Seeing Physics, Comparing Theory and Experiment: Emergent Collectivity, Perspective/Correlations, Precision data, Theoretical accuracy, Parameters

Comments from a PR C editor

Not much new but maybe useful….

R. F. Casten
Yale and MSU-FRIB

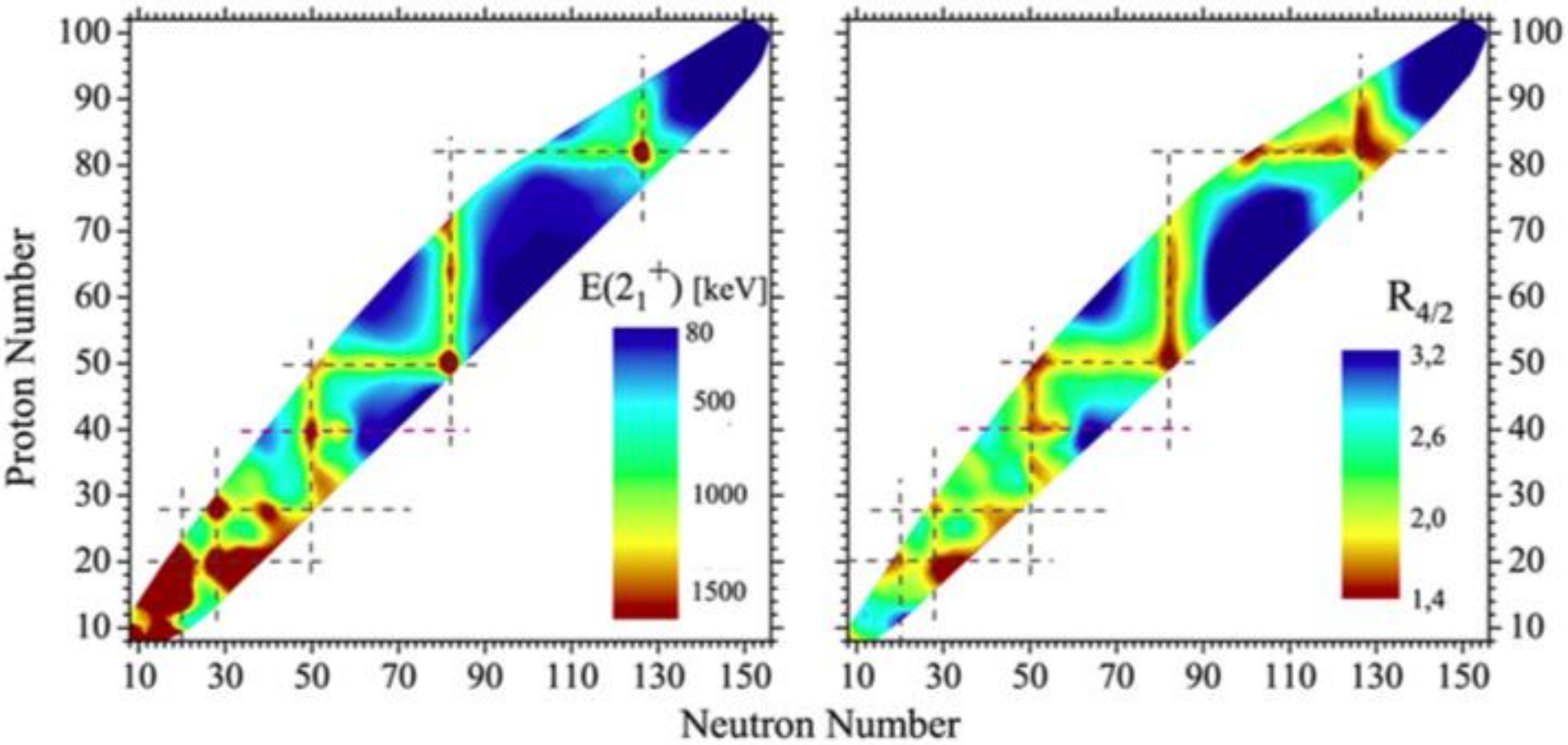
Workshop on Transitional Nuclei

Padova,
May 22-25, 2018

First: Physics is easy and fun!!

God-Grandaughter

The Evolution of Structure



Think about this: Chaos to order, emergent collectivity
Challenge: how can these complex many-body systems exhibit such regular patterns?

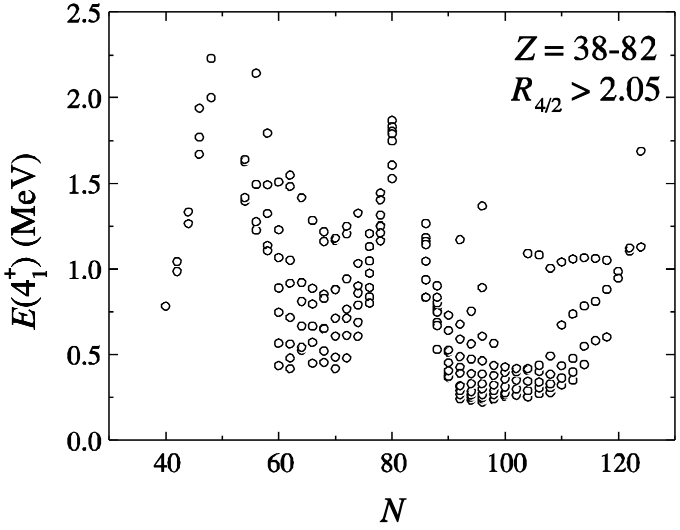
Order from chaos: Single particle basis leading to emergent collectivity. Symmetries.

Single particle and collective motion

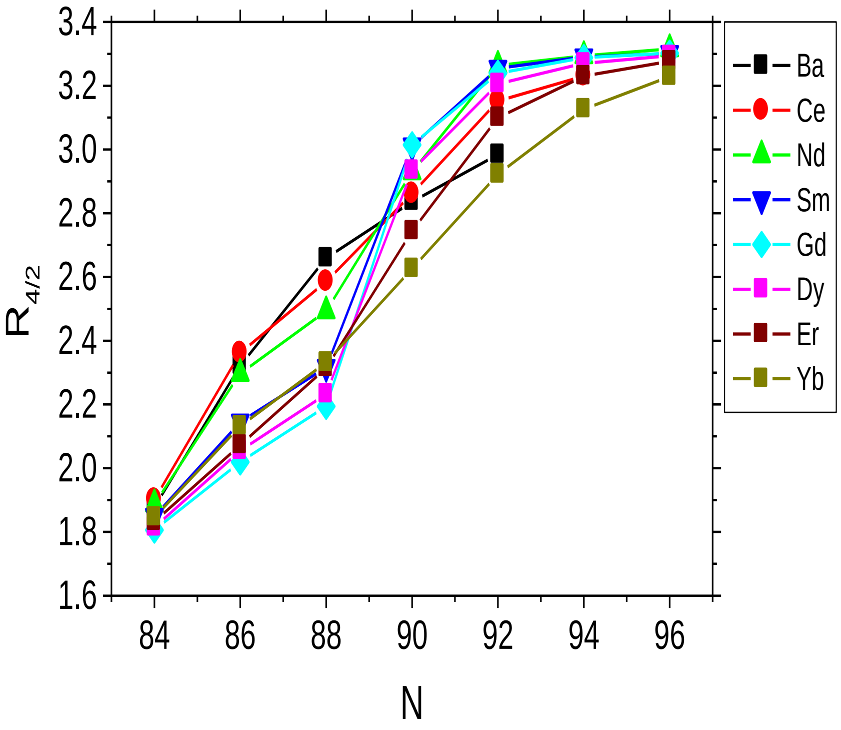
Single particle and collective behavior – common to many systems

Perspectives, correlations, and “fake news” correlations

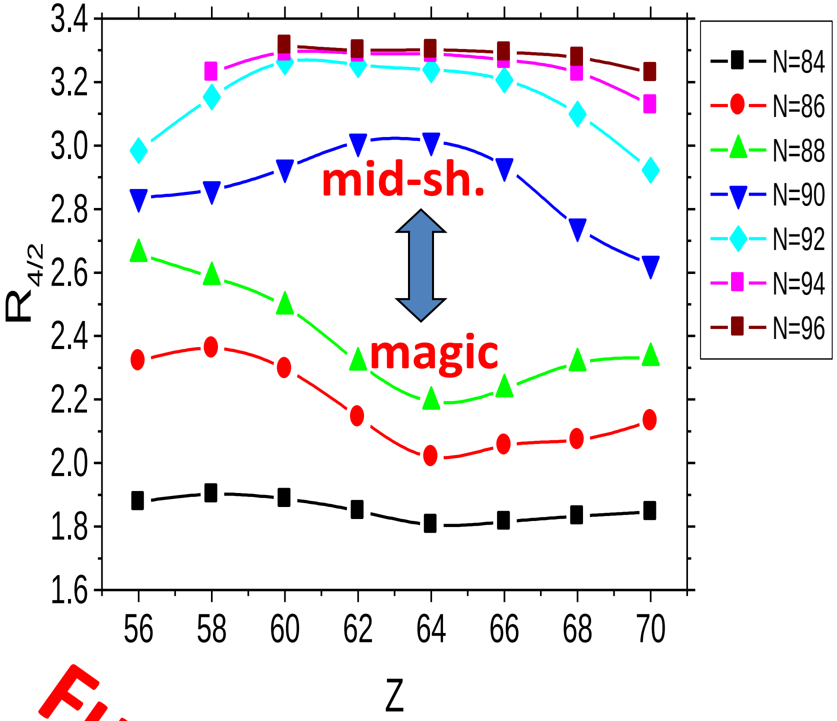
Structural evolution: Look at data from different perspectives



