Internship for 2nd year Master or final year of Engineering School - 2023-2024
Specialties: physics, imaging, computer science, bioinformatics, data science, and related disciplines.
Duration: 5 to 6 months, based on candidate availability

Design of realistic numerical phantoms of *C. elegans* for 3D image reconstruction.

Hosting research team

The candidate will join the *Laboratoire de Physique des Deux Infinis Bordeaux* (LP2IB), a Joint Research Unit of CNRS-IN2P3 and the University of Bordeaux (UMR 5797). The laboratory specializes in utilizing techniques derived from nuclear physics for research in fundamental physics, health, and the environment. The candidate will be part of the **multidisciplinary team iRiBio (Interactions Ionizing Radiations and Biology)**, combining expertise in physics, computer science, chemistry, and biology to address challenges related to the **characterization of biological organisms**, focusing on microscopic models such as cells and microorganisms. The supervisor will be Claire MICHELET, a physicist specialized in **three-dimensional (3D) imaging**. The research project is in collaboration with Pascal DESBARATS, a computer scientist at LaBRI (Computer Science Research Laboratory of Bordeaux), and Jean-François GIOVANNELLI, a data scientist at the IMS laboratory (Integration from Material to System), experts in inversion problems and image reconstruction techniques.

Context of the internship

3D microtomography is an indispensable tool in the analysis of matter, particularly living matter. It enables direct imaging, without the need for physical sectioning, on preserved biological samples, which closely resemble their native state. The internship addresses the issue of **3D image reconstruction in the case of incomplete acquisition data.** This situation may occur for various reasons: *i) temporal constraints*, to limit the experiment's duration or minimize radiation exposure, for instance; *ii) physical constraints*, because some geometrical limitations prevent access to certain measurement angles. All these limitations serve as sources of errors in the reconstructed images, hindering their interpretation. The present internship is part of a research project aiming to develop innovative methods of image reconstruction to overcome these limitations. Methodologically, the idea is **to leverage *a priori* knowledge about the object**, including its structure, the presence of discontinuities, expected distribution types, etc. These constraints will guide the reconstruction algorithm towards realistic solutions.

Objectives and missions

The study will be conducted on **the biological model *Caenorhabditis elegans*** (*C. elegans*), a multicellular microorganism approximately 1 mm in length. *C. elegans* is internationally recognized as a reference model for studying major biological functions (genetics, aging, neurosciences), and extensive data are already available[1]. The core mission of this internship is **to design realistic numerical *C. elegans* phantoms**, ensuring accurate microstructure and chemical composition, based on existing experimental data provided by confocal, electron, proton, and synchrotron X-ray imaging (Fig. 1). These phantoms will serve several research purposes:

- **Development of image reconstruction algorithms:** *i)* for identifying pertinent parameters suitable for deployment as minimizers in reconstruction methods; *ii)* for training neural networks involved in artificial intelligence (AI) based algorithms.
- **Evaluation of the accuracy of tomographic images:** *i)* for direct testing of image reconstruction codes; *ii)* for *in silico* experiments using Monte Carlo (Geant4) simulation[2].

Although the core mission of the internship is the design of the phantoms, **involvement of the candidate in these research topics** is possible and can be discussed according to the candidate's interest and skills. The

[1] https://www.wormatlas.org/ ; http://www.wormbook.org/ ; http://celegans.tomoseq.genomes.nl/
[2] C. Michelet *et al.*, "A Geant4 simulation of X-ray emission for three-dimensional proton imaging of microscopic samples", Physica Medica 94, p. 85-93, 2022.

intern will be proposed to be associated with a scientific publication in an international peer-reviewed journal, before the public release of the phantoms.

Added value

While the issue of this internship is framed within proton microtomography (MT), its implications extend far beyond. It directly relates to **synchrotron radiation MT, electron MT**, and could also contribute to advancements in **medical imaging** (especially Positron Emission Tomography - PET), non-destructive testing, radar imaging, astrophysics, and beyond. Among the foreseen applications, the design of these phantoms will benefit research in AI-based reconstruction methods, with the goal of developing **AI that is frugal in terms of energy and environmental resources**.

In the context of biomedical research, the *C. elegans* phantoms will also be used as **biological references for studying chemical element distributions.** This set of references can significantly contribute to future biomedical research by addressing the following questions: How does the distribution of biologically relevant chemical elements change in the case of a metabolic disturbance? In what ways can a disruption of ion homeostasis in specific target organs influence the development of pathologies? Answering these questions will open up new avenues for investigating the homeostasis of mineral and metal ions, suspected to play **a critical role for example in neurodegeneration**, implicated in diseases such as autism, Alzheimer's, Parkinson's, as well as rare diseases like Amyotrophic Lateral Sclerosis and Charcot's disease.

Contact person

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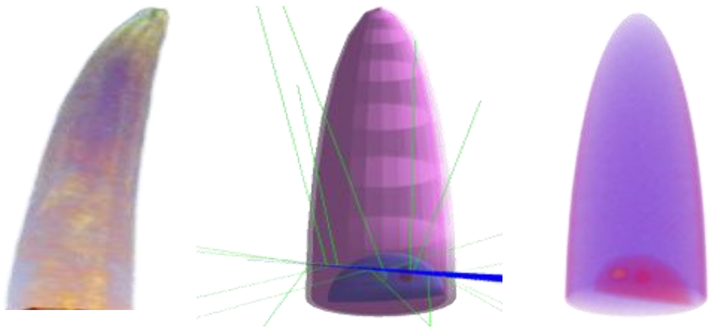

Figure 1: 3D images of the upper part of a *C. elegans*: experimental data (left); *in silico* experiments using Geant4 simulation (middle); tomographic reconstruction from simulated data (right).