Power Spectrum Extended, a new reconstruction method for post-adaptive optics short exposure imaging

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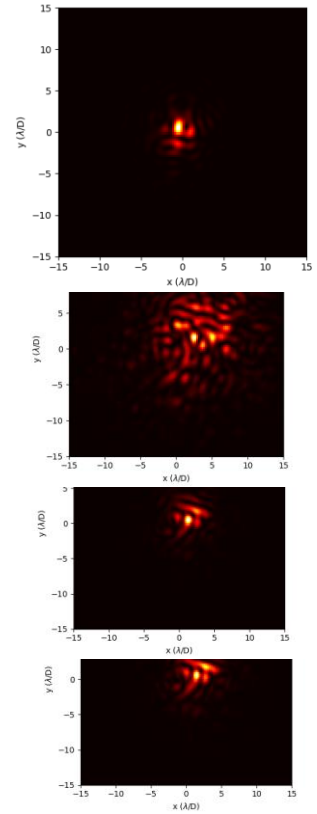
WAVEFRONT SENSING IN THE VLT/ELT ERA V

13TH - 15TH OCTOBER 2020

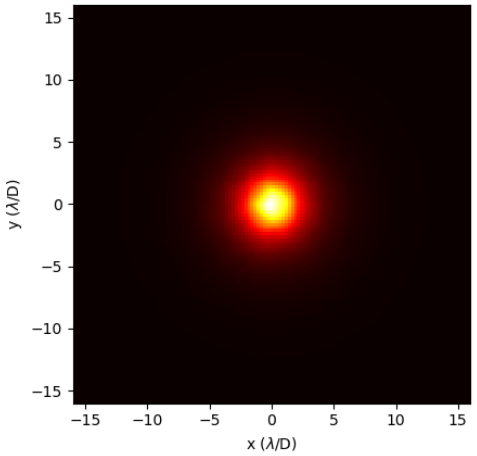
AO WORKSHOP WEEK II

The Lucky Imaging Technique[1] [2]



