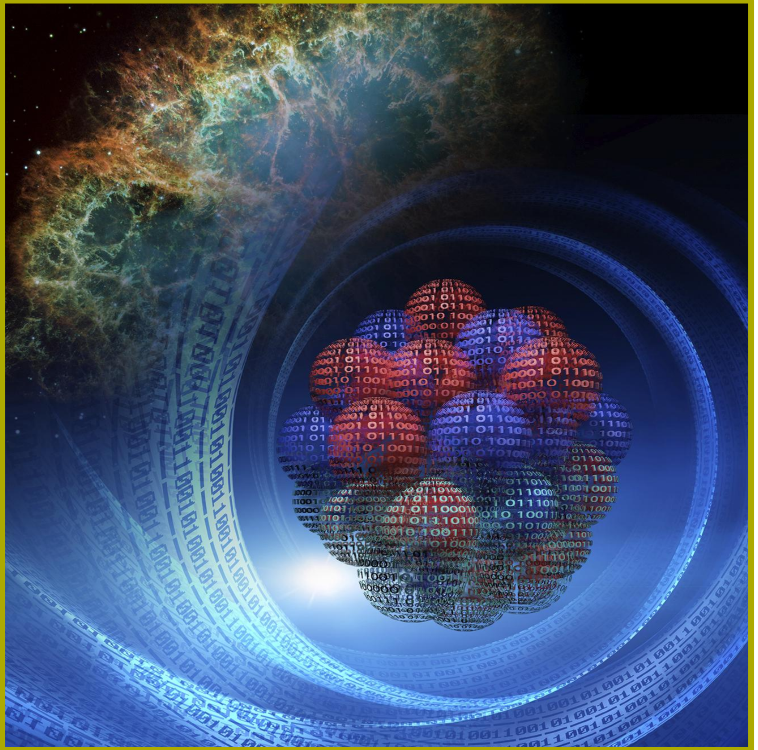
WOUTER RYSSENS



Andy Sproles, ORNL

Exploring the BSkG ~~mass~~ models

W. Ryssens

8th of June 2022

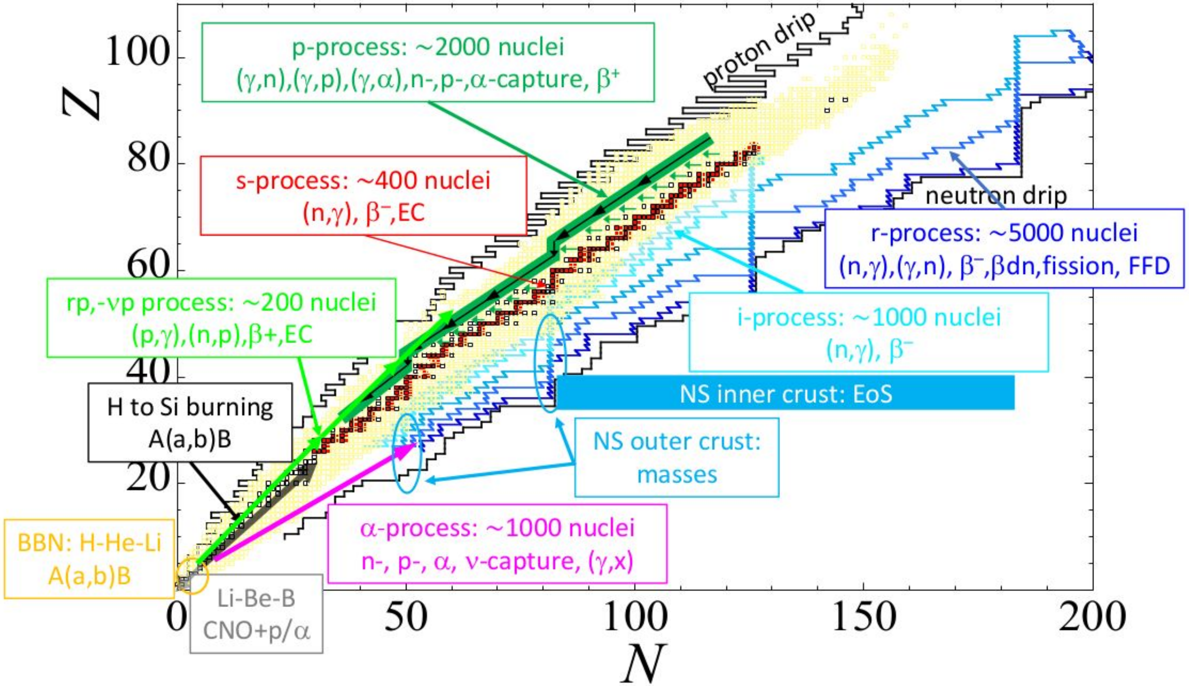
wryssens.com

wryssens@ulb.be

ULB

fnrs
LA LIBERTÉ DE CHERCHER

The challenge for nuclear theory



M. Arnould & S. Goriely, Prog. Part. Nuc. Phys. **112,** 103766 (2020).

Intro: Skyrme EDFs

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

Intro: Skyrme EDFs

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

Local densities of a mean-field state

Intro: Skyrme EDFs

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

Coupling constants

Local densities of a mean-field state

Intro: Skyrme EDFs

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

Coupling constants

Energy (to be varied)

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

Energy (to be varied)

Local densities of a mean-field state

Strong points

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

Weak points

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

Intro: Skyrme EDFs

Coupling constants

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

Energy (to be varied)

