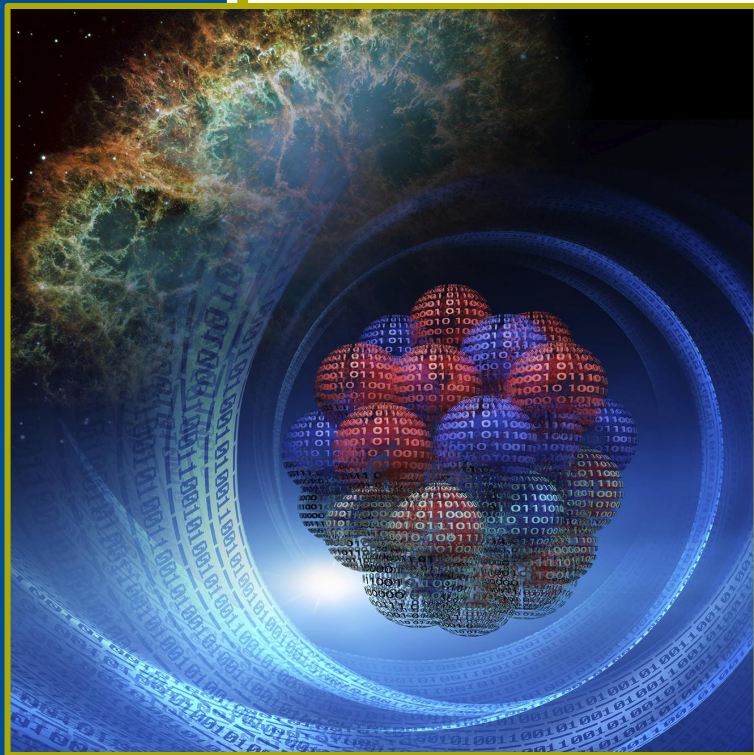




Andy Sproles, ORNL

Exploring the BSkG ~~mass~~ models

W. Ryssens

8th of June 2022



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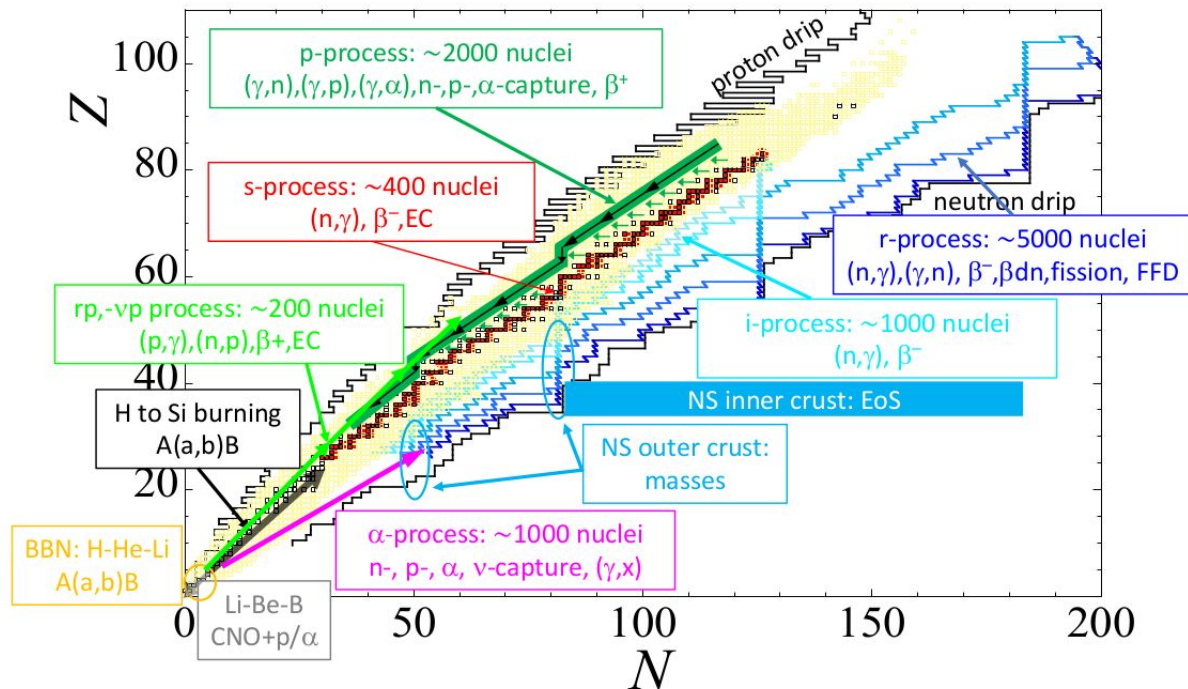
1 Introduction

2 $Z \sim 45$

3 Fission

4 Nuclear level densities

The challenge for nuclear theory



$$E \sim \int d^3r \left[C^\rho \rho(\mathbf{r})\rho(\mathbf{r}) + C^\tau \tau(\mathbf{r})\rho(\mathbf{r}) + \dots \right]$$



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Local densities of a mean-field state



Intro: Skyrme EDFs

$$E \sim \int d^3r \left[C^\rho \rho(\mathbf{r})\rho(\mathbf{r}) + C^\tau \tau(\mathbf{r})\rho(\mathbf{r}) + \dots \right]$$

Coupling constants

Local densities of a mean-field state

The diagram shows the Skyrme energy density functional equation. The coupling constants C^ρ and C^τ are enclosed in blue boxes, and the local densities $\rho(\mathbf{r})\rho(\mathbf{r})$ and $\tau(\mathbf{r})\rho(\mathbf{r})$ are enclosed in red boxes. A blue line connects the blue boxes to the label 'Coupling constants'. A red line connects the red boxes to the label 'Local densities of a mean-field state'.

