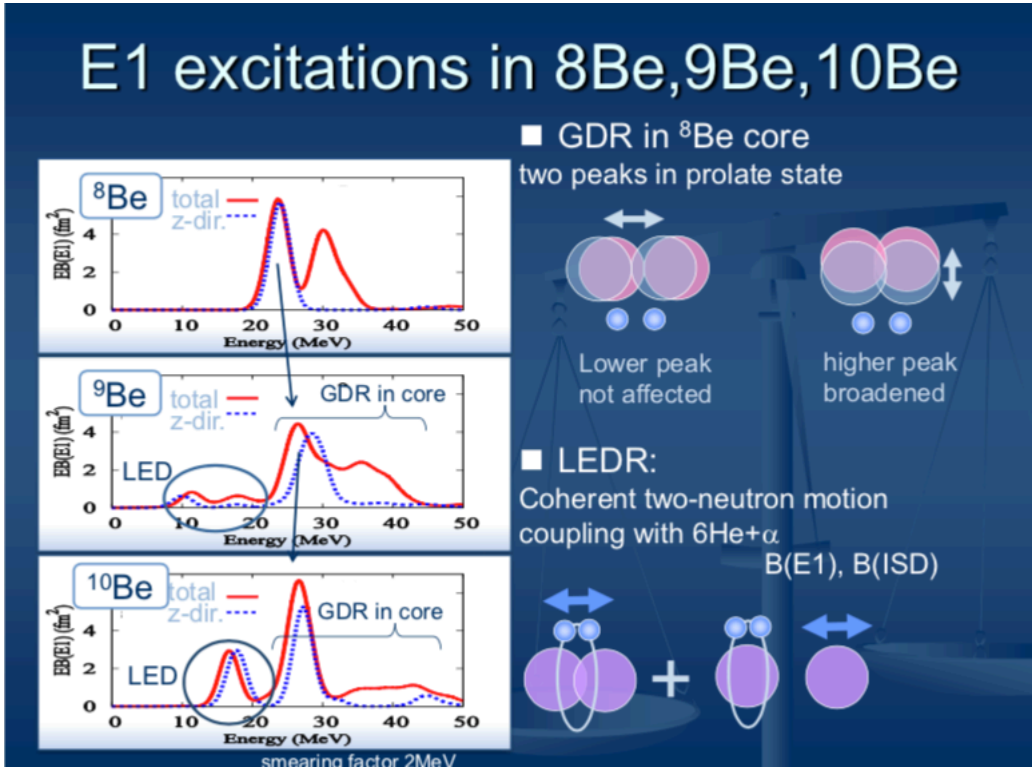
TRIUMF

Response function as a probe for clustering

Example:



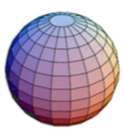
Y. Kanada-En'yo, WNCP 2017

Do these features emerge from first principles?
We study this in:

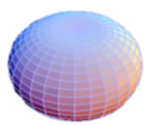
- *ab initio symmetry-adapted* approach
- ability to see intrinsic deformation

Symmetry-adapted no-core shell model (SA-NCSM)

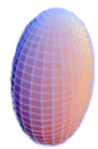
Collective basis based on deformation and vibrations plus rotations:



(0 0)
sphere

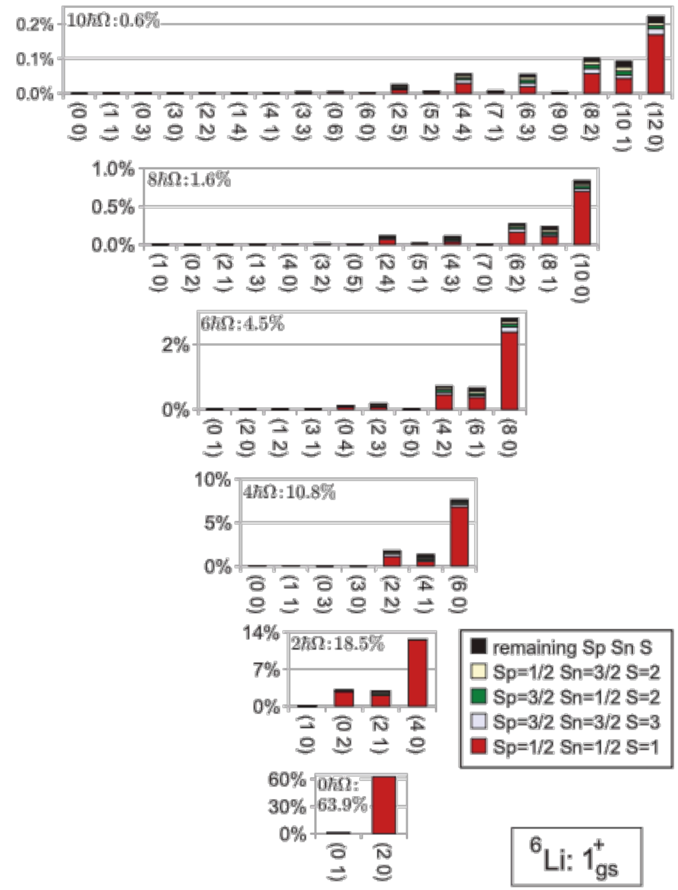


(0 μ)
oblate



(λ 0)
prolate

Realistic interactions have a preference for a small subset of possible basis states (an emergent symmetry).



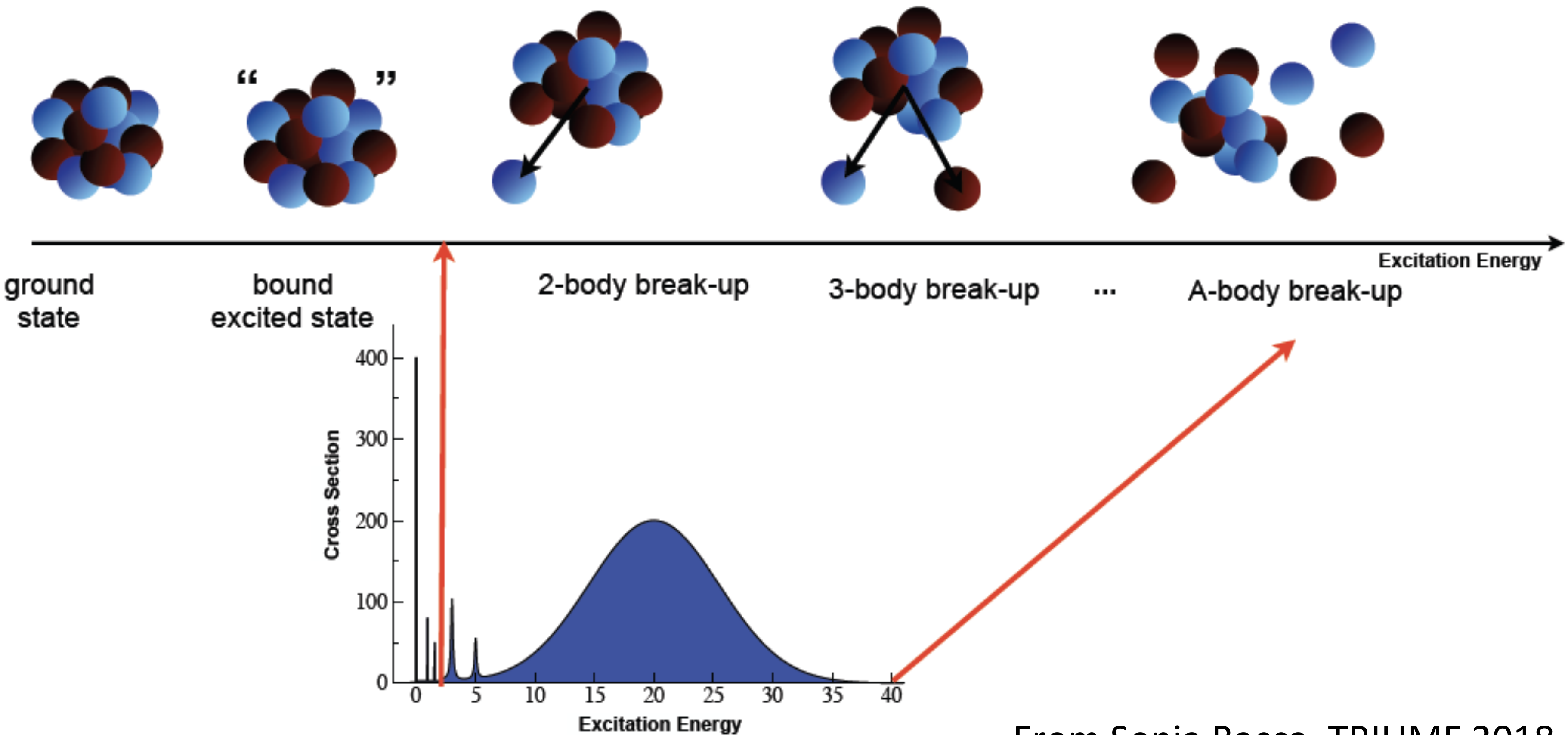
T. Dytrych, et al., Phys. Rev. Lett. **111** (2013) 252501