Another example of different perspectives



Onset of deformation



Onset of deformation

as a

quantum phase transition

mediated by a

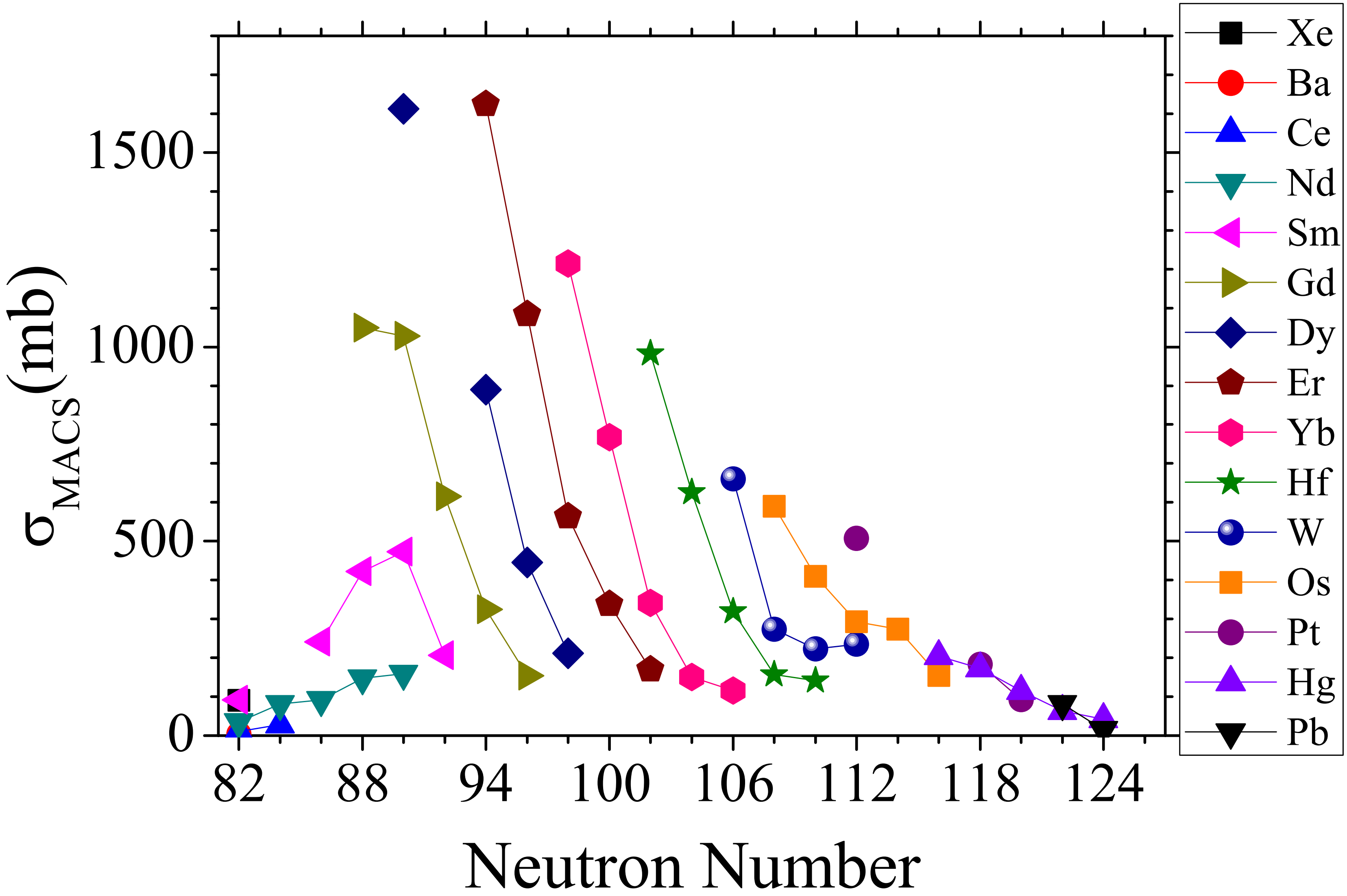
change in proton shell structure

driven by

the p-n interaction

Further interpretation

Neutron capture MACS at 30 keV in the rare earth region
Looking at data from different perspectives



A Couture, RF Casten and R. Burcu Cakirli, PRC 96, 061601R (2017)

Neutron capture MACS at 30 keV in the rare earth region
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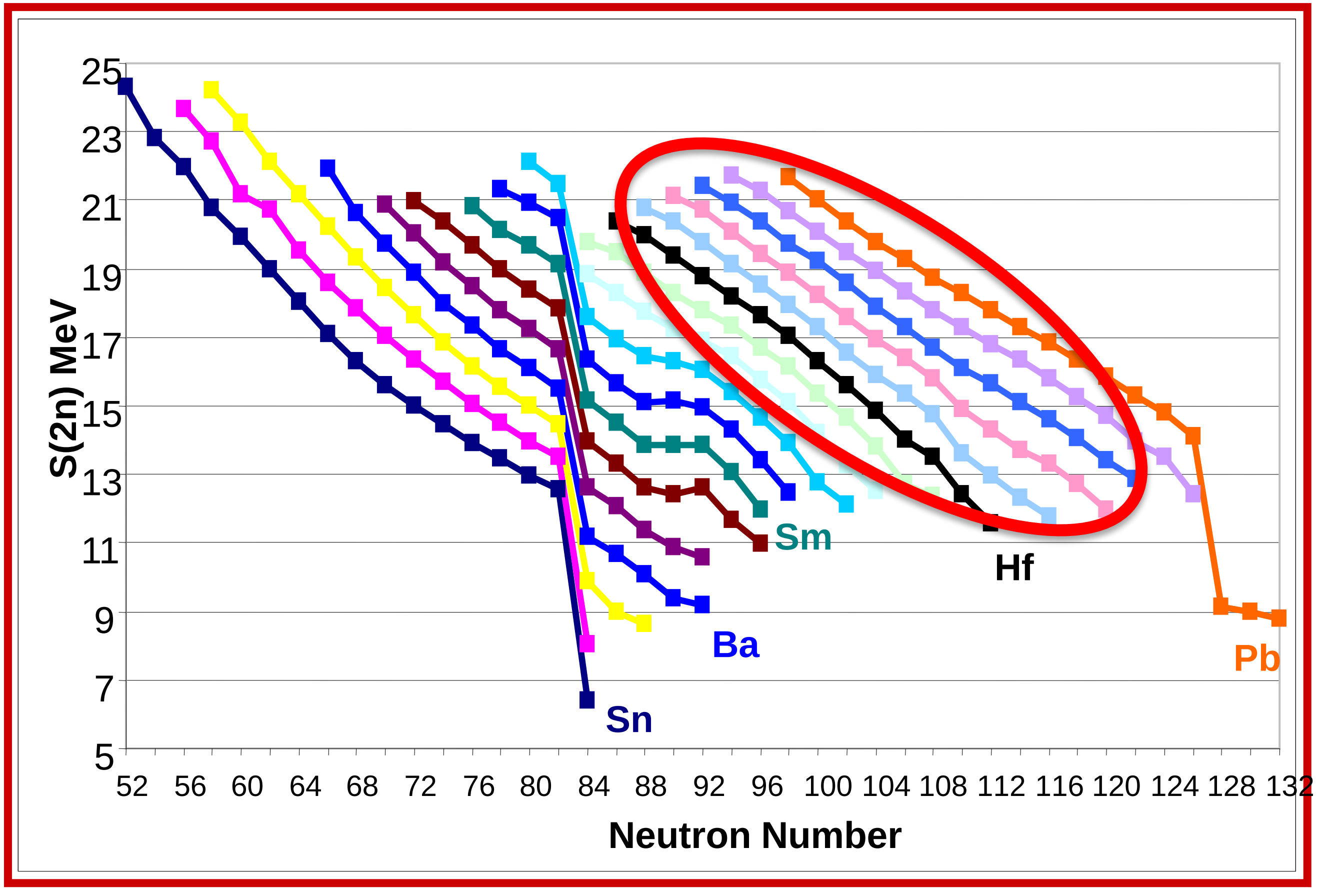