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Coupling constants

Energy (to be varied)

Local densities of a mean-field state

The diagram shows the Skyrme Energy Density Functional (EDF) equation. The energy E is enclosed in a yellow box, with a yellow line pointing to the text 'Energy (to be varied)'. The integrand is enclosed in large square brackets. Inside, the coupling constants C^ρ and C^τ are enclosed in blue boxes, with a blue line pointing to the text 'Coupling constants'. The local densities $\rho(\mathbf{r})\rho(\mathbf{r})$ and $\tau(\mathbf{r})\rho(\mathbf{r})$ are enclosed in red boxes, with a red line pointing to the text 'Local densities of a mean-field state'. The integral is over d^3r .

Intro: Skyrme EDFs

$$E \sim \int d^3r \left[C^\rho \rho(\mathbf{r})\rho(\mathbf{r}) + C^\tau \tau(\mathbf{r})\rho(\mathbf{r}) + \dots \right]$$

Diagram illustrating the Skyrme Energy Density Functional (EDF) equation:

- Energy (to be varied):** Indicated by a yellow box around E and a yellow line pointing to it.
- Coupling constants:** Indicated by a blue line pointing to the coefficients C^ρ and C^τ .
- Local densities of a mean-field state:** Indicated by a red line pointing to the density terms $\rho(\mathbf{r})\rho(\mathbf{r})$ and $\tau(\mathbf{r})\rho(\mathbf{r})$.

Strong points

- **Microscopic** approach
- # of **observables** accessible
- Feasible for **1000's** of nuclei

Weak points

- Simple ansatz
- **Phenomenological** form
- Fitting of **coupling constants**

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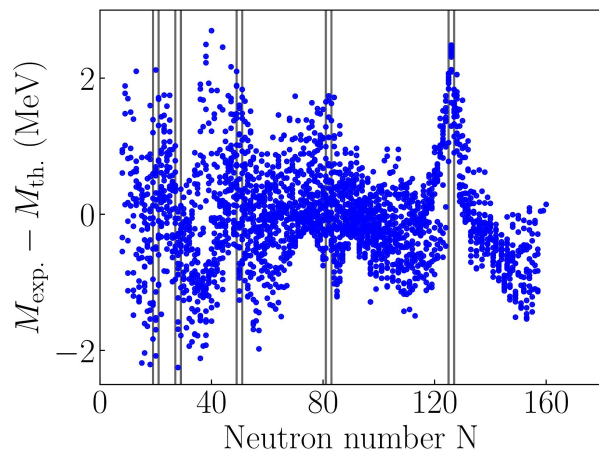
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Brussels models

- **20-25** parameters
- grasp physics of the entire chart
- Fit protocol includes:
 - 1000's of masses
 - 100's of charge radii
 - INM properties

Intro: BSkG1/2



Global performance

$\sigma^2(\text{MeV})$	BSkG1	BSkG2	HFB-14	FRLDM
Masses	0.741	0.678	0.729	0.808
Radii (fm)	0.027	0.027	0.039	-

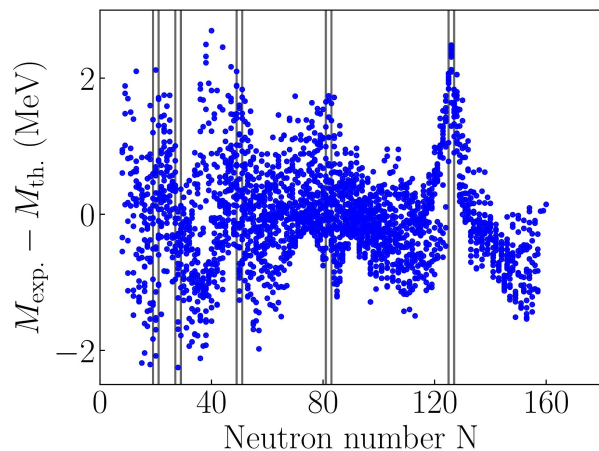
BSkG1: G. Scamps et al., EPJA 57, 333 (2021);

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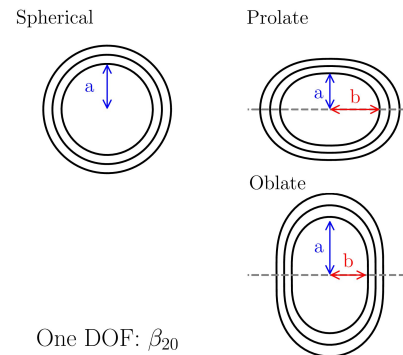
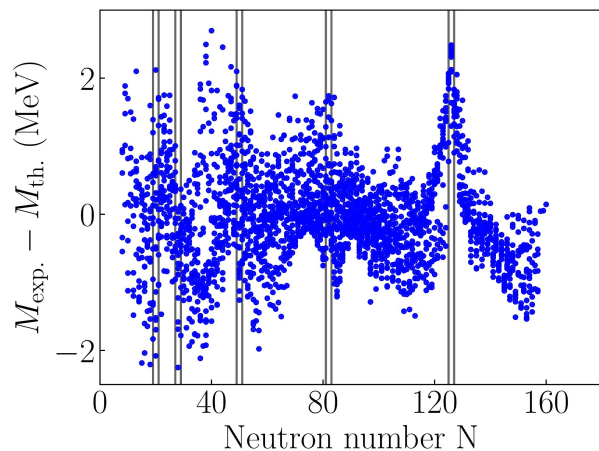
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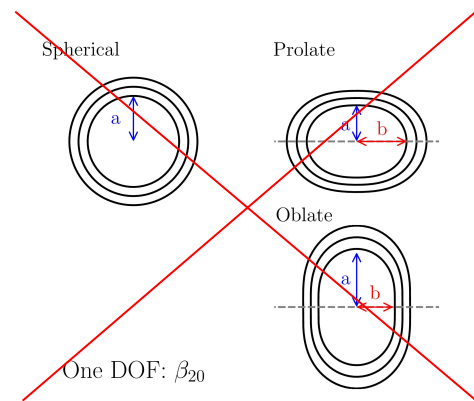
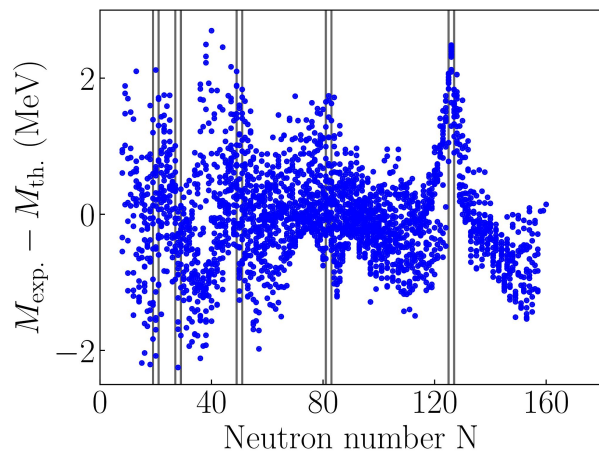
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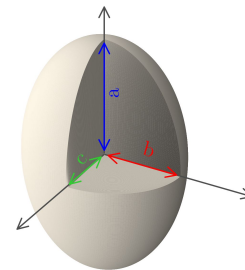
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Two DOF: (β_{20}, β_{22}) or (β, γ)