Continuum problem

Lorentz Integral Transform Method (LIT)

$$R(\omega) = \sum\!\!\!\!\!\!\int_f \left| \left\langle \psi_f \left| \mathrm{O} \right| \psi_0 \right\rangle \right|^2 \delta(E_f - E_0 - \omega)$$

Depending on E_f, many channels may be involved



From Sonia Bacca, TRIUMF 2018

SA-NCSM + LIT

$$|\Psi_0\rangle \longrightarrow M_{00}, D_{1\mu}, Q_{2\mu} \longrightarrow |v_1\rangle = \frac{\hat{O}\,|\Psi_0\rangle}{\sqrt{\langle\Psi_0|\,\hat{O}^\dagger\hat{O}\,|\Psi_0\rangle}}$$

calculate ground state wave function in *ab initio* SA-NCSM

choose operator of interest

construct pivot vector for Lanczos algorithm

tridiagonalize Hamiltonian and construct LIT

$$L(E_x,\Gamma) = -\frac{1}{\Gamma}\mathrm{Im}\left[\frac{\langle\Psi_0|\,O^\dagger O\,|\Psi_0\rangle}{z - a_0 - \frac{b_1^2}{z-a_1-\frac{b_2^2}{z-a_2-\dots}}}\right]$$

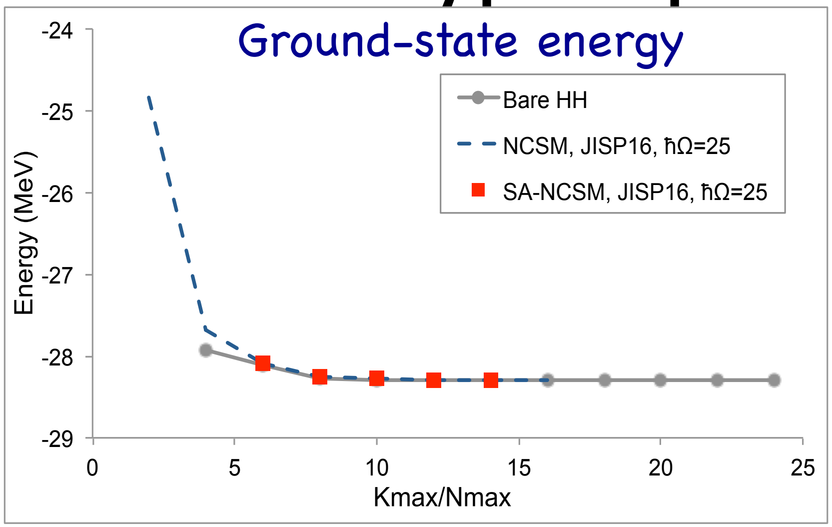
Energy Parameter

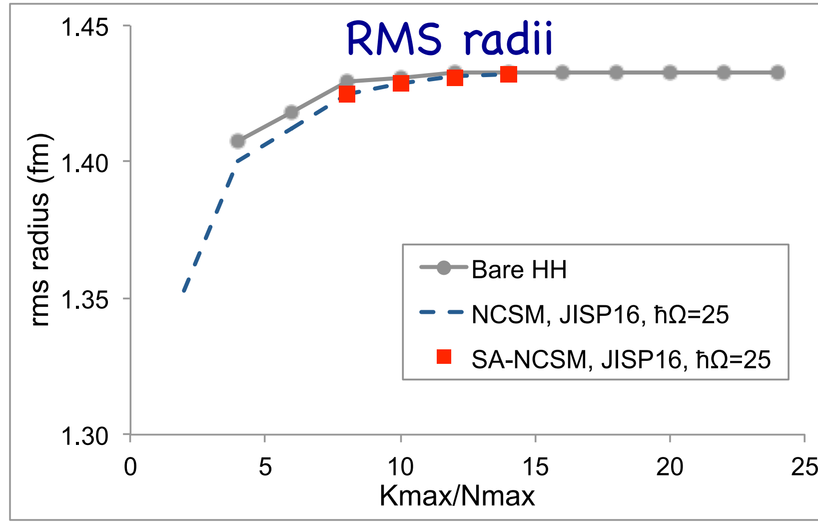
Lanczos coefficients

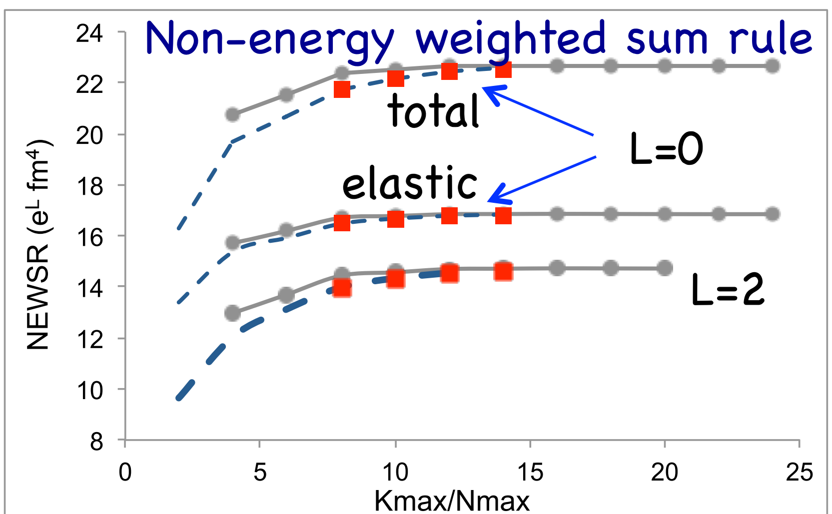
take $\Gamma \to 0$ to approximate discrete strength/response

$$L(E_x,\Gamma) = \frac{\Gamma}{\pi}\int \mathrm{d}\omega \frac{R(\omega)}{(\omega - E_x)^2 + \Gamma^2}$$