Local densities of a mean-field state

Strong points

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

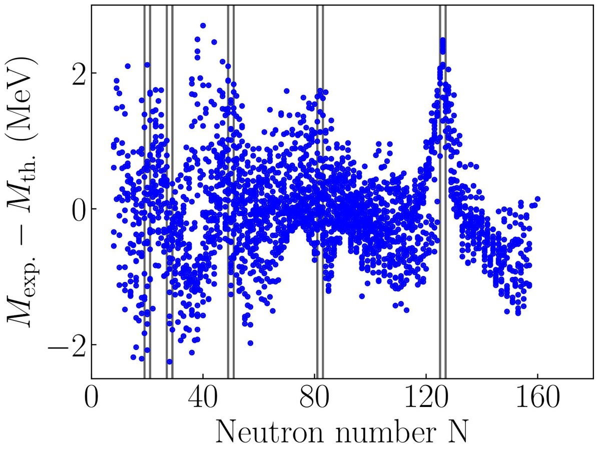
Weak points

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

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

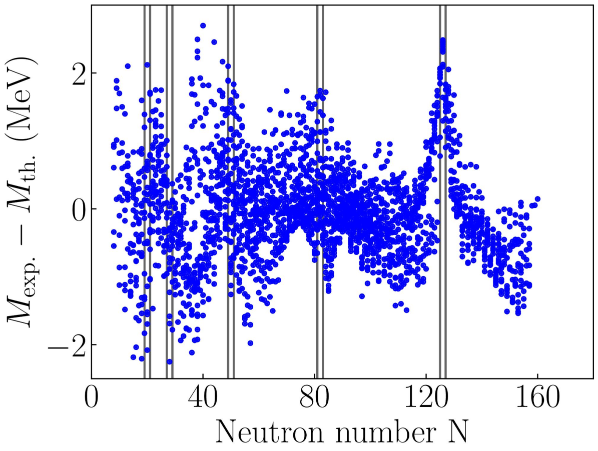


Global performance

σ^2(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);
BSkG2: W. Ryssens et al., in preparation.
HFB-14: S. Goriely et al., PRC ***75***, 064312 (2007).
FRDM: P. Möller et al., At. Data Nucl. Data Tables, **109-110** (2016).

Intro: BSkG1/2

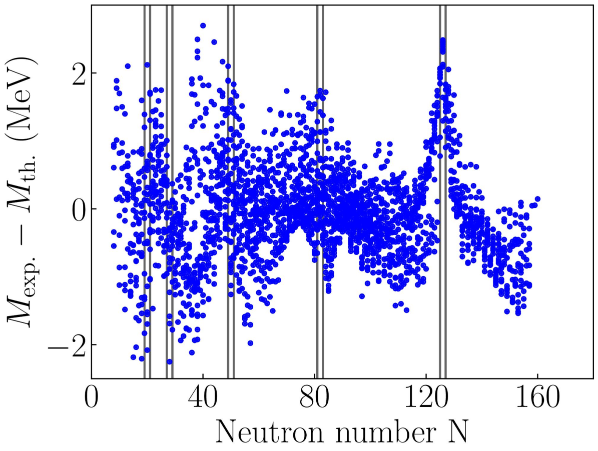


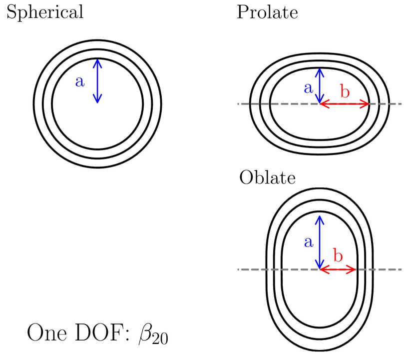
Global performance

σ^2(MeV)	**BSkG1**	**BSkG2**	HFB-14	FRLDM
Masses	0.741	**0.678**	0.729	0.808
Radii (fm)	0.027	**0.027**	0.039	-
Primary B.	0.87	**0.45**	0.61	0.79
Secondary B.	0.86	**0.45**	0.70	1.35
Isomers	0.45	**0.48**	0.93	1.04

BSkG1: G. Scamps et al., EPJA 57, 333 (2021);
BSkG2: W. Ryssens et al., in preparation.
HFB-14: S. Goriely et al., PRC ***75***, 064312 (2007).
FRDM: P. Möller et al., At. Data Nucl. Data Tables, **109-110** (2016).

Intro: BSkG1/2



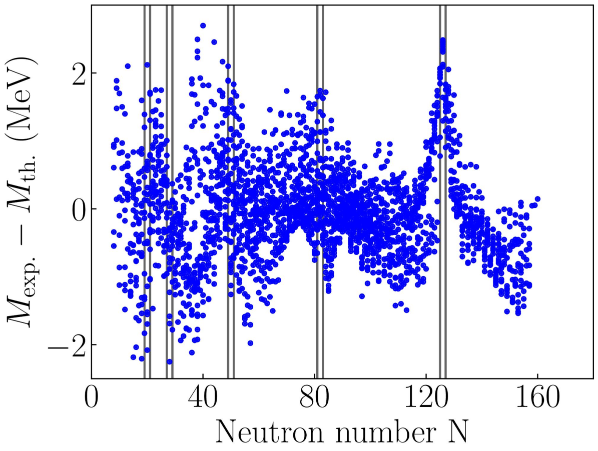


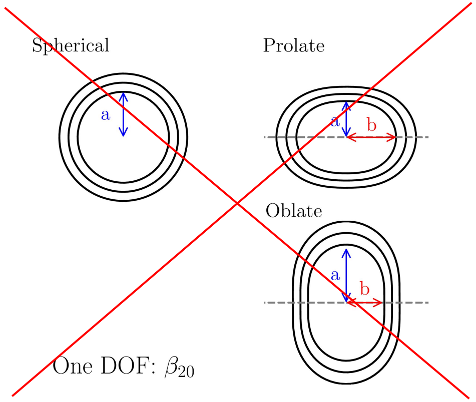
Global performance

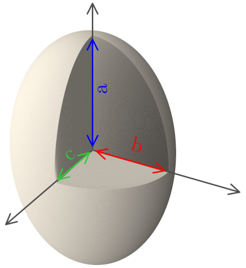
σ^2(MeV)	**BSkG1**	**BSkG2**	HFB-14	FRLDM
Masses	0.741	**0.678**	0.729	0.808
Radii (fm)	0.027	**0.027**	0.039	-
Primary B.	0.87	**0.45**	0.61	0.79
Secondary B.	0.86	**0.45**	0.70	1.35
Isomers	0.45	**0.48**	0.93	1.04

BSkG1: G. Scamps et al., EPJA 57, 333 (2021);
BSkG2: W. Ryssens et al., in preparation.
HFB-14: S. Goriely et al., PRC ***75***, 064312 (2007).
FRDM: P. Möller et al., At. Data Nucl. Data Tables, **109-110** (2016).

