First *ab initio* symplectic-model results for light and medium-mass nuclei

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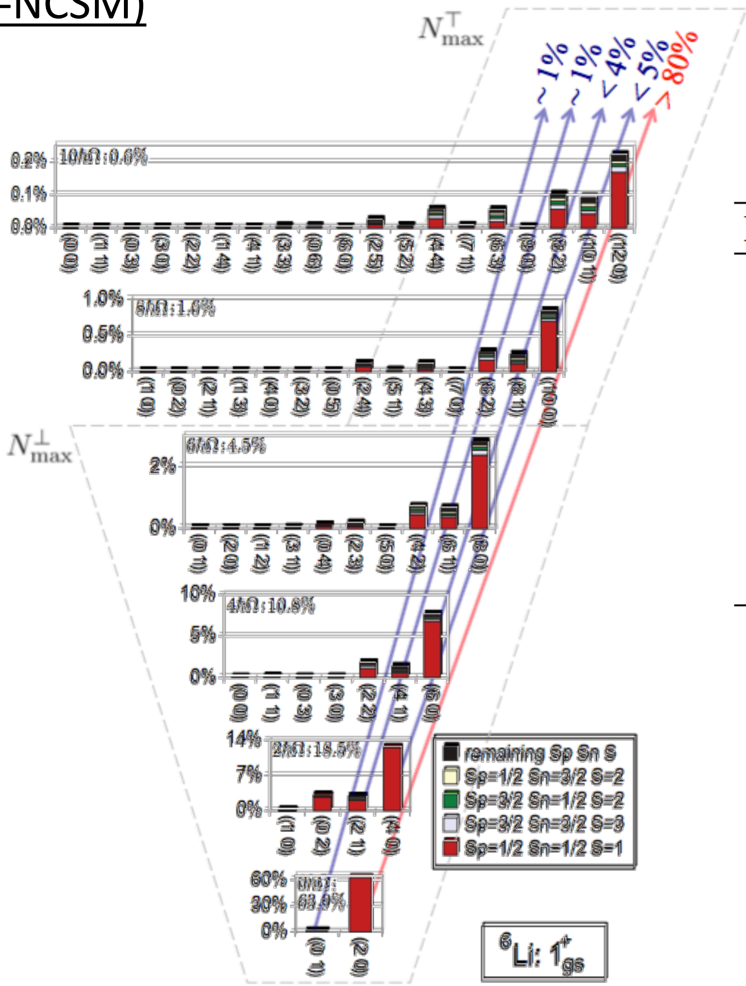
Motivation

<u>*Ab initio* symmetry-adapted no-core shell model (SA-NCSM)</u>



	Lowest spin		Largest deformation + symplectic excitations	
Nucleus	$(S_p\, S_n\, S)$	Probability (%)	$(\lambda_0\, \mu_0)$	Probability (%)
^{6}Li	$(\frac{1}{2}\, \frac{1}{2}\, 1)$	93.24	(2 0)	93.11
^{8}B	$(\frac{1}{2}\, \frac{1}{2}\, 1)$	85.58	(2 1)	82.32
^{8}Be	(0 0 0)	85.21	(4 0)	85.06
^{12}C	(0 0 0)	55.60	(0 4)	49.03
	[(0 1 1), (1 0 1)]	[29.19]	[(1 2)]	[22.52]
^{16}O	(0 0 0)	78.42	(0 0)	77.33
^{20}Ne	(0 0 0)	79.73	(8 0)	79.30

