Laboratory for Interdisciplinary Physics (LIPhy, Grenoble)
140 rue de la Physique , F-38402 St Martin d'Hères

Funded PhD thesis offer

Period : 2026-2029 (ideally starting October 1st)

Location : LIPhy, University Grenoble Alpes campus, St martin d'Hères, France

Context : MIAI Chair GeoSuperRes 2025-2029

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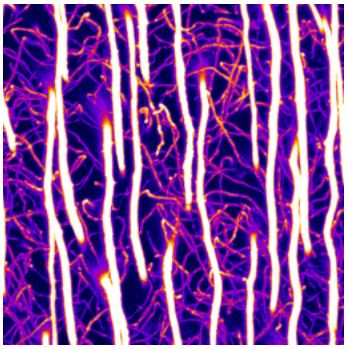
Physics- and biology-informed deep-learning super-resolution imaging of cellular networks in tooth dentin

Your profile: you are completing a **Master of Science** or **Engineering degree** in one of the following topics : **computer vision**, **physics of complex systems**, **optics**, **applied mathematics** or **biomedical engineering**, with a solid training in **machine learning** and **image processing** ?

You wish to acquire new skills in deep-learning applied to biomedical imaging in an international context of scientific excellence ?

Background: microscopic cellular porosity in human teeth is currently believed to play a key role in sensitivity.



In a recent study, we showed for the first time that this porosity is much more complex than currently thought in dentistry[1] (image on the left is a Z-projection of the stained porosity over 10 µm emphasizing dense 3D connectivity). However, **the precise impact of the network connectivity and topology is still poorly understood**. Ultimately, such studies primarily rely on our capacity to image even the finest cellular connections (< 500 nm). Confocal fluorescence microscopy has the potential to image this porosity network, but requires the highest achievable resolution ~ 200-400 nm. This typically limits the field of view to ~ 200 x 200 µm^2 in practice, which is largely insufficient to map a whole tooth cross section of ~ 1 cm^2. **To address this imaging challenge we are currently developing new methods for fast imaging using deep-learning super-resolution (SR) methods**[2]. This essentially involves training SR models on high- and low-resolution (HR/LR) data pairs to restore HR on images acquired much faster.

1. L Chatelain, N Tremblay, E Vennat, E Dursun, D Rousseau, A Gourrier (2025) *Cellular porosity in dentin exhibits complex network characteristics with spatio-temporal fluctuations* PLOS One 20, e0327030.

2. L. Anderson, L. Chatelain, N. Tremblay, K. Grandfield, D. Rousseau, A. Gourrier (2025) *Biology-driven assessment of deep learning super-resolution imaging of the porosity network in dentin* https://arxiv.org/abs/2510.08407

Our offer: **In this project, we wish to develop new SR models based on recent architectures for supervised and unsupervised learning, that could better capture the specificity of the porosity network in dentin in terms of topology and geometry. A secondary objective is to improve current Image Quality Assessment (IQA) metrics to better quantify SR efficiency.** Those are the main limitations identified during a first PhD on this topic in our group (Mineralized Tissues – Optics & Imaging team) in collaboration with D. Rousseau's team of experts in image and complex systems analysis from the LARIS (University of Angers).

Your PhD Goals:

- **identify the fundamental structural determinants of dentin porosity networks**: the structure of the cellular porosity network is organized on at least two characteristic length-scales, but its precise topology and geometry is still not well characterized. Following classical approaches from crystallography and physics of disordered systems, an accurate characterization of the network needs to be developed. This aims to derive a model containing key physics and biology parameters to model the network in terms of elementary components and statistical variance, i.e. characterize short- and long-range order/disorder of the system.
- **develop new physics- and biology-informed SR models**: so far, we only tested CNNs, Residual Attention Neworks and GANs which showed variable performances. More recent models built on Transformers, Diffusion etc. are expected to provide better performance. A central question is how to use the physics and biology structural priors to design more efficient and frugal SR models. In particular, the porosity network topology and geometry should be taken into account, e.g. to define adequate loss functions, or define the type and structure of the SR model architecture.
- **develop new IQA metrics:** assessing the reliability of generated HR images and quantifying the nature and degree of errors is of utmost importance for biomedical studies. So far, we found that most common IQA metrics failed to match visual perception and expert analytical pipelines. More recent metrics will tested and developed tailored for our purposes using structural analysis.

This PhD will be funded by the MIAI Chair GeoSuperRes, aiming to improve SR model design by leveraging on geometry and topology.

Your working environment: this work will be based at the LIPHY, located on the University Grenoble Alpes campus in an exceptional mountain scenery. Our research lab offers unique interdisciplinary expertise at an international level and hosts numerous collaborators from various parts of the world in a sportive and relaxed atmosphere with state of the art technical and scientific support.

The project will be performed in close collaboration with P. Adibi (LIPhy) and D. Rousseau (LARIS Angers), both computer vision and machine learning experts and other local collaborators in Grenoble's rich AI environment. Other colleagues from the biomechanics (E. Vennat, CentraleSupelec) and medical (M. Riou, B. Fournier, APHP, Univ. Paris Cité) fields will also be involved.