Ecole doctorale PHENIICS
particules, hadrons, énergie, noyau,
instrumentation, imagerie, cosmos et simulation

Université Paris-Saclay

Cours de formation doctorale 2021

Titre : A journey into nuclear structure theory

Intervenant(s) : J.-P. Ebran, U. van Kolck, T. Duguet, V. Somà, G. Hupin, B. Bally, D. Lacroix, E. Khan, R.D. Lasseri, D. Regnier

Durée (en heure + répartition dans la semaine):
15 h (cf planning)

Langue du cours: English/Français

Atomic nuclei – bound or resonant states of nucleons, which themselves are excitations of Quantum Chromodynamics (QCD) vacuum with baryon quantum number B=1 – are the epitome of complex systems. This is reflected in the vast diversity of their structure properties, where the onset of static correlations, the strong unbalance between proton and neutron numbers, or weak binding effects can lead to phenomena such as nuclear deformation, superfluid instabilities, clustering of nucleons into tightly bound subunits, development of a skin or a halo, etc. Such nontrivial spatial distributions of nucleons within nuclei translate into specific patterns in (i) excitation modes, with elementary excitations being accompanied by collective ones, e.g. vibrations and rotations, (ii) de-excitation processes (electroweak decays where photons and leptons are emitted, nucleon emissions, cluster radioactivity, fission, ...) and (iii) reaction patterns.

This rich phenomenology has prompted the development of many different theoretical approaches, each attempting to build a satisfactory description of nuclear phenomena, and each coming with their own strength and limits in terms of the kind of nucleus they can describe, the type of feature they can access, etc.

The present set of lectures aims at discussing where we stand in nuclear structure and reaction theory, what are the current challenges and on-going progress, according to the following outline:

1. Monday:
   9h30-11h30 J.-P. Ebran: ***General Introduction***
   We'll start with a general discussion about nuclear phenomena, and expose various strategies one can design in order to achieve an accurate, yet computationally affordable description of nuclear properties. All these approaches will be discussed in more depth by the corresponding experts.

   17h00-18h30 Ubirajara van Kolck : ***Nuclear Effective Field Theories***

2. Tuesday :
   9h15-10h45 Thomas Duguet: ***Solving many-body Schroedinger's equation via so-called expansion methods***
   11h00-12h30 Vittorio Somà*: Recent progress in ab initio calculations of medium-mass nuclei*

3. Wednesday:
   9h15-10h45 Guillaume Hupin
   11h00-12h30 Benjamin Bally: ***The nuclear Energy Density Functional***

4. Thursday :

9h30-10h30 Elias Khan: ***Nuclear clustering within the covariant energy density functional approach***

10h45-12h15 D. Regnier : Time-dependent approaches of the nuclear many-body problem

5. Friday

9h15-10h45 Denis Lacroix: ***Quantum computing simulation of complex quantum systems***

11h00-12h30 Raphaël Lasseri: ***An introduction to Machine Learning for Theoretical Physics: From data-driven "theories" to interpretable representations***

Date : 2021 May 31st-June 4th

Location : Online

Prerequisite : quantum mechanics concepts (experimentalist fellows are welcome)