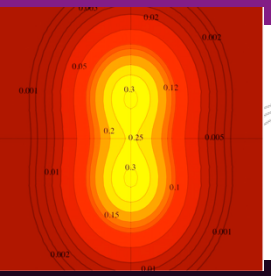
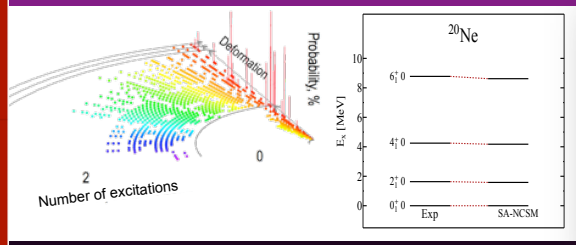
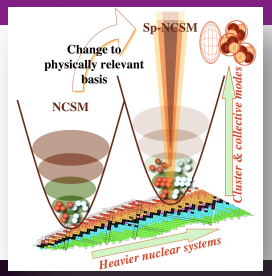
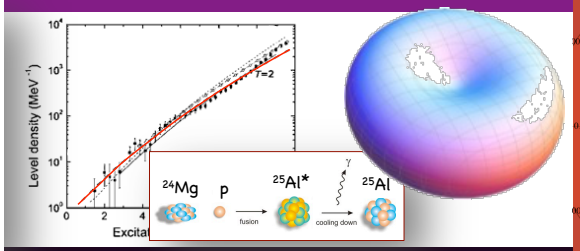
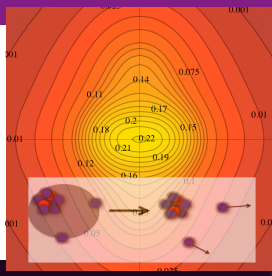









Lessons from the ab initio symmetry-adapted no-core shell model

Kristina Launey

… LSU Team …

Jerry Draayer, Tomas Dytrych, Robert Baker, Ali Dreyfuss, David Kekejian, Grigor Sargsyan, Harvey Shows, Logan Woolsey, Sean Laughlin

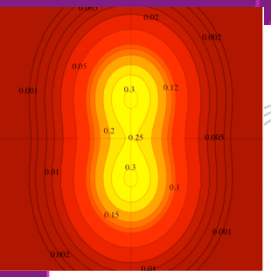
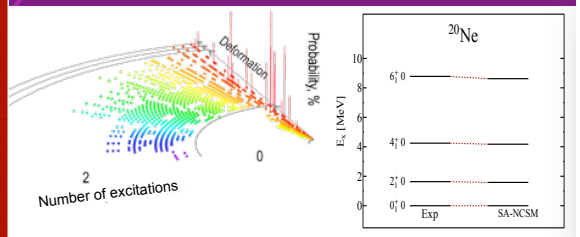
In collaboration with

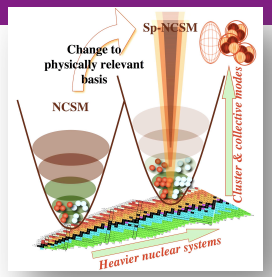
Iowa State U. – J. Vary & P. Maris
Czech Republic – D. Langr & T. Oberhuber
Princeton U. – W. Tang

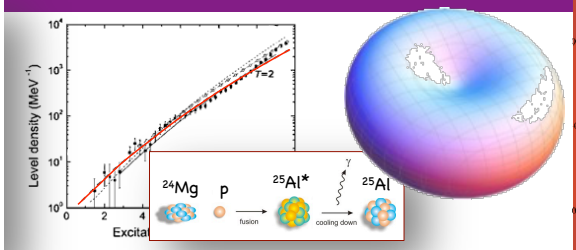
HPC Resources
NSF/U. of Illinois …*BlueWaters*
LSU…*SuperMike-II*

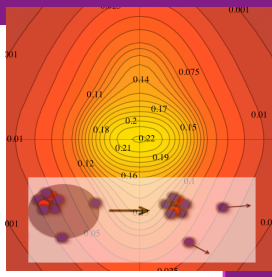
Supported by NSF & DOE-EPSCoR

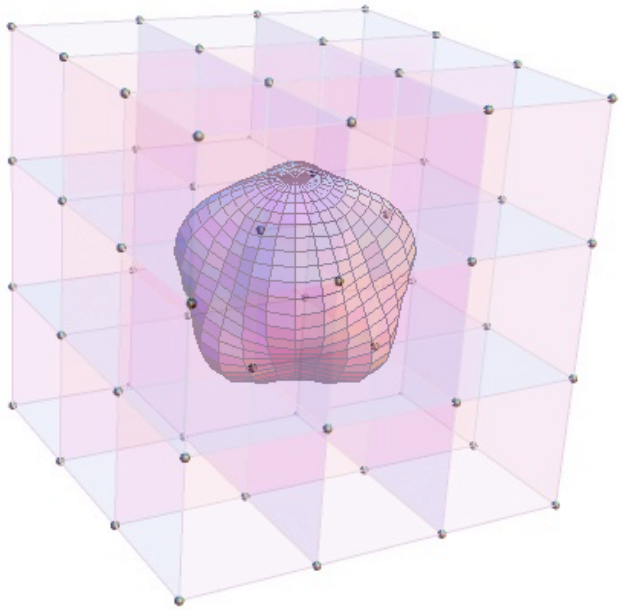
LSU



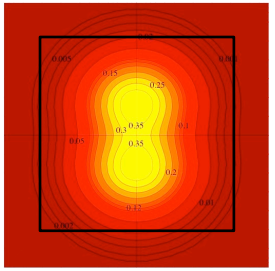






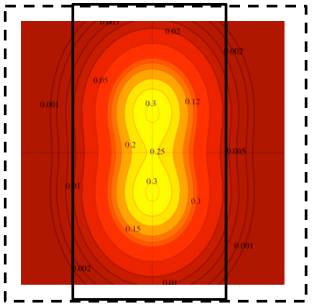
NCSM

Total HO quanta
N_{max}



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

Total HO quanta
N_{max}
+
Distribution:
z, x, y

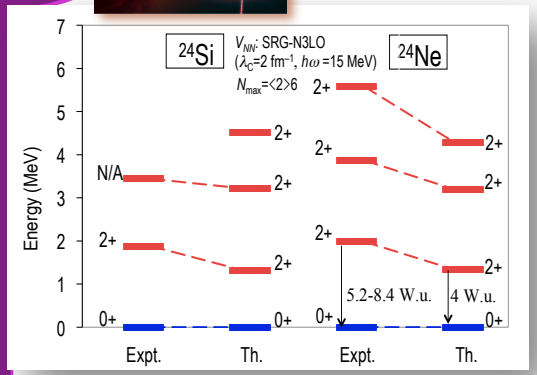


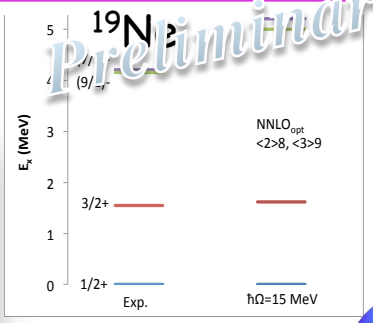
LSU code (LSU3shell): sourceforge.net/projects/lsu3shell

Dytrych, Launey, Draayer, et al., Phys. Rev. Lett. 111 (2013) 252501

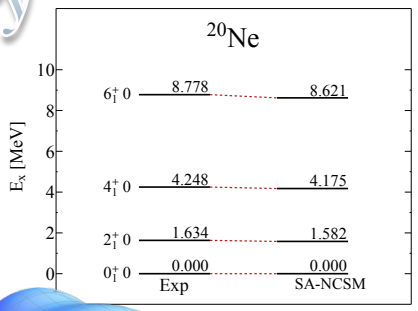
Launey, Dytrych, & Draayer, Prog. Part. Nucl. Phys. 89 (2016) 101

Deformed (in intrinsic frame)…

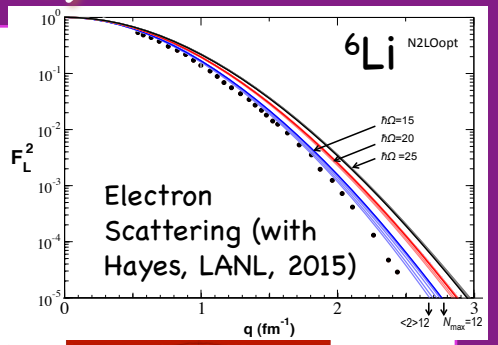


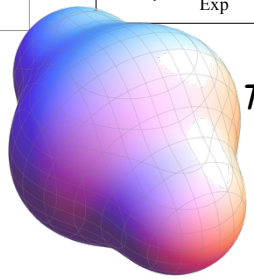


Preliminary



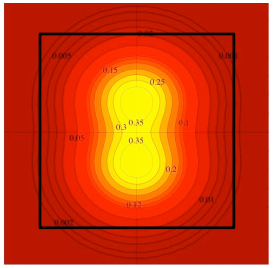
Robert Baker, LSU

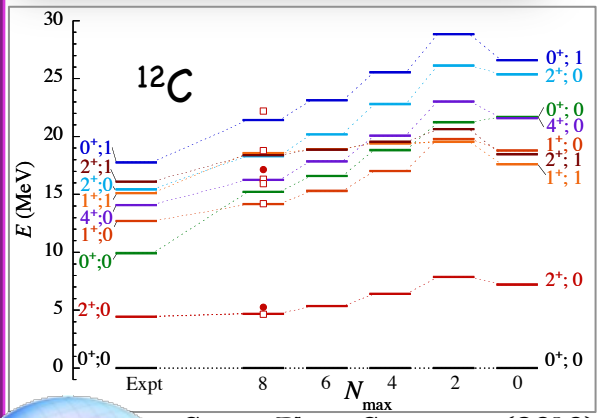




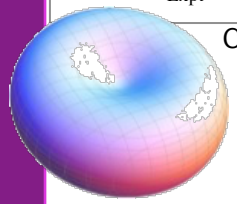
NCSM

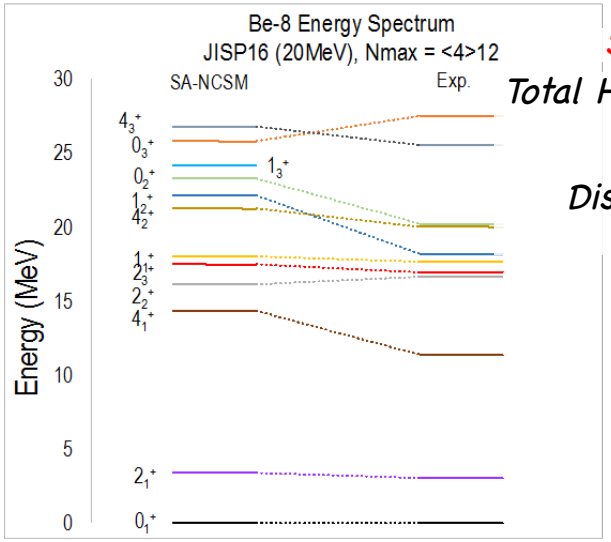
Total HO quanta N_{max}





Comp. Phys. Commun. (2016)

