COMEX5, Krakow, 2015



Dynamics of Low-Lying modes

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Response of the nucleus to external probes



Macroscopic picture of Giant resonances – Multipole decomposition



From majimak.com/blog

Time-dependent approach







An advertisment

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The TDHF code Sky3D*

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- Paper itself is open access
- Detailed subsidiary manual
- Code from CPC program library (or directly from me)





A few selected results



Mixed strength functions



$$S(E) = \sum_{\nu} \langle 0|F|\nu \rangle \langle \nu|\bar{F}|0 \rangle \delta(E - E_{\nu})$$

F and F-bar different operators – can learn about individual matrix elements

Identify normal modes

Calculations is ²⁰⁸Pb monopole resonances with SkO Skyrme force

D. Almehed and P. D. Stevenson, J. Phys. G 31, S1819 (2005)

$^{76}Se @ HI\gamma S$

NRF Technique



Red triangles: P. M. Goddard, N. Cooper, V. Werner, G. Rusev, P. D. Stevenson. A. Rios, C. Bernards, A. Chakraborty, B. P. Crider, J. Glorius, R. S. Ilieva, J. H. Kelley, E. Kwan, E. E. Peters, N. Pietralla, R. Raut, C. Romig, D. Savran, L. Schnorrenberger, M. K. Smith, K. Sonnabend, A. P. Tonchev, W. Tornow and S. W. Yates, Phys. Rev. C 88, 064308 (2013) Above threshold data: P. Carlos, H. Beil, R. Bergre, J. Fagot, A Leprêtre, A. Veyssière and G. Solodukhov, Nucl. Phys. A **258**, 365 (1976)

TDHF in ⁷⁶Se

1. Applying a regular E1 dipole kick



Time-dependent response to dipole kick. Skyrme force NRAPR from A. Steiner, M. Prakash, J. Lattimer and P. Ellis, Phys. Rep. **411**, 325 (2005)

Response in 76Se

Using NRAPR Skyrme interaction



- Missing spreading width (of course)
- structure from K-splitting and single particle effects



Dependence on Skyrme parameterisation

NRAPR vs SkI4 vs SLy4



Forcing the nucleus





Driven density derivatives









Something more exotic - ¹³²Sn



Calculation with KDEOv1 [Agrawal, Shlomo & Kim Au, PRC72, 014310 (2005)



Kicking the valence states against the rest



t [zs]

-0.001



Power Spectrum / Strength







- TDHF is used to probe nucleus and to study the response
- can get strength functions for multipole modes, and also study mixing
- Low-lying strength explored by non-multipolar kicks, and by driving at a (nearly) fixed frequency
- Strong low-lying response by setting single valence neutron level against core

Collaborators:

P. M. Goddard (Surrey), P.-G. Reinhard (Erlangen), J. A. Maruhn (Frankfurt), A. S. Umar (Vanderbilt), D. Almehed (Surrey)

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UK Science and Technology Facilities Council

Sky3d code



An advertisment

- Modern style Fortran (95/2003)
- Parallelized with OpenMP & MPI
- Very standard conforming compiles anywhere (so far)

000	Sky3D-Code — bash — 80×27	
	bash	
~/codes/s	sky3d/Sky3D-Code] hare \$ make	
gfortran -	-03 -c params.f90	
gfortran -	-O3 -c forces.f90	
gfortran -	-03 -c grids.f90	
gfortran -	-O3 -c fourier.f90	
gfortran -	-O3 -c trivial.f90	
gfortran -	-O3 -c levels.f90	
gfortran -	-O3 -c densities.f90	
gfortran -	-O3 -c sequential.f90	
gfortran -	-03 -c moment.f90	
gfortran -	-O3 -c coulomb.f90	
gfortran -	-O3 -c meanfield.f90	
gfortran -	-03 -c inout.f90	
gfortran -	-O3 -c twobody.f90	
gfortran -	-O3 -c fragments.f90	
gfortran -	-03 -c pairs.f90	
gfortran -	-O3 -c energies.f90	
gfortran -	-O3 -c static.f90	
gfortran -	-O3 -c external.f90	
gfortran -	-O3 -c dynamic.f90	
gfortran -	-03 -c user.f90	
gfortran -	-03 -c main3d.f90	
fortran -	-O3 -o sky3d.seq params.o grids.o levels.o fourier.o forces.o sequenti	
al.o inout	o coulomb.o trivial.o densities.o fragments.o twobody.o energies.o st	
atic.o mea	infield.o dynamic.o pairs.o moment.o main3d.o user.o external.o -lfftw3	
-llapack		
[~/codes/s	ky3d/Sky3D-Code] hare \$	

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Image: Proper biling <th< th=""><th></th></th<>	
MODULE Forces	_
USE Params, ONLY: db,scratch,wflag, hbc, e2, pi	
IMPLICIT NONE	
SAVE	
! Record defining pairing	
ITTE Pairing	
REAL(ab) :: voprot, voneut, rnoopr	
END TIPE Pairing	
TYPE Force	
(HARACTER(8) :: name	
INTEGER :: ex.zpe	
REAL(db) :: h2m(2)	
REAL(db) :: t0,t1,t2,t3,t4	
REAL(db) :: x0,x1,x2,x3,b4p	
REAL(db) :: power	
TYPE(Pairing) :: vdi ! volume-delta	
TYPE(Pairing) :: dddi ! density-dependent delta	
END TYPE Force	
! include predefined forces	
INCLUDE 'forces.data'	
! now the structure used in the run itself	
INTEGER :: 1pair	
TYPE(Pointing) :: n Incining parameters actually used	
L change and mass number in static case for pairing	
REAL(db) :: h2ma L average h2m over n and n used in some nlaces	
REAL(db) :: nucleon mass	
! derived "b" and Slater coefficients	
REAL(db) :: b0,b0p,b1,b1p,b2,b2p,b3,b3p,b4,b4p,slate	
CONTAINS	
SUBROUTINE read_force	
CHARACTER(8) :: name, pairing	