CREATIS STROBE MIAI Cluster IA

# Single-pixel XRF-computed tomography

PhD Project

May 27, 2026

We announce the opening of a PhD Project starting in October 2026. The project is funded for three years by MIAI. This is a collaboration between three laboratories: CREATIS (Lyon, France), STROBE/IAB (Grenoble, France), and CEA (IRIG MEM, Grenoble, France).

**Keywords** Ghost Tomography, Computational X-rays, Image Reconstruction, Deep Learning.

**Overview** This doctoral project aims to develop a groundbreaking 3D imaging technique for non-destructive elemental analysis by merging the principles of single-pixel (ghost) imaging (GI) with X-ray fluorescence (XRF) computed tomography (ghost tomography, GT). Conventional XRF imaging faces significant limitations in detection efficiency, energy resolution, and scalability, particularly for large samples or long exposure times. This project will overcome these challenges by creating a novel computational imaging modality, building upon the recent demonstration of XRF-GI in both laboratory and synchrotron settings [3, 2].

**Workplan** Single-pixel XRF GI has proven effective for 2D chemical spatial mapping, but it lacks resolution along the beam path. Recent experiments have demonstrated the feasibility of XRF-GT with synchrotron light [1], but its implementation with common laboratory sources has yet to be demonstrated and would have a far superior impact in the field. The first phase of the project will extend 2D XRF GI to three dimensions (i.e., XRF-GT) by acquiring structured illumination data from multiple angular projections of the sample, and then developing dedicated reconstruction algorithms for this multiplexed data to recover the volumetric chemical maps. A critical scientific challenge to be addressed is the correction of X-ray fluorescence self-attenuation. Uncorrected, this effect causes severe artifacts that are amplified during 3D reconstruction. The project will integrate advanced self-attenuation correction models directly into the reconstruction pipeline, building upon existing strategies [7] to ensure quantitative accuracy.

The second phase of the project will aim to drastically reduce exposure times to enable low-dose imaging of sensitive samples. Two complementary strategies will be pursued. First, the project will develop machine learning-based reconstruction techniques capable of producing high-fidelity images from extremely low-signal, noisy data. By leveraging a combination of supervised and self-supervised learning, inspired by the Noise2Ghost framework [4], these algorithms will be designed to denoise measurements corrupted by Poisson-Gaussian noise, allowing for significantly shorter integration times. Second, the project will explore a hybrid imaging approach inspired by pansharpening, fusing high-spectral-resolution data from the single-pixel detector with high-spatial-resolution data from a 2D camera (recently suggested by [5]). By developing a novel algorithm to combine these data streams, the number of required angular projections could be reduced dramatically, potentially enabling 3D imaging of non-rotatable samples. The successful completion of this PhD will deliver a powerful, low-dose 3D XRF imaging platform with superior sensitivity and speed for applications in materials science, biology, and cultural heritage, with data analysis facilitated by software such as PyMCA [6].

The final phase of this PhD project will be dedicated to the practical implementation of the developed methods on the newly built MusitoX multimodal X-ray imaging platform. This validation stage will yield the first experimental results on real use cases, bridging the gap between theoretical frameworks and actual imaging performance. This work will be carried out in close collaboration with our consortium partners, ensuring cross-disciplinary synergy and rigorous benchmarking of the proposed approaches.

**Skills** The successful candidate will develop a comprehensive and highly interdisciplinary skill set throughout the PhD project. They will gain a deep understanding of X-ray physics, particularly the principles of X-ray fluorescence (XRF) spectroscopy, photoelectric absorption, and fluorescence processes, along with expertise in both laboratory-based and synchrotron X-ray imaging techniques. A core focus will be on mastering computational imaging, specifically the theory and practice of single-pixel (ghost) imaging and structured illumination, including the underlying mathematics of compressive sensing and multiplexing. The candidate will become proficient in tomographic reconstruction methods, learning to develop and apply algorithms to create 3D volumetric images from projection data while specifically addressing complex physical artifacts like X-ray fluorescence self-attenuation.

In parallel, the candidate will acquire advanced data science and machine learning expertise. This includes developing and applying deep learning models, such as convolutional neural networks, for critical tasks like image reconstruction and denoising extremely low-signal data corrupted by Poisson-Gaussian noise. They will gain hands-on experience with self-supervised and unsupervised learning paradigms, which are essential for training models when ground-truth data is scarce. The project will also hone their skills in sophisticated signal and image processing, spectral analysis, and the fusion of multi-modal data. Computationally, the candidate will become highly proficient in scientific programming with Python, using key libraries like NumPy, SciPy, and scikit-learn, and will master machine learning frameworks such as PyTorch or TensorFlow for algorithm development.

**How to apply?** Please send a curriculum, a motivation letter, and your academic records before **June 19th** to nicolas.ducros@creatis.insa-lyon.fr, emmanuel.brun@inserm.fr, nicola.vigano@cea.fr.

## References

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