Lecturer: Xavier Roca-Maza

Title: Nuclear equation of state from ground and excited state properties of nuclei.

The nuclear equation of state (EoS) at zero temperature (*T*) can be expressed as the energy (*E*) per particle (*A*) or pressure ($P=-\partial E/\partial V|_A$) of an infinite system of neutrons and protons in their ground state ($\mu = e + P/\rho$). This ideal system is of particular interest for different reasons: i) Coulomb and finite-size effects are avoided (by construction) making comparisons among different models easier; ii) sound methods exist to solve the many-body problem in this limit; iii) neutrons and protons away from the surface of the nucleus approximately behave as those of the infinite system (saturation density); or iv) neutron star outer core is thought to be made of neutrons and few protons in β–equilibrium with electrons and muons; among others.

The properties of this ideal system can be studied from laboratory data only via nuclear models. Most nuclear models are based on two pillars: the Hamiltonian and a sound many-body method. While accurate and systematically improvable many-body methods exist, this is not exactly the case of the nuclear effective Hamiltonian that has not been fully characterized yet. Density functional theory (DFT) constitute a potentially exact alternative that do not require the knowledge of the Hamiltonian. The disadvantage is that there is no formal or systematic approach to build the energy density functional (EDF), the central ingredient in DFT.

Different EDFs have been proposed in the literature. Those are commonly based on nuclear phenomenology and are, at the moment, the most competitive nuclear models available for the description of ground state properties and collective excitations in nuclei.

In these lectures, we will learn how to extract useful information on the EoS from some selected laboratory data on the basis of nuclear DFT.

The lectures will be (*tentatively*) organized as follows:

1. **Introduction and phenomenology:** schematic models and sum rules will be introduced in order to set some basic ideas
2. **Theoretical models with emphasis in DFT**: introduction to DFT and comparison with other approaches on the prediction of the nuclear EoS, some selected nuclear data, …
3. **Theoretical errors and correlations:** how model parametrizations are actually obtained and the relevance of an error and correlation analysis
4. **Current status on the determination of the EoS around saturation from experimental data:** state-of-the-art and some perspectives.

References (not exhaustive, references therein might be useful):

X. Roca-Maza and N. Paar, ***Progress in Particle and Nuclear Physics*** 101 (2018) 96-176
G. Colò, ***Advances in Physics***: X 5, 1740061 (2020)
M. Oertel *et al*., ***Rev. Mod. Phys***. 89, 015007 – Published 15 March 2017
Michael Bender *et al*., ***Rev. Mod. Phys***. 75, 121 (2003)
X Roca-Maza *et al.* (2015) ***J. Phys. G: Nucl. Part. Phys.*** 42 034033
Bohr A and Mottelson B (1998) *Nuclear Structure.* Chap. 6, Vol II (London: World Scientific)