# Symmetry unrestricted Skyrme mean-field study of heavy nuclei

Wouter Ryssens*, M. Bender† & P.-H. Heenen*

Université Libre de Bruxelles*, IPN Lyon†

# Summary

# The nuclear landscape

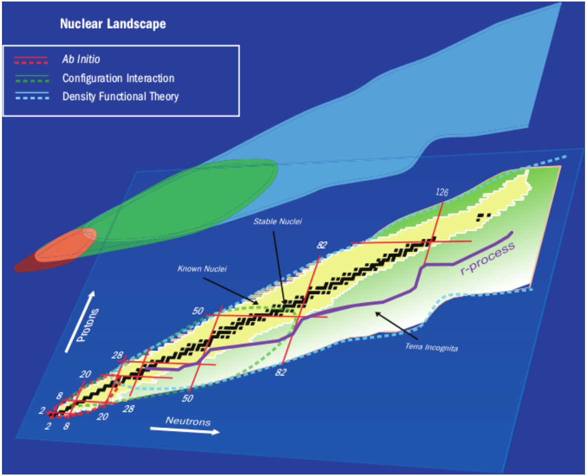


Figure from G.F. Bertsch et al., SciDAC Review 6, 48 (2007).

# Self-consistent Energy Density Functional calculations

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$\rho(\vec{r}), \tau(\vec{r}), \ldots$

$\uparrow$

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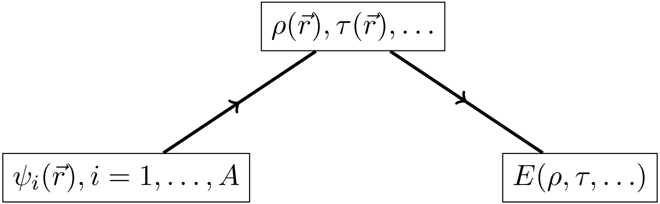

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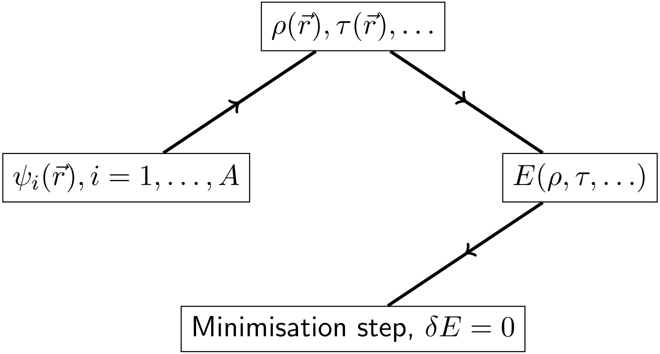

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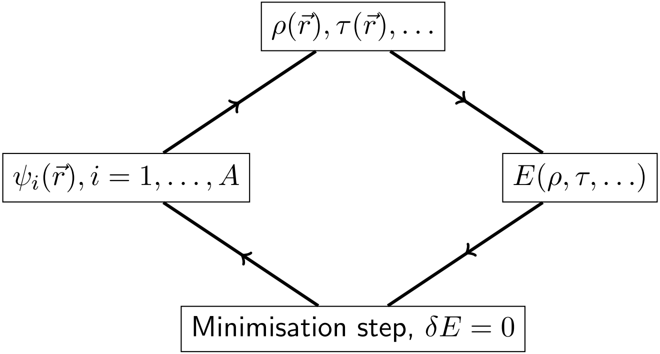

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- $(\approx)$ 10 parameters
- fitted on doubly-magic binding energies and charge radii

# The Sly5sX family

## SLy5

- General EDF
- Widely used and succesful
- Rather bad at fission
- Unsafe to use! (2011)

