Functional « Theories » @ Orsay

Researchers: M. Grasso, E. Khan, J. Libert, J. Margueron, P. Schuck.

Emeritus: N. Van Giai.

Post-doc: D. Pena-Arteaga.

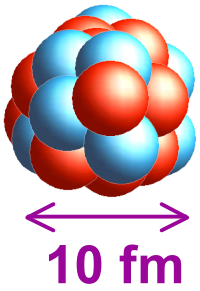
PhD: J.-P. Ebran, A. Fantina, H. Liang.

Advantages of Functional « Theories »

Going towards the drip lines, towards heavy nuclei, towards astrophysics.

Self-consistent mean field theories and beyond (HFB, QRPA, RMF, RHF, GCM, …)

Properties of finite systems:
masses, radii, pairing, evolution of the shells, deformation, collective modes, molecular states, …

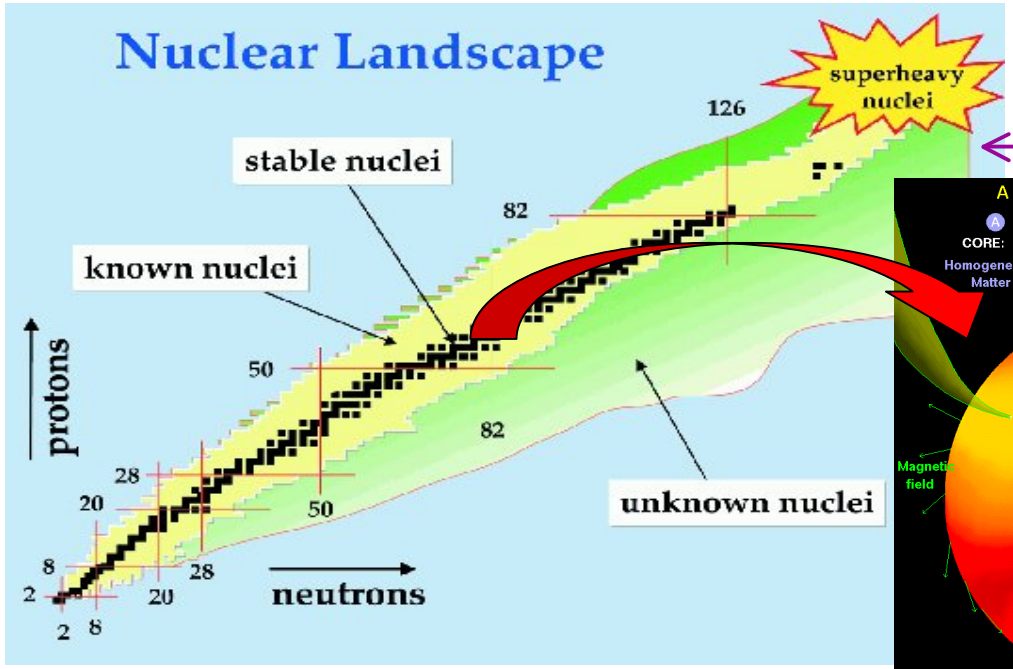


↔

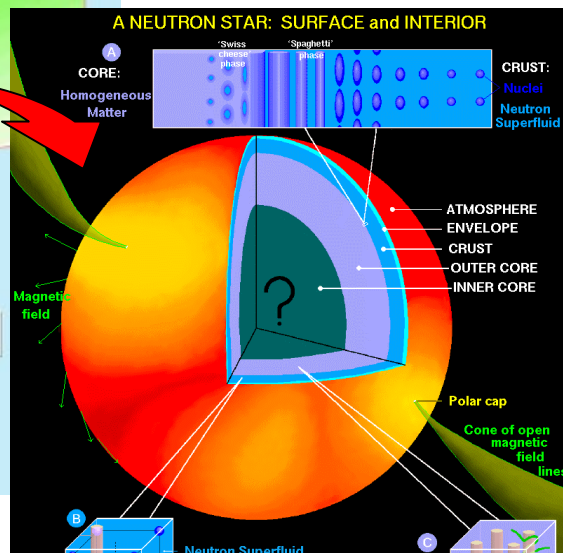
General properties of matter:
incompressibility, symmetry energy equation of state, …

↔

Application to neutron stars and supernovae:
Masses, radii, cooling, Glitches, neutrinos processes, …



20 km



Developpement of new functionals

BCP functional

No link with effective force, the density-functional reads:

From BHF in infinite matter

$$E=T_0+E_{inf}+E_{FR}+E_{s.o.}+E_{coul}+E_{pair}$$

Phenomenological surface contribution

$$E_{int}^{FR}[\rho_n,\rho_p]=\frac{1}{2}\sum_{t,t'}\left\{\int\int dr dr' \rho_t(\mathbf{r})v_{t,t'}(\mathbf{r}-\mathbf{r}')\rho_{t'}(\mathbf{r}')-\gamma_{t,t'}\int dr \rho_t(\mathbf{r})\rho_{t'}(\mathbf{r})\right\}$$

with $v_{t,t'}(r)=V_{t,t'}e^{-r^2/r_0^2}$

⇨ ***Only 5 parameters***

Baldo, Schuck, Vinyes, PLB 663, 390 (2008) (spherical nuclei),
Robledo, Baldo, Schuck, Vinyes, PRC 77, 051301 (2008) (deformed nuclei).