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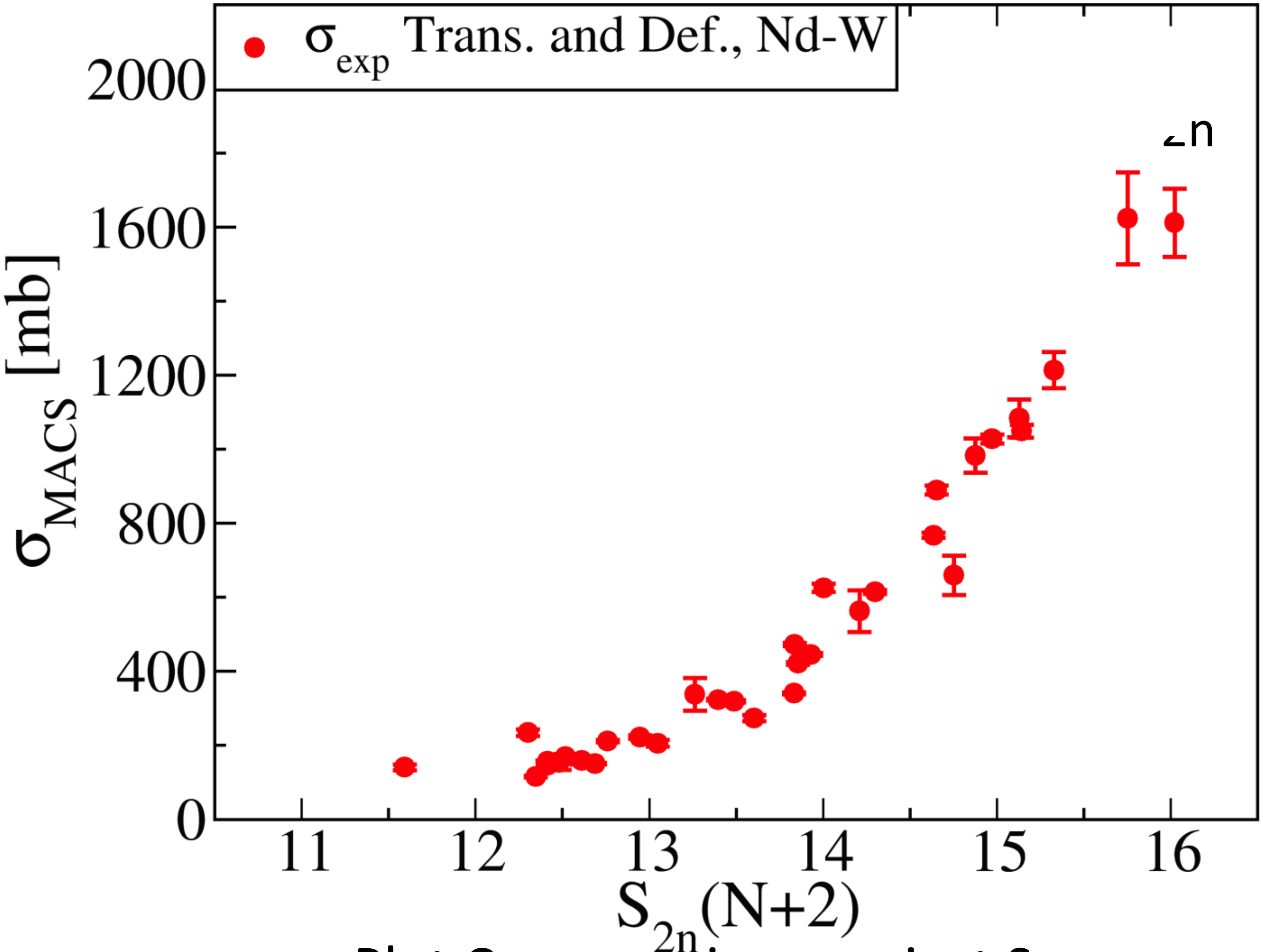
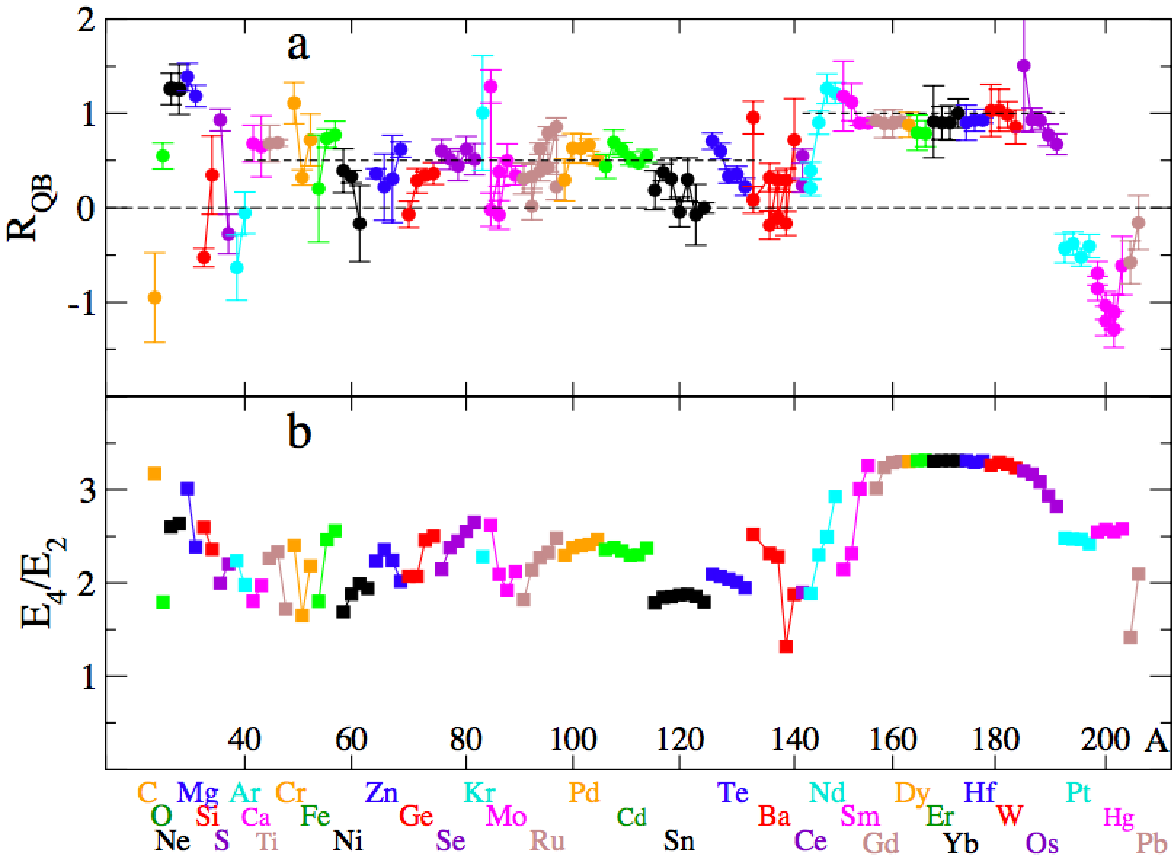


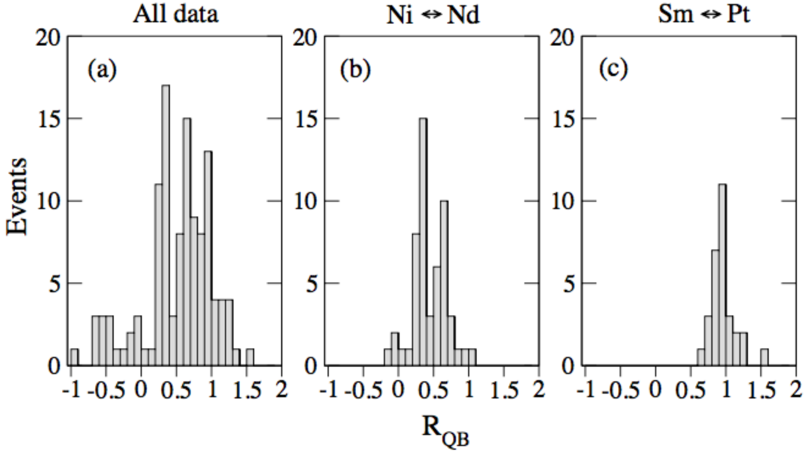
Plot Cross sections against S_{2n}

A Couture, RF Casten and R. Burcu Cakirli, PRC 96, 061601R (2017)

B(E2) values and Q moments

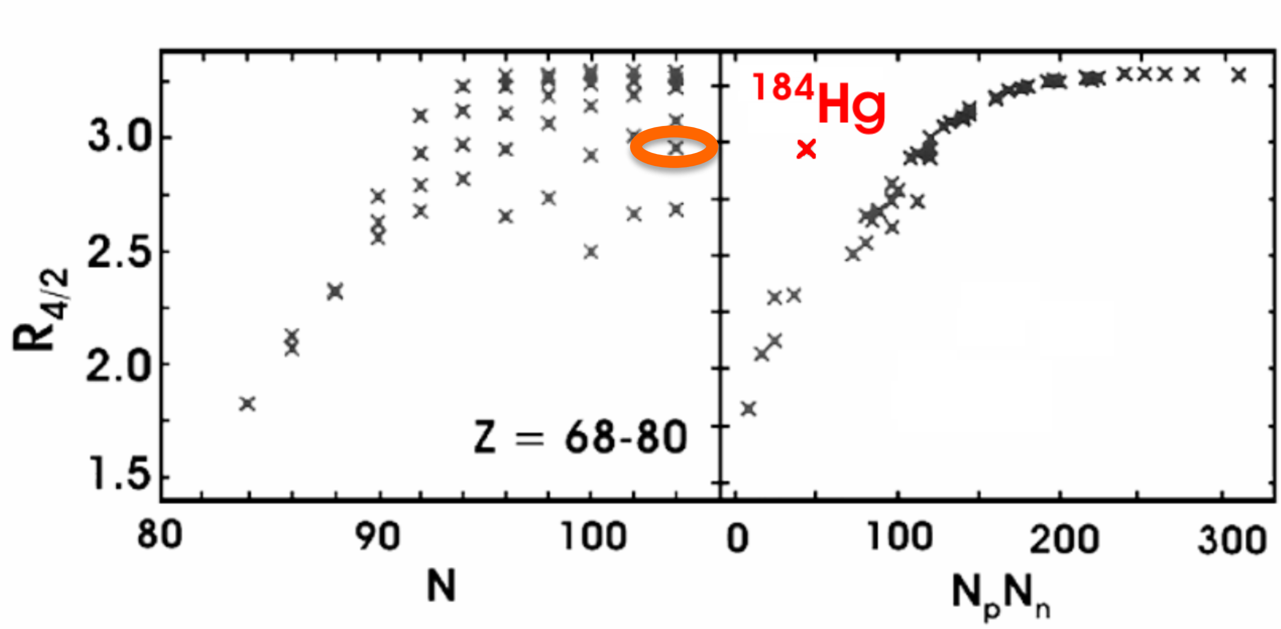


Q(2+)/B(E2: 0^+-2^+)



Y. Sharon, N.Koller et al, preprint

Different perspectives, one more example



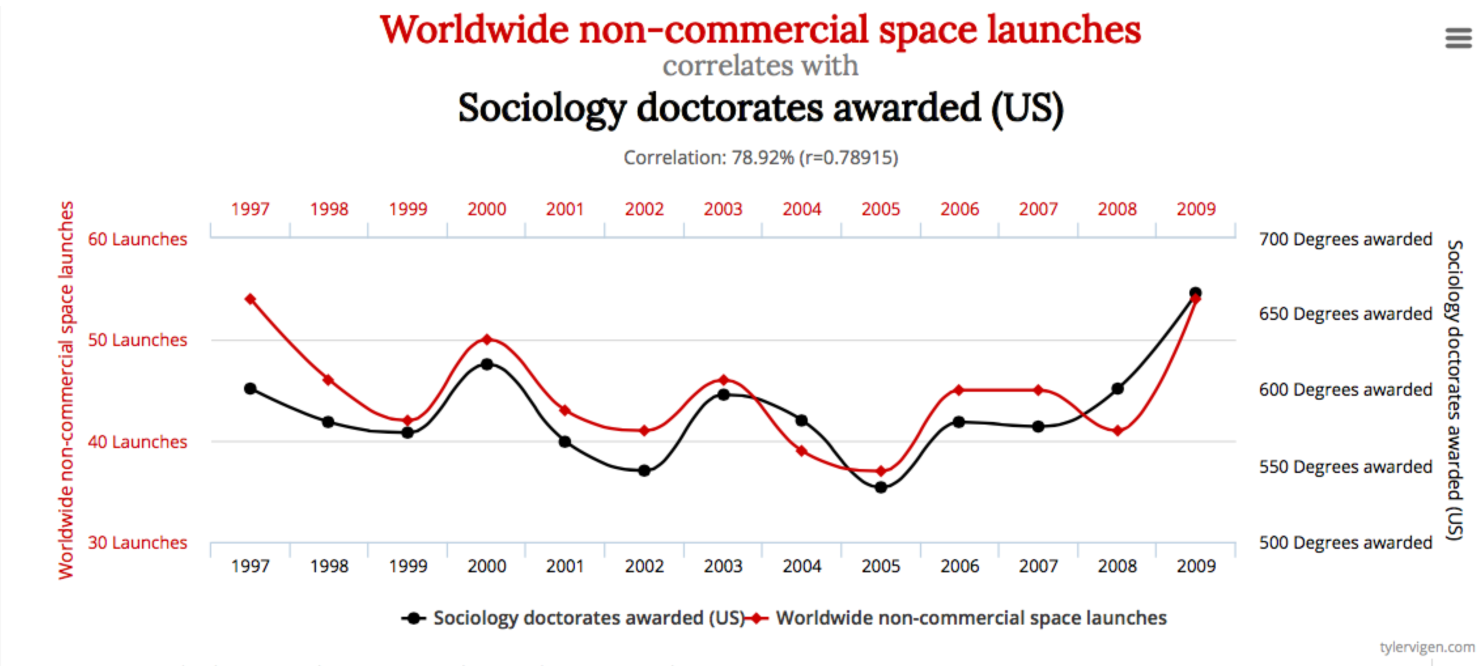
Which is the anomalous nucleus?