Intro: BSkG1/2







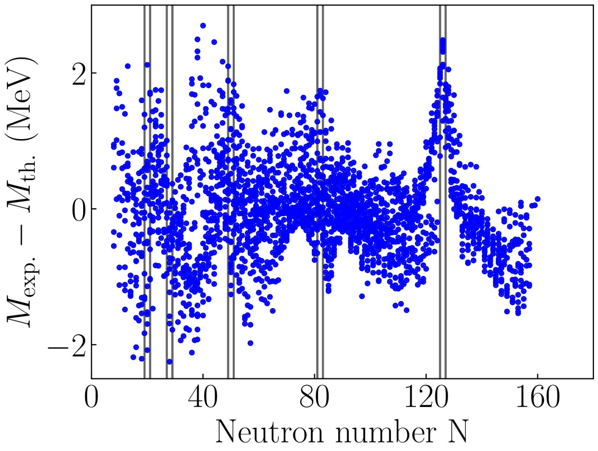
Two DOF: (β_{20}, β_{22}) or (β, γ)

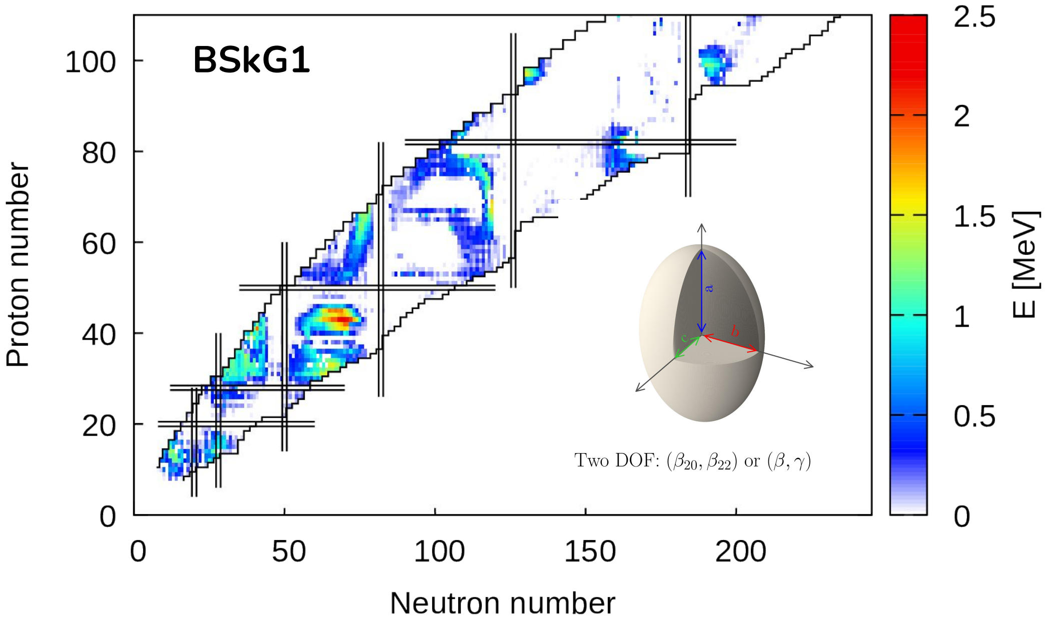
Global performance

σ^2(MeV)	**BSkG1**	**BSkG2**	HFB-14	FRLDM
Masses	0.741	**0.678**	0.729	0.808
Radii (fm)	0.027	**0.027**	0.039	-
Primary B.	0.87	**0.45**	0.61	0.79
Secondary B.	0.86	**0.45**	0.70	1.35
Isomers	0.45	**0.48**	0.93	1.04

BSkG1: G. Scamps et al., EPJA 57, 333 (2021);
BSkG2: W. Ryssens et al., in preparation.
HFB-14: S. Goriely et al., PRC ***75***, 064312 (2007).
FRDM: P. Möller et al., At. Data Nucl. Data Tables, **109-110** (2016).