HF with DD-M3Y

Adjusted on G-matrix calculations + zero-range density-dependent force.
Folding models for nucleons-nucleus and nucleus-nucleus scattering.
Applications in neutron stars and finite nuclei. *Than, Khoa, Van Giai, PRC 80, 064312 (2009).*

Extension of Skyrme forces in the spin channel

Cf my talk @ Niigata Symposium *J.M., Sagawa, JPG 36, 125102 (2009),*
J.M., Goriely, Grasso, Colo, Sagawa, JPG 36, 125103 (2009).

Relativistic approaches

RHFB

Density-dependent meson coupling, Gogny force for the pairing,
Inclusion of the Fock terms and the rho-tensor coupling,
→ better systematics.

Long, Ring, Van Giai, Meng, to appear in PRC (2010).

Deformed RHFB

J.-P. Ebran (PhD).

J.-P. Ebran, E. Khan, M. Grasso, D. Vretenar, in preparation.

RHF + RPA

Isospin corrections for superallowed Fermi β decay (ud-CKM matrix element).

Liang, Van Giai, Meng, PRC 79, 064316 (2009).

Spin-isospin charge-exchange modes.

Liang, Van Giai, Meng, PRL 101, 122502 (2008).

Deformed RMF + QRPA

Low lying E1 strength in 132Sn - 166Sn.
The pygmy mode get spread as the nucleus get deformed.

Pena-Arteaga, Khan, Ring, PRC 79, 034311 (2009).

Pairing properties

Deriving pairing interaction from bare nuclear interaction

Adjustement of a density-dependent contact pairing interaction on:

- $^1S_0$ low-energy phase shift,
- Pairing gap in uniform matter (symmetric & asymmetric).

→ Good reproduction of the OEMS with the bare interaction.

J.M., Sagawa, Hagino, PRC 76, 064316 (2007),
J.M., Sagawa, Hagino, PRC 77, 054309 (2008).

Constrains on the pairing interaction (surf/vol)

Using pairing vibrations in exotic neutron rich nuclei,

Test different pairing forces, transition densities.

→ ^{136}Sn is a good candidate.

Khan, Grasso, J.M., PRC 80, 044328 (2009).

Beyond the mean field

Self-consistent RPA

No use of the quasiboson approximation.
Proper elimination of non-physical states.
Good agreement with the exact results in a three-level Lipkin model.

Gambacurta, Catara, Grasso, PRC 80, 014303 (2009),
Delion, Schuck, Dukeslky, PRC 72 064305 (2005).

Functional with surface peaked effective mass

A. Fantina (PhD), see my talk.

Fantina, J.M., Donati, Pizzochero, to be submitted.

Alpha-condensation in N=Z nuclei

Use a true condensate wave function.
Hoyle state in ^{12}C is well reproduced.
4 α condensate in ^{16}O: $0_1^+ \rightarrow O_6^+$ exp. states

Funaki, Yamada, Horiuchi, Roepke,
Schuck, Tohsaki, PRL 101/082502

Applications to Nuclear Astrophysics

Nuclear inputs for nuclei-synthesis scenarii

Developpement of accurate mass models,
E1 strength for the *r*-process.

Khan, Pena-Arteaga
in collaboration with S. Goriely.

Properties of neutron stars

Structure of the crust,
Supergiant collective modes,
Calculation of specific heat,
Cooling of neutron stars.

Chamel, Naimi, J.M., Khan, PRC 75, 055806 (2007),
Monrozeau, J.M., Sandulescu, PRC 75, 065807 (2007),
Grasso, Khan, J.M., Van Giai, NPA 807, 1 (2008),
Chamel, J.M., Khan, PRC 79, 012801 (2009),
Fortin, Grill, J.M., Sandulescu, ArXiv: (nucl-th).

Effet of huge magnetic fields (magnetars).

Pena-Arteaga, Grasso, Khan, in preparation.

Microscopic inputs for supernovae models

Equation of state,
T-dependence of the effective mass,
e-capture cross section,
ν interactions.

Fantina, Khan, J.M., in collaboration with
P. Pizzochero and Meudon-observatory.

Nuclear incompresibility.

Khan, PRC 80, 011307, 057302 (2009).