Identify deviant behavior

Time out – warning:

BEWARE OF FALSE CORRELATIONS!

More false correlations



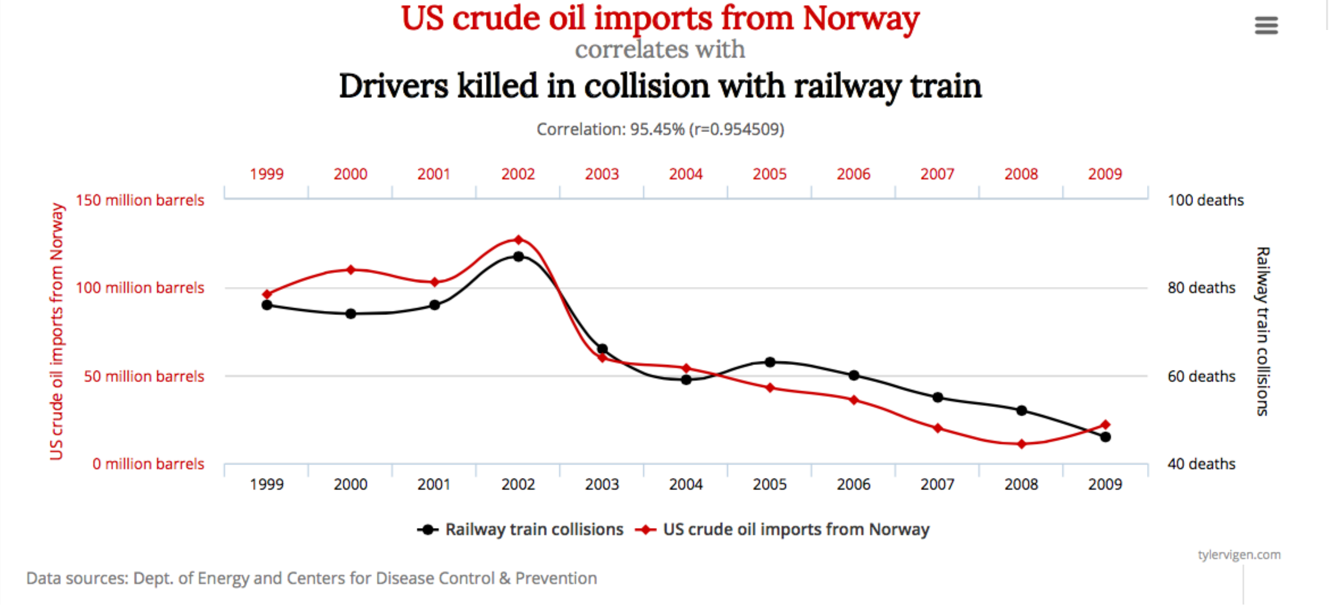
Worldwide non-commercial space launches

correlates with

Sociology doctorates awarded (US)

Correlation: 78.92% (r=0.78915)

Data sources: Federal Aviation Administration and National Science Foundation



US crude oil imports from Norway

correlates with

Drivers killed in collision with railway train

Correlation: 95.45% (r=0.954509)

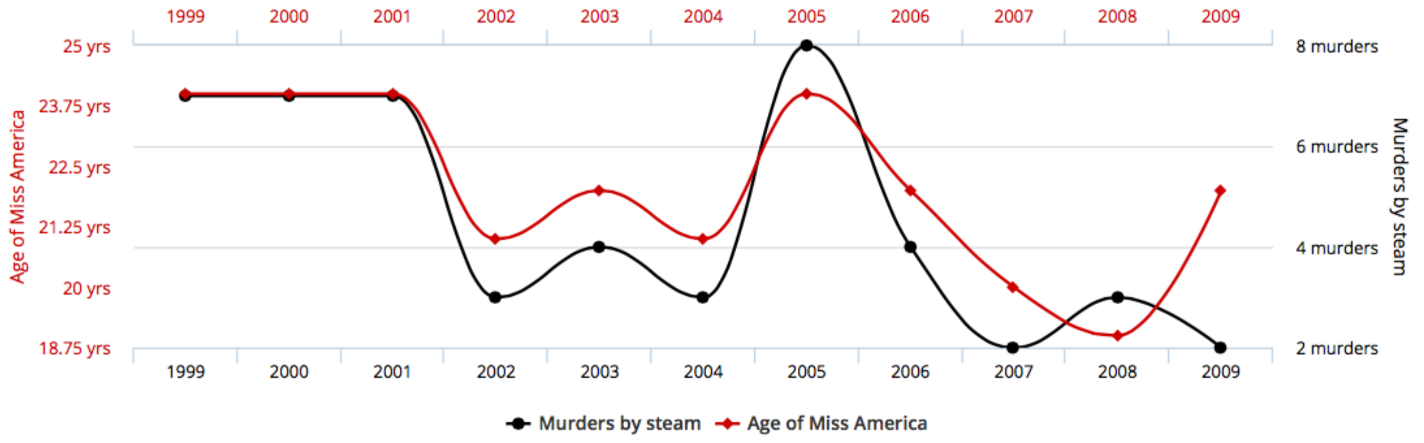
Data sources: Dept. of Energy and Centers for Disease Control & Prevention

Age of Miss America

correlates with

Murders by steam, hot vapours and hot objects

Correlation: 87.01% (r=0.870127)



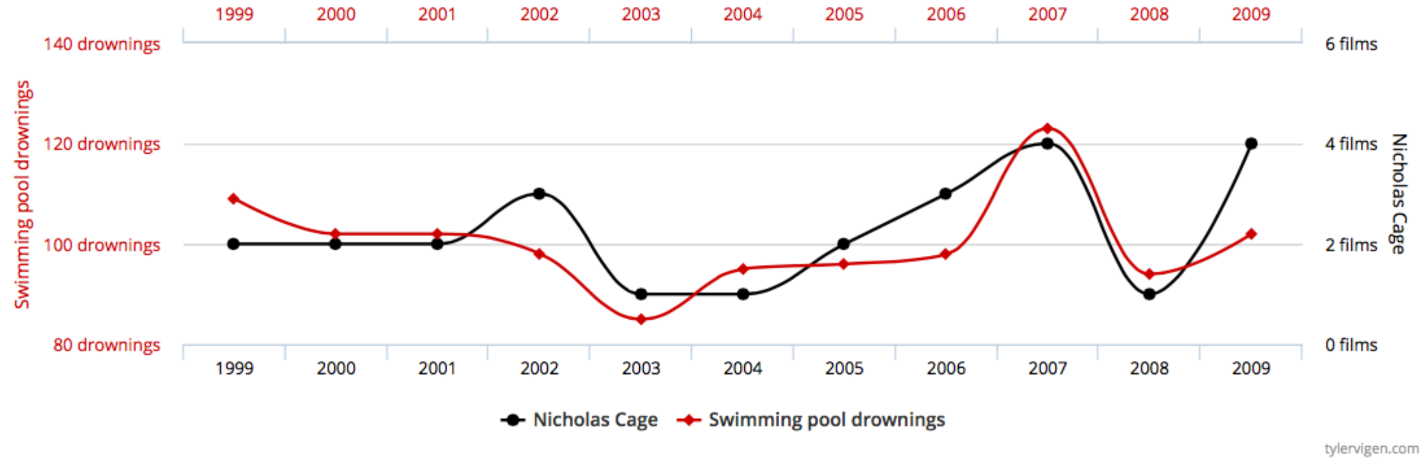
Data sources: Wikipedia and Centers for Disease Control & Prevention

Number of people who drowned by falling into a pool

correlates with

Films Nicolas Cage appeared in

Correlation: 66.6% (r=0.666004)