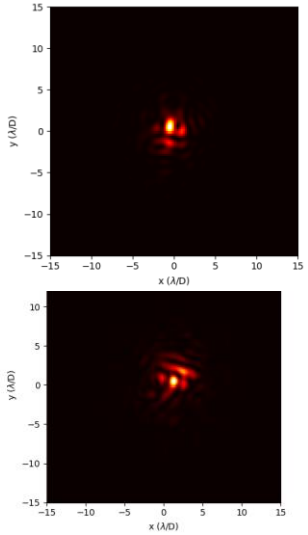
Short exposure sequence

Long-time exposure



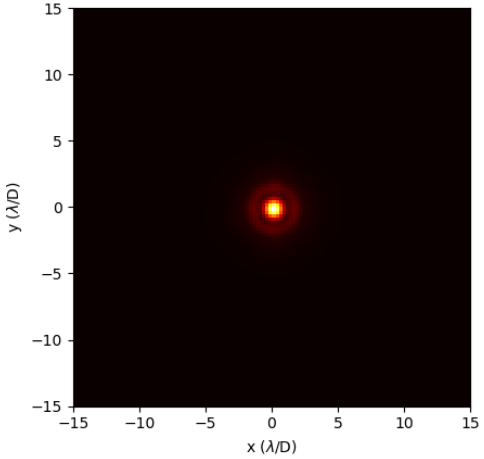
Long-time image

selection



Selected short exposure sequence

Reconstruction

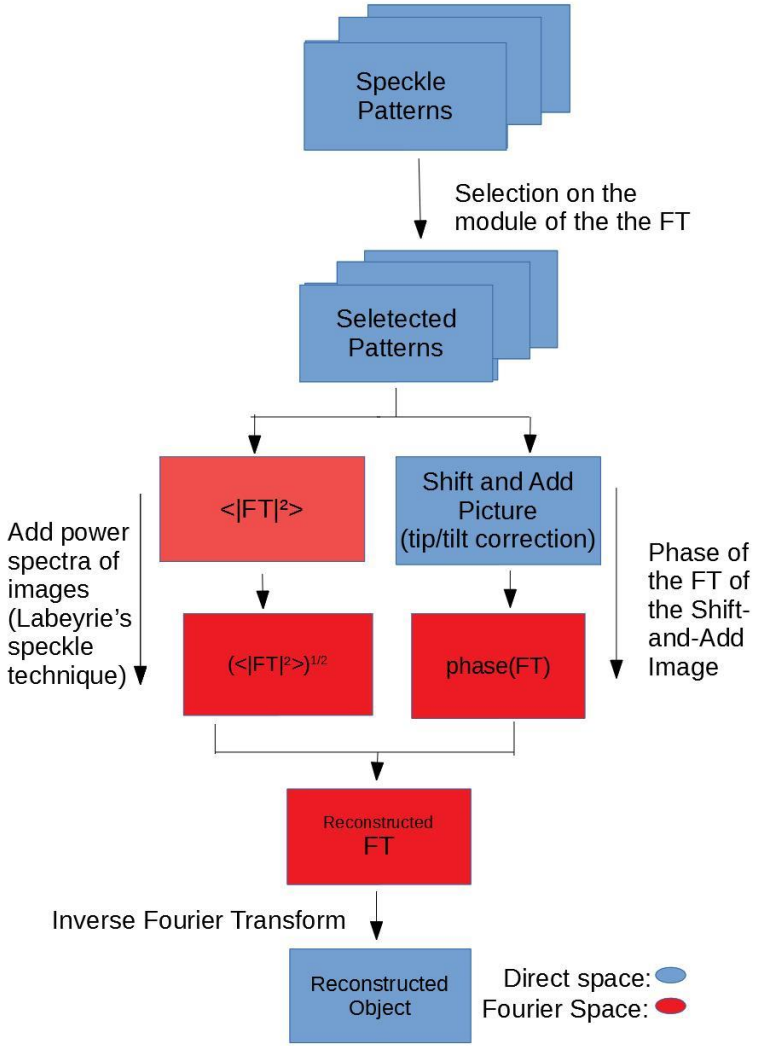


Lucky Image

(1) Fried, D. L. (1978)

(2) Baldwin, J. E., Tubbs, R. ., Cox, G. ., Mackay, C. D., Wilson, R. W., & Andersen, M. . (2001).

