SCIENCES SORBONNE UNIVERSITÉ

Master thesis proposal

INSP/ SU, Campus P. et M. Curie (Jussieu)
Director: Massimiliano Marangolo

Title: Many-body quantum dynamics in ion-ion collisions

Keywords: highly charged ions, ion accelerators, collision dynamics, x-ray and ion spectroscopy

Scientific description:

When multicharged ions interact with matter, the latter is subjected to strong fields (which can reach up to 10^9 V/cm), often for extremely short durations (from femtoseconds to a few attoseconds) inducing electronic dynamics that are more or less understood. In more details, when an ion interact with a target, it may capture target electrons (charge exchange), lose part of its own electrons (ionization) or the latter may be promoted in excited states (excitation). Charge exchange is by far the dominant process at low velocity (typically at center-of-mass energies of a few keV to a few 100 keV) while ionization and excitation dominate in the high velocity regime, the so-called perturbative regime. In between, all the primary electronic processes reach their optimum probability and are of the same order of magnitude. While these processes are well understood for the simplest 3-body system, namely proton on hydrogen, their description quickly becomes complicated when we address N-body collisions. This happens when we change the atomic numbers of the collision partners and the number of electrons present on the ion and/or target. Indeed, the latter not only induce a static screening of the positive nucleus but also participate in the dynamics itself (electron-electron interactions may dominate in some cases). Knowledge of cross sections of these electronic processes is the keystone for understanding the energy deposition of ions in (hot or cold) matter with applications in many areas of research such as plasma physics (stellar / interstellar plasmas or inertial confinement fusion plasmas), material modifications and characterization, hadrontherapy or accelerator development.

For several years, the ASUR team at INSP has been developing a cross-beam experiment to carry out ion-ion collisions for atomic physics. Two platforms equipped with electron cyclotron ion sources and their beam line are under installation at INSP. A dedicated collision chamber has been manufactured as well as an ion spectrometer currently being developed and tested (in collaboration with the CMAP laboratory at GANIL[1] where tests are also performed). A Silicon Drift Detector X-ray detector has recently been fully characterized in terms of efficiency and resolution. Our experimental approach involves not only measuring the ion charge states after the collision, but also performing coincidence measurements (thanks to our new acquisition system, FASTER[2]) between the charge state and the emitted X-rays by the partners during the collision to get information on the populated excited states.

The internship/Ph.D. will take place mostly at INSP. After a full characterization of the ion beams (intensity, shape, transmission of the beam line), the ion-ion collision experiments at low velocity will be performed in our SIMPA facility with our two ion platforms (FISIC and SIMPA[3]). In the future, the FISIC platform will be moved and installed at the ion storage ring CRYRING in Germany at the GSI/FAIR accelerator[4] to investigate more energetic collisions.

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[1] GANIL : Grand accélérateur National d'Ions Lourds (https://www.ganil-spiral2.eu/fr/)

[2] FASTER : Fast Acquisition System for nuclEar Research (http://faster.in2p3.fr/)

[3] https://w3.insp.upmc.fr/recherche-2/equipes-de-recherche/agregats-et-surfaces-sous-excitations-intenses/agregats-et-surfaces-sous-excitations-intenses-equipements/

[4] https://www.gsi.de/en/work/research/appamml/atomic_physics/experimental_facilities

Techniques/methods in use: The candidate will learn the methods of production and transport of multicharged ion beams using an ECRIS (Electron Cyclotron Resonance Ion Source) and a beam transport. She/he will become familiar with acquisition systems, X-ray and ion spectroscopy techniques.

Applicant skills: Knowledges in one or several following topics will be a plus: atomic physics, particle collisions, accelerator physics, x-ray spectroscopy, ion spectroscopy, data analysis.

Industrial partnership: N

Internship supervisor: Emily Lamour (lamour@insp.jussieu.fr; tel 01 44 27 4518) and Christophe Prigent (prigent@insp.jussieu.fr)

Internship location: INSP, Sorbonne Université, 4 place Jussieu, 75005 Paris

Possibility for a Doctoral thesis: Y (to be financed via the doctoral school)