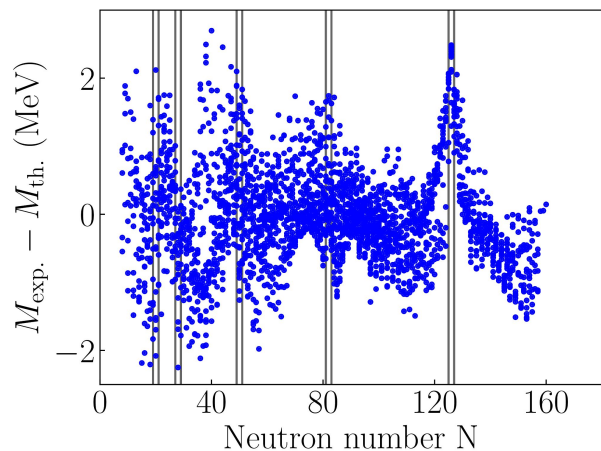
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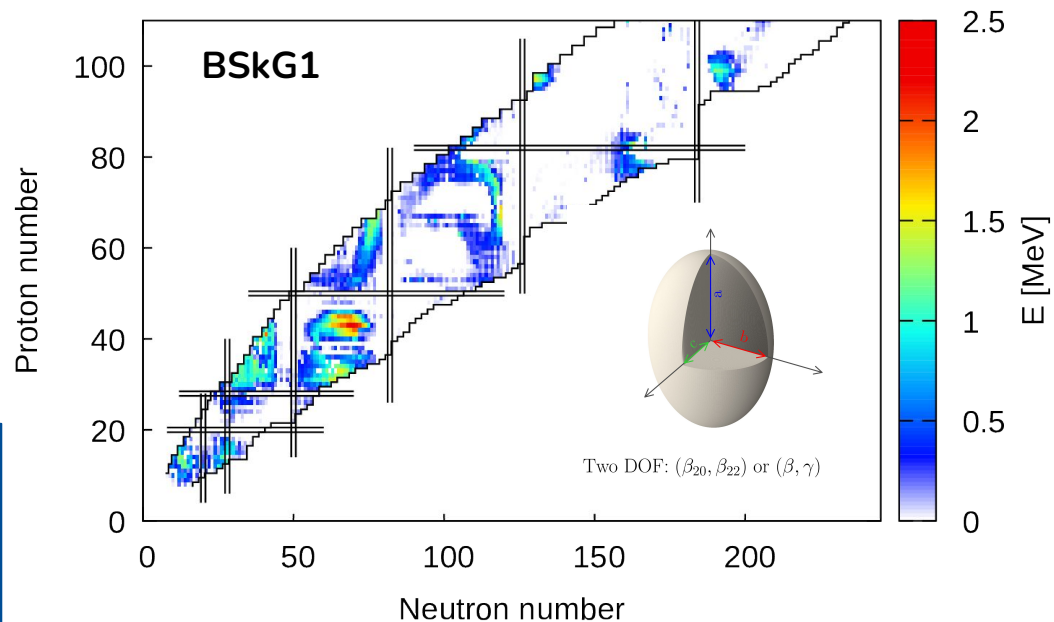
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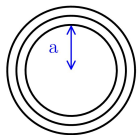
BSkG2: W. Ryssens et al., in preparation.

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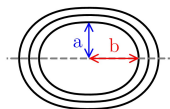
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III. Modelspace: nuclear deformation

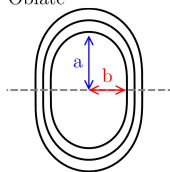
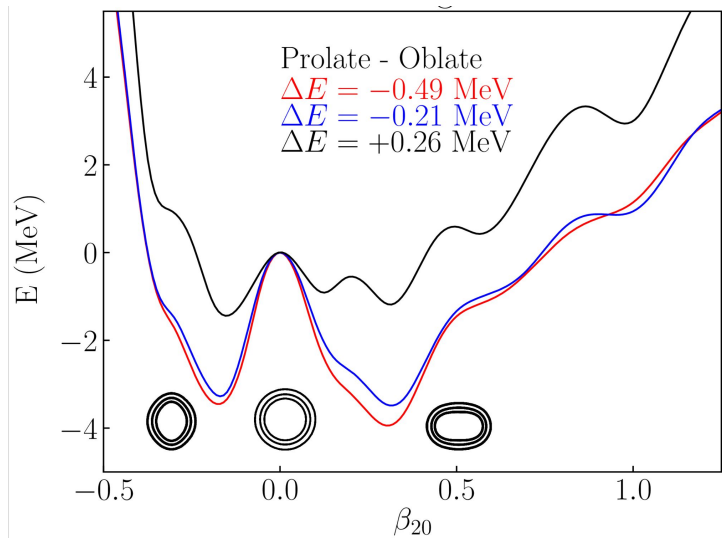
Spherical