^{4}He benchmark with Hyperspherical Harmonics



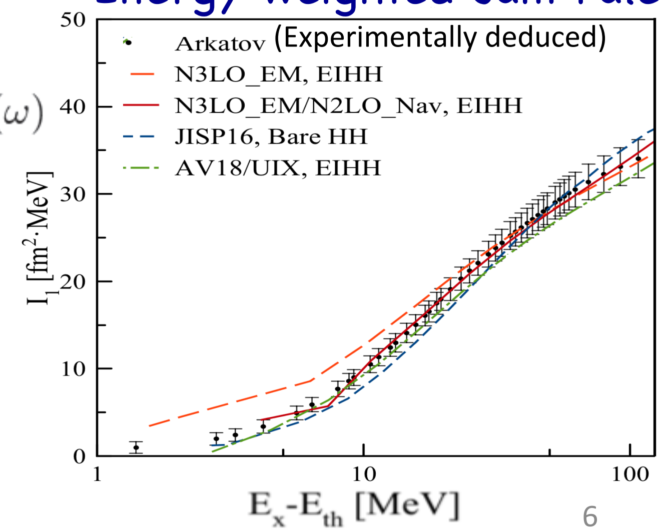




Sum rules

$$m_n = \int_0^\infty d\omega\ \omega^n R(\omega)$$

Energy weighted sum rule

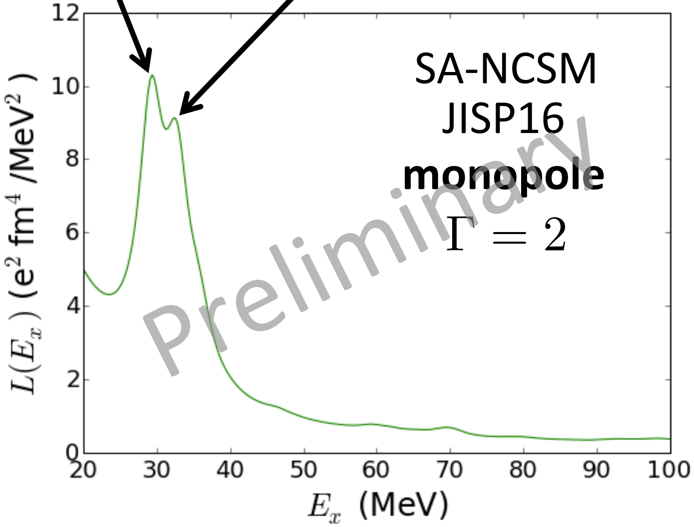


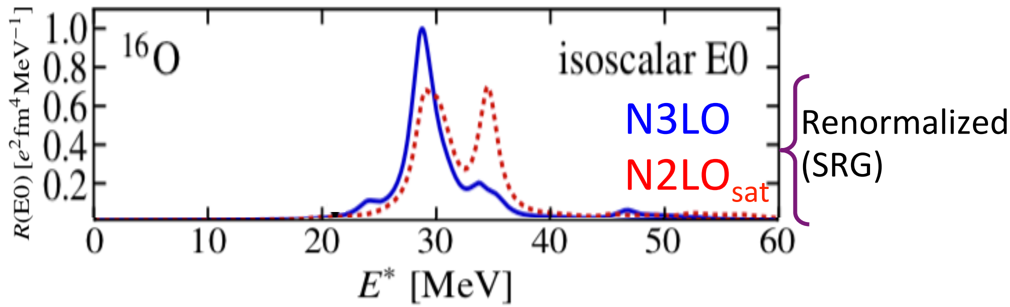
(2 0) + (4 2) (>50%), spin-0

(2 0) spin-0 + (4 2) spin-2 (~30%)