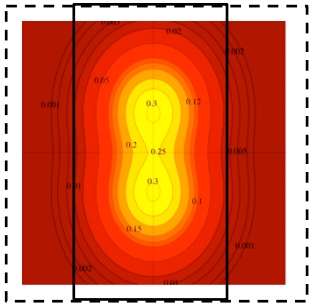




Harvey Shows, LSU

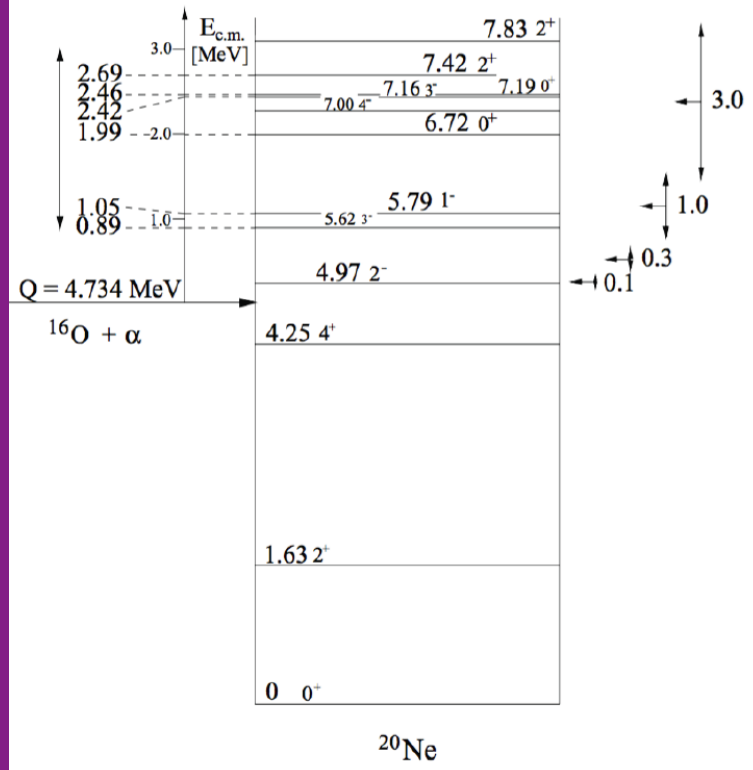
SA-NCSM

Total HO quanta N_{max} + Distribution: z, x, y



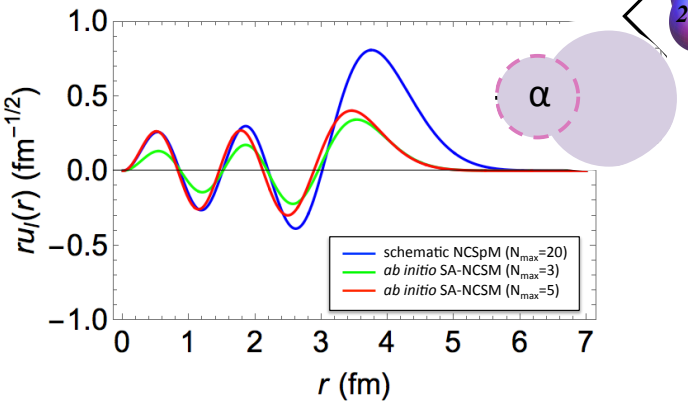
Deformation/collectivity: important in nuclear wave functions

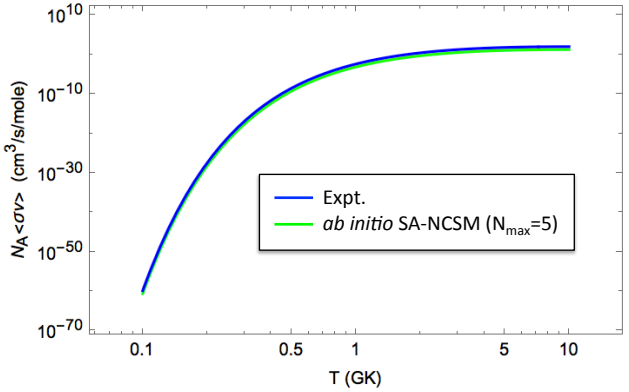
Effect on X-ray Burst Nucleosynthesis

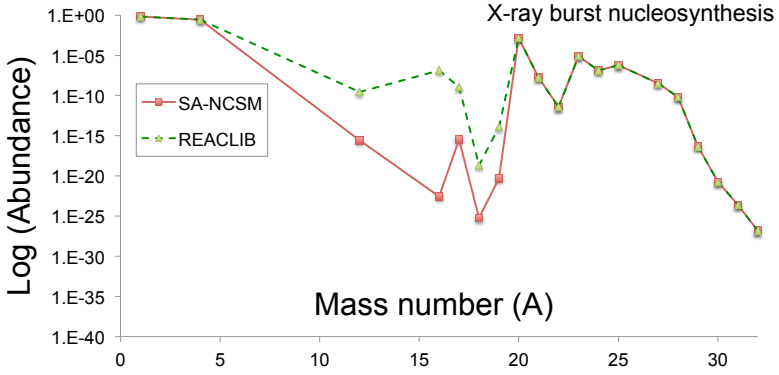


$^{16}\mathrm{O}(\alpha,\gamma)^{20}\mathrm{Ne}$

Ali Dreyfuss, LSU







Wave functions from *ab initio* SA-NCSM

Reaction rates

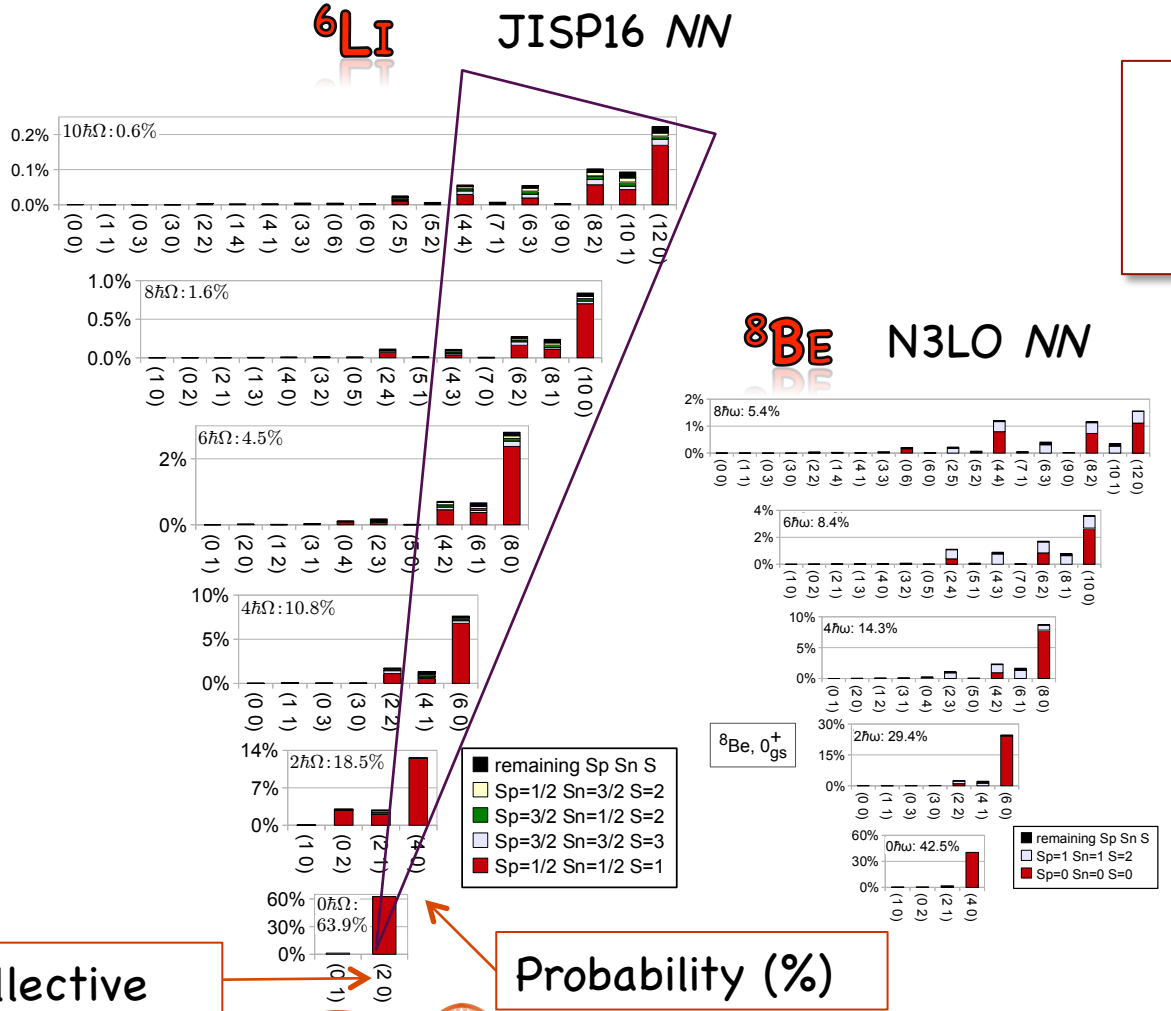
Nucleosynthesis simulations: XRB abundance pattern

Orderly pattern from first principles

Symmetry-adapted No-core Shell Model (SA-NCSM)