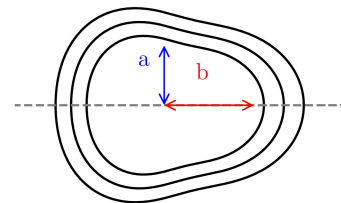
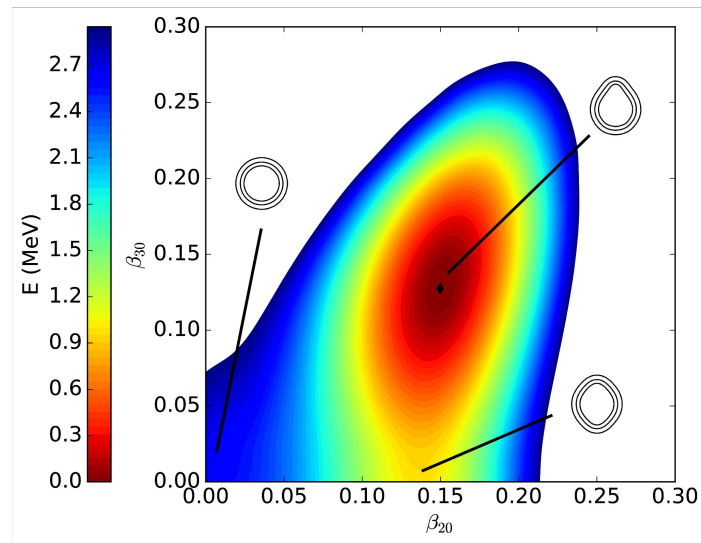
Prolate



Oblate

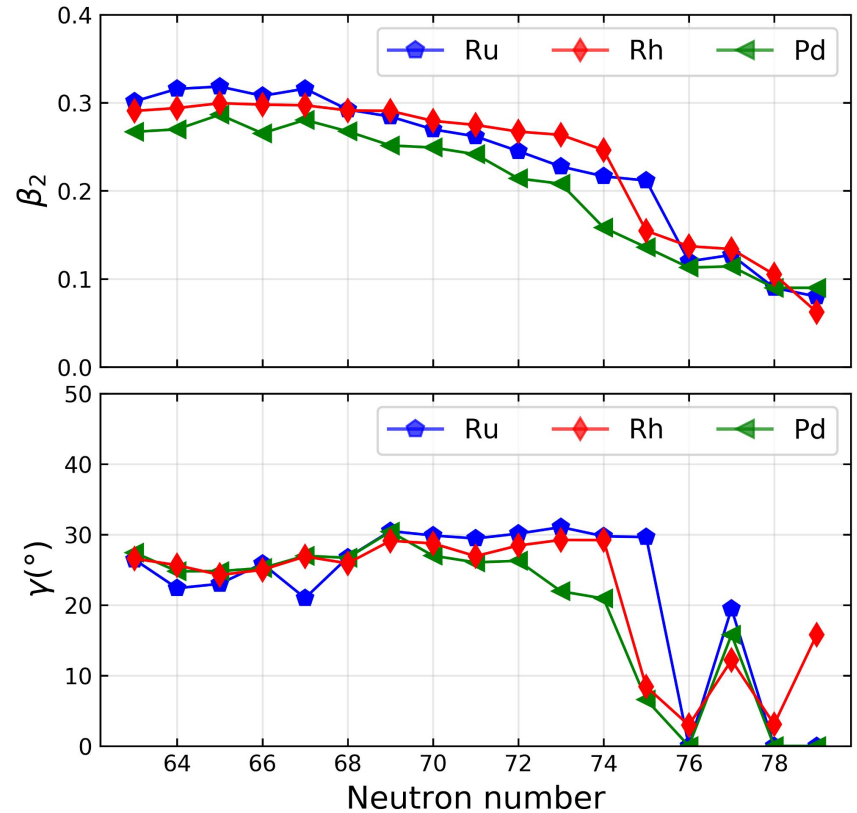
One DOF: β_{20} 

Reflection-asymmetric (RA)