E. Chabanat *et al.*, Nucl. Phys. A. **635** (1998)

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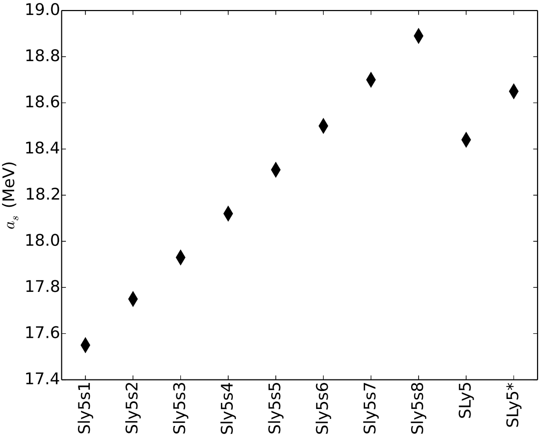
**SLy5***

- Refit of SLy5
- Similar properties
- Safe!
- Even worse at fission . . .

A. Pastore *et al.*, Phys. Scr. T154, 014014 (2013)

# The Sly5sX family

$$E_{drop} = a_v A - a_s A^{\frac{2}{3}} - a_c \frac{Z^2}{A^{\frac{1}{3}}} - a_A \frac{(A-2Z)^2}{A}$$



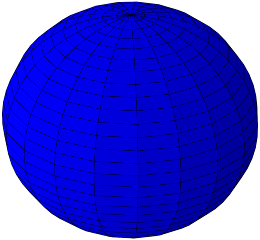
# Symmetries

$$\#\{\text{Symmetric Slater Determinants}\}$$
$$\leq$$
$$\#\{\text{Asymmetric Slater Determinants}\}$$

# Symmetries

# Rotational Symmetry

$\beta_2 = 0$



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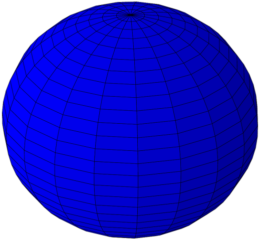
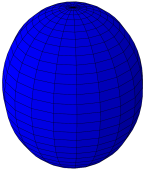


$\beta_2 > 0$



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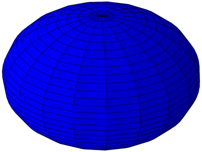

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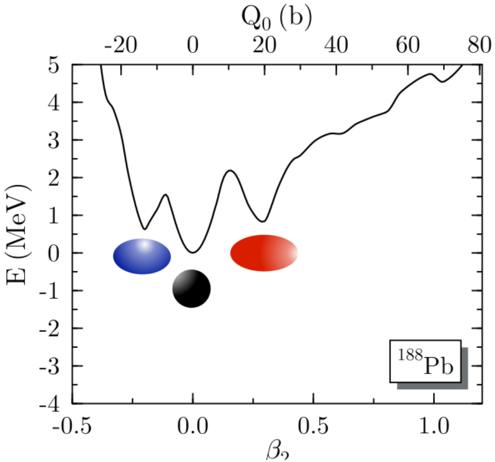


Figure from M. Bender *et al.*, PRC **69**, 064303 (2004)

# Parity

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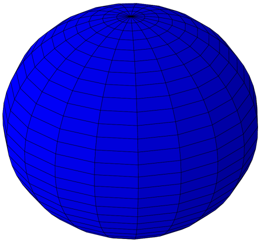

