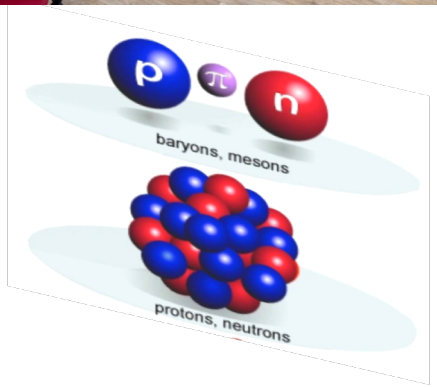
IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

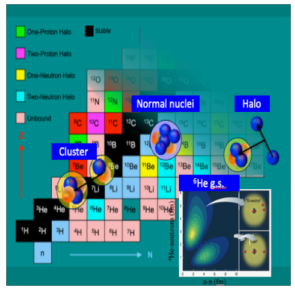
cnrs

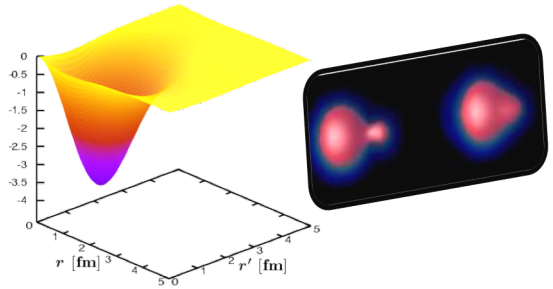
université PARIS-SACLAY

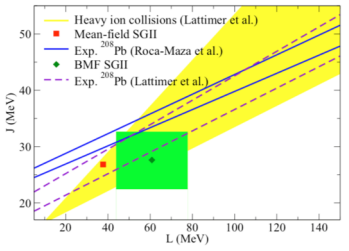
Université de Paris

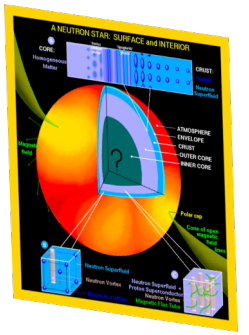
Nuclear Physics Theory team (Theory Pole)











Nuclear Physics Theory team

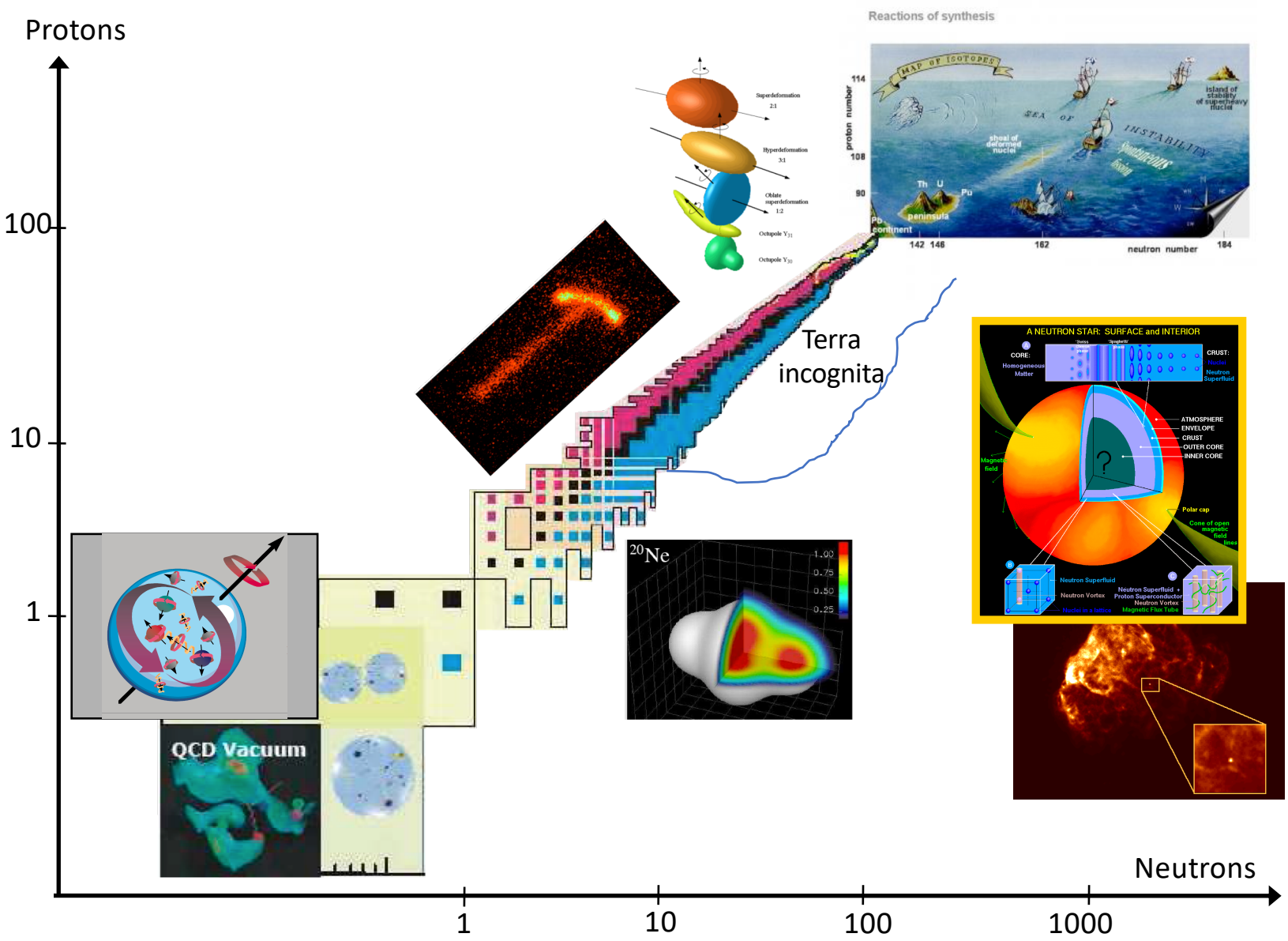
- Permanent (9+1)
  - Pierre Arthuis (CR)
  - Marcella Grasso* (DR)
  - Chloë Hebborn (CR)
  - Guillaume Hupin (CR)
  - Elias Khan (Pr)
  - Denis Lacroix (DR)
  - Paolo Napolitani (CR)
  - Michael Urban (DR)
  - Bira van Kolck* (DR)
  - + Jaume Carbonell (DR)