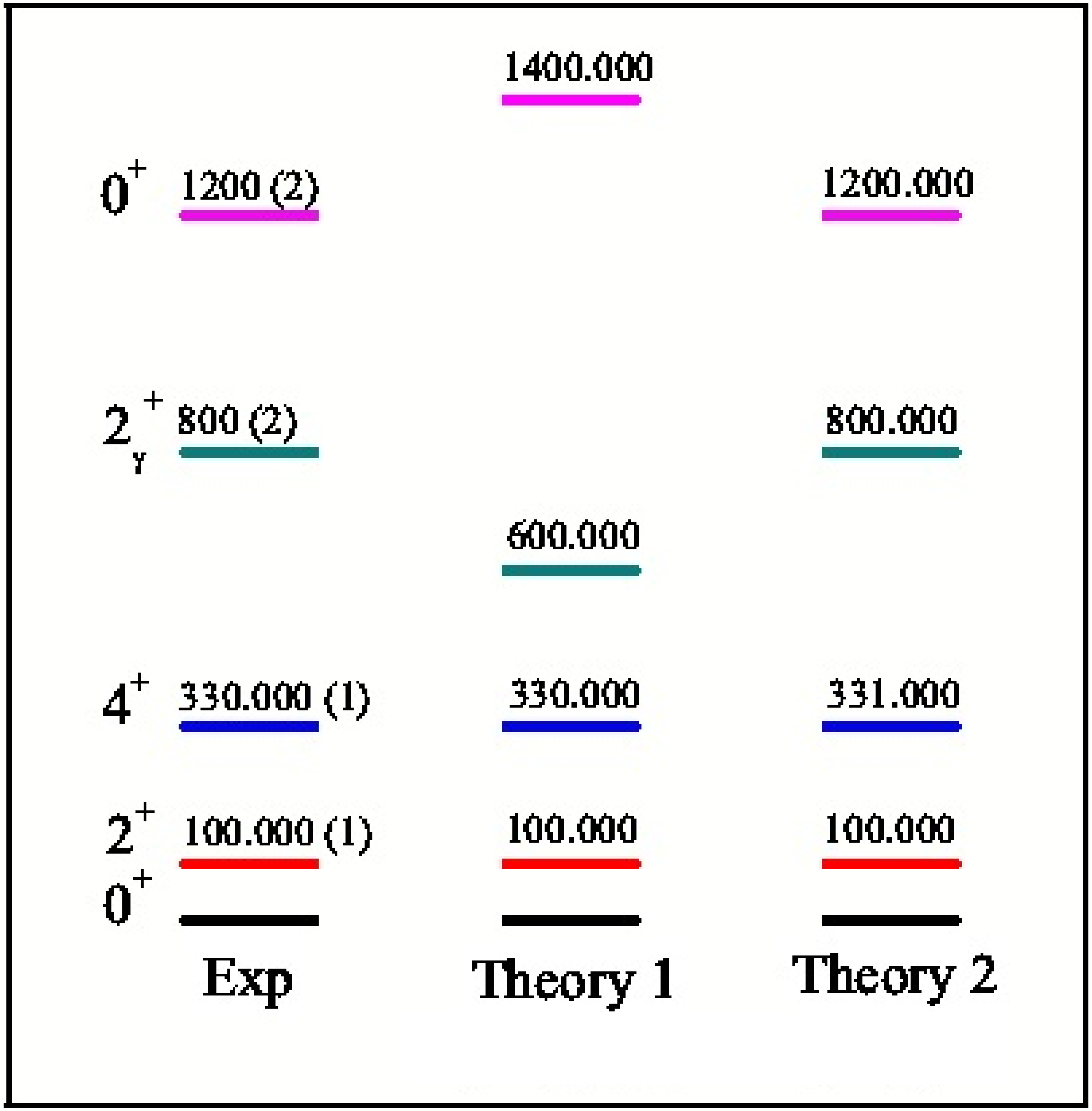


Data sources: Centers for Disease Control & Prevention and Internet Movie Database

Theoretical accuracy, precise data, weighting data, key observables, parameters

A very simple first example:

Which theory is better

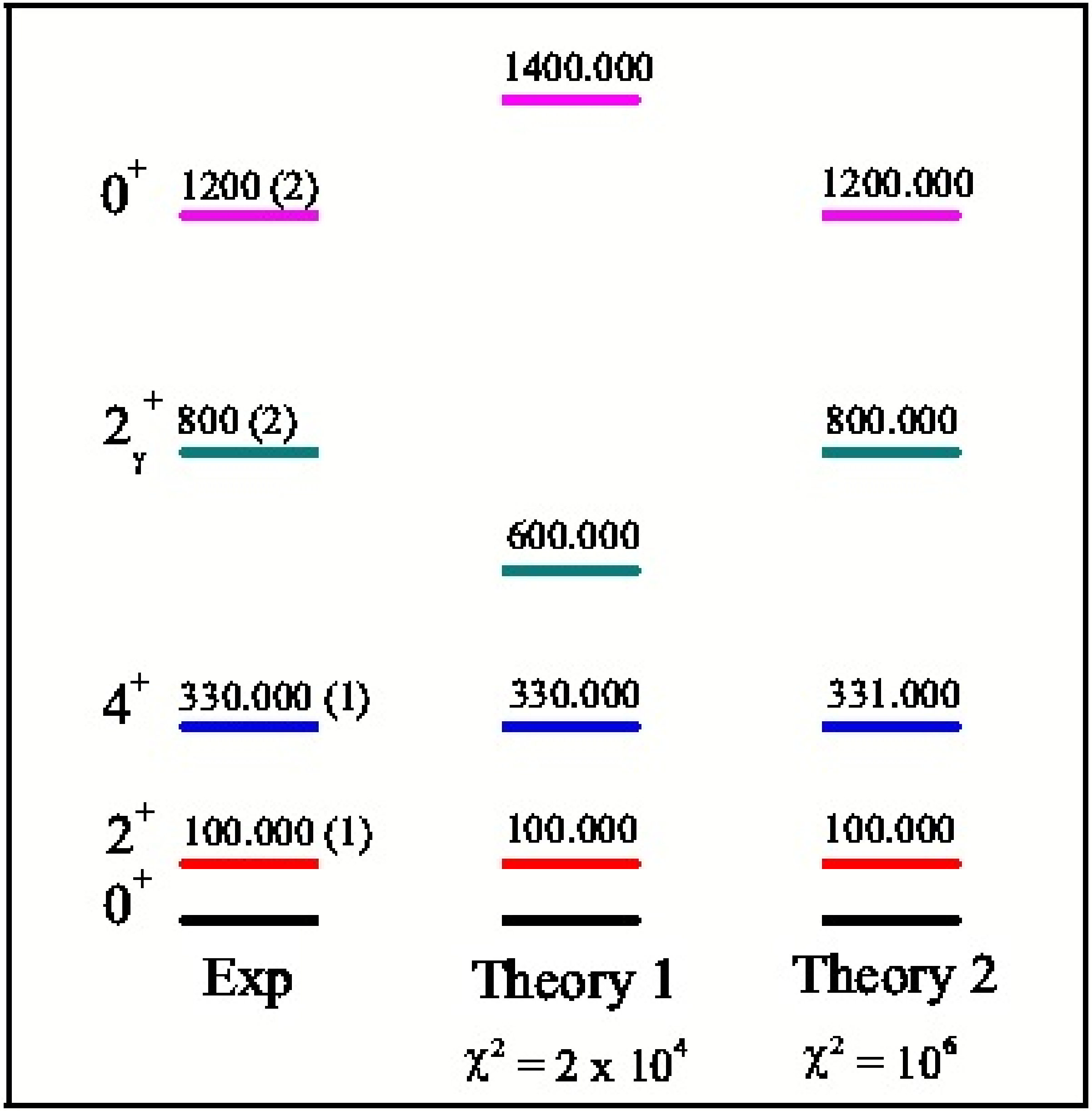


Now look at χ^2

$$\chi^2 = \sum_{i=1}^{k} \left(\frac{O_i(exp) - O_i(theor)}{\sigma_i}\right)^2$$

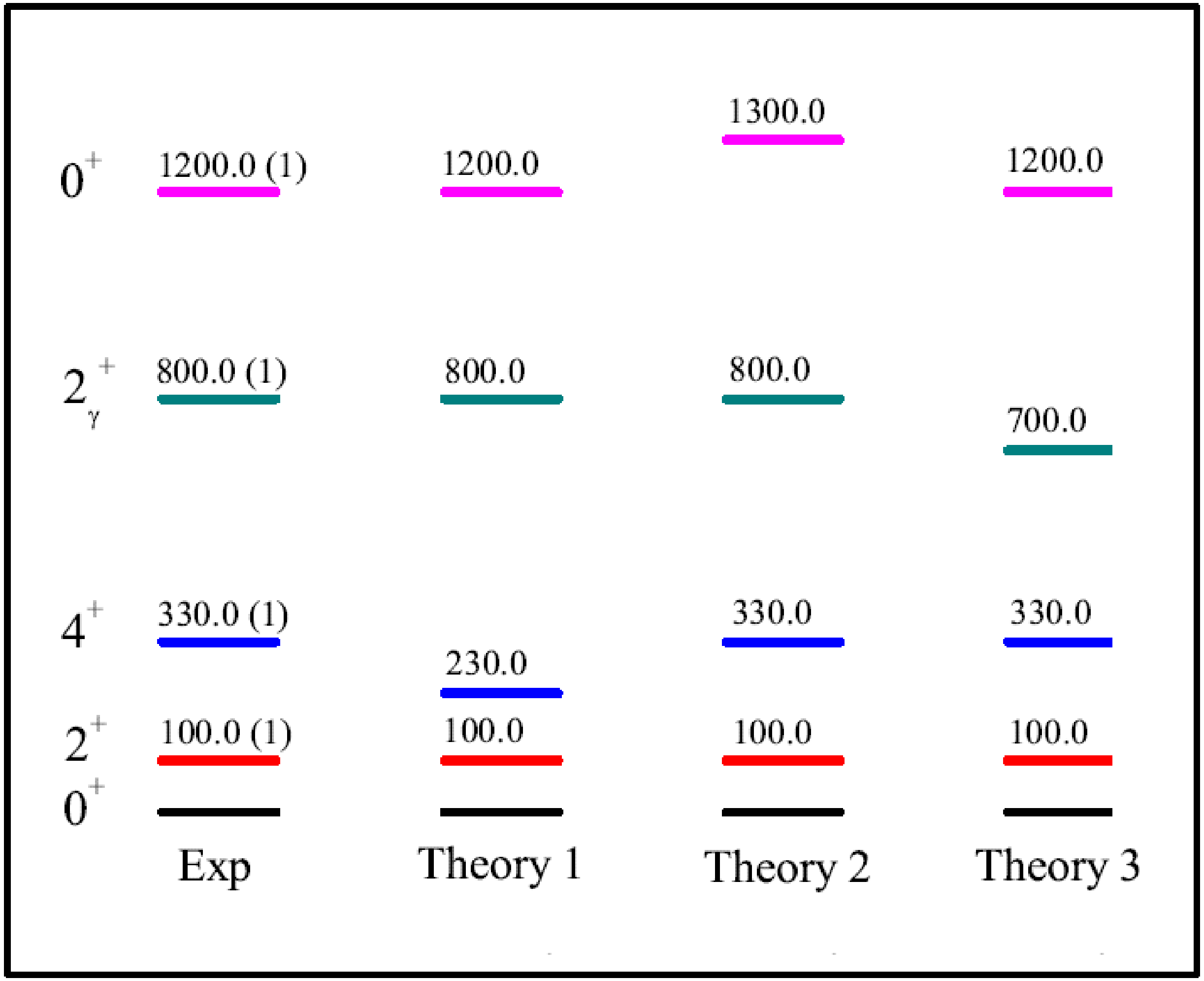
Ironically, super-precise data can lead you astray

