Joint deconvolution and super-resolution of astronomical images

Keywords – Deconvolution, sparsity, super-resolution, Euclid mission

Context

Weak gravitational lensing is a very promising probe of modern cosmology (Schneider et al. 2006). Under General Relativity, light is known to follow the curvature of space-time, which is affected by massive objects. This causes distortions in the observed shapes of distant galaxies. The Euclid spacecraft plans to observe billions of galaxies with the goal of measuring their shape and extract the weak lensing signal. However, the observed galaxy images have themselves been blurred by the instrument's Point Spread Function (PSF), which can be thought of as a convolution kernel applied to the galaxy images. They are also afflicted by noise.

Sparsity has been shown to be a powerful tool to solve a large number of inverse problems, including deconvolution of noisy images. In the particular case of galaxy images affected by a PSF, Farrens et al. (2017) recently proposed one such method. Some use cases, in particular for the Euclid mission, require some improvements of this approach: this internship's goal is to study and implement one such improvement.

Super-resolution

Explicit deconvolution of galaxy images from the PSF is a key element of a recently proposed approach for the calibration of weak lensing measurements, a step of paramount importance to derive the cosmological information. It has been successfully applied on real data from a ground-based telescope (Zuntz et al. 2017). However, in the case of Euclid, images will further suffer from undersampling due to the optical sensor sizes (Ngolè et al. 2015).

The goal of this internship is thus to extend the deconvolution method of Farrens et al. (2017) to simultaneously perform the deconvolution and superresolve the galaxy image. This will require using several exposures (*i.e.* different images containing the same galaxy) at once, which makes the super-resolution part of the problem quite similar to that studied in Ngolè et al. (2015).

Outline of project objectives

The internship will be broadly divided into the following main blocks and objectives:

1. Reach an understanding of the required methods and previous works; in particular, the intern will need to be very comfortable with the Farrens et al. (2017) paper and using the associated software[1].

2. Establish how to add in the simultaneous super-resolution step through a modification of the optimization problem to be solved.

3. Implement and thoroughly test the necessary updates to the code.

4. Apply the upgraded deconvolution method on downsampled, Euclid-like data.

Depending on the intern's knowledge of topics of interest at the beginning of the internship and their efficiency in solving the above tasks, more could be added at their discretion – for instance combining their super-resolution approach with other generalizations of the method.

[1] `https://github.com/sfarrens/sf_deconvolve`

Candidate

The candidate should be a Master 2 (or equivalent) student in applied maths/signal processing/data science. Knowledge in optimization and sparsity-based methods would be a plus. Experience coding in Python is not required, but would be advantageous.

Internship

The internship will take place in the CosmoStat laboratory, under the supervision of Jean-Luc Starck and Samuel Farrens.

- *Deadline for applications:* February 28th, 2018.
- *Contact:* Samuel Farrens (samuel.farrens@cea.fr).
- *Duration:* 4-6 months.
- *Possibility to continue on for a PhD:* Yes.

References

Farrens, S., Mboula, F. N., & Starck, J.-L. 2017, Astronomy & Astrophysics, 601, A66

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Schneider, P., Kochanek, C., & Wambsganss, J. 2006, Gravitational Lensing: Strong, Weak and Micro: Saas-Fee Advanced Course 33, Vol. 33 (Springer Science & Business Media)

Zuntz, J., Sheldon, E., Samuroff, S., et al. 2017, arXiv preprint arXiv:1708.01533