Two DOF: β_{20}, β_{30} 

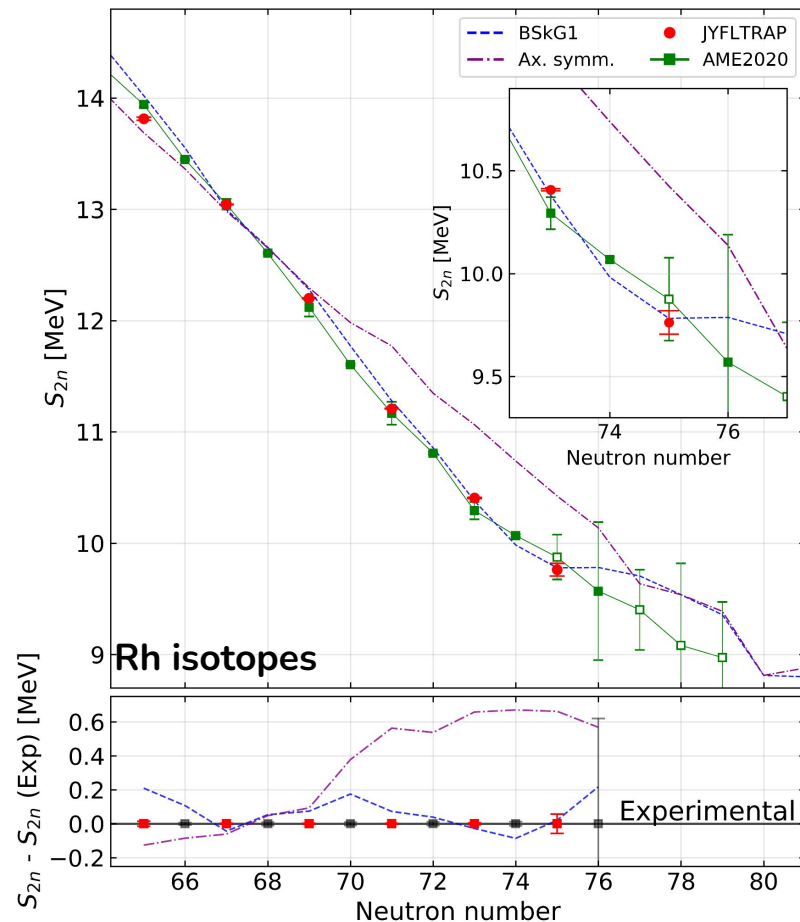
Z~45

- Mass measurements @ JYFLTRAP
 - $^{110-112-114-116-118}\text{Rh}$ (Z=45)
 - ground and isomeric states



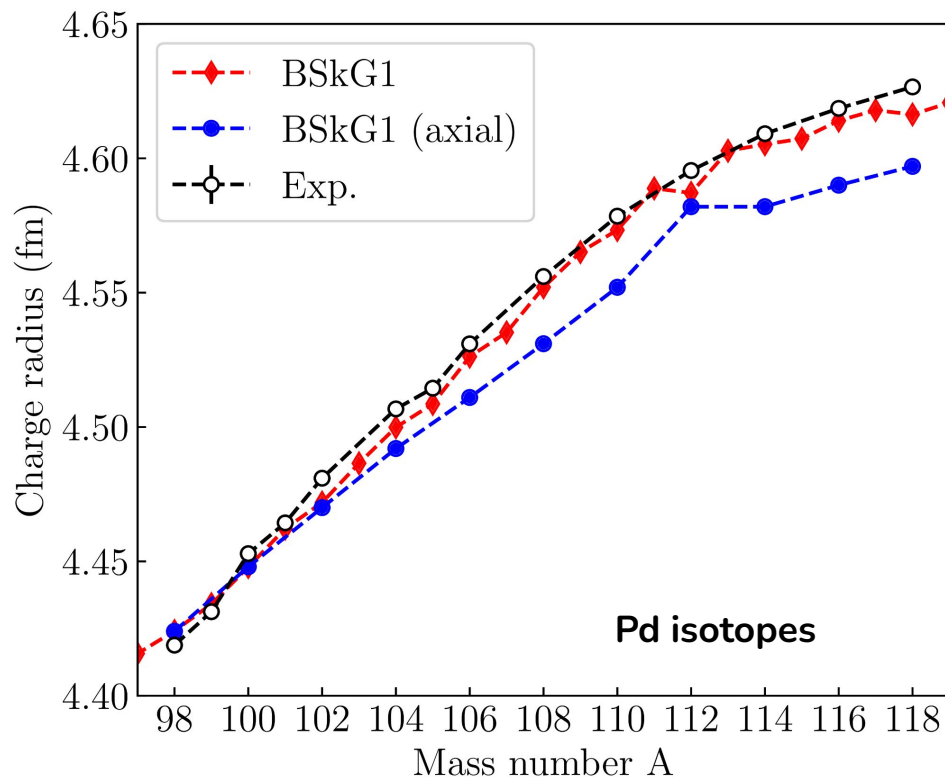
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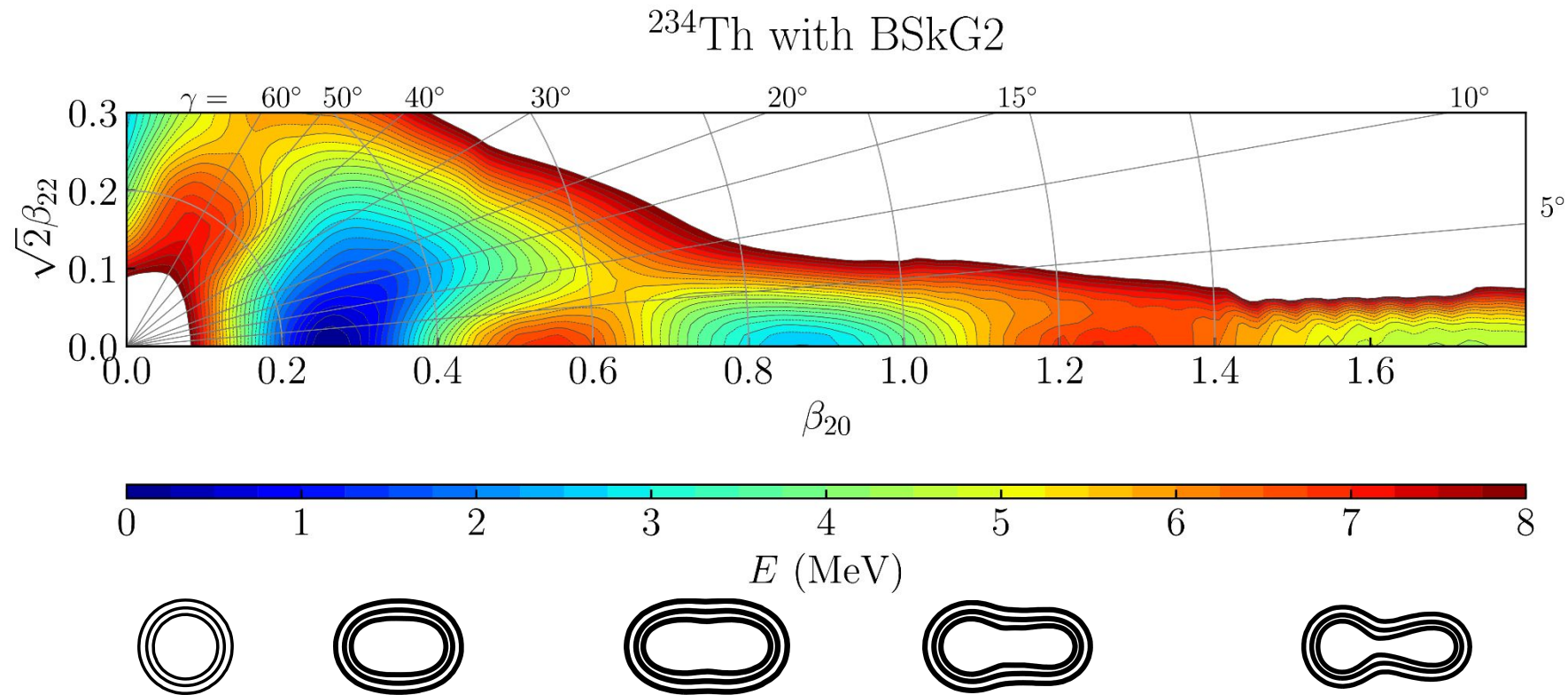