Intro: BSkG1/2



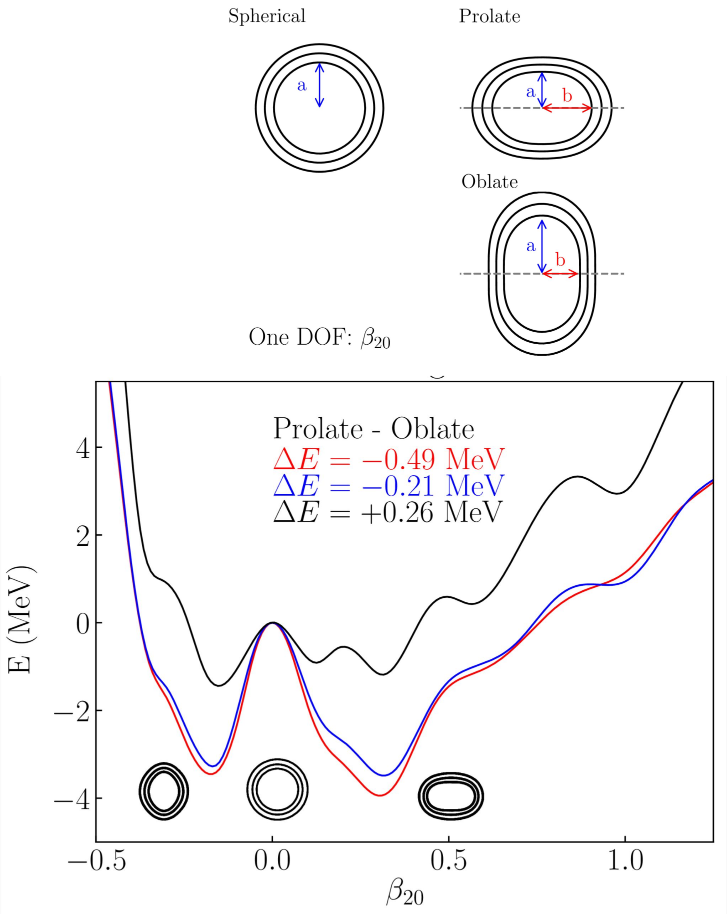


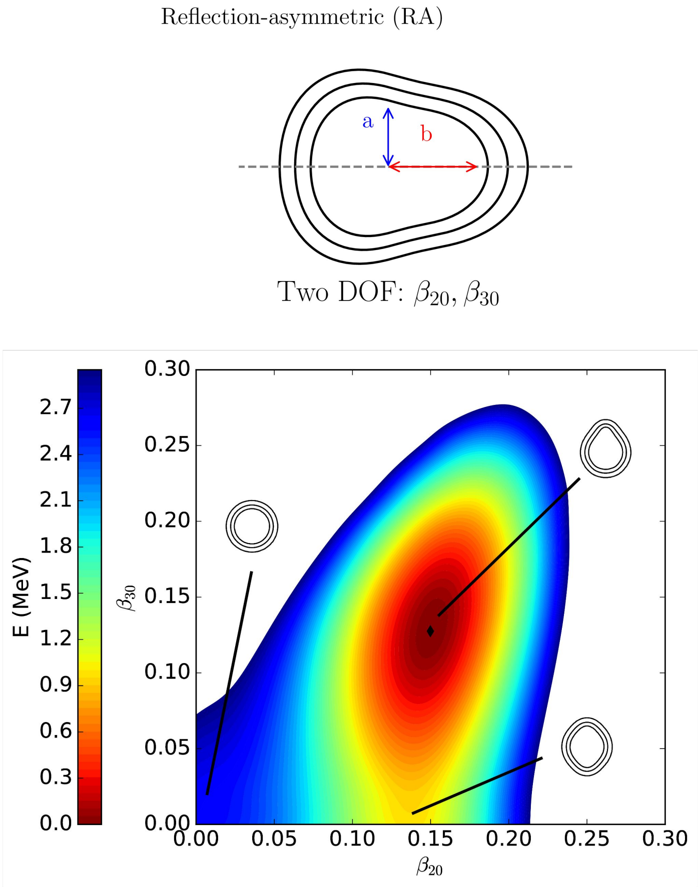
Global performance

σ^2(MeV)	**BSkG1**	**BSkG2**	HFB-14	FRLDM
Masses	0.741	**0.678**	0.729	0.808
Radii (fm)	0.027	**0.027**	0.039	-
Primary B.	0.87	**0.45**	0.61	0.79
Secondary B.	0.86	**0.45**	0.70	1.35
Isomers	0.45	**0.48**	0.93	1.04

BSkG1: G. Scamps et al., EPJA 57, 333 (2021);
BSkG2: W. Ryssens et al., in preparation.
HFB-14: S. Goriely et al., PRC ***75***, 064312 (2007).
FRDM: P. Möller et al., At. Data Nucl. Data Tables, **109-110** (2016).

