

## Activities of the Bordeaux-Bruxelles-GANIL-Lyon-Saclay SR- & MR EDF collaboration

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Jeremy Sadoudi, Cédric Simenel, Vittorio Soma, Kouhei Washiyama

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# Who are we?

Benoît Avez	CEN Bordeaux-Gradignan France
Benjamin Bally	CEN Bordeaux-Gradignan France
Michael Bender	CEN Bordeaux-Gradignan France
Karim Bennaceur	IPN Lyon, France
Dany Davesne	IPN Lyon, France
Thomas Duguet	Irfu, CEA Saclay, France
Paul-Henri Heenen	Université Libre de Bruxelles, Belgium
Veerle Hellemans	(formerly UL Bruxelles), now Notre Dame, USA
Guillaume Hupin	GANIL, France
Denis Lacroix	GANIL, France
Thomas Lesinski	(formerly IPN Lyon), now Oak Ridge NL, USA
Jacques Meyer	IPN Lyon, France
Jeremy Sadoudi	Irfu, CEA Saclay, France
Cédric Simenel	Irfu, CEA Saclay, France
Vittorio Soma	Irfu, CEA Saclay, France
Kouhei Washiyama	GANIL, France (present), UL Bruxelles (near future)

... + *friends*.

## What are the goals of our joint projects?

- ▶ construction of numerical tools for single-reference energy density functional (SR-EDF) calculations (also known as self-consistent mean-field, “Hartree-Fock” or “Hartree-Fock-Bogoliubov”)
- ▶ construction of numerical tools for multi-reference energy density functional (MR-EDF) calculations (also known as symmetry-restored Generator Coordinate Method (GCM) or “beyond-mean-field methods”)
- ▶ construction of numerical tools for time-dependent single-reference energy density functional (TD SR-EDF) calculations (also known as “time-dependent Hartree-Fock”) and approaches “beyond”
- ▶ construction of effective energy density functionals for such calculations
- ▶ validation of such effective energy density functionals
- ▶ description of phenomena of the low-energy structure and dynamics of stable, exotic, and superheavy nuclei of current and future interest

## Goals:

- ▶ reach "spectroscopic quality" (better single-particle energies, isospin properties, ...) with "richer" functionals
- ▶ reduce phenomenology in the functionals
- ▶ construct regularizable interactions safely usable in MR-EDF calculations

## Current sub-projects:

- ▶ **tensor terms**  
T. Lesinski, M. Bender, K. Bennaceur, T. Duguet, J. Meyer  
PRC 76 (2007) 014312
- ▶ **generalized Skyrme functionals**
- ▶ **establishing the link to first principles of the strong interaction and the many-body problem**  
⇒ talk by T. Duguet
- ▶ **Effective interaction/EDF for time-dependent methods**  
⇒ talk by D. Lacroix

- ▶ **tensor terms in deformed nuclei**  
M. Bender, K. Bennaceur, T. Duguet, P.-H. Heenen, T. Lesinski, J. Meyer  
PRC 80 (2009) 064302
- ▶ **tensor terms in odd- $A$  and rapidly rotating nuclei**  
(postdoc project of V. Hellemans)
- ▶ **surface energy with tensor terms by semi-infinite nuclear matter HF calculations**  
(K. Bennaceur, J. Meyer *et al.*, paper in preparation)
- ▶ **identification and characterization of finite-size instabilities of energy functionals with tensor terms with the help of RPA in infinite nuclear matter**  
D. Davesne, M. Martini, K. Bennaceur, and J. Meyer  
PRC 80 (2009) 024314

- ▶ **intrinsic DFT (HK theorem and KS scheme for self-coupled systems)**  
J. Messud, M. Bender, and E. Suraud, PRC 80 (2009) 054314  
J. Messud, PRC 80 (2009) 054614 (TDiDFT)
- ▶ **regularize MR-EDF for spurious divergences, finite steps and branch cuts**  
D. Lacroix, T. Duguet, and M. Bender, PRC 79 (2009) 044318  
M. Bender, T. Duguet, and D. Lacroix, PRC 79 (2009) 044319  
T. Duguet, M. Bender, K. Bennaceur, D. Lacroix, T. Lesinski, PRC 79 (2009) 044320  
⇒ talk by M. Bender
- ▶ **symmetry restoration with energy density functionals**  
T. Duguet and J. Sadoudi, arXiv:1001.0673  
⇒ talk by J. Sadoudi

- ▶ Particle-number and angular-momentum restored MR-EDF mixing of triaxial states  
M. Bender and P.-H. Heenen, PRC 78 (2008) 024309  
⇒ M. Bender's talk at Niigata
- ▶ dynamical pairing correlations and diabatic states within MR-EDF  
(postdoc project of B. Avez)  
⇒ talk by B. Avez
- ▶ SR and MR EDF schemes to calculate odd-A nuclei  
(thesis work of Benjamin Bally)
- ▶ new algorithm to evaluate contractions and overlaps: construction of the canonical basis of the Bogoliubov transformation between two different sets of quasiparticle states  
⇒ talk by M. Bender

# Construction of numerical tools for time-dependent SR-EDF calculations and beyond

- ▶ Time-dependent SR EDF with pairing  
B. Avez, C. Simenel, Ph. Chomaz, PRC 78 (2008) 044318  
⇒ poster by B. Avez at Niigata
- ▶ Development and application of Adiabatic TD-EDF  
⇒ talk by D. Lacroix
- ▶ Alternative approach to pairing and other correlations:  
Density Matrix Functional theory  
⇒ another talk by D. Lacroix



- ▶ **Shape coexistence in the neutron-deficient  $Z \approx 82$  region**  
T. Grahn *et al*, NPA 801 (2008) 83 and PRC 80 (2009) 014323  
paper in on systematics in preparation
- ▶ **Shell structure of (deformed) transactinide nuclei**  
S. Ketelhut *et al*, PRL 102 (2009) 212501  
R.-D. Herzberg *et al*, EPJA 42 (2009) 333  
paper on systematics in preparation
- ▶ **Evolution of signatures for shell structure**  
M. Bender, G. F.Bertsch, P.-H. Heenen, PRC 78 (2008) 054312  
⇒ M. Bender's talk at Niigata