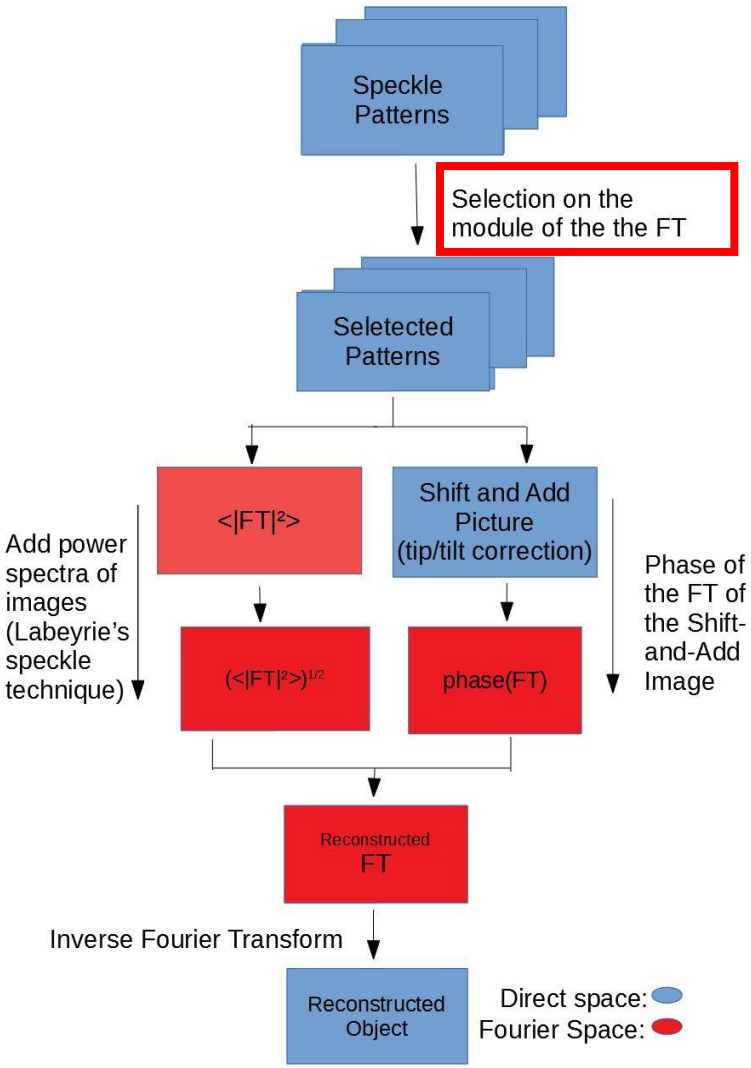
Power Spectrum Extended[3] : Method



- Select the best short exposures.
- Recover the modulus of the Fourier transform of the object, via the Labeyrie speckle technique.
- Revover the phase of the Fourier transform of the object via the shift and add method.
- Reconstruct the object by inverting the Fourier transform.

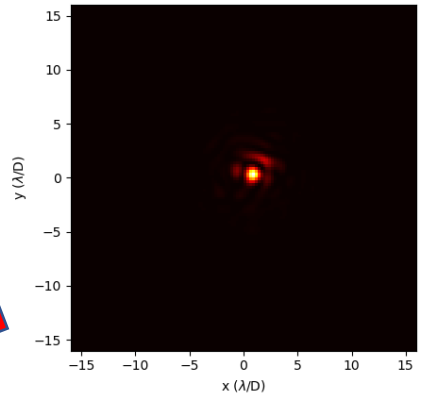
(3) Cottalorda, E., Aristidi, E., Carbillet, M., Guinard, M., & Vourc, S. (2020).

A new method of selection

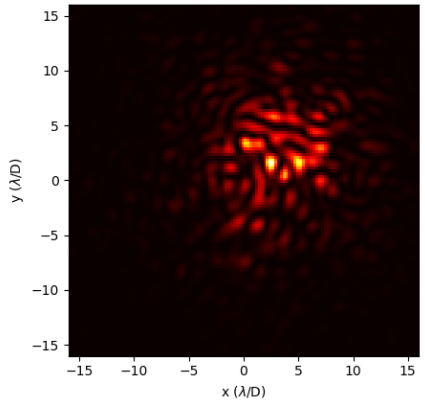


For each short –exposure :

- Compute the power spectrum.
- Estimate r_0 for the first three frequels.
- Select the images with the highest r_0.

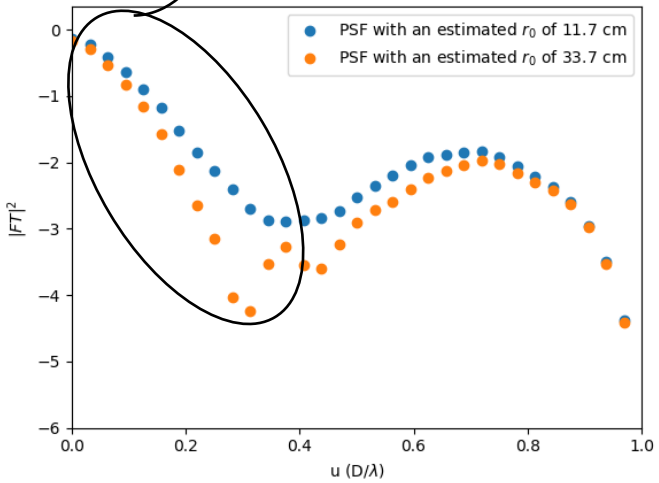


PSF Simulation with estimated r_0 of 33,7 cm.



