Master 2 ICFP : Soft matter and biological physics

Internship proposal 2025-2026

Title: *Single-cell response to X-ray irradiation in the presence of radio-enhancing metallic nanoparticles.*

Location : IJCLab, CNRS UMR 9012
Université Paris-Saclay – Bat 104, campus d'Orsay.

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Duration : 4-5 months

Context :

Despite major progress in cancer treatment, particularly in radiotherapy (RT), tumor response heterogeneity still limits therapeutic efficacy. Understanding how cancer cells adapt to X-ray–induced stress is therefore crucial.Two laboratories in Orsay, IJCLab and ISMO (Institut des Sciences Moléculaires d'Orsay), are collaborating to investigate these processes at the single-cell level, aiming to evaluate the impact of radio-enhancing metallic nanoparticles (NPs). Such NPs can increase tumor toxicity under irradiation without increasing the absorbed dose. At IJCLab, research focuses on individual cellular responses to irradiation, which are difficult to capture using conventional population-averaged methods. Videomicroscopy, combined with the original *CellLineageTrack* (CLT) algorithm, enables continuous single-cell tracking, reconstruction of lineage trees over time, and characterization of cell fate after irradiation.At ISMO, research focuses on the development and assessment of NPs capable of localizing within tumors, enhancing energy absorption and/or generating additional reactive oxygen species (ROS) responsible for the expected toxicity. While the physical and chemical effects of NPs are well established, their precise biological consequences remain poorly understood.
The collaboration thus aims to link microscopic observations with multi-scale mechanisms in order to optimize NP use in RT and improve clinical efficacy**.**

Internship Proposal :

By continuously tracking cell populations exposed to ionizing radiation, the IJCLab approach enables the reconstruction of cellular lineage trees (Fig. 1) and the evaluation of parameters such as cell-cycle duration, motility, and senescence probability (Fig. 2).
Moving beyond endpoint measurements, this method provides a dynamic and integrative view of irradiation responses. Integrating this approach with ISMO's study of radio-enhancing metallic NPs represents a particularly promising convergence.
The internship objective is therefore to combine quantitative videomicroscopy and radiosensitization to build a dynamic, multi-scale map of cellular responses to X-ray irradiation in the presence of nanoparticles. This will make it possible to explore, in real time, how NP exposure influences repair probability, senescence, or cell death after X-ray irradiation.

Methodologies :

Two complementary approaches will be used:

1. Experimental:
    - Culture of a breast cancer cell line.
    - Optimization (concentration, duration, etc.) of metallic NP application and radiosensitization under X-ray irradiation (dose optimization).
    - Real-time videomicroscopy.
2. Analytical:
    - Use and improvement of the CLT algorithm developed at IJCLab.
    - Analysis of the experimental datasets obtained.

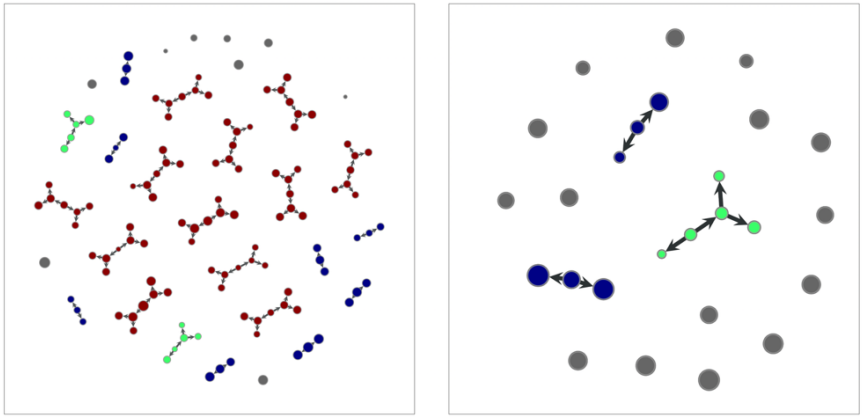

Figure 1 : Lineage trees reconstructed by the CLT algorithm on a cell population (MCF7 human breast cell line) after 96 h without (a) and with (b) 5 Gy X-ray irradiation. Each point represents a cell, with the diameter proportional to cell size. Colors visualize phenotypic differences within a globally homogeneous-appearing cell population.

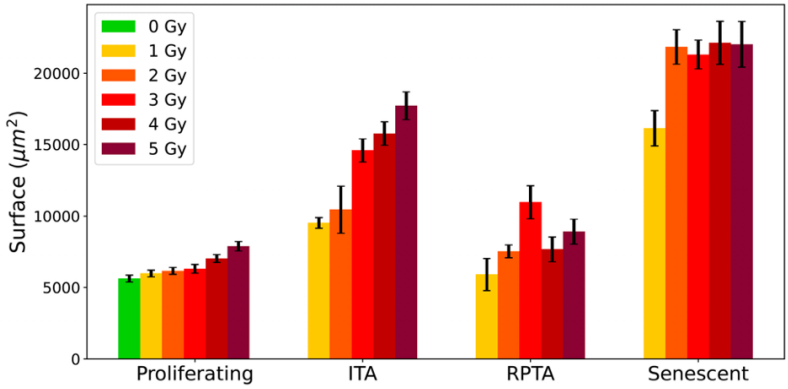

Figure 2 : **Key result obtained using CLT:** Example of phenotype differentiation in the MCF7 cell line. Observed parameter: cell area as a function of X-ray dose.
Four subpopulations are detected: (1) proliferating cells (normal mitosis), (2) cells in transient proliferation arrest (ITA), (3) cells in transient arrest followed by re-proliferation (RPTA), and (4) senescent cells.
Other parameters, such as motility, further discriminate cell subtypes and reveal correlations.

Work Environment :

The internship will take place within the *Health Division* (about twenty members) of the IJCLab laboratory which hosts around 700 staff members. Supervision will be provided by a biologist (O.S.) for the experimental part and a physicist (S.P.) for algorithm development. The PhD student responsible for the CLT algorithm development, currently in her final year, will also provide occasional assistance. Collaboration with ISMO will focus on optimizing the use of radio-enhancing NPs.

Desired Profile :

The internship is intended for a motivated M2 student with a background in fundamental physics and a strong interest in the physics-biology-chemistry interface, in the biological mechanisms, and in experimental approaches to explore them. Prior knowledge of Python programming is essential.

PhD Continuation :

YES. Independent funding applications are in progress. The student will also be eligible to apply to the *No. 576 PHENIICS* doctoral school.

References :

- https://gitlab.in2p3.fr/josephine.courouble/celltrack
- J. Courouble, B. Klebowski, O. Seksek, P. Jakubczyk, S. Lacombe, E. Porcel, J. Depciuch & M. Parlinska-Wojtan (2026) Proton beam-induced effects of platinum nanoparticles and their intracellular localization. *Colloids and Surfaces B Biointerfaces*. 257: 115154.