First-principle: light nuclei, low-energy dynamics

Emergence of a simple pattern in complex nuclei

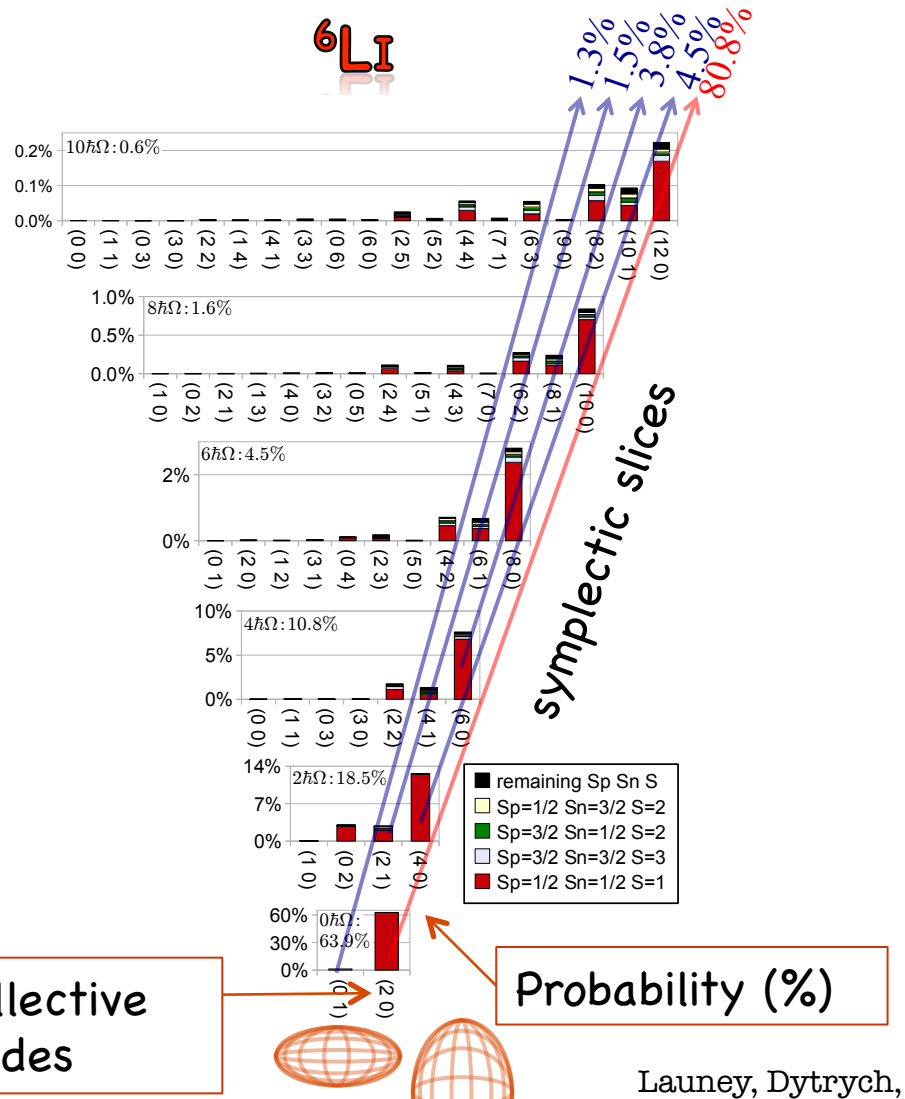


Collective modes

Probability (%)

Dytrych, Launey, Draayer, et al., PRL 111 (2013) 252501

Symplectic symmetry from first principles



First-principle: light nuclei, low-energy dynamics

Emergence of a simple pattern in complex nuclei

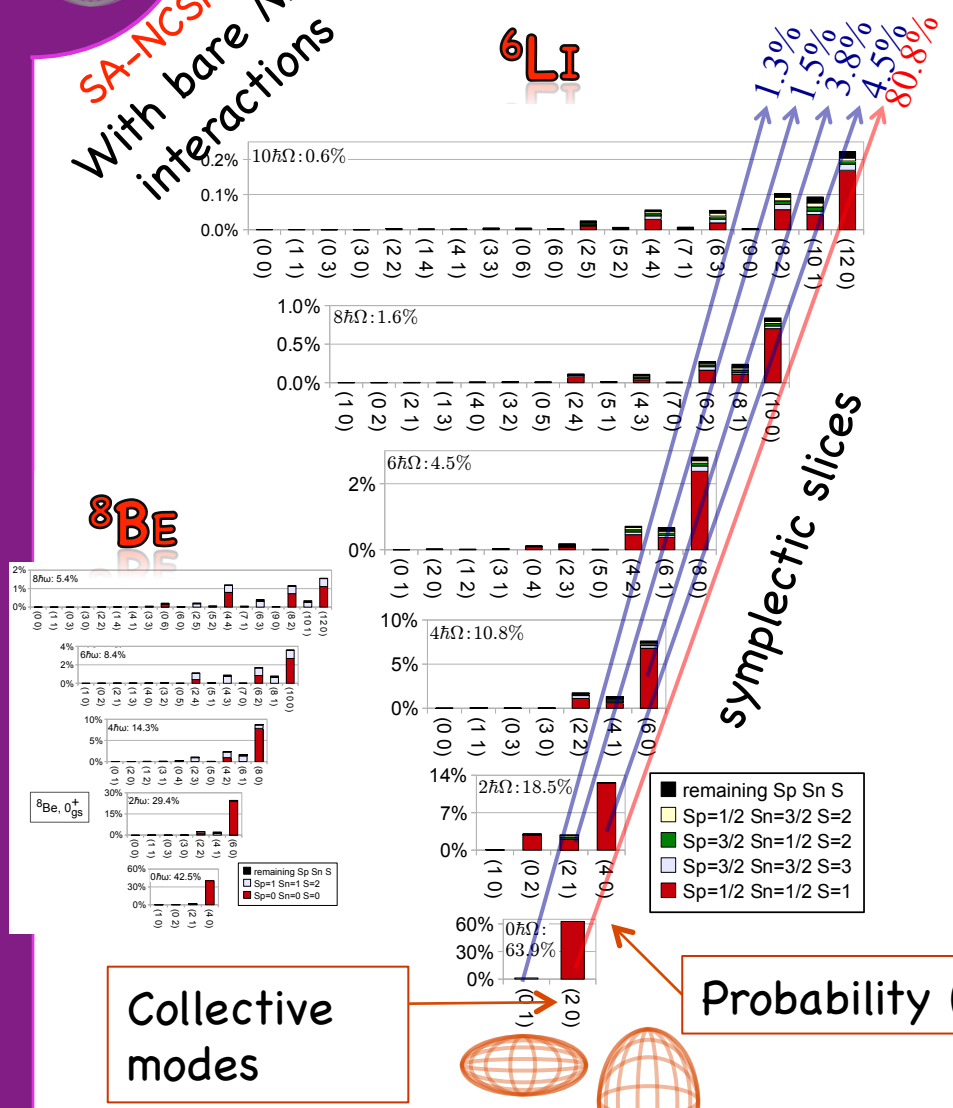
Origin

- Symplectic symmetry - *approximate* symmetry in atomic nuclei

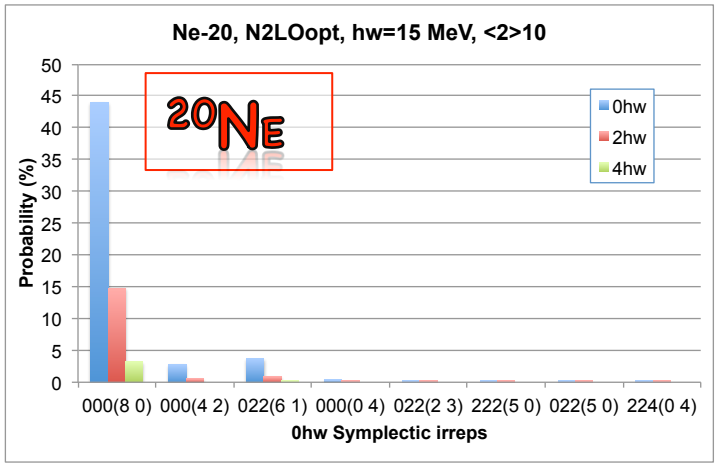
Launey, Dytrych, Draayer, Prog. Part. Nucl. Phys. 89 (2016) 101

What can we learn from symplectic symmetry?

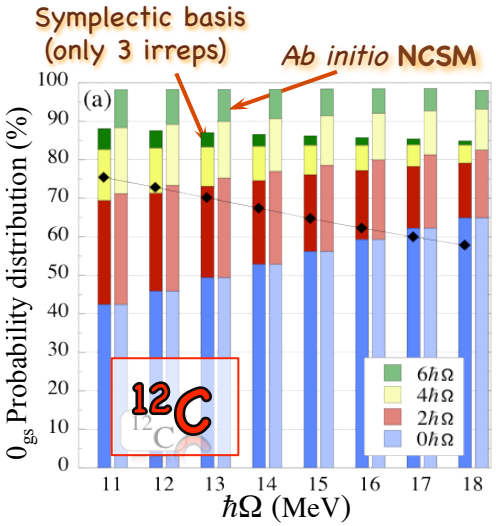
SA-NCSM
With bare NN interactions



Light & intermediate-mass nuclei



With effective interactions



Dytrych, KDL, Bahri, Draayer, Vary, Phys. Rev. Lett. 98 (2007) 162503

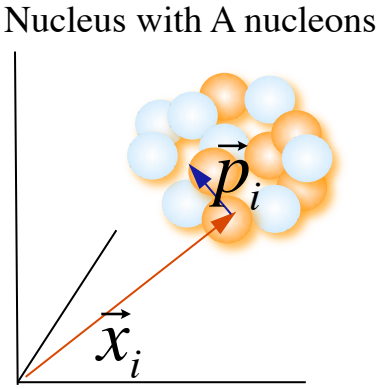
What is Symplectic Symmetry?

