SCIENCES SORBONNE UNIVERSITÉ

Master thesis proposal

INSP INSTITUT DES NANOSCIENCES DE PARIS

Directeur
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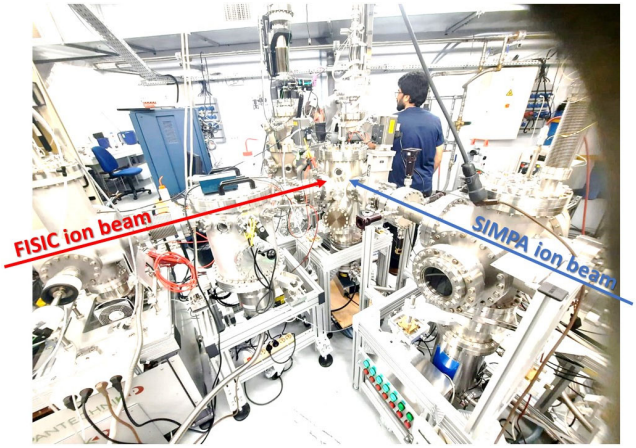
Title: Quantum dynamics in ion-ion / ion-atom collisions

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

Scientific description: (a figure may be included)

Study of primary electronic processes in collisions between ions and matter is of great importance in many research domains. Such interactions occur in interstellar media, at the edges of tokamak plasmas, in inertial fusion plasmas or are used to characterize or modify the properties of materials and even in tumor treatments via hadrontherapy. In fact, when multicharged ions interact with matter, the latter is subjected to strong fields (which can reach up to 10^{11} V/m), often for extremely short durations (from femtoseconds to a few attoseconds) inducing complex electronic dynamics. For instance, in ion-atom or ion-ion collisions, the incoming ion may capture electrons (charge exchange) from the other partner, loses part of its own electrons (ionization) or the latter may be promoted in excited states (excitation). The probability (or cross-section) of electronic processes depends on the relative velocity between the two collision partners but also on the number of electrons initially bound to each nucleus. While the collision dynamics are fairly well understood at low (molecular regime) and high (perturbative regime) velocities, the intermediate regime is characterized by the fact that, there, all the primary electronic processes reach their optimum probability with amplitudes of the same order of magnitude. This makes difficult measurements of a well-defined process and enforces the use of sophisticated non-perturbative theoretical approaches.

For several years, the ASUR team at INSP has been developing a cross-beam experiment to carry out ion-atom and ion-ion collisions. The goal is not only to investigate the pure 3-body problem (a bare heavy ion colliding with a hydrogenic target as a benchmark) but also to study the role of additional electrons whether they are initially in a ground state configuration or in an excited one. For example, the probability of transferring an electron from the He^+ ion to the O^{6+} ion during a collision depends on the initial oxygen configuration (either $1s^2$ or 1s2s).



Two platforms, named FISIC[1] and SIMPA[2], are now installed at INSP for the investigation in ion–atom and ion–ion collisions. Each platform is equipped with an electron cyclotron ion source and its beam line capable of delivering ion beams well characterized in terms of current, flux and shape. Dedicated collision chambers for ion-atom and ion-ion experiments are in preparation. For collisions with atoms, an effusive jet will be installed with the possibility to adjust the atomic density. Two detection systems will be used: a Silicon Drift Detector to record the X-rays emitted during the collisions and an ion spectrometer (developed in collaboration with the CIMAP laboratory at GANIL[3]) to measure the different charge states of the ion products. Our experimental approach is to perform coincidence measurements (thanks to our new acquisition system, FASTER[4]) between the charge state and the emitted X-rays to get information on the populated excited states after electron exchange.
The internship will take place at INSP in our SIMPA[5] facility for collision experiments in the low-velocity regime. For the next step (during the PhD period), the FISIC platform will be moved and installed at the ion storage ring CRYRING in Germany at the GSI/FAIR accelerator[6] to investigate collisions a thousand times more energetic with heavier ions so as to explore the "terra incognita" regime for atomic physics.

Techniques/methods in use: X-ray and ion spectroscopy techniques, multicharged ion sources, numerical acquisition system.

Applicant skills: knowledge in atomic physics

Industrial partnership: No (specify the company)

Internship supervisor(s) (name, email, phone, …): Emily Lamour (lamour@insp.jussieu.fr; tel 01 44 27 4518) and Christophe Prigent (prigent@insp.jussieu.fr)

Internship location: INSP (Campus Jussieu)

Possibility for a Doctoral thesis: Yes

[1] FISIC : Fast Ion Slow Ion Collisions
[2] SIMPA : Source d'Ions Multichargés de PAris
[3] GANIL : Grand accélérateur National d'Ions Lourds (https://www.ganil-spiral2.eu/fr/)
[4] FASTER : Fast Acquisition System for nuclEar Research (http://faster.in2p3.fr/)
[5] SIMPA : Sources d'Ions Multichargés de PAris
[6] https://www.gsi.de/en/work/research/appamml/atomic_physics/experimental_facilities