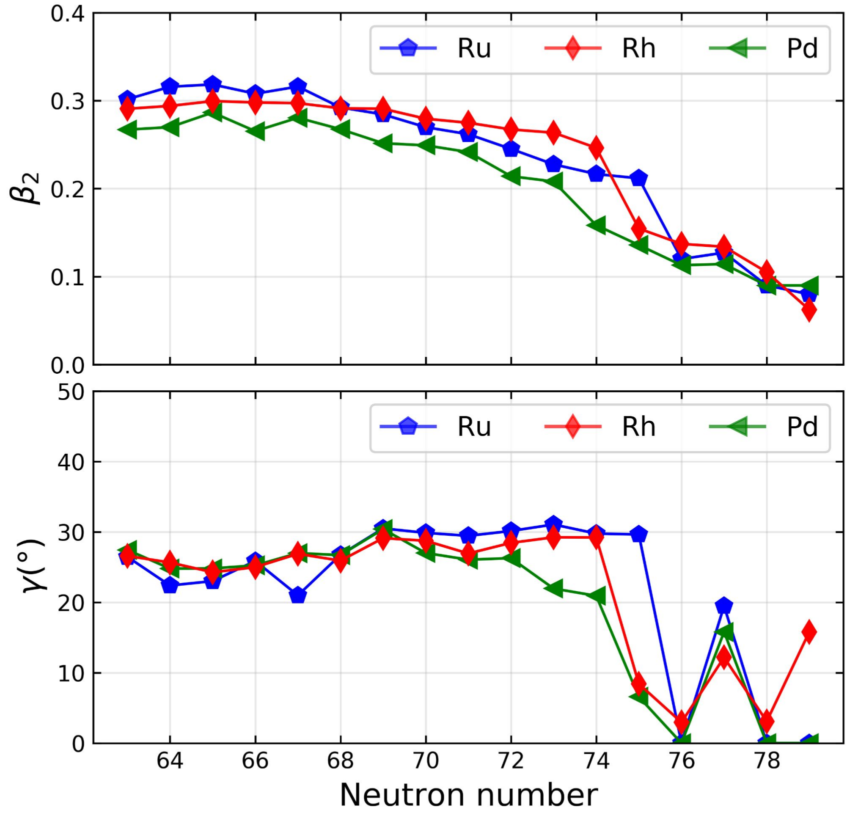
III. Modelspace: nuclear deformation





Z~45

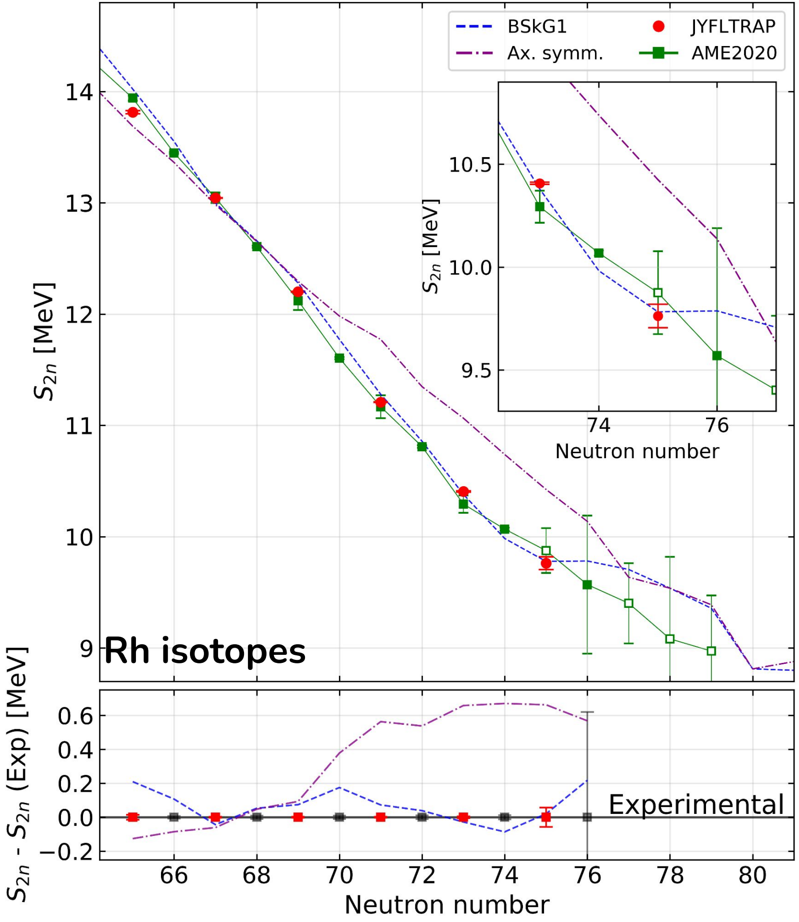
- Mass measurements @ JYFLTRAP
  - $^{110-112-114-116-118}$Rh (Z=45)
  - ground and isomeric states



M. Hukkanen et al., in preparation.

Z~45

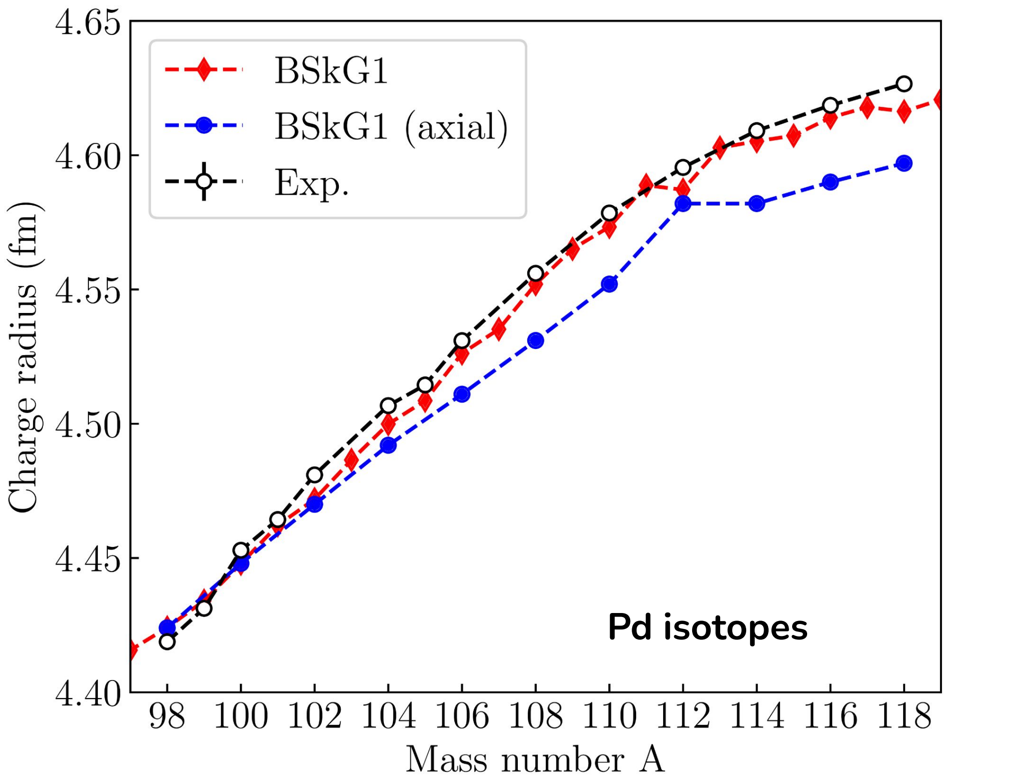
- Mass measurements @ JYFLTRAP
  - $^{110-112-114-116-118}$Rh (Z=45)
  - ground and isomeric states
- BSkG1 description
  - mass evolution well reproduced