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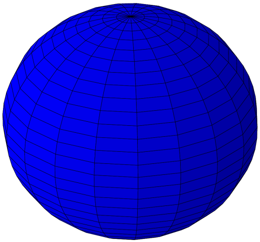
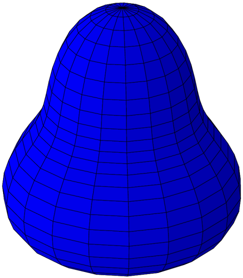
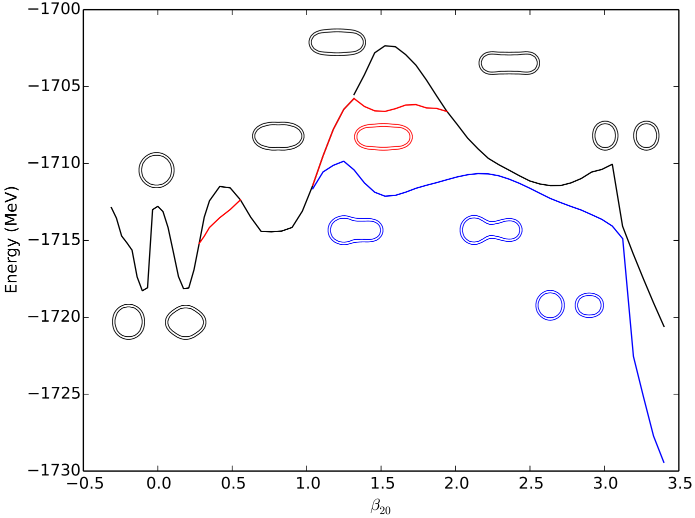


$\beta_3 \neq 0$



# Deformation of $^{226}$Ra

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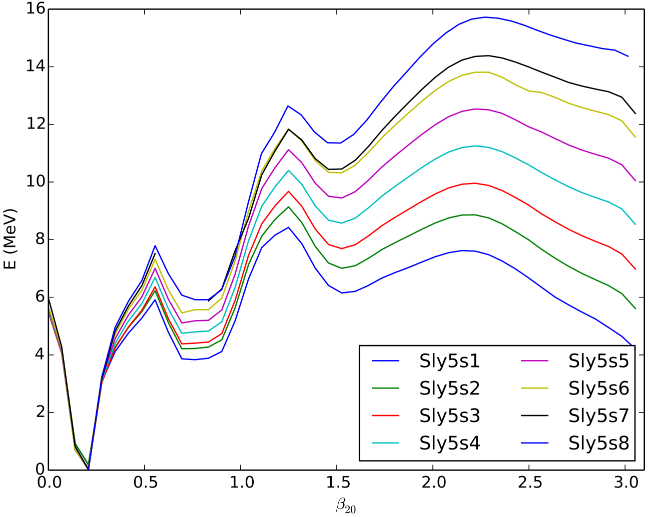
# Fission Barriers



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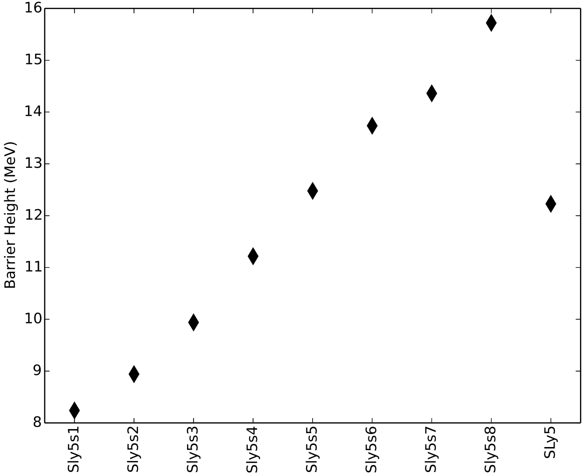
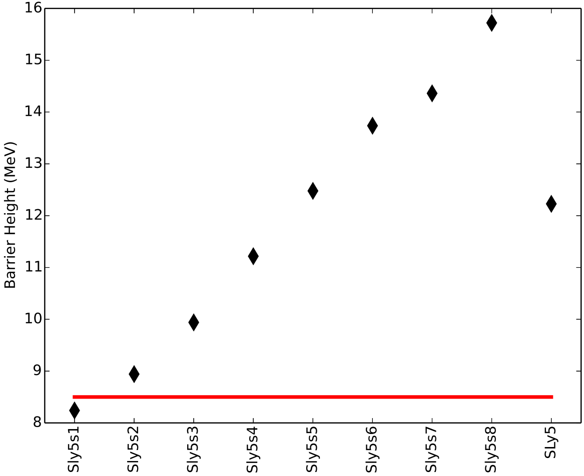


# Fission Barriers

Data from RIPL-3, R Capote *et al.*, Nuclear Data Sheets 110 (2009)



# Conclusion

Density Functional Theory

- Tool to study the entirety of the nuclear chart.
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Density Functional Theory

- Tool to study the entirety of the nuclear chart.
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What is new?