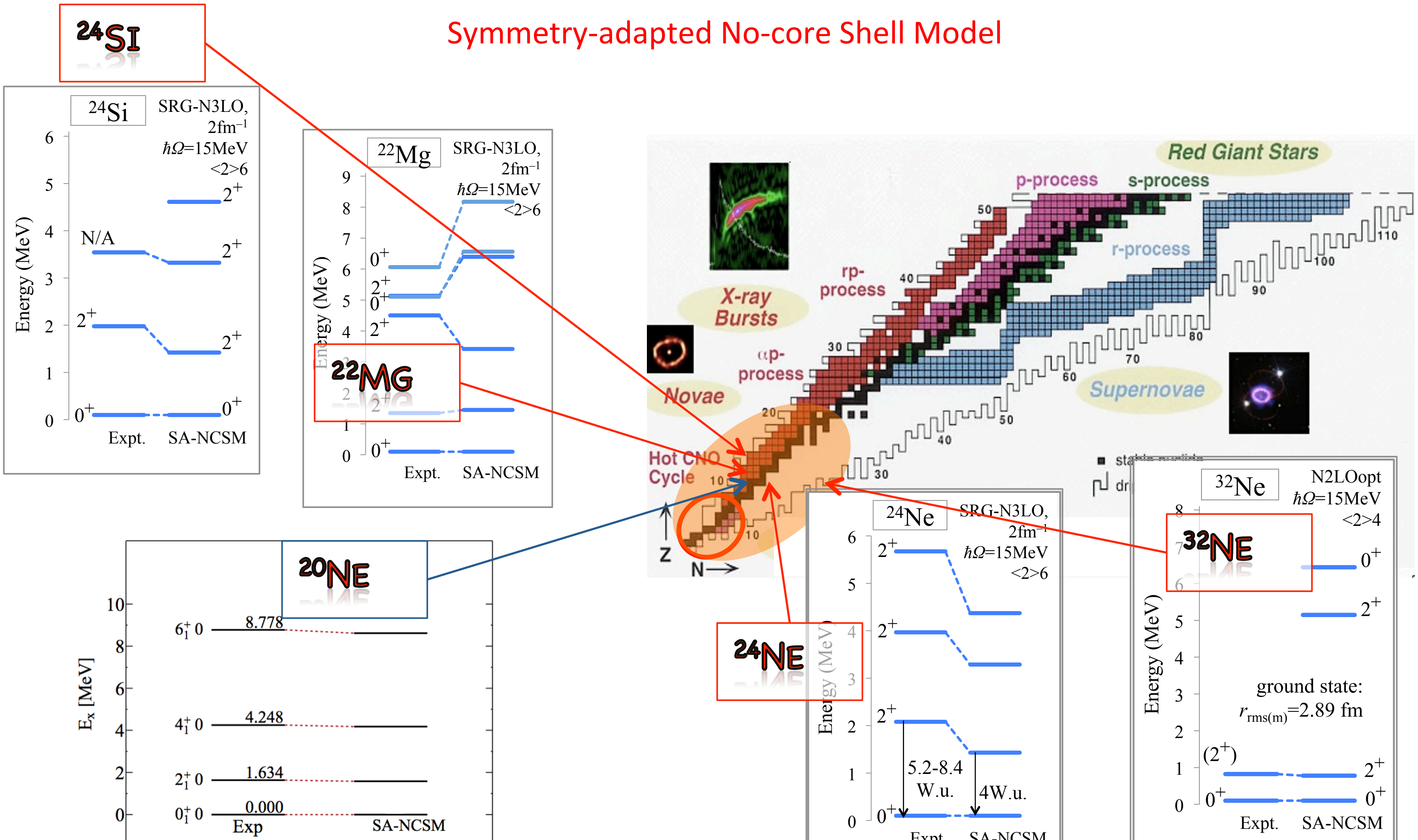
Symplectic symmetry arises naturally from first principles.

T. Dytrych, et al., Phys. Rev. Lett. **111** (2013) 252501
J.P. Draayer, et al., Prog. Part. Nucl. Phys. (2016), doi:10.1016/j.ppnp.2016.02.001.

