M2 Internship Position
Self-Supervised Learning for Astronomical Imaging

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

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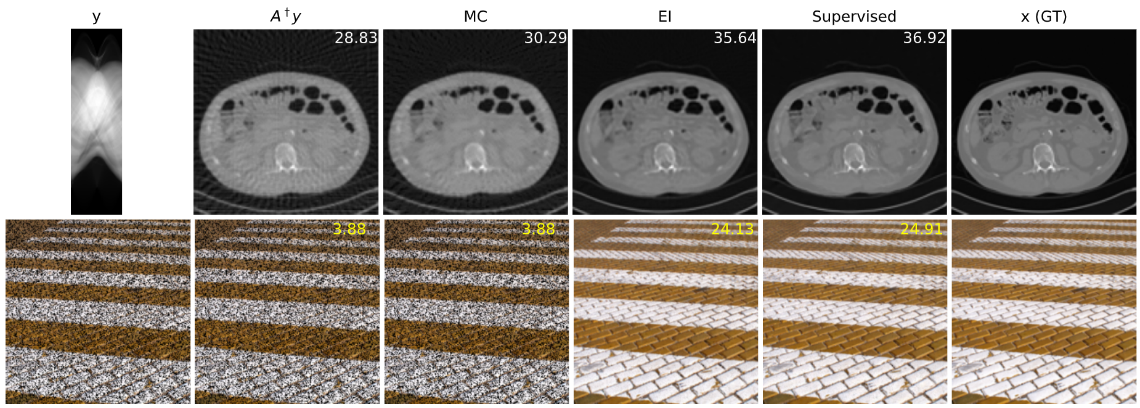

Figure 1: **Learning to image from only measurements [1]**. Training an imaging network through just measurement consistency (MC) does not significantly improve the reconstruction over the simple linear pseudo-inverse. However, by enforcing invariance in the reconstructed image set, *equivariant imaging* (EI) performs almost as well as a fully supervised network. **Top**: sparse view CT reconstruction, **Bottom**: pixel inpainting. PSNR is shown in the top right corner of the images.

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 of astronomical imaging [2], we usually only have access to incomplete measurements of the underlying images, thus hindering this learning-based approach. Learning from measurement data alone is impossible in general, as the incomplete observations do not contain information outside the range of the sensing process.

Recent advances in self-supervised learning methods have highlighted the possibility of learning from measurement data alone if the underlying signals are invariant to groups of transformations such as translations or rotations [3, 4]. The potential of these self-supervised methods has been demonstrated on various inverse problems, including computed tomography and magnetic resonance imaging [1, 5] (see Figure 1).

However, these methods cannot handle (partially) unknown sensing processes (e.g., where the noise distribution is not fully known or the forward process is not well calibrated), which are common in many astronomical imaging applications (e.g., angular differential imaging of circumstellar environments, see Figure 2). This project will explore new approaches to tackle such problems, investigate their theoretical properties, and propose practical self-supervised learning algorithms using deep learning.

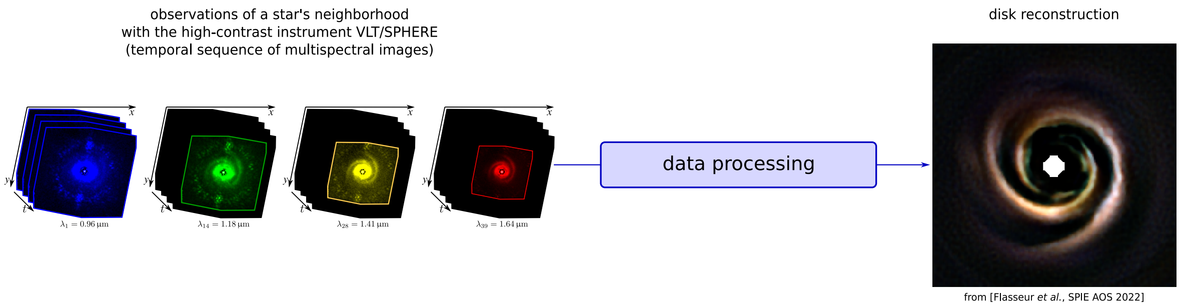

Figure 2: Multispectral image reconstruction of faint circumstellar environments from high contrast angular spectral differential Imaging (ASDI) data [6].

Internship Goals The main goals of the internship will be:

1. Understand the challenges and fundamental limitations of self-supervised learning in the context of astronomical imaging.
2. Propose new practical deep learning-based self-supervised algorithms.
3. Study the theoretical properties of the proposed algorithms.

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., scikit-learn, pytorch, etc.). 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 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 stipent of 614€ gross monthly.

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 2024 with a start date in fall 2024. 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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