

M2 Internship Position

Learning to reconstruct from noisy data alone with applications to astronomical imaging

Keywords Inverse problems, statistical learning, self-supervised learning, astronomical imaging, deep learning

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Figure 1: Self-supervised learning algorithms (Noise2Void, Neighbor2Neighbor, SURE, UNSURE) can learn to remove noise from degraded images without any access to a dataset of ground-truth (clean) images. However, this learning task is particularly challenging with the noise is spatially correlated, and the exact correlation is a priori unknown.

Context In recent years, deep neural networks have obtained state-of-the-art performance in multiple imaging inverse problems, such as computed tomography and image super-resolution. Networks are generally trained with supervised pairs of images and associated measurements. However, in various applications, such as astronomical imaging [1], we usually only have access to noisy measurements of the underlying images, thus hindering this learning-based approach.

Recent advances in self-supervised learning methods for imaging have highlighted the possibility of learning from measurement data. The potential of these self-supervised methods has been demonstrated on various inverse problems, including medical imaging [2, 3] (see Figure 1) and remote sensing [4]. A long list of references and tutorial slides can be found here.

In particular, the Unknown Noise level Stein's Unbiased Risk estimator (UNSURE) method [5] has shown that is possible to learn an (almost) optimal denoiser from noisy data alone, without knowledge of the noise level. However, this method has only been demonstrated under simplistic assumptions on the noise correlation using simple datasets. The goal of this project is to explore new extensions of the UNSURE method and evaluate it on high-contrast Angular Spectral Differential Imaging (ASDI) data of circumstellar environments (see Figure 2).

Internship Goals The main goals of the internship will be:

1. Understand the challenges and fundamental limitations of self-supervised learning, and the specific challenges in the context of astronomical imaging.
2. Extend the UNSURE algorithm [5] to handle complex noise covariances.
3. Evaluate the developed algorithms on real high-contrast ASDI data.

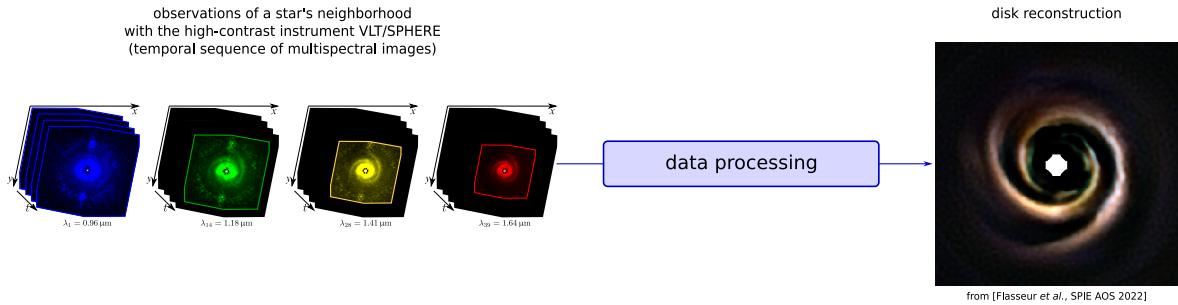


Figure 2: Multispectral image reconstruction of faint circumstellar environments from high-contrast ASDI data [6].

Required Qualifications The applicant should have a background in applied mathematics or computer science, and be part of a master degree in topics around machine learning, signal processing and/or optimization. They should be proficient in Python programming and have some experience with machine learning libraries (e.g. pytorch). Some knowledge of high-dimensional statistics is considered beneficial but not required.

Application Potential applicants are invited to write Julián and Loïc with any questions about the project or even to meet us at ENS Lyon. Applicants can contact us at julian.tachella@ens-lyon.fr and loic.denis@univ-st-etienne.fr. Please include a CV, your recent grades, and a statement of interest in your application email.

Research environment: ENS Lyon is a small-size research-driven university in France, that is consistently ranked among the best universities in France. The applicant will benefit from a stimulating environment of research scientists in machine learning, signal processing, and physics, with weekly seminars given by international experts and weekly reading groups on topics around machine learning.

Stipend The student will receive a monthly stipent of 659€ gross.

PhD thesis This internship position provides a unique opportunity to acquire the knowledge and skills to continue—if the internship is successful—onto a PhD position that will be advertised in 2025 with a start date in fall 2025. The PhD work will build on the internship results and address applications in astronomical imaging. The PhD position will be funded by the PEPR ORIGINS project.

References

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