sd-Shell nuclei in selected spaces

Leading symplectic irrep configurations

Symmetry-adapted No-core Shell Model

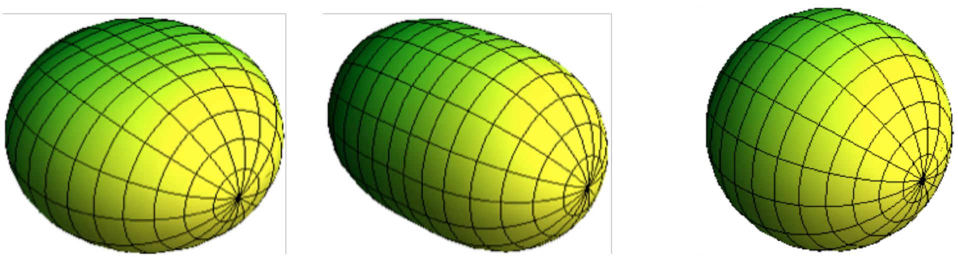


Ab initio description (converged selected spaces)
(NNLO$_{opt}$, ħΩ=15 MeV, 13 HO shells)

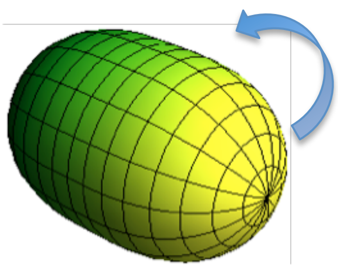
Significance of symplectic basis

The symplectic basis naturally contains:

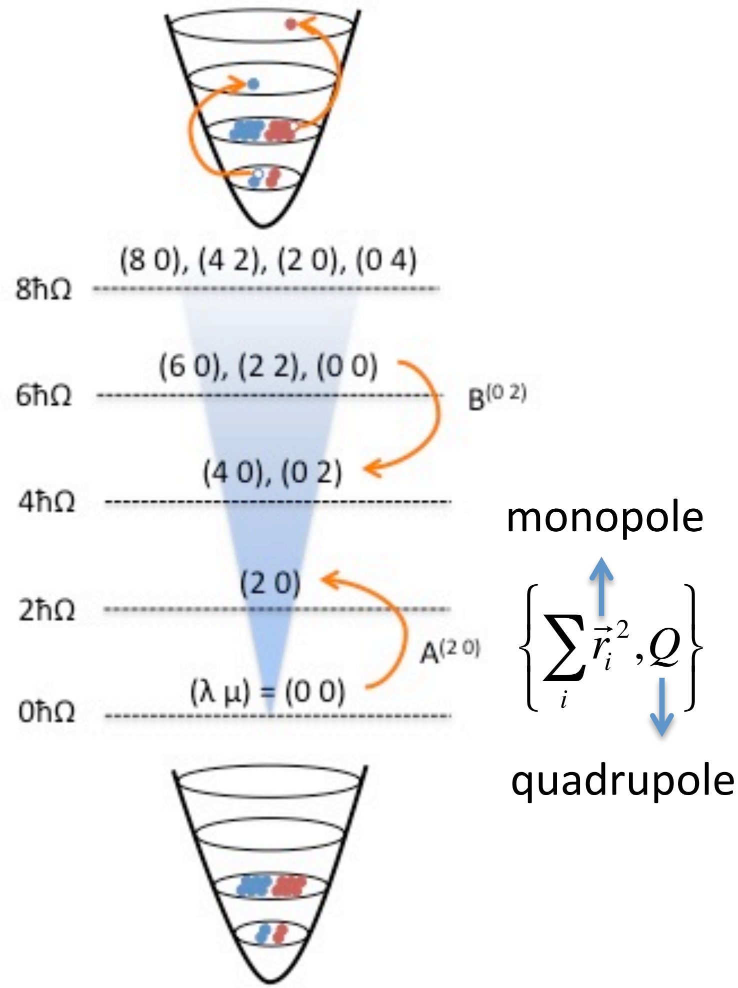
1) deformation



2) rotation



3) “giant-resonance” $2\hbar\Omega$ 1p-1h excitations
4) multiples of these excitations to high N_{max}



Method

Efficient construction of symplectic basis:
In SU(3)-coupled basis, we diagonalize an Sp(3,R)-preserving scalar operator

