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

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Guillaume Hupin, Denis Lacroix, Thomas Lesinski, Jacques Meyer,
Jeremy Sadoudi, Cédric Simenel, Vittorio Soma, Kouhei Washiyama

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Who are we?

Benoît Avez  
Benjamin Bally  
Michael Bender  
Karim Bennaceur  
Dany Davesne  
Thomas Duguet  
Paul-Henri Heenen  
Veerle Hellemans  
Guillaume Hupin  
Denis Lacroix  
Thomas Lesinski  
Jacques Meyer  
Jeremy Sadoudi  
Cédric Simenel  
Vittorio Soma  
Kouhei Washiyama

CEN Bordeaux-Gradignan France  
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IPN Lyon, France  
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Irfu, CEA Saclay, France  
Université Libre de Bruxelles, Belgium  
(formerly UL Bruxelles), now Notre Dame, USA  
GANIL, France  
GANIL, France  
(formerly IPN Lyon), now Oak Ridge NL, USA  
IPN Lyon, France  
Irfu, CEA Saclay, France  
Irfu, CEA Saclay, France  
Irfu, CEA Saclay, France  
GANIL, France (present), UL Bruxelles (near future)

\ldots + 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
Construction of effective energy density functionals

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
 Validation of effective energy density functionals

- 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 hemp of RPA in infinite nuclear matter
  D. Davesne, M. Martini, K. Bennaceur, and J. Meyer
  PRC 80 (2009) 024314
Developing a consistent formalism for SR- and MR-EDF

- **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**
  ⇒ talk by J. Sadoudi
Construction of numerical tools for SR- and MR-EDF calculations

- 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
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’s talk at Niigata