Problem is not the precision data per se but the lack of a perspective with which to assess it. How good do we expect the theories to be? Include 10 keV “range” on theory:



~ 800 ~ 0.01

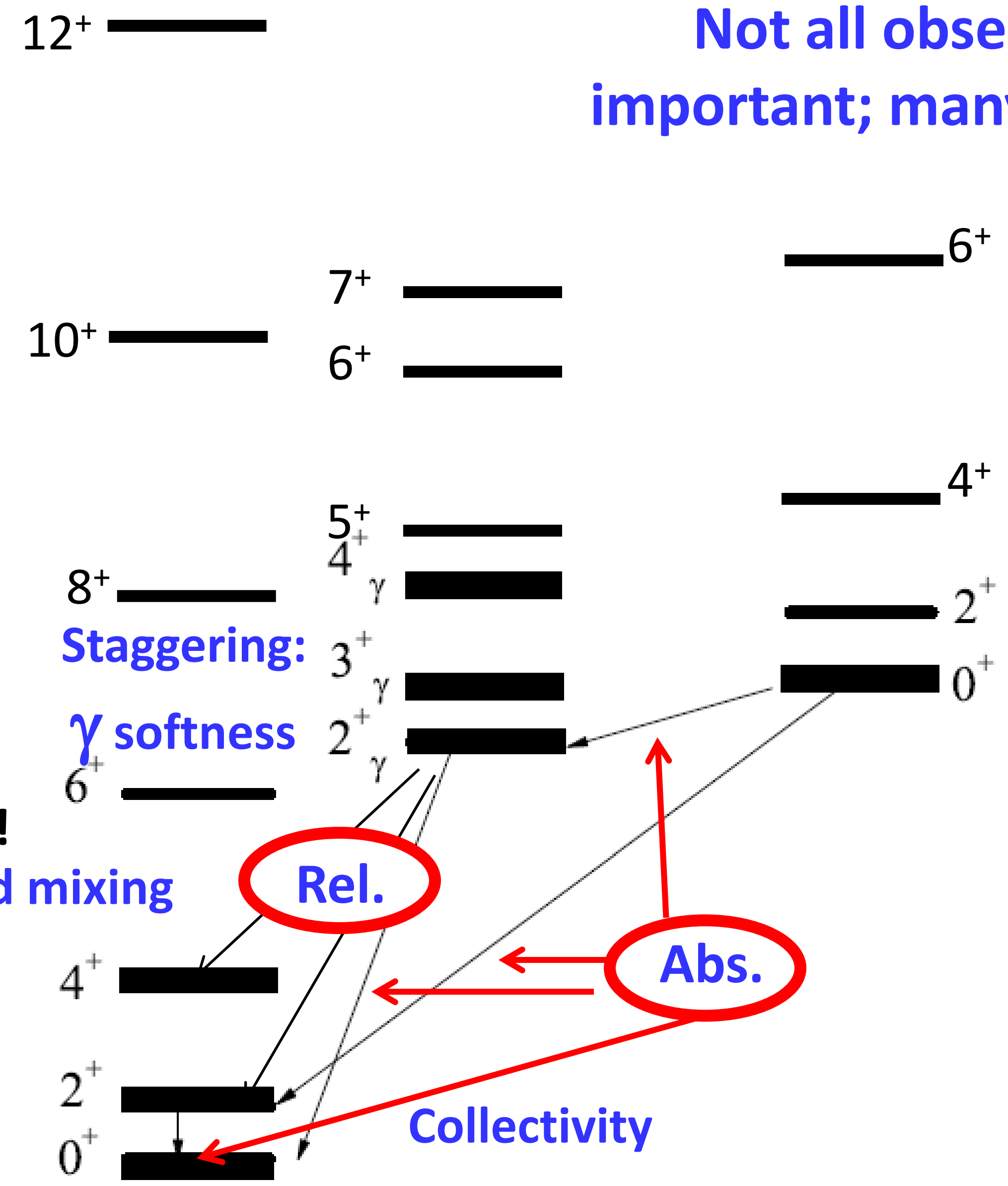
Observable-dependent uncertainties



Theoretical reliability estimates: Yrast: Few keV ; Vibrations ~ 100 keV

χ^2 ~1000 1

Not all observables equally important; many test same physics



Advice to theorists: B(E2) ratios!!

Staggering: γ softness

Band mixing

Rotational spacings

Collectivity

Vibrational bandhead energies

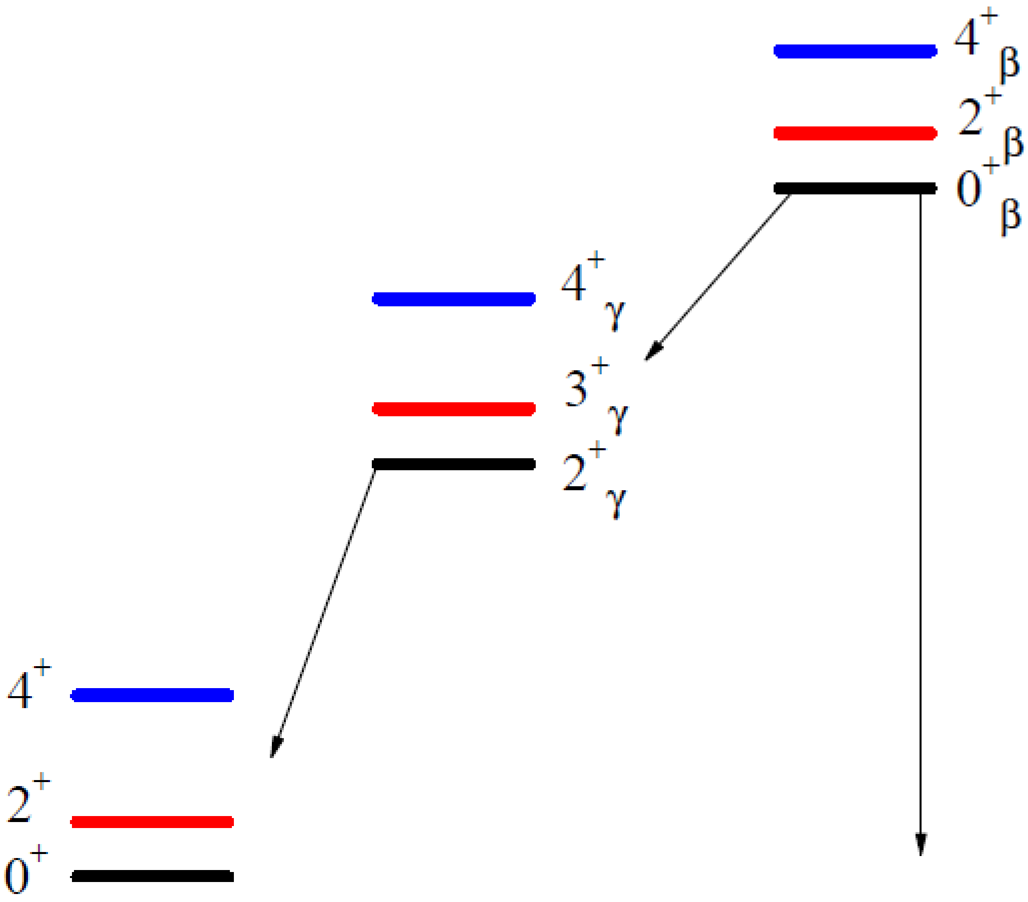
Including many yrast levels in a χ^2 test overweights that physics. The more, the worse it gets.

What are the key observables for testing collective models?