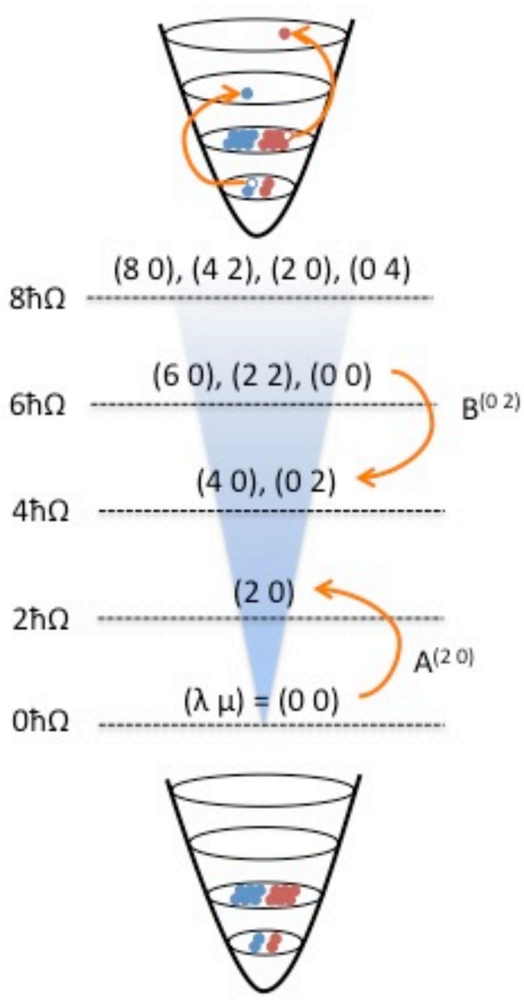
$$\left[\hat{A}^{(2\ 0)} \times \hat{B}^{(0\ 2)}\right]^{(0\ 0)}$$

The resulting eigenvectors are symplectic basis states of the form

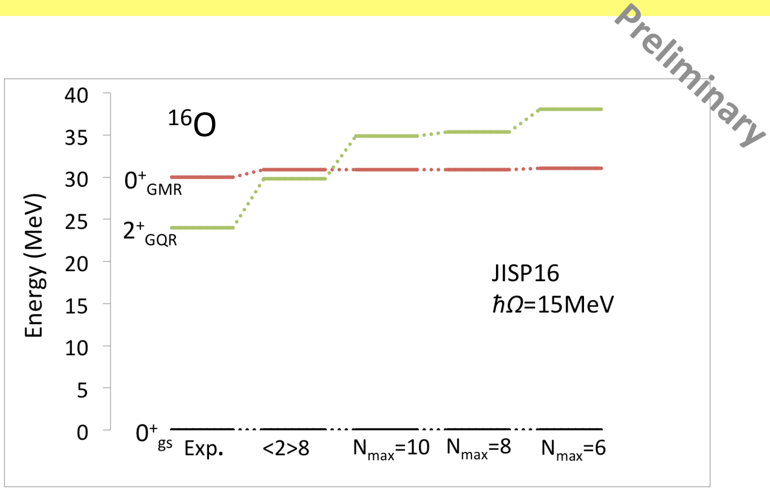
$$|\mathrm{Sp}(3,\mathbb{R})\rangle = \sum_i \alpha_i \, |\mathrm{SU}(3)_i\rangle$$

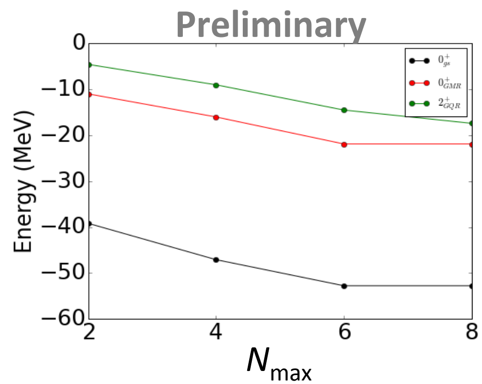
Calculating many-body Hamiltonian in symplectic basis:
Reduced to using known realistic interaction matrix elements in SU(3) basis with highly scalable computing code.