^{16}O

SA-NCSM allows us to examine the underlying shape and dynamics

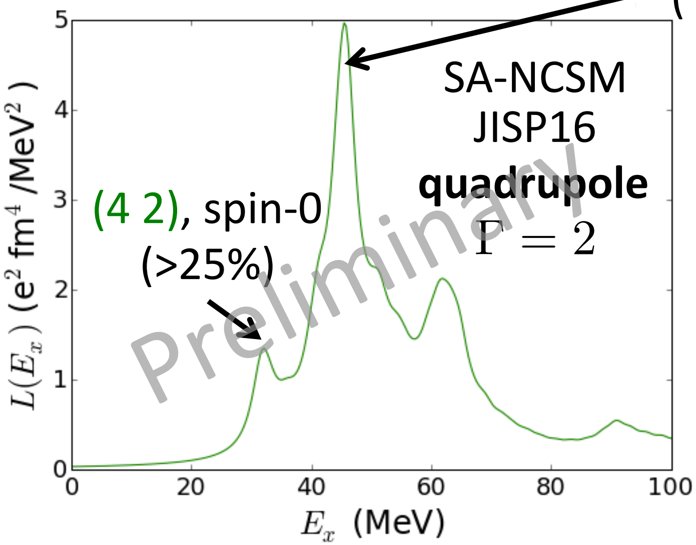


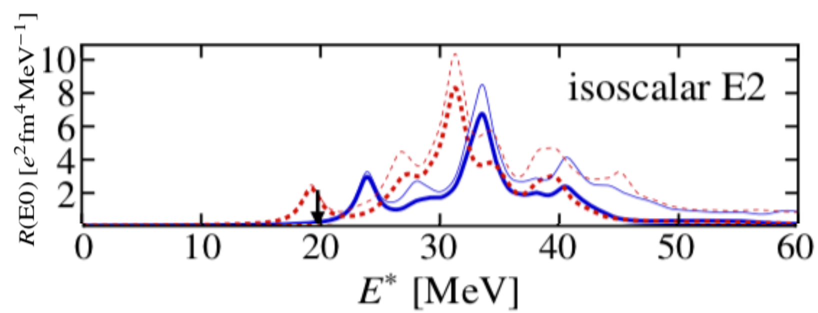


Stumpf, et al., arXiv:1709.06840

(2 0) spin-0 + (4 2) spin-2 (~30%)

(4 2), spin-0 (>25%)