- PhD & Postdocs

ALMIRANTE Giorgio
AYCHET-CLAISSE Samuel
CHAMSEDDINE Mohamad
DEHGHANI Alireza
DIDIER-PICHAT Rodrigue
HEITZ Louis
PALANIAPPAN Viswanathan
STELLIN Gianluca
YAGHI Osama
WU Feng
ZHANG Jing

Topics

- **Nuclear interaction & Nuclear structure**: Ab initio methods and few-body systems, EDF, clustering
- **Nuclear dynamics**: direct and compound reactions, transport, excitations, decays
- **Nuclear astrophysics**: neutrons stars, neutrino oscillations, evaluation of reaction rates
- **Interdisciplinary research:** applications and emerging technologies
- **Collaboration with experimentalists**: experiments, cross section interpretations, shell structure

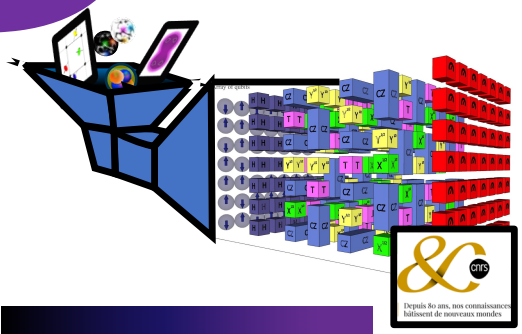

Protons
100
10
1
Neutrons
1
10
100
1000
Reactions of synthesis
MAP OF ISOTOPES
SEA OF INSTABILITY
island of stability of superheavy nuclei
shoal of deformed nuclei
peninsula
Th U Pu
Pb continent
proton number
neutron number
114
108
90
142 146
162
184
Superdeformation 2:1
Hyperdeformation 3:1
Oblate superdeformation 1:2
Octupole Y31
Octupole Y30
Terra incognita
A NEUTRON STAR: SURFACE and INTERIOR
CORE: Homogeneous Matter
CRUST: Nuclei Neutron Superfluid
ATMOSPHERE
ENVELOPE
CRUST
OUTER CORE
INNER CORE
Magnetic field
Polar cap
Cone of open magnetic field lines
Neutron Superfluid
Neutron Vortex
Nuclei in a lattice
Neutron Superfluid + Proton Superconductor
Neutron Vortex
Magnetic Flux Tube
20Ne
1.00
0.75
0.50
0.25
QCD Vacuum

Thematics of the team—Global view and Emergence of new projects

Nuclear structure
Nuclear excitation
Few-body
and Clustering

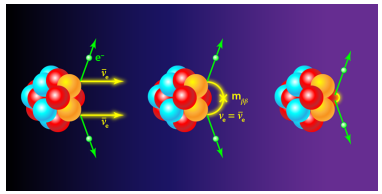
Emergent fields
AI, Quantum comp.

Micro theory
Nuclear reactions
Heavy-ions reactions
Fission



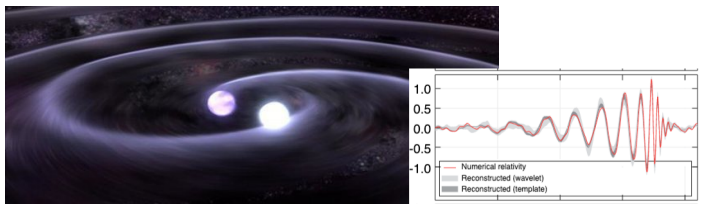
Astrophysical
reaction rates,
Neutrino oscillations

Ab-initio theory
Reactions with
light systems



Nuclear EOS
Nuclear astrophysics
Hyper-nuclei

Link between
Nuclear physics and
Gravitational waves



Few-body reactions
Optical potentials

Research topics developed in the team
(without Marcella)