M. Hukkanen et al., in preparation.

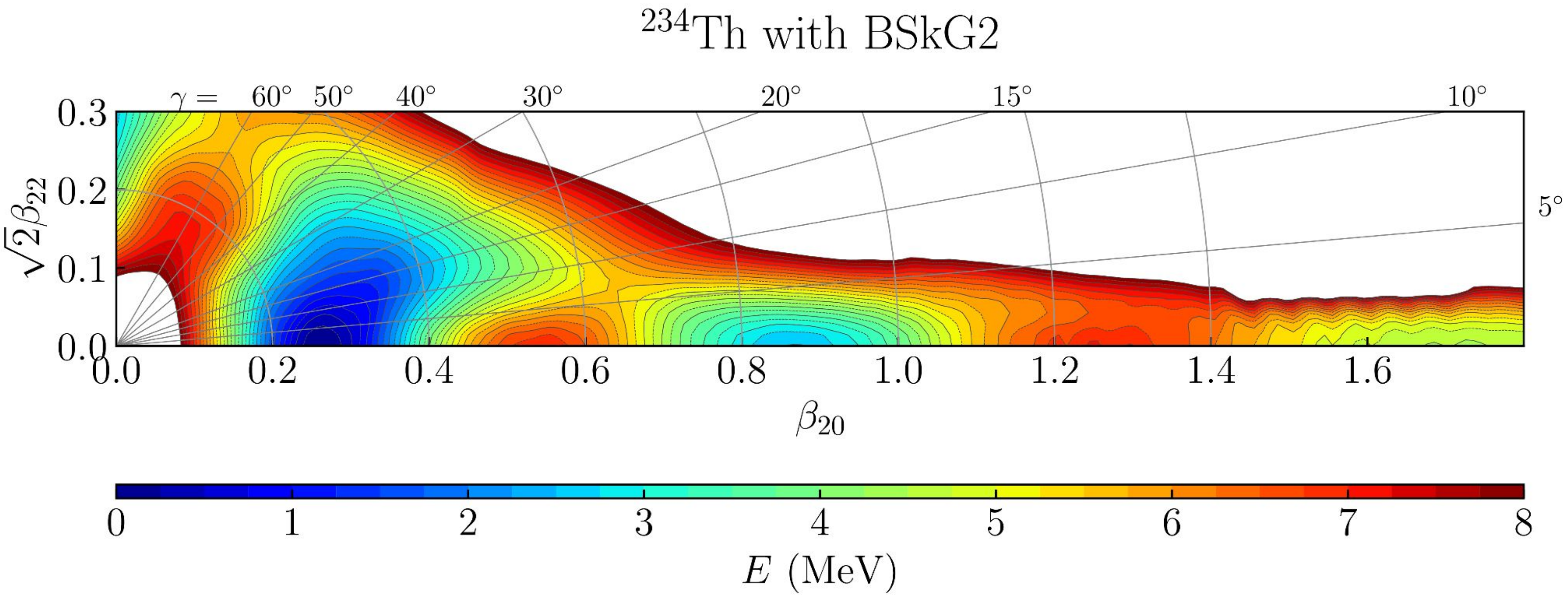
Z~45

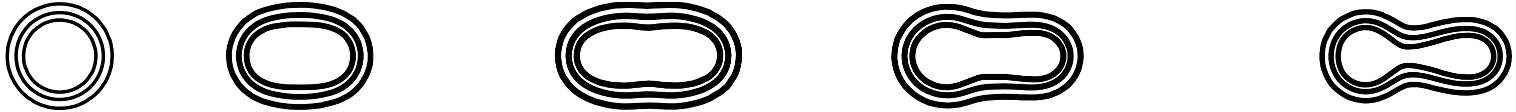
- Mass measurements @ JYFLTRAP
  - $^{110\text{-}112\text{-}114\text{-}116\text{-}118}Rh$ (Z=45)
  - ground and isomeric states
- BSkG1 description
  - mass evolution well reproduced
  - excellent description of Pd radii
  - ground states even-N Rh



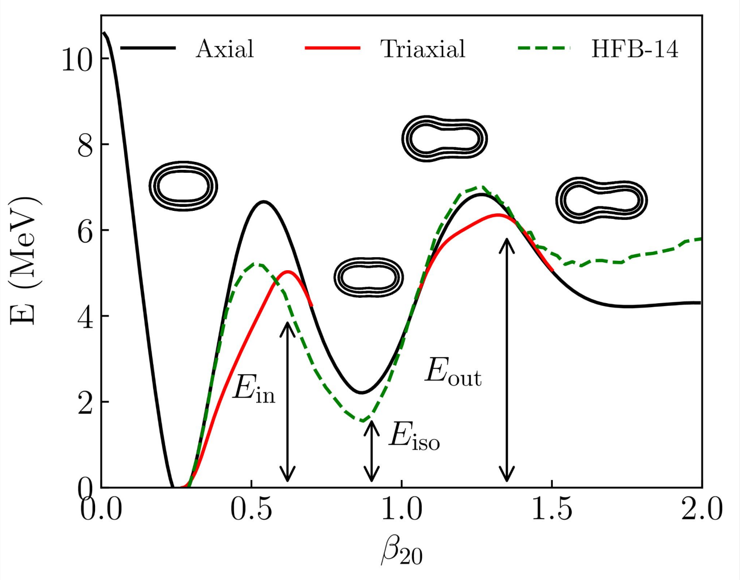
S. Geldhof et al., PRL 128, 152501 (2022).