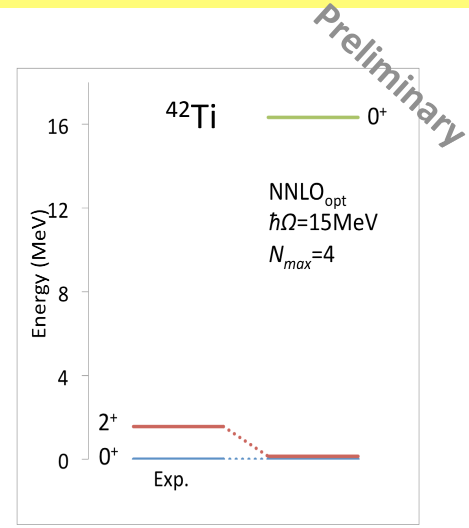
Eigenvalue problem of a matrix of small dimension (some cases can be solved on laptop).



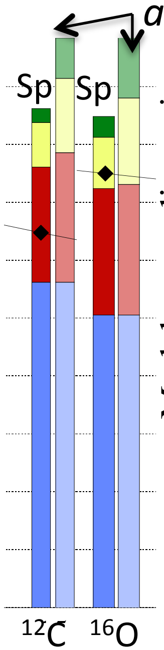
^{16}O and ^{42}Ti: spectra and giant resonances

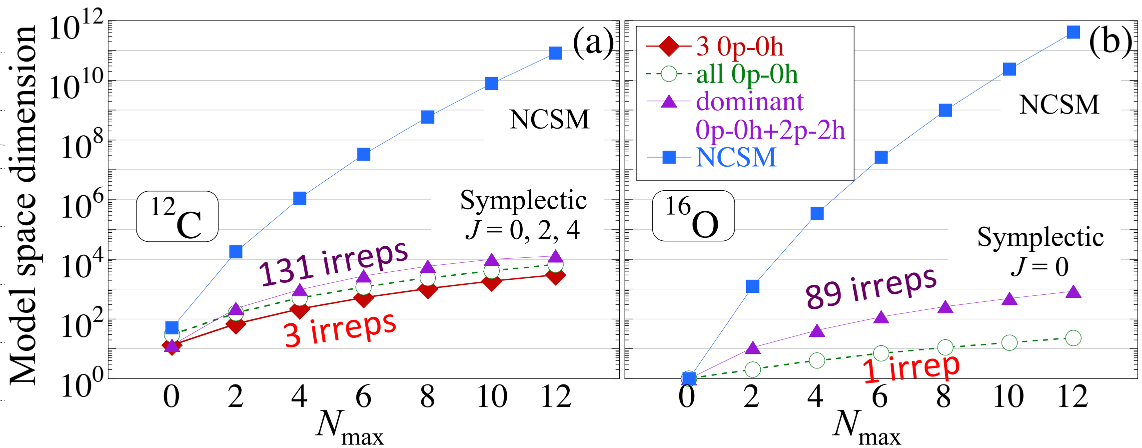




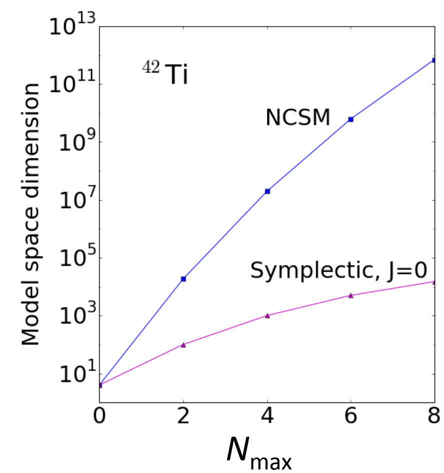


ab initio wave functions





T. Dytrych, et al., Phys. Rev. Lett. **98** (2007) 162503



A few symplectic irreps capture a major portion of the physics;
for *ab initio* studies, several hundred symplectic irreps may be needed.

Thanks!

SA-NCSM coupling