Nuclear interaction & Nuclear structure

- Nuclear effective field theories: excited baryons in Chiral EFT, matching nuclear EFTs to lattice QCD [Bira]
- antinuclear forces and structure [Bira, Guillaume]
- nuclear forces and currents from EFT, new probes in few-body systems [Bira, Guillaume, Pierre]
- halo and cluster states with Halo/Cluster EFT, and Cluster phenomenology [Bira, Chloë, Elias]
- Development of energy density functional model for nuclear structure [Elias, Denis]
- Generator Coordinate Methods and their extensions [Elias, Denis]
- Expansion of ab initio methods over the nuclear chart [Pierre]

Research topics developed in the team

Nuclear dynamics

- Towards the modeling of complex reactions with ab-initio methods [Guillaume, Pierre]
- development of microscopic models for heavy-ion collisions beyond mean field in the low (few MeV per nucleon) to intermediate (200 MeV per nucleon) energy range. Semiclassical approaches (Boltzmann), quantum approaches (TDHF). [Paolo]
- Microscopic quantum transport theories including stochastic methods [Denis]
- Description of low energy nuclear phenomena: collective excitation, fission, … [Denis, Elias]
- Few-body methods to describe direct reactions used to probe exotic nuclei [Chloë]
- Development of phenomenological and more microscopic optical potentials [Chloë]

Nuclear astrophysics

- Cluster formation in heavy-ion collisions as a function of time and density and links with the nuclear equation of state. [Paolo]
- Application of nuclear models to nuclear astrophysics [Elias]
- Description of neutrons stars [Michael]
- Quantum information in neutrino oscillations [Denis]
- Evaluation of astrophysical reaction rates [Chloë]

Research topics developed in the team

Interdisciplinary research, applications and emerging technologies

- Fermi liquids: dissipation, chaos, large-amplitude fluctuations and bifurcations. [Paolo]
- fast heavy-ion-collisions solution for medical applications through deep-learning [Paolo]
- Superfluidity and strongly interacting Fermi gas [Michael, Denis]
- Machine learning and Quantum Machine Learning [Guillaume, Denis]
- Quantum computing applied to many-body systems [Denis, Guillaume]
- Nuclear tests of global symmetries (lepton number, baryon number, etc) [Bira]
- expansion around unitarity for nucleons and atoms [Bira, Guillaume]
- Development of automated expression and code generation for many-body methods [Pierre]

Collaboration with experimentalists

- Interpretation of reactions of astrophysical interest [Chloë with F. Hammache and N. de Sereville]
- Single-particle shell structure and related reactions [Chloë with O. Sorlin, Elias with D. Verney]
- 2 alpha decay experiment [Elias with experimentalists from pôle nucléaire and CEA]
- Contribution in communities and projects on the EoS and the dynamics of exotic nuclei [Paolo, member of FAZIA]
- Nuclear density profiles for neutron-knockout experiments with R3B @ GSI/FAIR [Pierre with T. Aumann & A. Schwenk]
- Nuclear density profiles for scattering off (un)stable isotopes with SCRIT & ESPRI @ RIBF [Pierre with K. Tsukada & J. Zenihiro]

Publications in 2024 @IJCLab (15 PR, 3 PLB, 1PRL, 1NIM)

- **Nuclear interaction & Nuclear structure**
- **Nuclear dynamics**
- **Nuclear astrophysics**
- **Interdisciplinary research**
- **Links with experiments**

- Use of quantality in nuclei and many-body systems
- Improved action for contact effective field theory
- Two-body double pole and three-body bound states: Physical and unphysical quark masses
- Four-boson first excited state near two-body unitarity
- Limits on an improved action for contact effective field theory in two-body systems
- Weinberg, effective field theories, and time-reversal violation
- Lepton-neutron interaction and S-wave low-energy parameters
- Effects of finite temperature and pairing correlations in multi- Λ hypernuclei
- Randomized low-rank decompositions of nuclear three-body interactions
- Construction of Continuous Collective Energy Landscapes for Large Amplitude Nuclear Many-Body Problems
- Ab initio framework for nuclear scattering and reactions induced by light projectiles
- Superfluid fraction in the slab phase of the inner crust of neutron stars
- Effect of the equation of state for dilute neutron matter on the composition of the inner crust of neutron stars
- New Skyrme parametrizations to describe finite nuclei and neutron star matter with realistic effective masses
- Superfluid fraction in the rod phase of the inner crust of neutron stars
- Entanglement in selected binary tree states: Dicke or total spin states or particle-number-projected BCS states
- Neutron-proton pairing correlations described on quantum computers
- Quantum Computing for High-Energy Physics: State of the Art and Challenges
- Solving the Lipkin model using quantum computers with two qubits only with a hybrid quantum-classical technique based on the generator coordinate method
- Novel device to study double-alpha decay at the FRS Ion Catcher
- Phase-space methods for neutrino oscillations: Extension to multibeams
- Towards Precision Muonic X-ray Measurements of Charge Radii of Light Nuclei
- Ab initio investigation of the Li 7 (p,e+e-) Be 8 process and the X17 boson