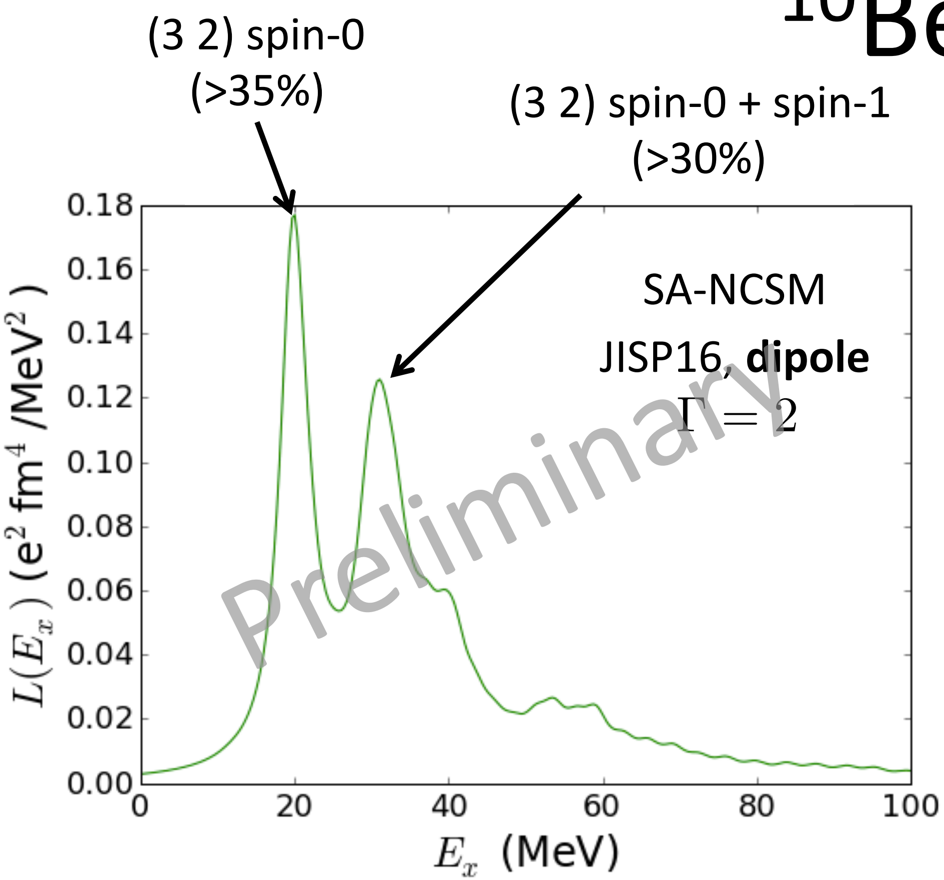
<u>Important results</u>

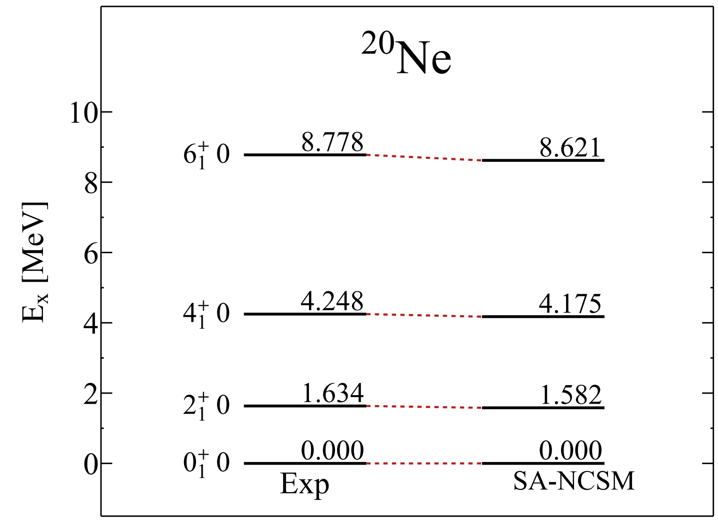
(2 0) describes giant monopole/quadrupole resonance: 1p-1h vibration of the spherical ground state

(4 2) spin-0 is deformed 2p-2h configuration (third 0^+)

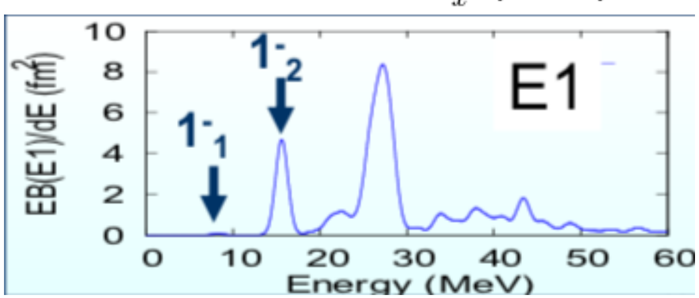
^{10}Be

SA-NCSM allows us to examine the underlying shape and dynamics





LIT in progress…



lowest 1^- doesn't contribute to E1 strength

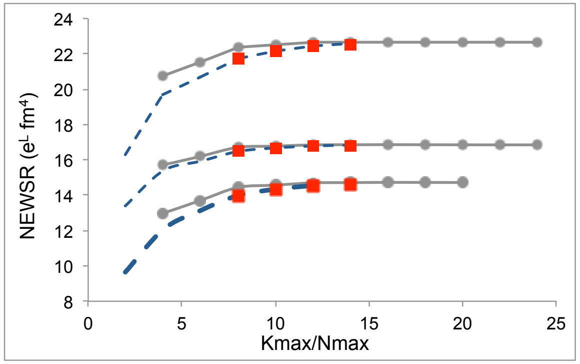
Y. Kanada-En'yo, PRC **93** 024322