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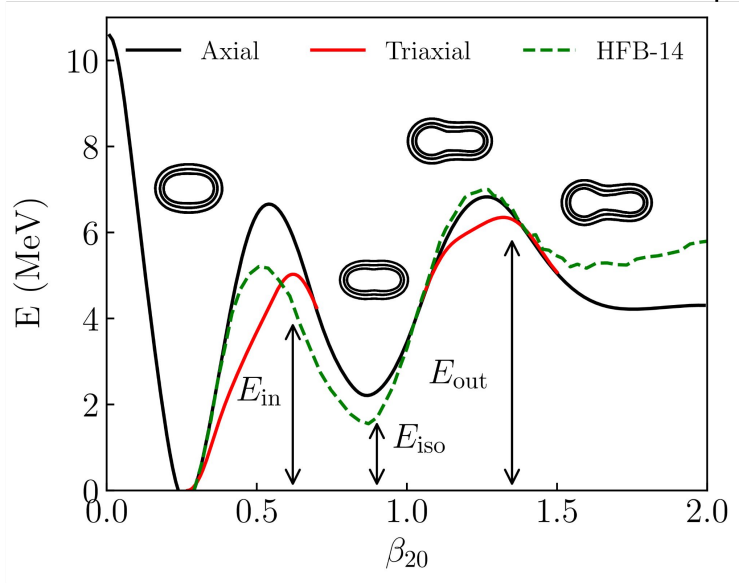
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 - excellent description of Pd radii
 - ground states even-N Rh



Fission: ^{234}Th as example



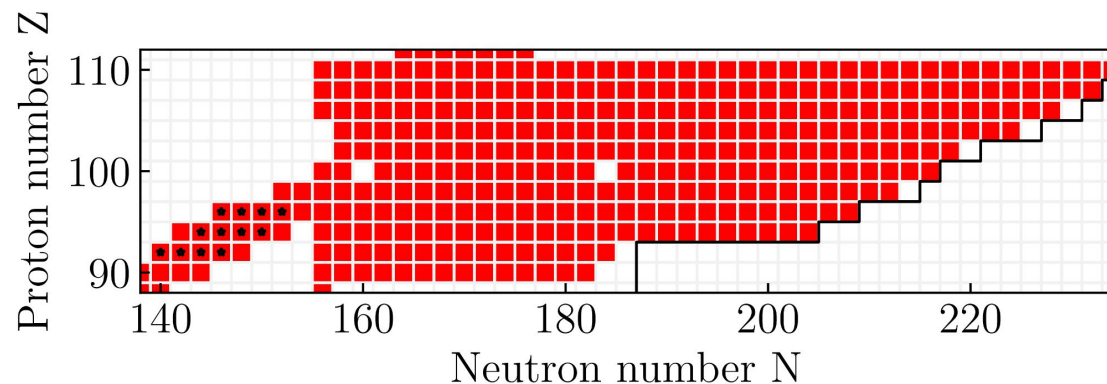
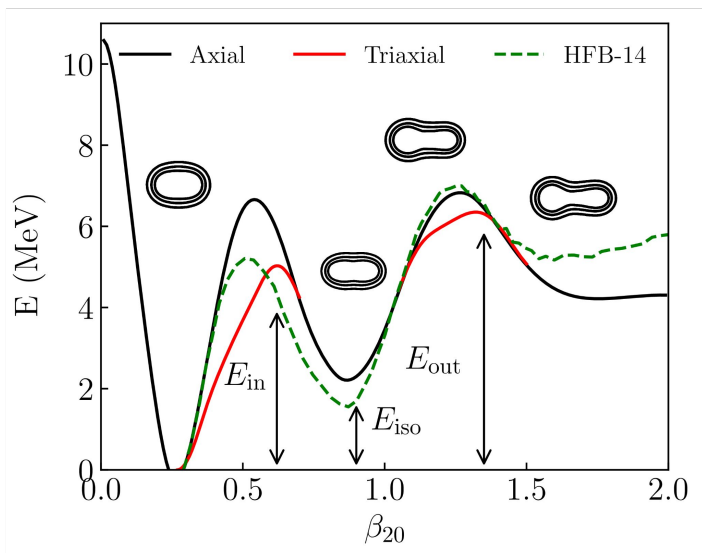
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Triaxial deformation changes landscape

- Large lowering of **inner** barrier
- No effect on fission **isomer**
- Small lowering of **outer** barrier
- Essentially **all** nuclei ($Z > 90$) are affected