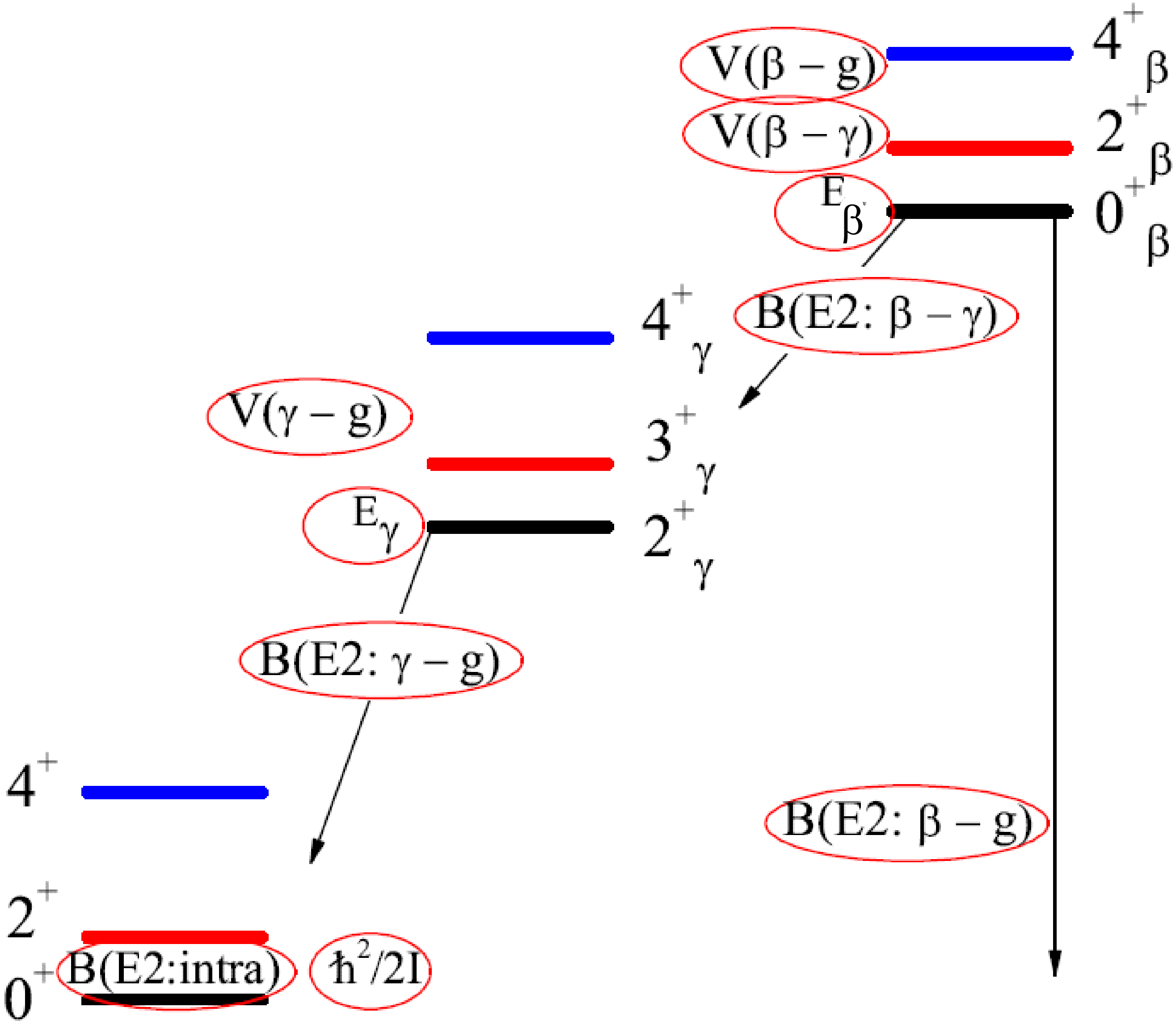
Parameters

Interpreting this level scheme with bandmixing

How many parameters?



Beware of parameters



Summary

Look at data from different perspectives

Look at correlations of observables

Choose observables that select specific physics – e. g., emergent collectivity

Beware of blind statistical optimizations

Always include estimates (quantitative or qualitative) of theoretically expected reliability

Do not multi-fit the same physics

Be conscious of the number and nature of (often hidden) parameters.

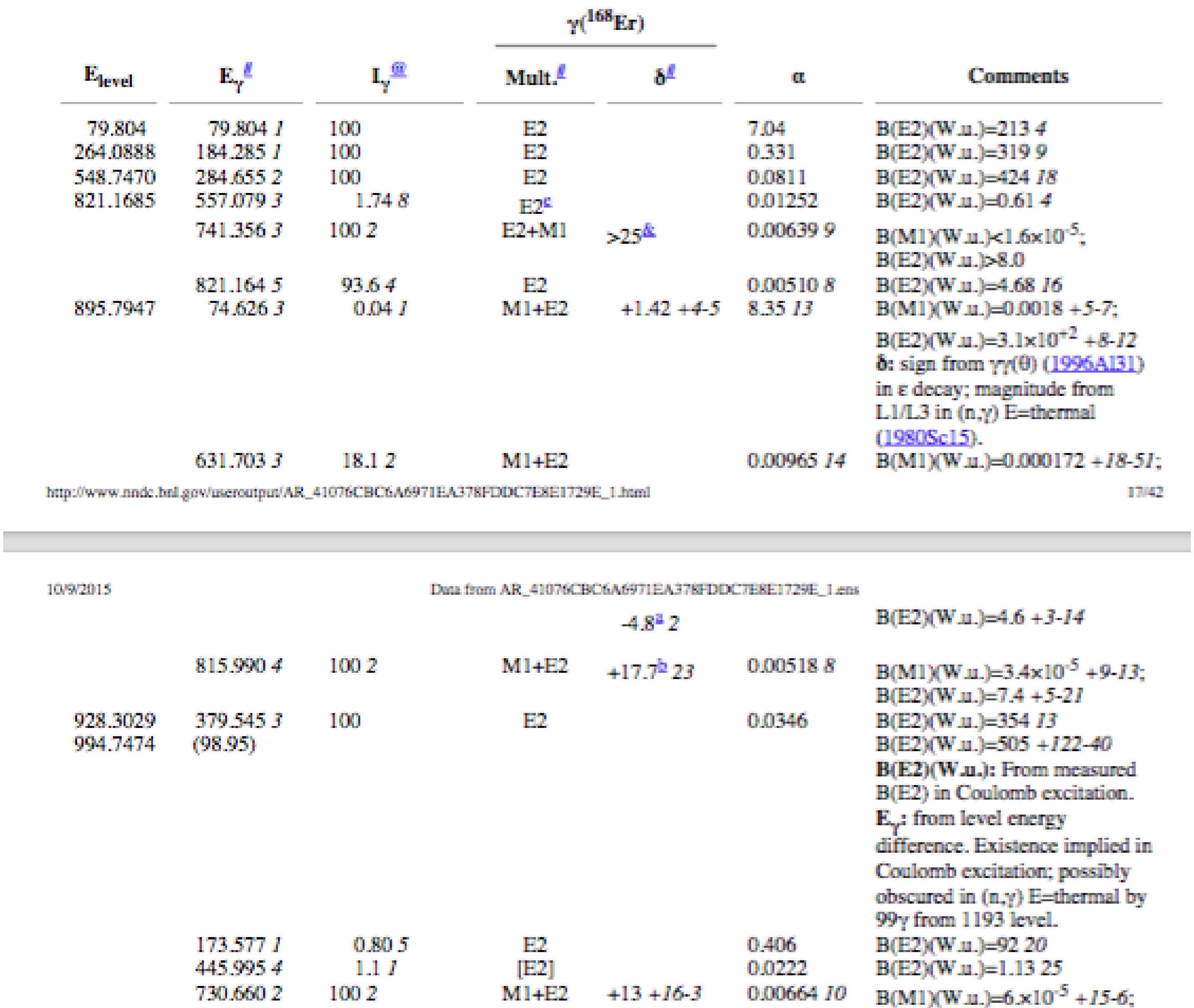
PR C, NNDC opportunity, and NUDAT capabilities

Advice to PR C authors from a PR C editor:

Suggest referees (5-7)
Name unwanted referees(no generic lists)
Asking for a second referee (the good and the risky)
NNDC vetting opportunity (new)

NUDAT – New features you might not be aware of

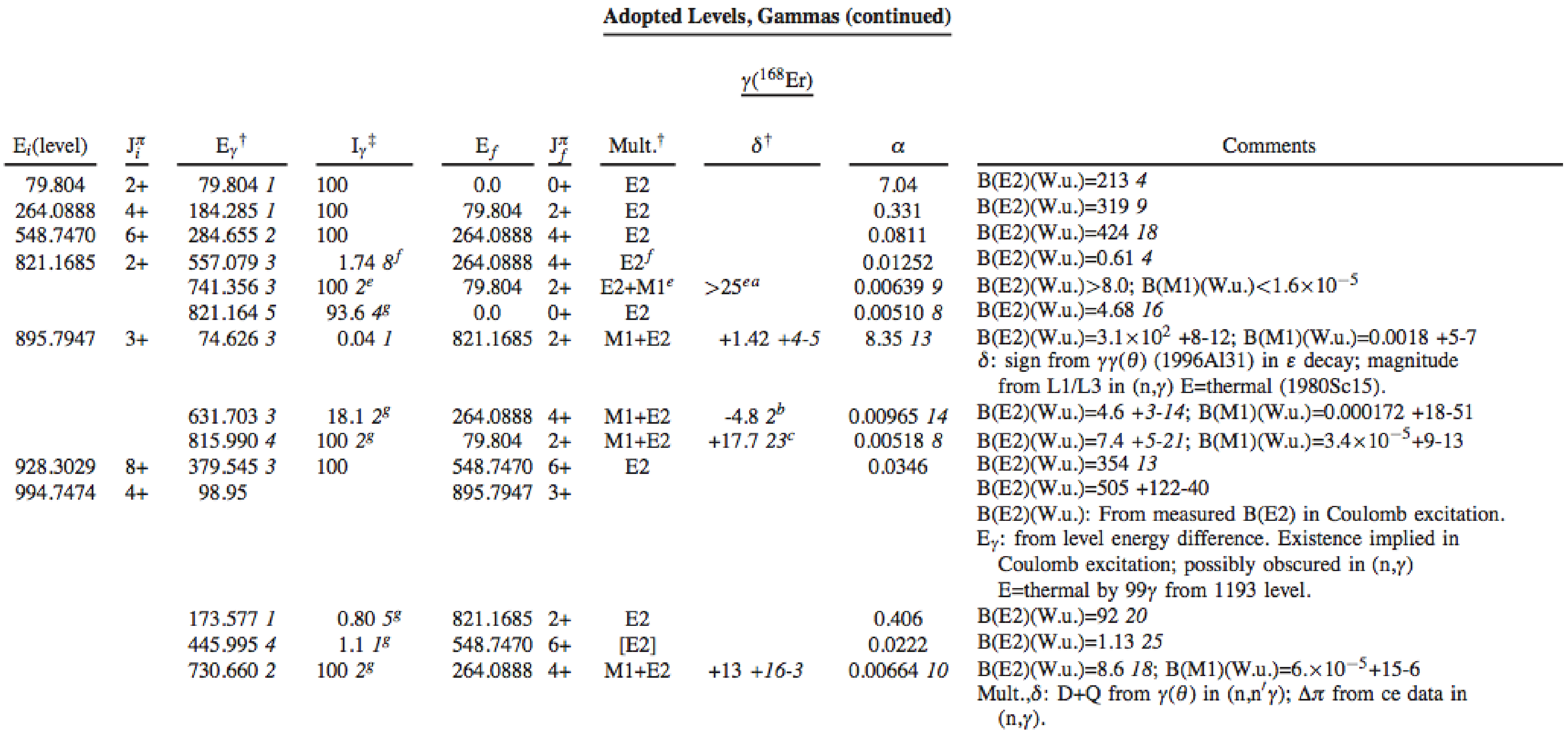
NNDC The format you may know--- UGH: WHY UGH?