Formal definition

All linear canonical transformations of the single-particle phase-space observables

$$x_{i\alpha} \rightarrow \sum_{\beta=x,y,z} a_{\alpha\beta} x_{i\beta} + b_{\alpha\beta} p_{i\beta}$$

$$p_{i\alpha} \rightarrow \sum_{\beta=x,y,z} c_{\alpha\beta} x_{i\beta} + d_{\alpha\beta} p_{i\beta}$$



that preserve the canonical commutation relation

$$\left[x_{i\alpha}, p_{j\beta}\right] = i\hbar\delta_{ij}\delta_{\alpha\beta}$$

Generators:

geometry

$$Q_{ij} = \sum_n x_{ni} x_{nj},$$

$$S_{ij} = \sum_n (x_{ni} p_{nj} + p_{ni} x_{nj}),$$

kinematics

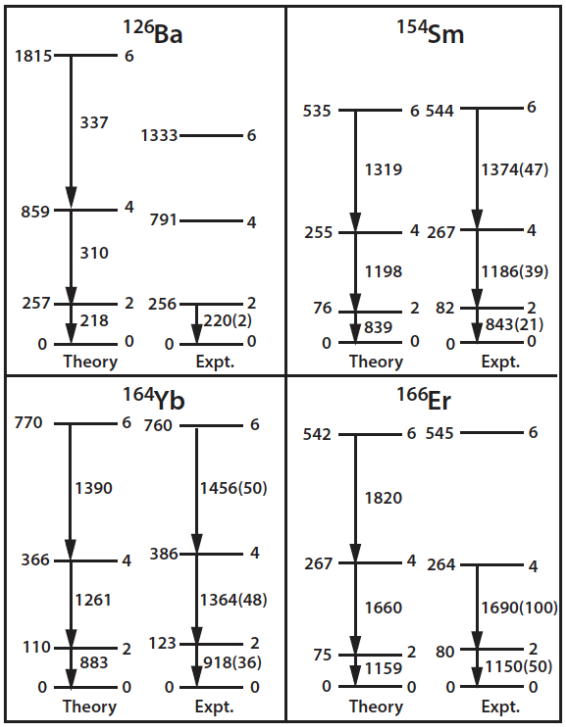
$$L_{ij} = \sum_n (x_{ni} p_{nj} - x_{nj} p_{ni}),$$

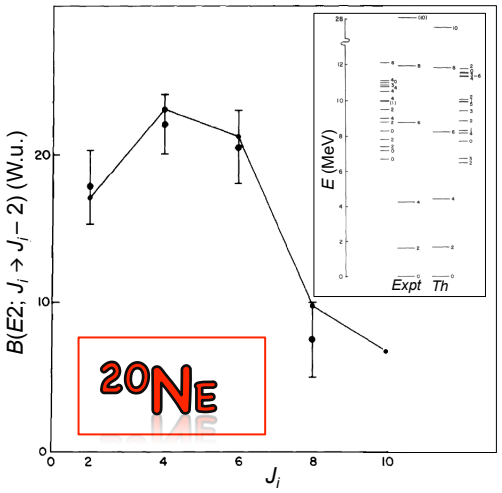
$$K_{ij} = \sum_n p_{ni} p_{nj},$$

Symplectic Model
Rosensteel & Rowe,
PRL 38 (1977) 10

Earlier studies … algebraic models

Quite successful, but symmetries were assumed *a priori:*
Typically 1 (a few) irrep(s) + symmetry-preserving interaction





J. Draayer, et al., Nucl. Phys. A419, 1 (1984)

No effective charges!

P. Park et al., Nucl. Phys. A. 414, 93 (1984)

D. J. Rowe, Rep. Prog. Phys. 48, 1419 (1985)

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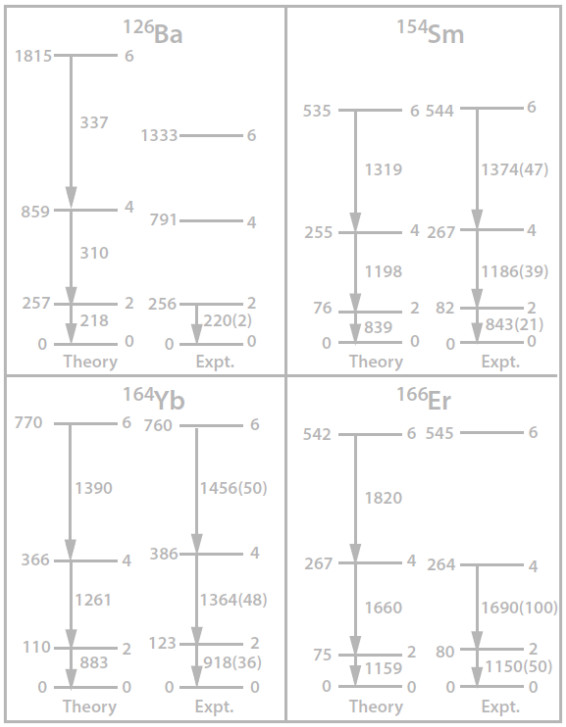
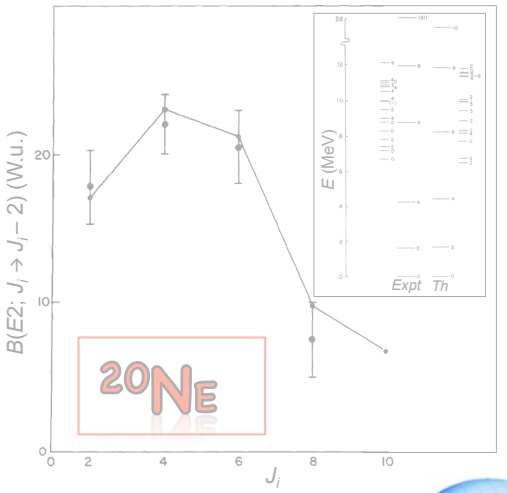


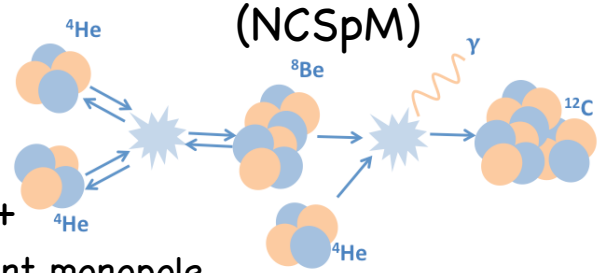
P. Park et al., Nucl. Phys. A. 414, 93 (1984)
D. J. Rowe, Rep. Prog. Phys. 48, 1419 (1985)



J. Draayer, et al., Nucl. Phys. A4[illegible] (1984)

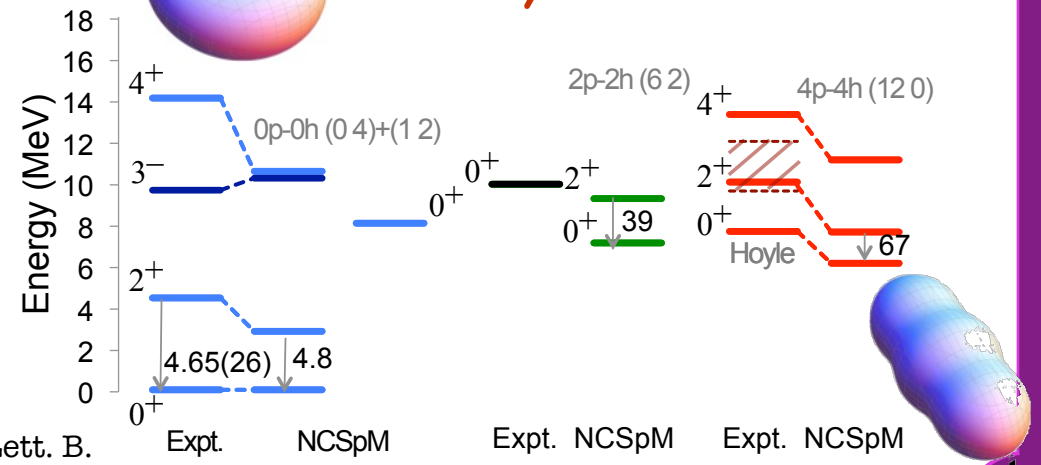
Realistic *NN* + schematic

Only 4 symplectic slices (NCSpM)



0+ Giant monopole resonance

Hoyle state in ^{12}C

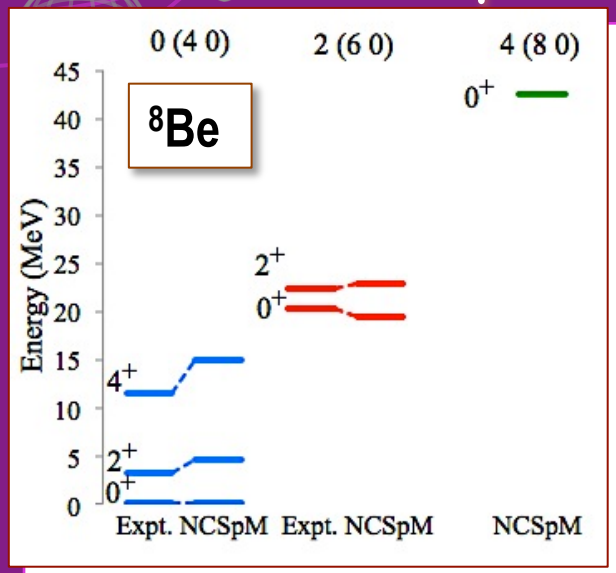


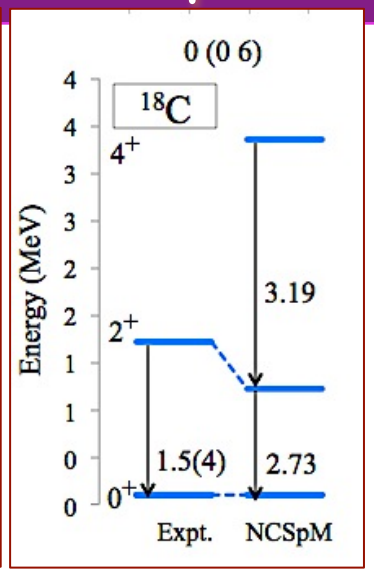
Dreyfuss, et al. Phys. Lett. B. 727, 511 (2013)