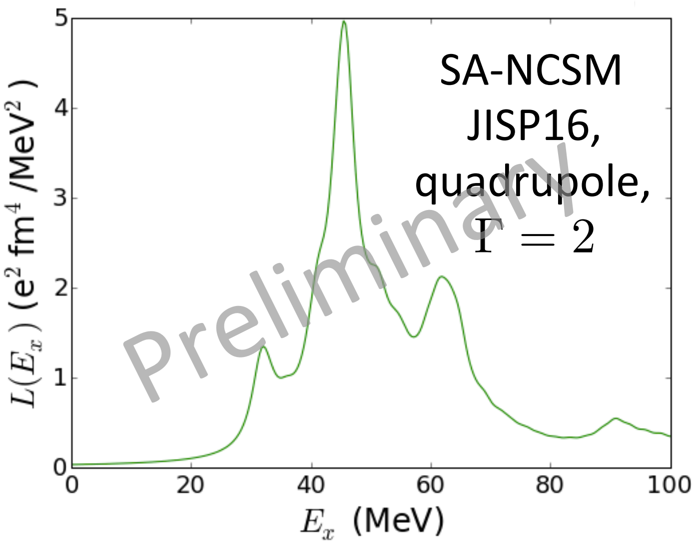
Summary

Successful combination of the *ab initio* Symmetry-Adapted No-Core Shell Model and the Lorentz Integral Transform Method

- benchmarked with Hyperspherical Harmonics

- *ab initio* sum rules and response functions are now feasible beyond the lightest nuclei





First steps in using the *ab initio* SA-NCSM with bare interactions to examine low-energy resonances

- Future work: examine intrinsic structure of soft/pygmy resonances
- Studies with chiral potentials