			$\gamma(^{168}$Er)			
E_{level}	E_γ[‡]	I_γ[@]	Mult.[‡]	δ[‡]	α	Comments
79.804	79.804 *1*	100	E2		7.04	B(E2)(W.u.)=213 *4*
264.0888	184.285 *1*	100	E2		0.331	B(E2)(W.u.)=319 *9*
548.7470	284.655 2	100	E2		0.0811	B(E2)(W.u.)=424 *18*
821.1685	557.079 *3*	1.74 *8*	E2[c]		0.01252	B(E2)(W.u.)=0.61 *4*
	741.356 *3*	100 2	E2+M1	>25[&]	0.00639 9	B(M1)(W.u.)<1.6×10^{-5}; B(E2)(W.u.)>8.0
	821.164 *5*	93.6 *4*	E2		0.00510 *8*	B(E2)(W.u.)=4.68 *16*
895.7947	74.626 *3*	0.04 *1*	M1+E2	+1.42 *+4-5*	8.35 *13*	B(M1)(W.u.)=0.0018 *+5-7*; B(E2)(W.u.)=$3.1\times10^{+2}$ *+8-12* **δ:** sign from γγ(θ) (1996Al31) in ε decay; magnitude from L1/L3 in (n,γ) E=thermal (1980Sc15).
	631.703 *3*	18.1 2	M1+E2		0.00965 *14*	B(M1)(W.u.)=0.000172 *+18-51*;

E_{level}	E_γ	I_γ	Mult.	δ	α	Comments
				-4.8[a] 2		B(E2)(W.u.)=4.6 *+3-14*
	815.990 *4*	100 *2*	M1+E2	+17.7[b] *23*	0.00518 *8*	B(M1)(W.u.)=3.4×10^{-5} *+9-13*; B(E2)(W.u.)=7.4 *+5-21*
928.3029	379.545 *3*	100	E2		0.0346	B(E2)(W.u.)=354 *13*
994.7474	(98.95)					B(E2)(W.u.)=505 *+122-40* **B(E2)(W.u.):** From measured B(E2) in Coulomb excitation. **E_γ:** from level energy difference. Existence implied in Coulomb excitation; possibly obscured in (n,γ) E=thermal by 99γ from 1193 level.
	173.577 *1*	0.80 *5*	E2		0.406	B(E2)(W.u.)=92 *20*
	445.995 *4*	1.1 *1*	[E2]		0.0222	B(E2)(W.u.)=1.13 *25*
	730.660 2	100 *2*	M1+E2	+13 *+16-3*	0.00664 *10*	B(M1)(W.u.)=$6.\times10^{-5}$ *+15-6*;

New format – YAAAY !!!!!



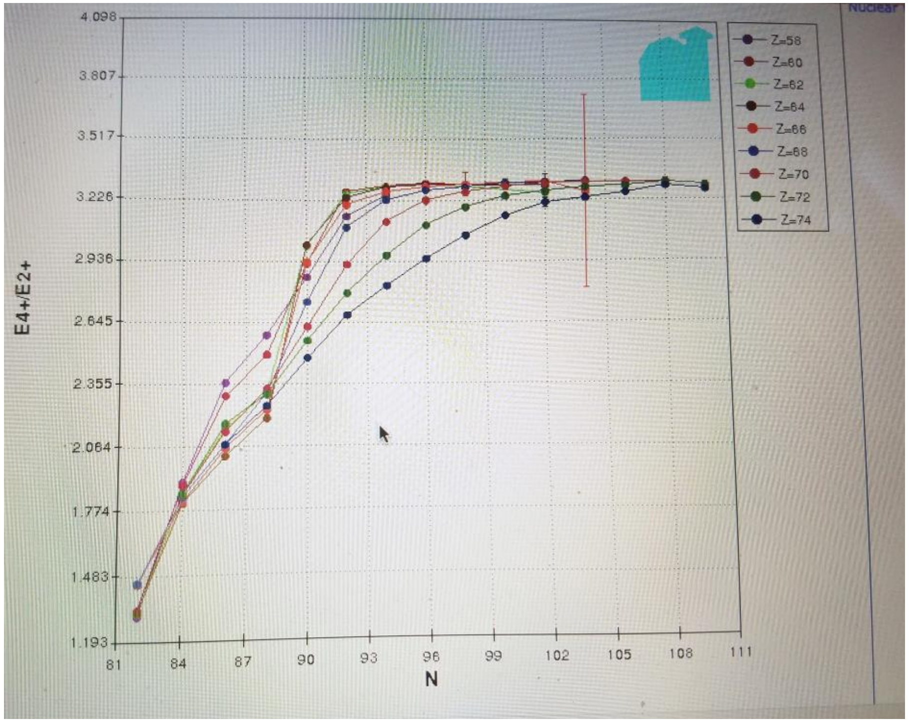
Adopted Levels, Gammas (continued)

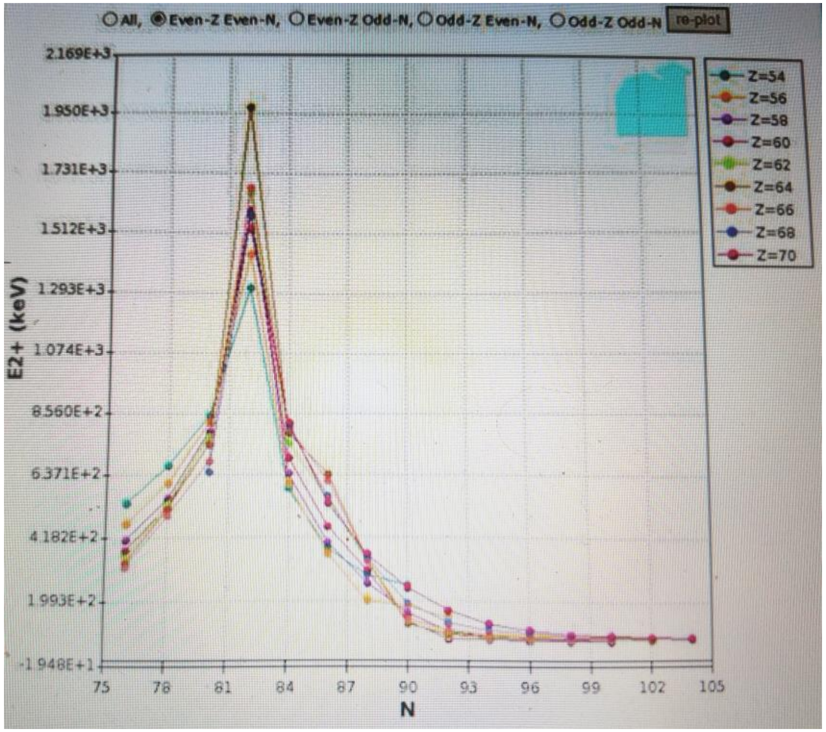
$\gamma(^{168}\mathrm{Er})$

E_i(level)	J_i^π	E_γ†	I_γ‡	E_f	J_f^π	Mult.†	δ†	α	Comments
79.804	2+	79.804 *1*	100	0.0	0+	E2		7.04	B(E2)(W.u.)=213 *4*
264.0888	4+	184.285 *1*	100	79.804	2+	E2		0.331	B(E2)(W.u.)=319 *9*
548.7470	6+	284.655 2	100	264.0888	4+	E2		0.0811	B(E2)(W.u.)=424 *18*
821.1685	2+	557.079 *3*	1.74 *8*[f]	264.0888	4+	E2[f]		0.01252	B(E2)(W.u.)=0.61 *4*
		741.356 *3*	100 *2*[e]	79.804	2+	E2+M1[e]	>25[ea]	0.00639 *9*	B(E2)(W.u.)>8.0; B(M1)(W.u.)<1.6×10^{-5}
		821.164 *5*	93.6 *4*[g]	0.0	0+	E2		0.00510 *8*	B(E2)(W.u.)=4.68 *16*
895.7947	3+	74.626 *3*	0.04 *1*	821.1685	2+	M1+E2	+1.42 *+4-5*	8.35 *13*	B(E2)(W.u.)=3.1×10^{2} +8-12; B(M1)(W.u.)=0.0018 +5-7 δ: sign from γγ(θ) (1996Al31) in ε decay; magnitude from L1/L3 in (n,γ) E=thermal (1980Sc15).
		631.703 *3*	18.1 *2*[g]	264.0888	4+	M1+E2	-4.8 *2*[b]	0.00965 *14*	B(E2)(W.u.)=4.6 *+3-14*; B(M1)(W.u.)=0.000172 +18-51
		815.990 *4*	100 *2*[g]	79.804	2+	M1+E2	+17.7 *23*[c]	0.00518 *8*	B(E2)(W.u.)=7.4 *+5-21*; B(M1)(W.u.)=3.4×10^{-5}+9-13
928.3029	8+	379.545 *3*	100	548.7470	6+	E2		0.0346	B(E2)(W.u.)=354 *13*
994.7474	4+	98.95		895.7947	3+				B(E2)(W.u.)=505 +122-40 B(E2)(W.u.): From measured B(E2) in Coulomb excitation. E_γ: from level energy difference. Existence implied in Coulomb excitation; possibly obscured in (n,γ) E=thermal by 99γ from 1193 level.
		173.577 *1*	0.80 *5*[g]	821.1685	2+	E2		0.406	B(E2)(W.u.)=92 *20*
		445.995 *4*	1.1 *1*[g]	548.7470	6+	[E2]		0.0222	B(E2)(W.u.)=1.13 *25*
		730.660 2	100 *2*[g]	264.0888	4+	M1+E2	+13 *+16-3*	0.00664 *10*	B(E2)(W.u.)=8.6 *18*; B(M1)(W.u.)=$6.\times10^{-5}$+15-6 Mult.,δ: D+Q from γ(θ) in (n,n′γ); Δπ from ce data in (n,γ).

Its not just convenience -- it reduces errors, enhances efficiency, enhances treating different data consistently.

New Features of NUDAT





Upcoming features: Choose category of nucleus
Plot one observable against another??

Thanks !!!

Backups

Why do some models have so many and others so few parameters? Can be misleading.

Compare above 10-15 parameter calculation with the IBA which obtains comparable or better fits with 2-3 parameters.

Why? It's the same physical system both are describing.

The IBA makes an ansatz: truncate shell model -- s,d bosons. That saves many parameters. But that ansatz is itself a choice, an assumption – to set to zero the amplitudes of many shell model configurations. Be aware of such facets.