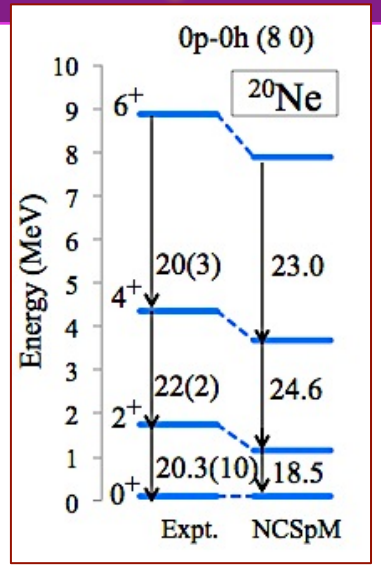
22 shells

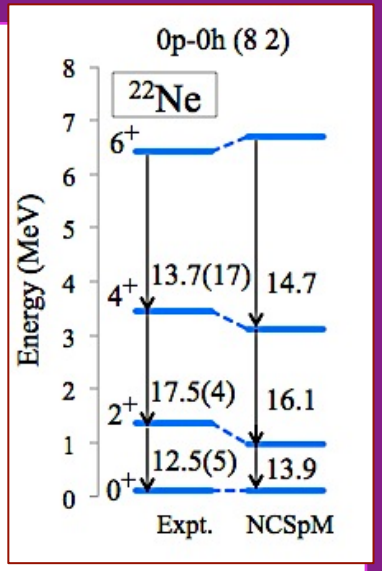
NCSpM … no parameter adjustment

15 shells

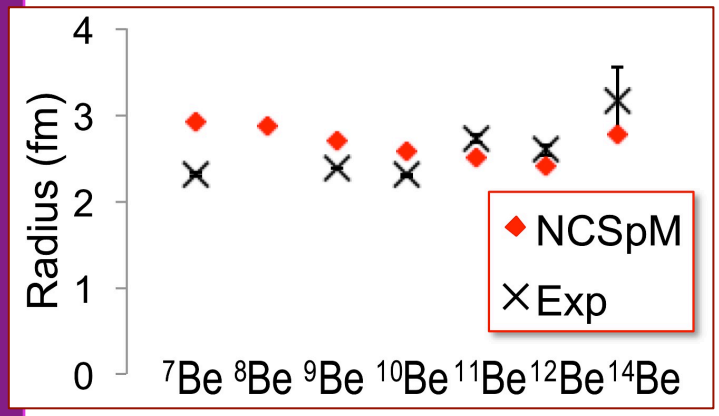




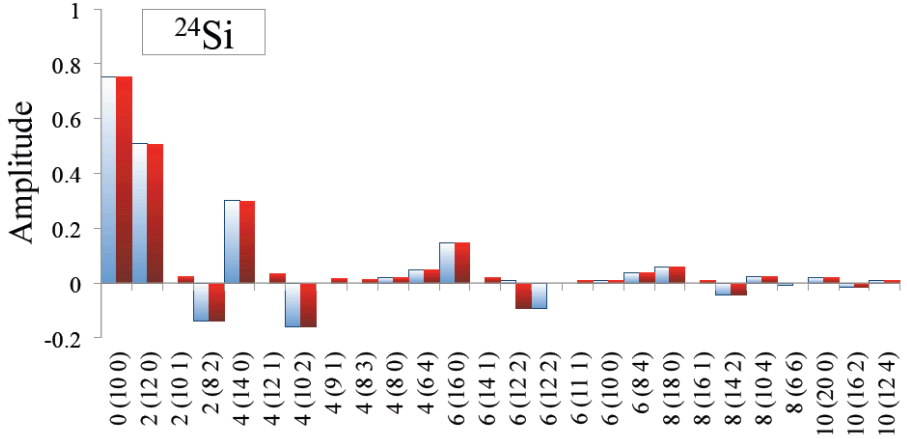




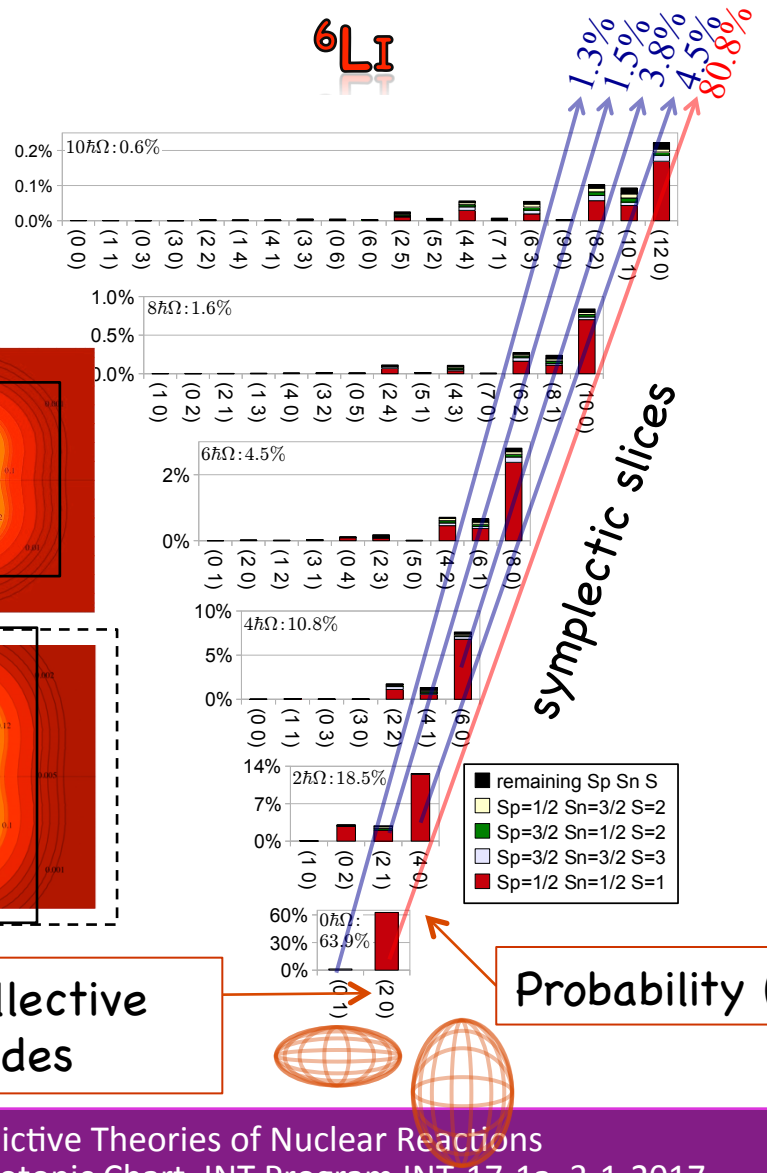
Tobin, et al., Phys. Rev. C 89 (2014) 034312

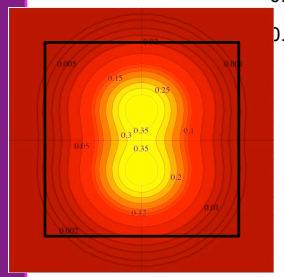


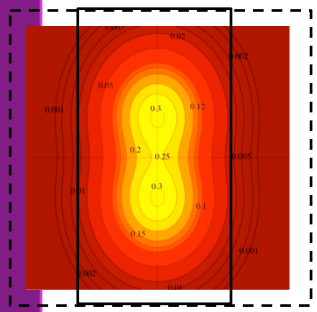
Mia Ferriss (LSU)
Undergraduate Honors Thesis



What can we learn from symplectic symmetry?



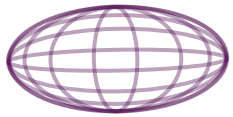




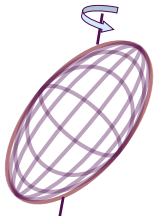
Collective modes

Probability (%)

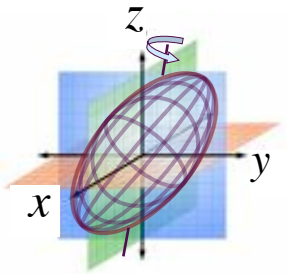
Symplectic slice:



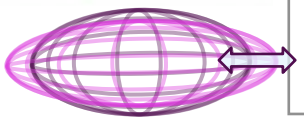
one equilibrium deformation (``shape")



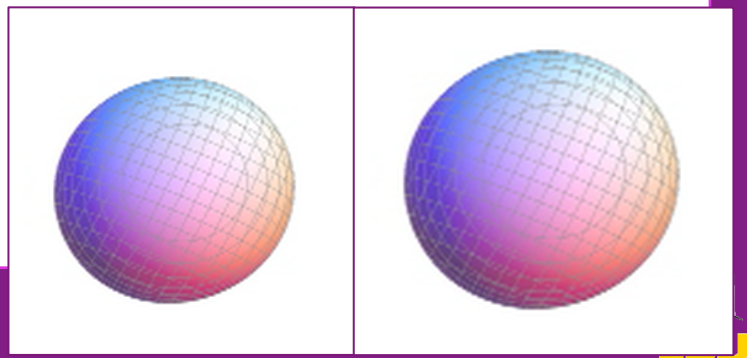
rotations



space orientation

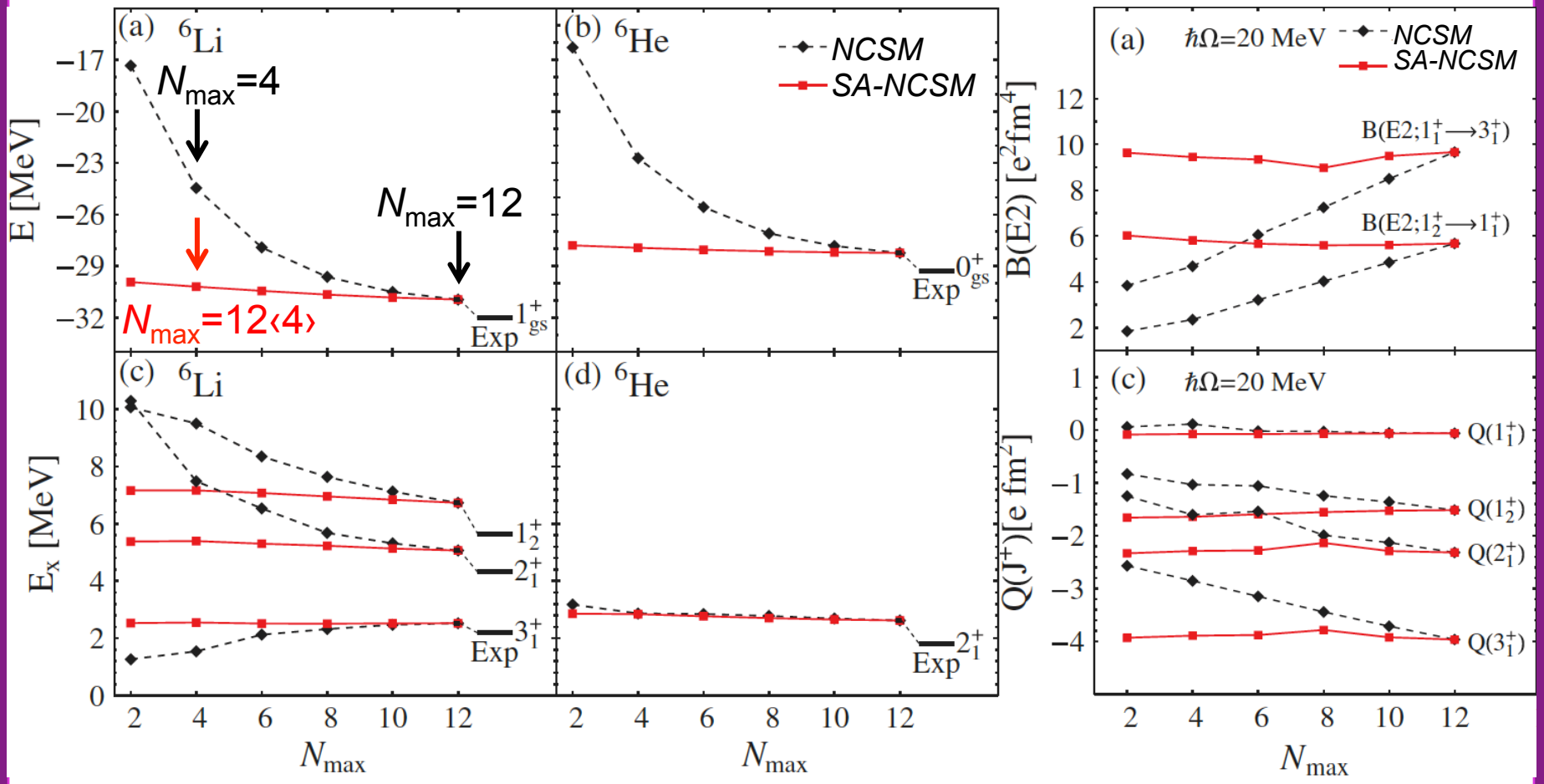


Vibrations
(of the giant resonance monopole (r^2)/ quadrupole (Q) type)