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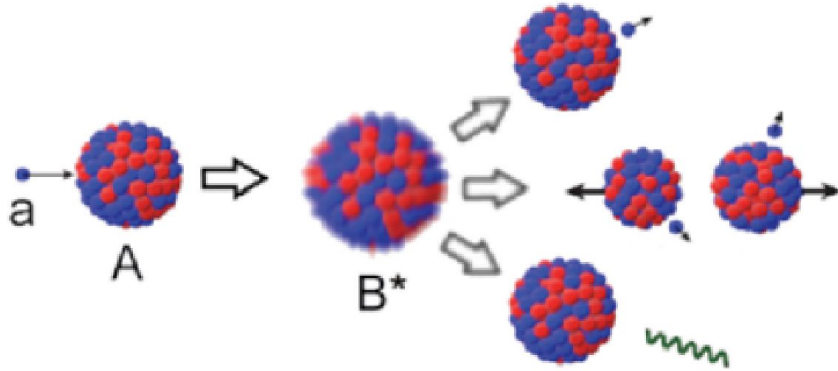
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Progress since last time

- calculation of (almost) all e-e barriers
- **including** collective inertia's

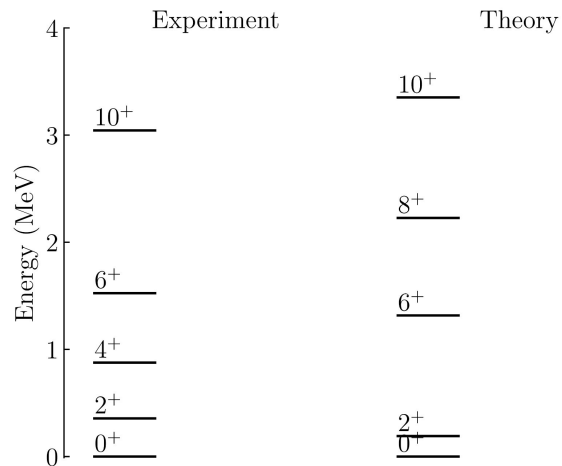
Nuclear level densities



Nuclear level densities

- required for **compound** reactions
- NLDs “count” phase-space
- **little** direct exp. information

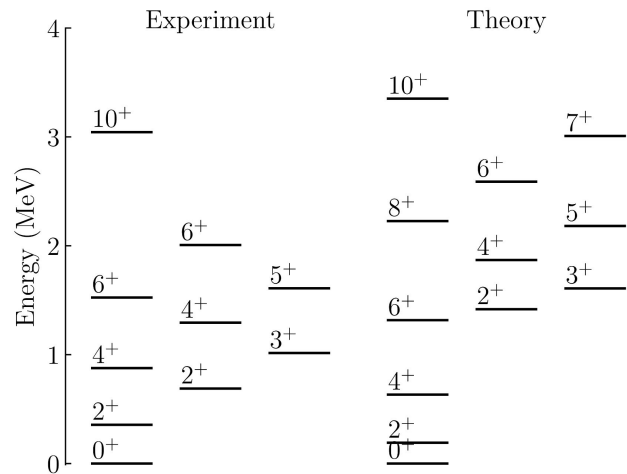
Nuclear level densities: ^{196}Pt



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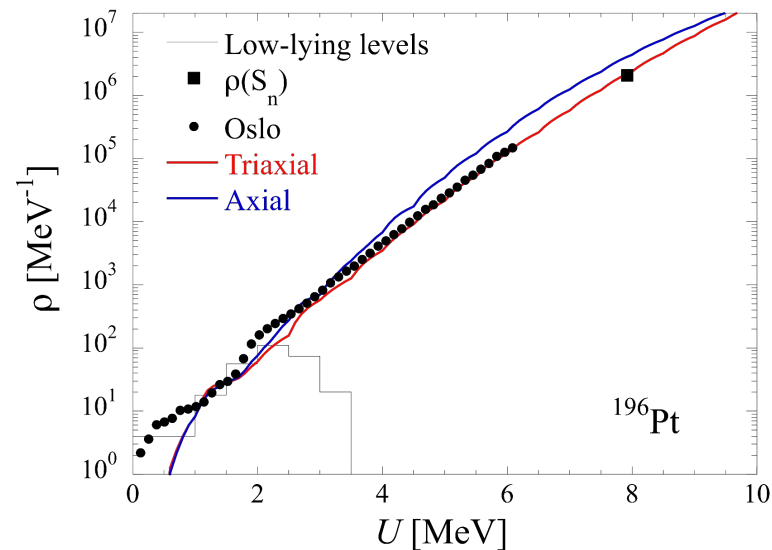
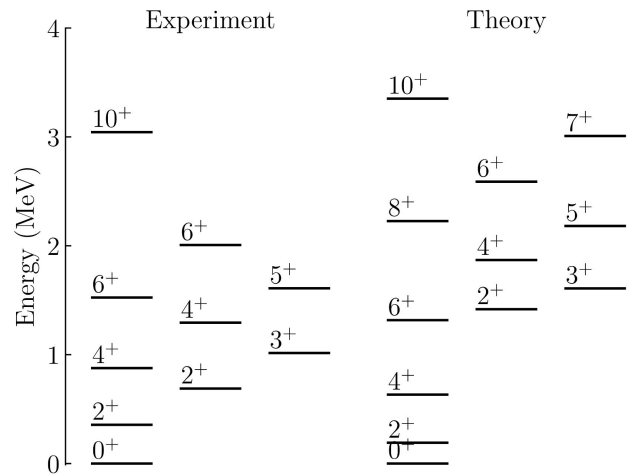
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Nuclear level densities: ^{178}Pt