Fission: ^{234}Th as example





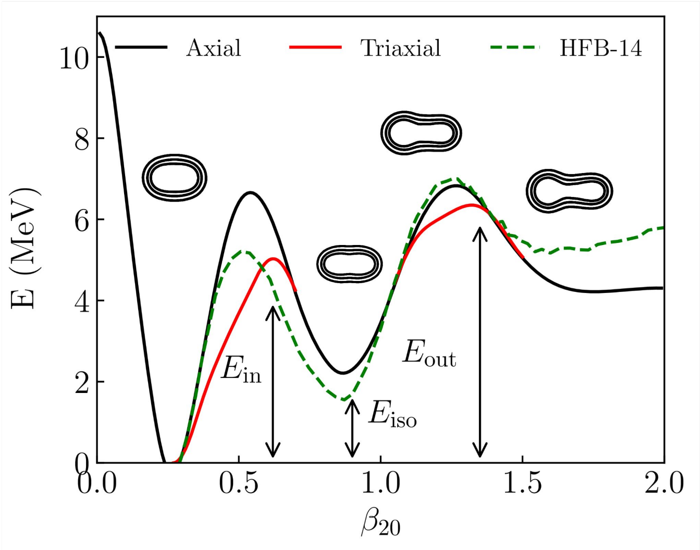
Fission: 234Th as example

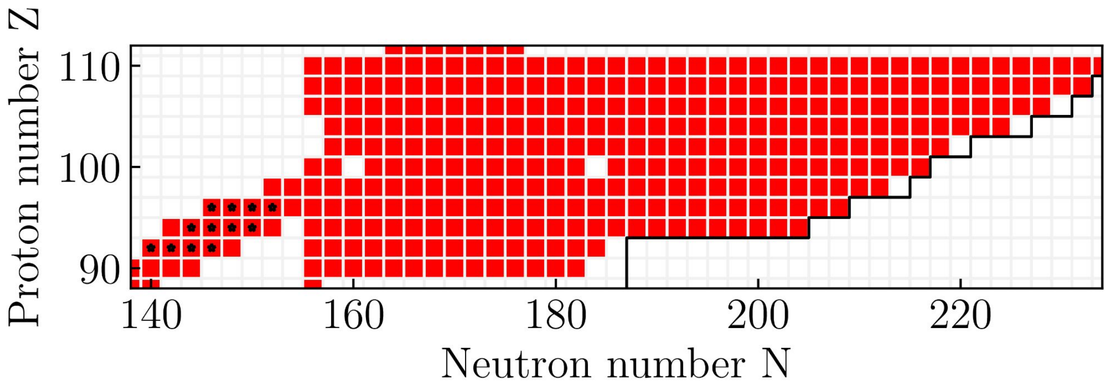


Triaxial deformation changes landscape

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

Fission: 234Th as example





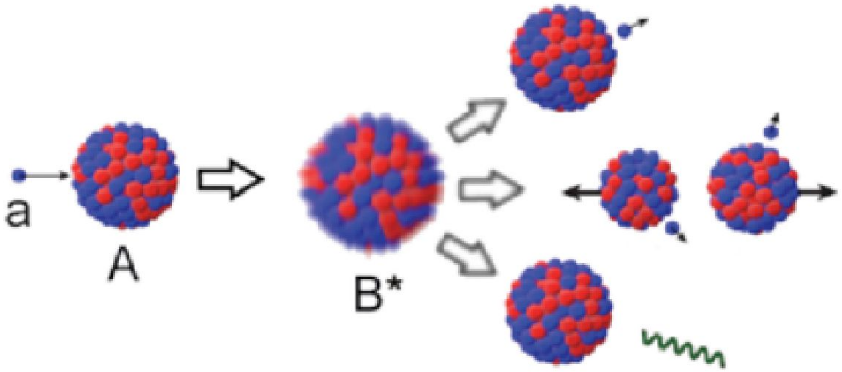
Triaxial deformation changes landscape

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

Progress since last time

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

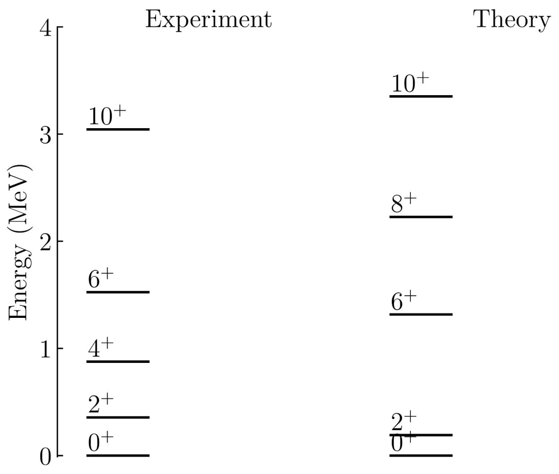
Nuclear level densities



Nuclear level densities

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

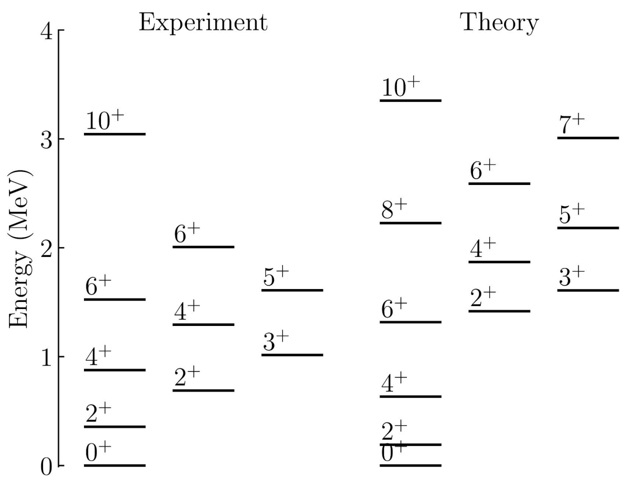
Nuclear level densities: ^{196}Pt



Nuclear level densities

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

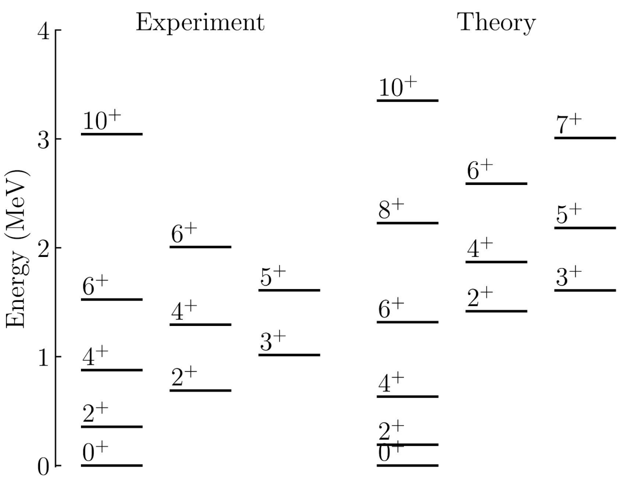
Nuclear level densities: ^{196}Pt

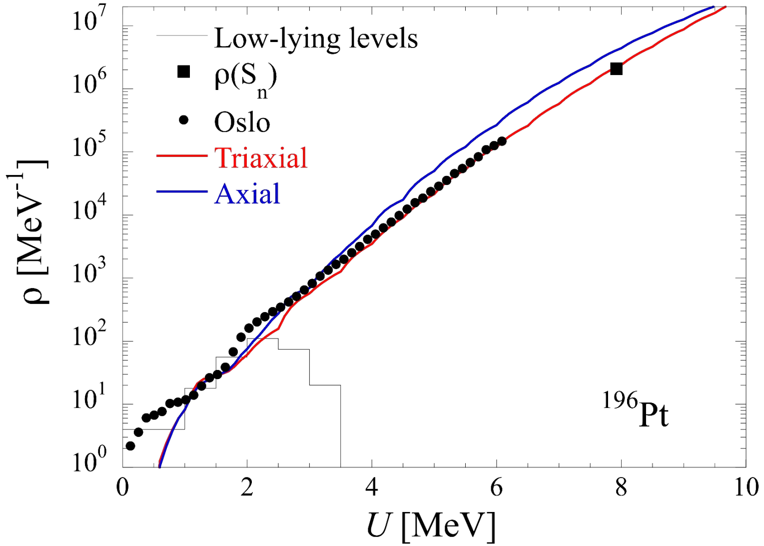


Nuclear level densities

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

Nuclear level densities: ^{178}Pt





Nuclear level densities

- required for compound reactions
- NLDs “count” phase-space
- little direct exp. information
- symmetries impact level structure