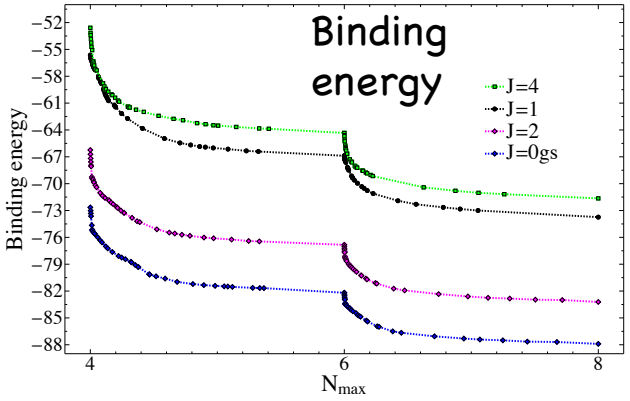


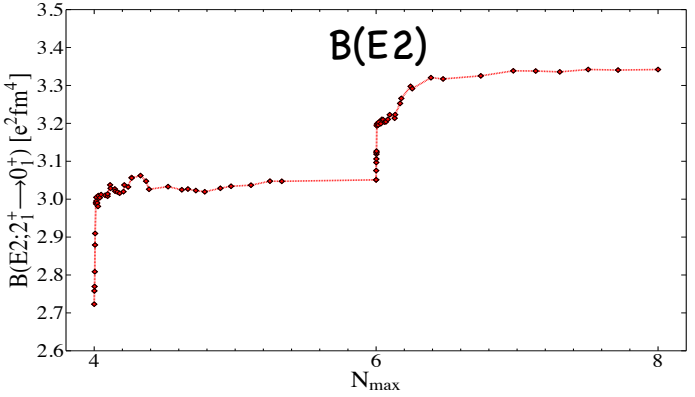
Efficacy of SA-NCSM: Li-6

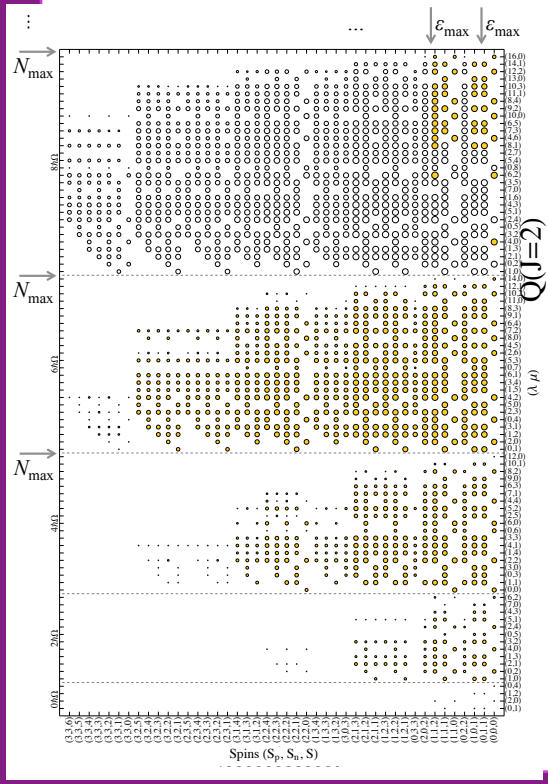
JISP16, ħω = 20 MeV

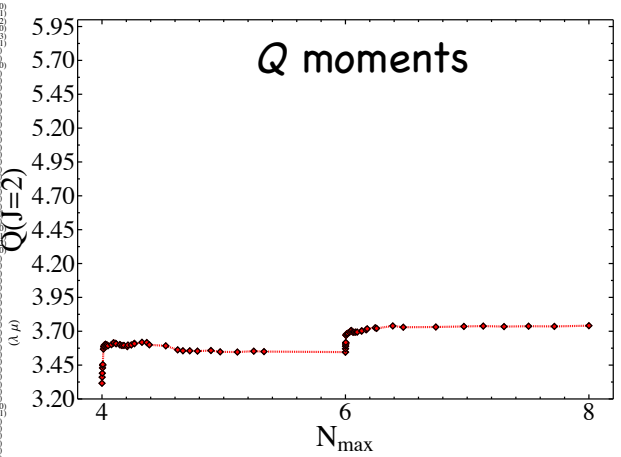


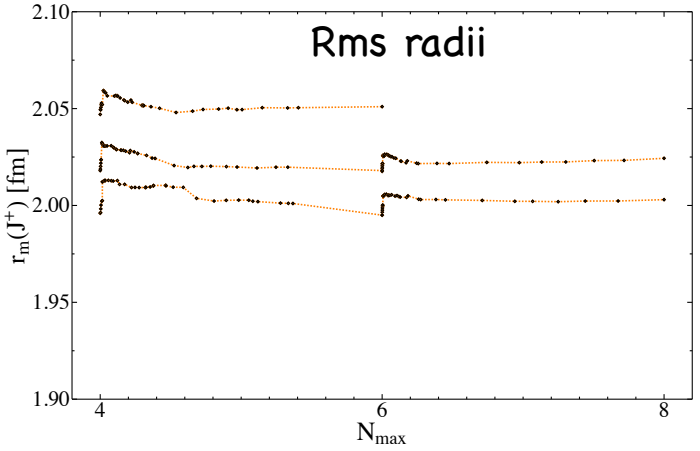
C-12: collectivity…







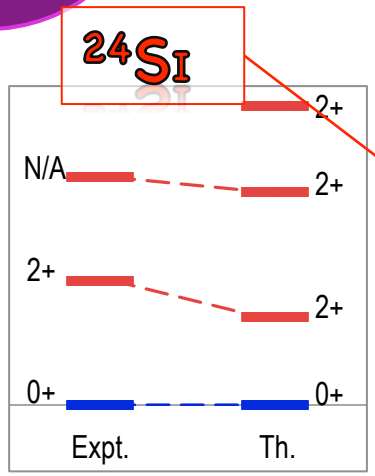


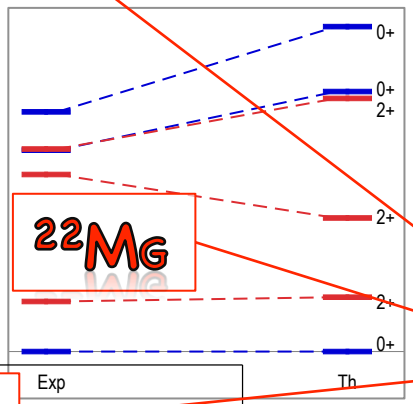


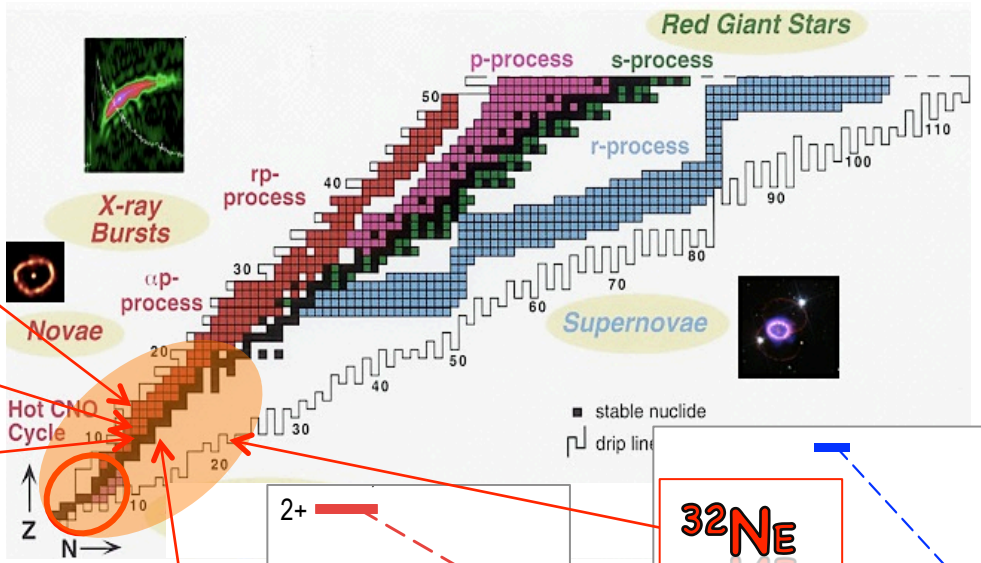
Ab Initio Nuclear Modeling in New Domains