Nuclear level densities

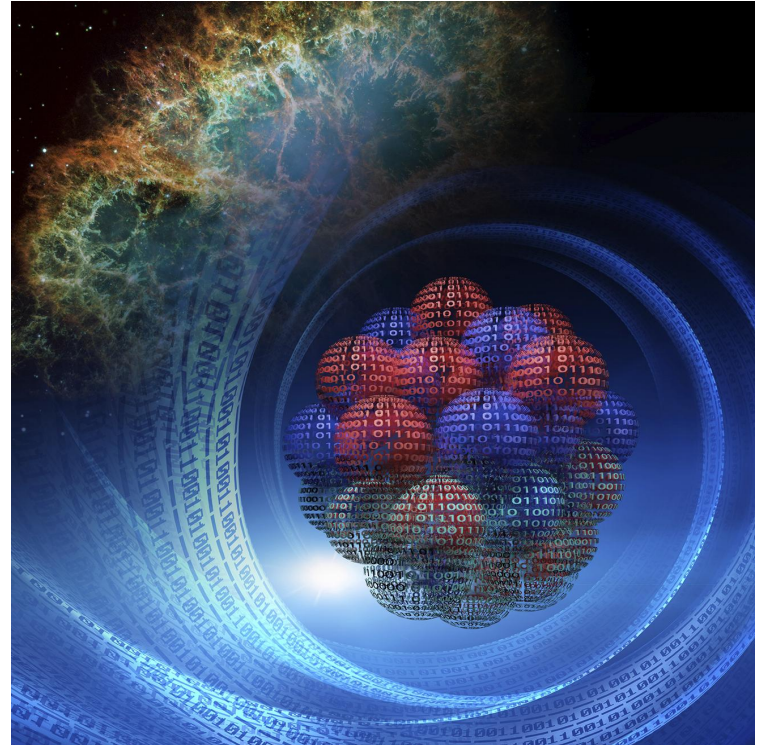
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NLDs with BSkG2

- systematic inclusion of triaxiality
- good reproduction of data

Conclusions and outlook

The BSkG2 model is **pretty damned good**.

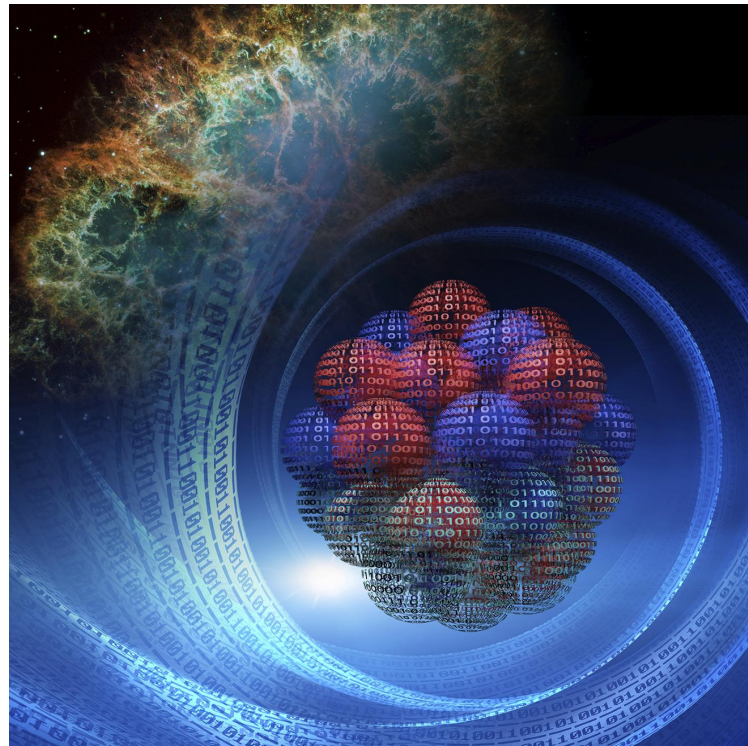


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Some further explorations:

- ✓ masses and radii around $Z=45$ (BSkG1)
- ✓ large-scale fission model
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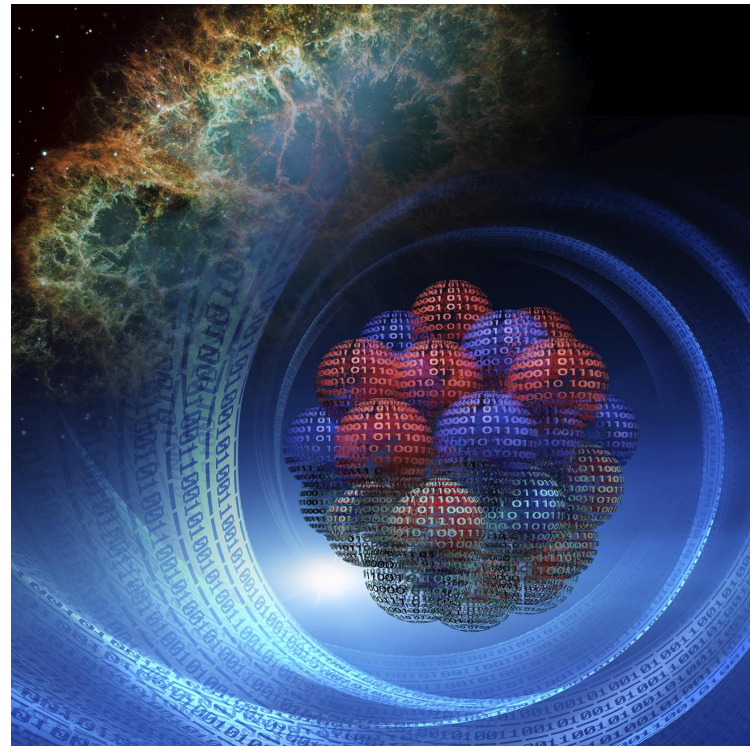
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The future:

- r-process => I. Kullman (ULB)
- elaboration of fission
 - odd nuclei => G. Scamps (UW)
 - fragments => J.-F. Lemaître (CEA)
- nuclear pasta => N. Shchechilin (ULB)
- BSkG3, focus on EOS => G. Grams (ULB)



Thank you for...

..... the collaboration!



S. Goriely
G. Grams
N. Chamel
N. Shchechilin

I. Kullman
L. Batail
V. Allard
L. Perot



S. Hilaire
J.-F. Lemaître



G. Scamps



M. Bender

..... the computing time!



..... the funding!



..... your attention!