- Possibility of breaking all discrete symmetries
- Generalized pairing (HFB) calculations.
- Controllable $a_s$ for improved description of fission (with stable functionals).

# Prospects

In progress/Immediate future:

- Rotational bands in parity broken nuclei,
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Long-term future:

- Restoration of broken symmetries
- Investigation of nuclear Schiff moment.

# Thanks!

Thanks to my collaborators:

- P.-H. Heenen (ULB)
- M. Bender (IPNL)
- K. Bennaceur (IPNL & Jyväskylä)

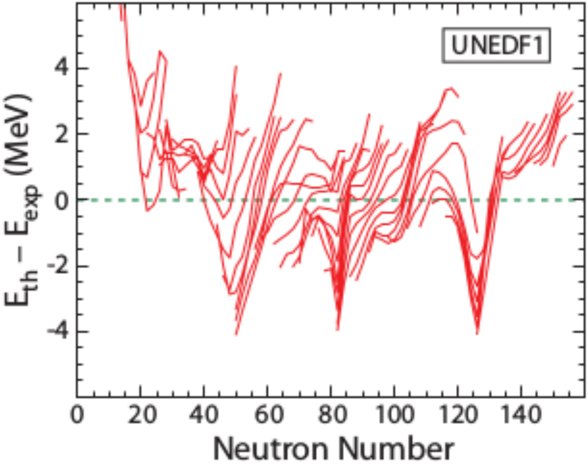
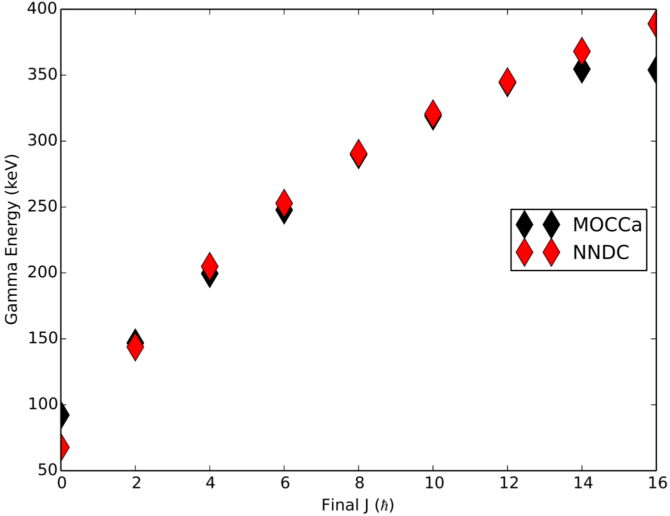



Figure from M. Kortelainen *et al.*, Phys. Rev. C 85, 024304


Gamma Energy (keV)
400
350
300
250
200
150
100
50
0
2
4
6
8
10
12
14
16
Final J (ħ)
MOCCa
NNDC

# Form of SLy5sX

$$
\begin{aligned}
E(\rho,\tau,\vec{j},J_{\mu\nu},\vec{s},\vec{T})_{T=0} &= b_1\rho^2 + b_3(\rho\tau - \vec{j}^2) + b_5\rho\Delta\rho \\
&+ b_7\rho^{2+\alpha} + b_9(\rho\nabla\vec{J} + \vec{j}\cdot\nabla\times\vec{s}) \\
&+ b_{10}\vec{s}^2 + b_{12}\rho^\alpha\vec{s}^2 \\
&+ b_{14}\left(\sum_{\mu\nu} J_{\mu\nu}J_{\mu\nu} - \vec{s}\cdot\vec{T}\right) \\
&+ b_{18}\vec{s}\cdot\Delta\vec{s} + b_{20}(\nabla\cdot\vec{s})^2
\end{aligned}
$$

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# Mesh calculations