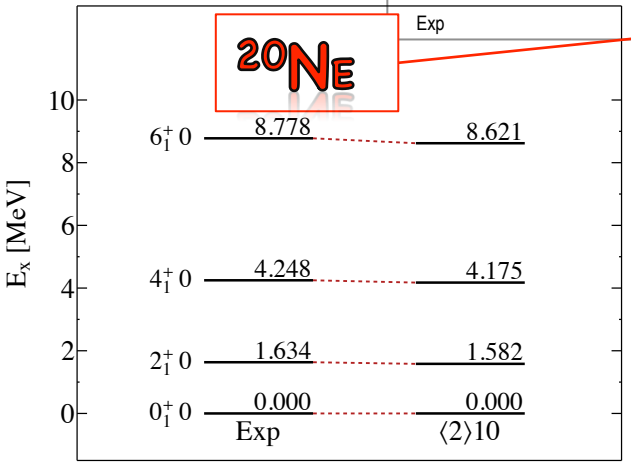
Symmetry-adapted No-core Shell Model

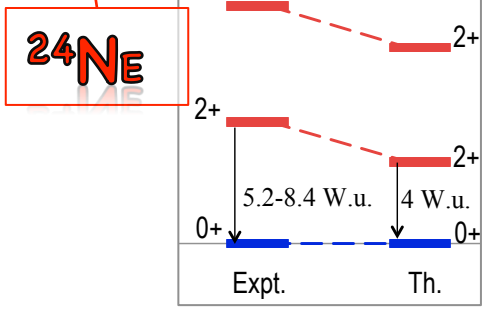
With bare *NN* interactions

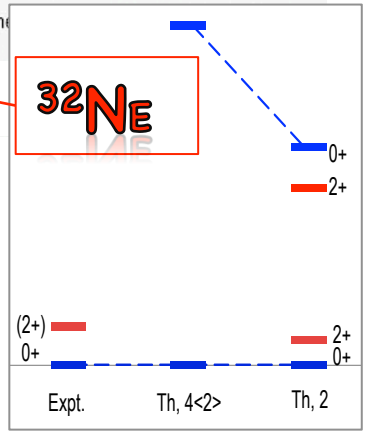




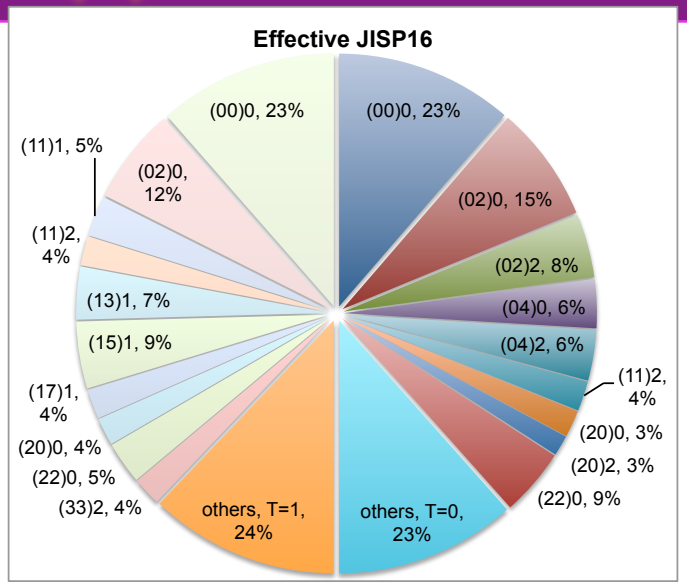


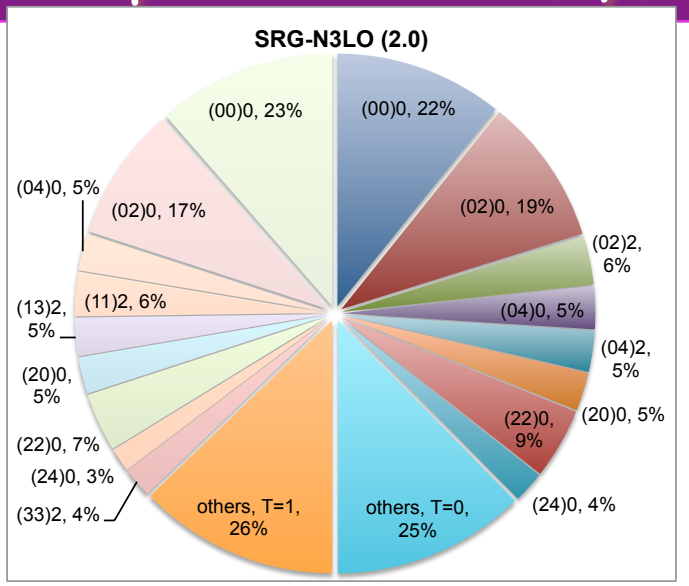


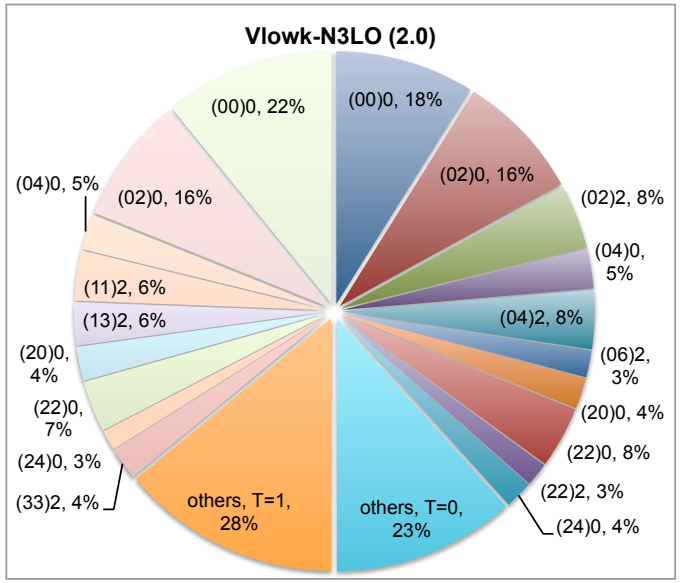


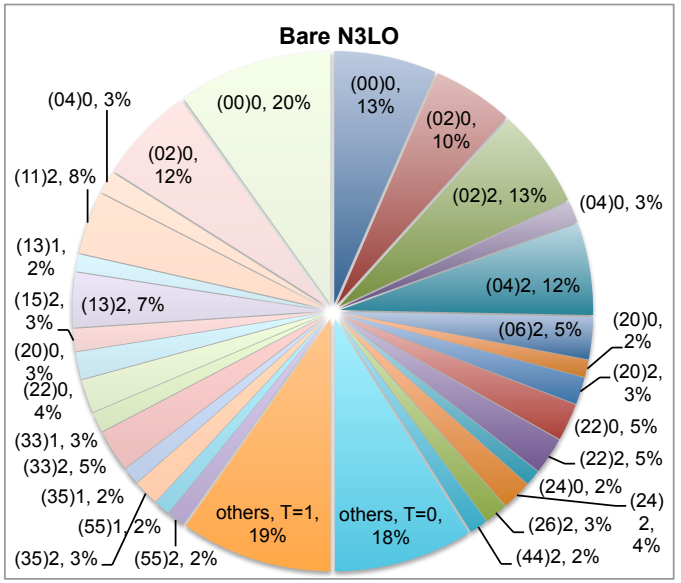


SU(3) *NN* interaction: keep track of x, y, & z



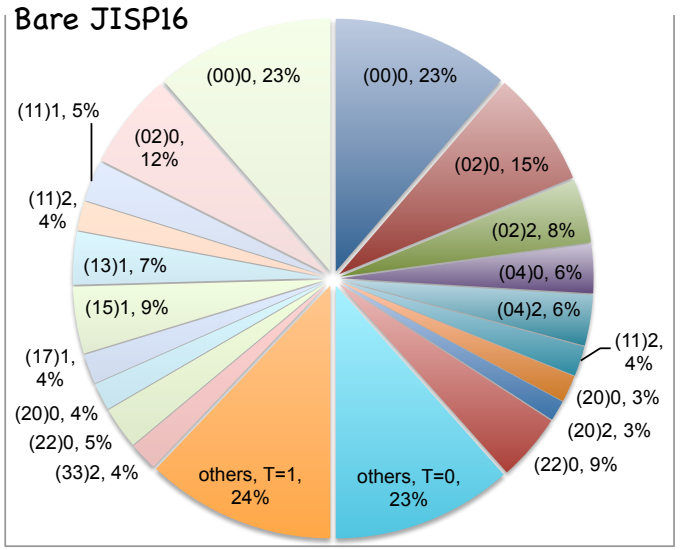


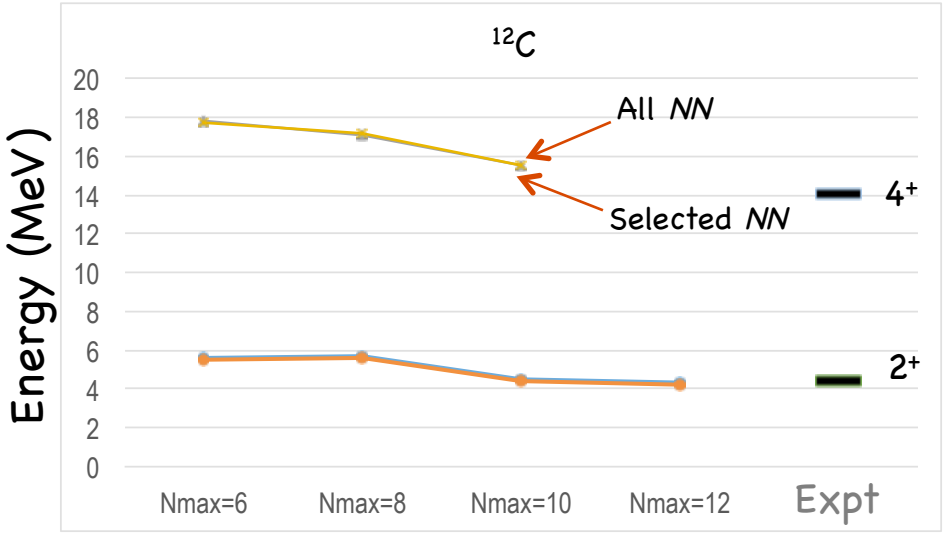




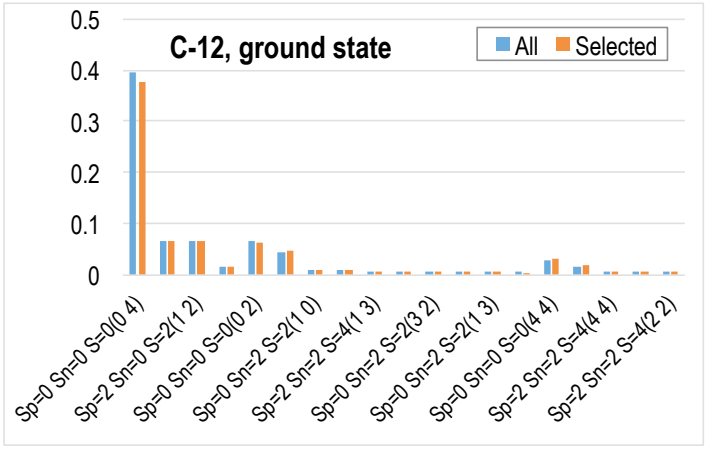
KDL et al., Int. J. Mod. Phys. E 24 (2015) 1530005