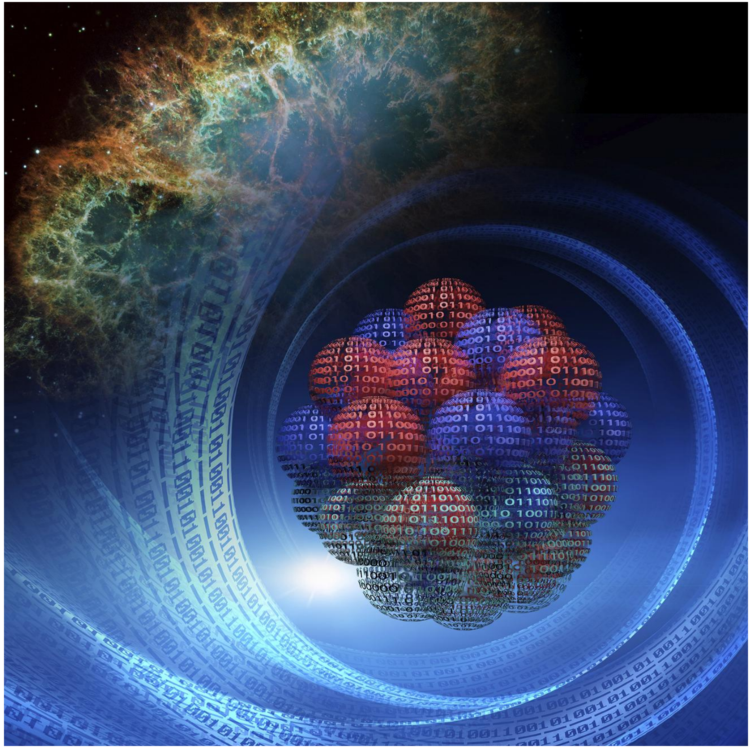
NLDs with BSkG2

- systematic inclusion of triaxiality
- good reproduction of data

W. Ryssens, S. Hilaire and S. Goriely, in preparation.

Conclusions and outlook

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

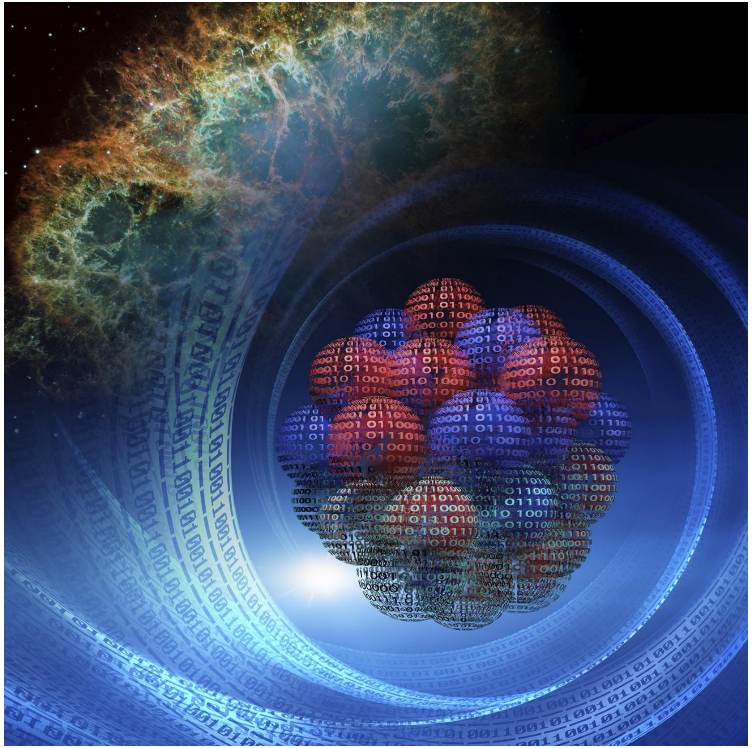


Conclusions and outlook

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

Some further explorations:

- ✓ masses and radii around Z=45 (BSkG1)
- ✓ large-scale fission model
- ✓ nuclear level density model



Conclusions and outlook

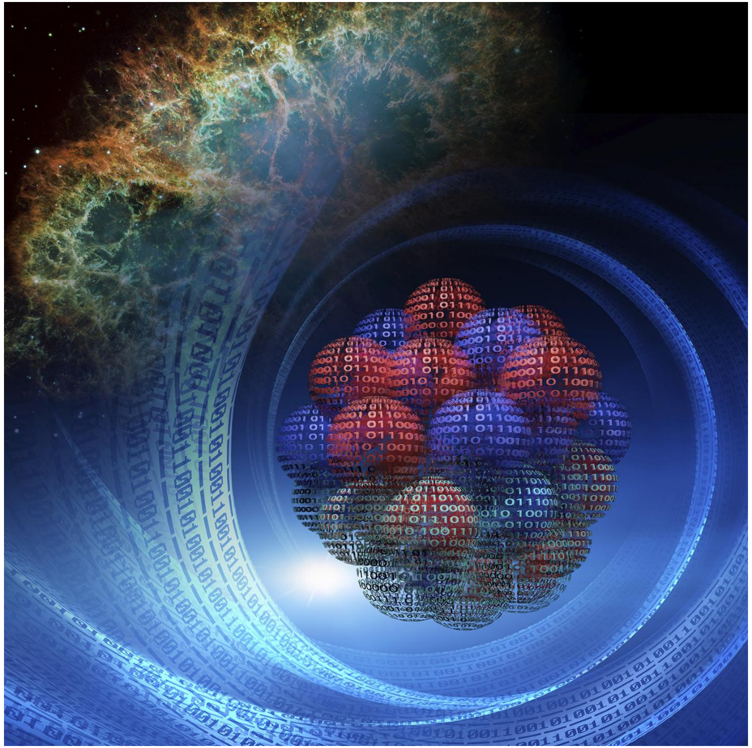
The BSkG2 model is **pretty damned good.**

Some further explorations:

- ✓ masses and radii around Z=45 (BSkG1)
- ✓ large-scale fission model
- ✓ nuclear level density model

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

G. Scamps

S. Hilaire
J.-F. Lemaître

M. Bender

...... the computing time!

...... the funding!

...... your attention!