Important pieces of the *NN* interaction

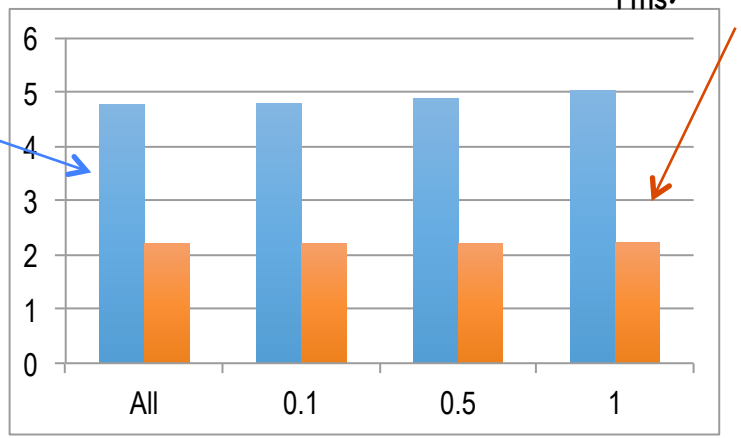




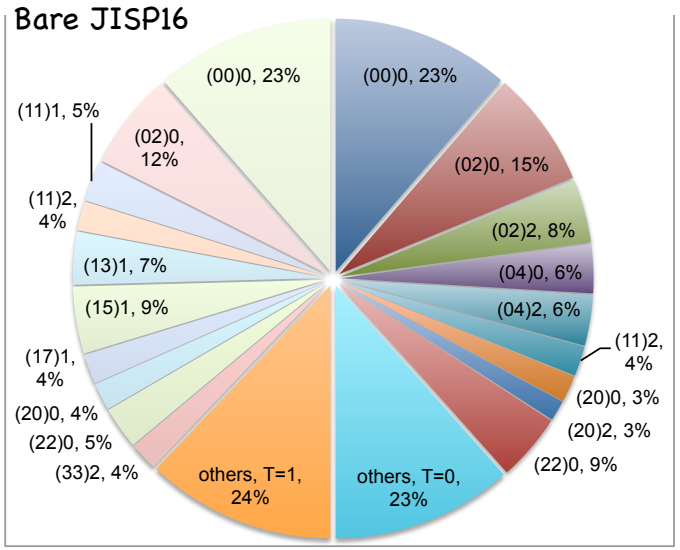
Grigor Sargsyan, LSU



B(E2), e^2fm^4

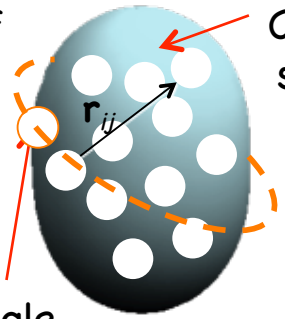


Important pieces of the *NN* interaction



Collectivity: emergent phenomenon

Interaction of each particle with nucleus quadrupole moment

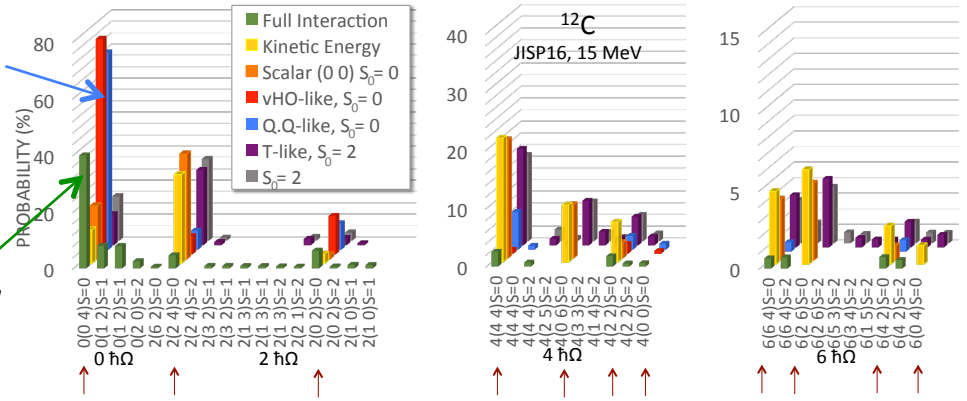


Collective structure

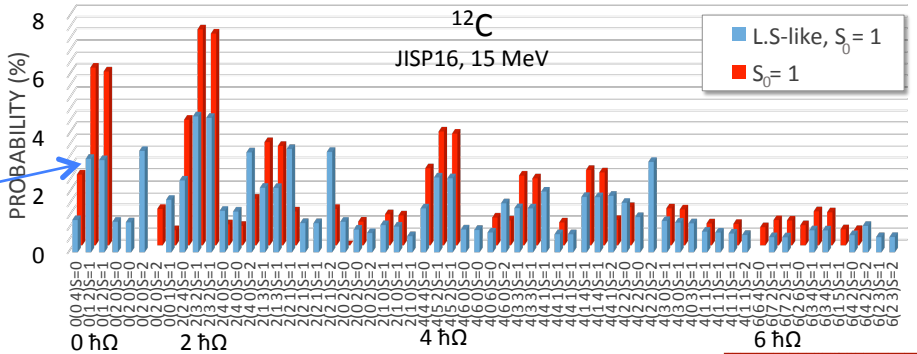
Single particle

Q.Q

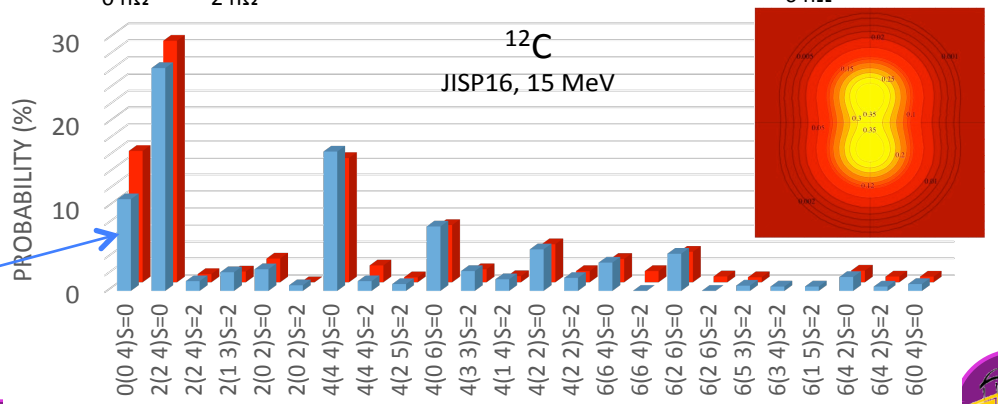
All *NN*



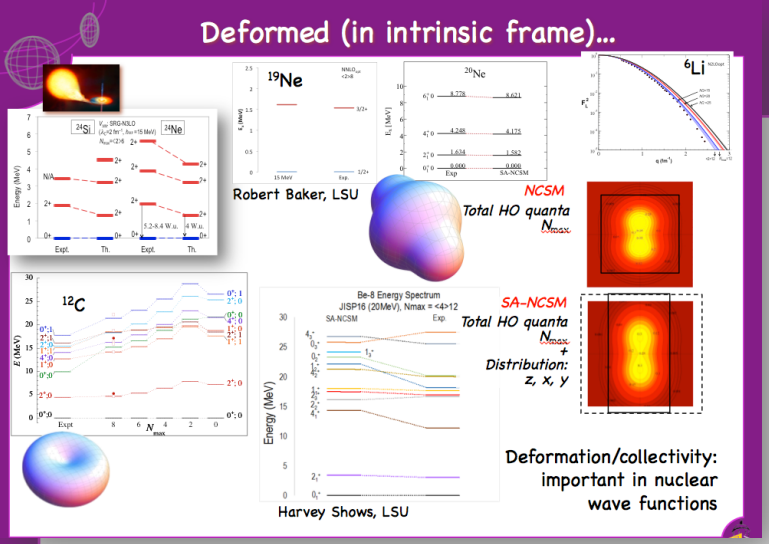
Spin-orbit



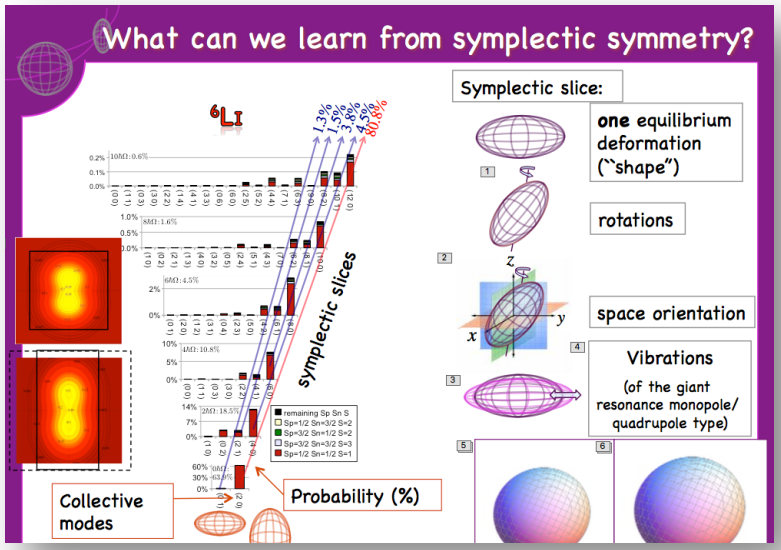
Tensor force



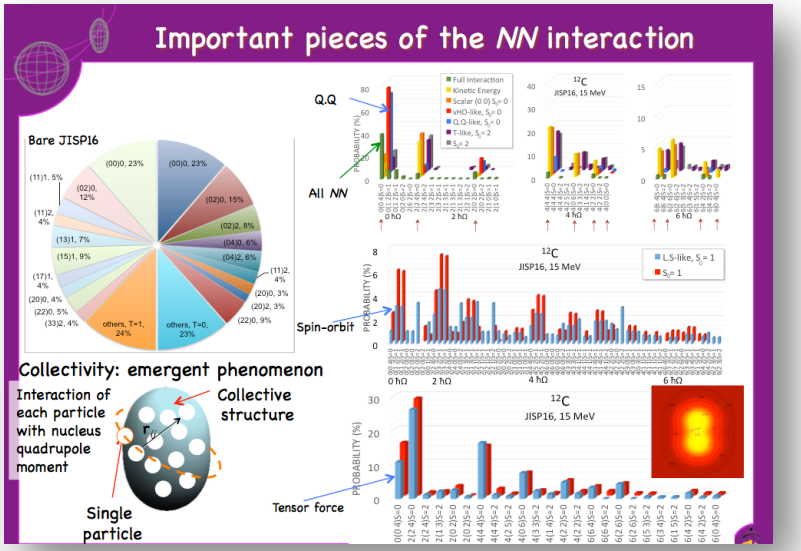
Conclusions



Deformation/collectivity: important in nuclear wave functions



Simple physics: "shape" + vibrations + rotations



Informing the inter-nucleon interaction...