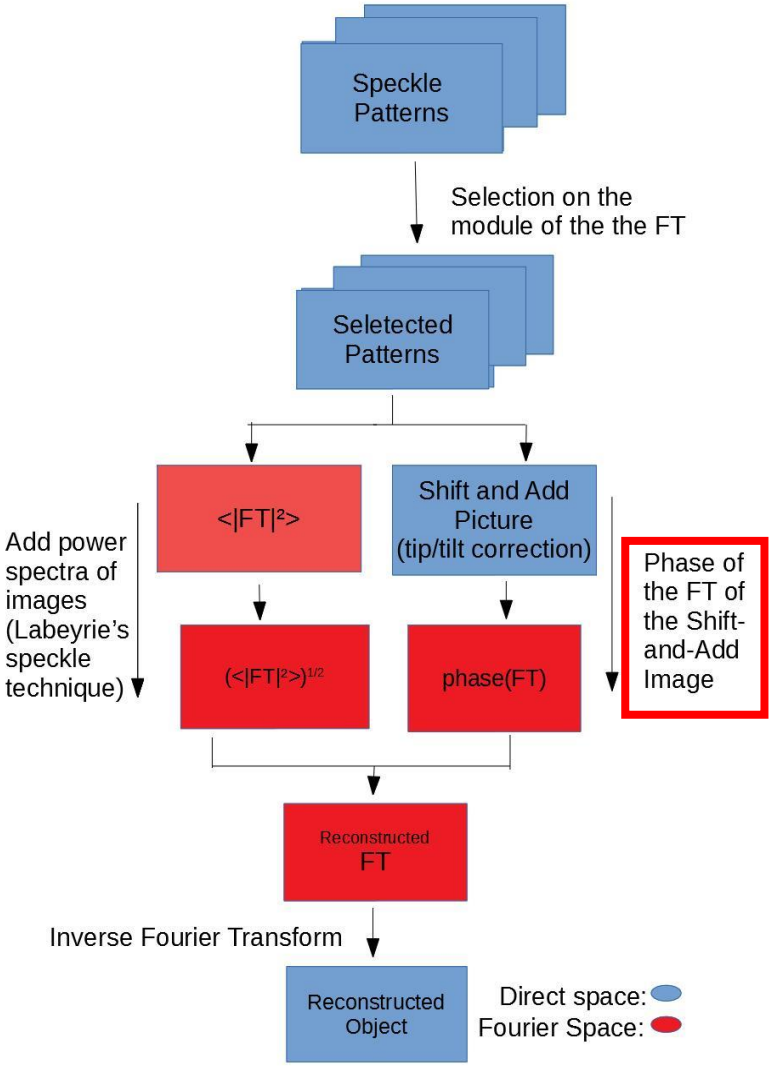
PSF Simulation with estimated r_0 of 11,7 cm..

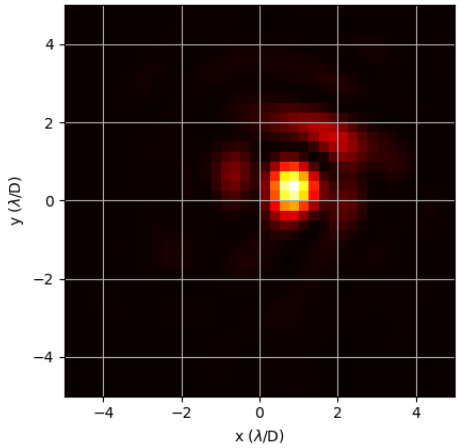
$$B(f) = e^{-6.88\left(\frac{\lambda f}{r_0}\right)^{\frac{5}{3}}}$$



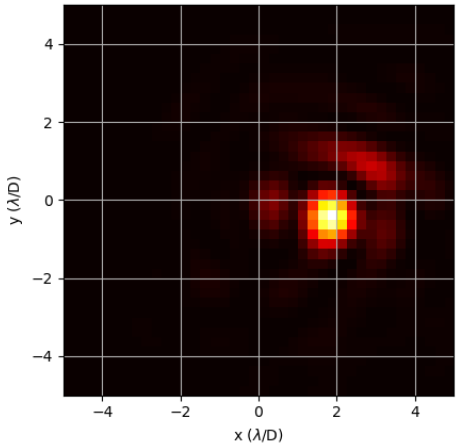
Power Spectrum.

A new method of alignement



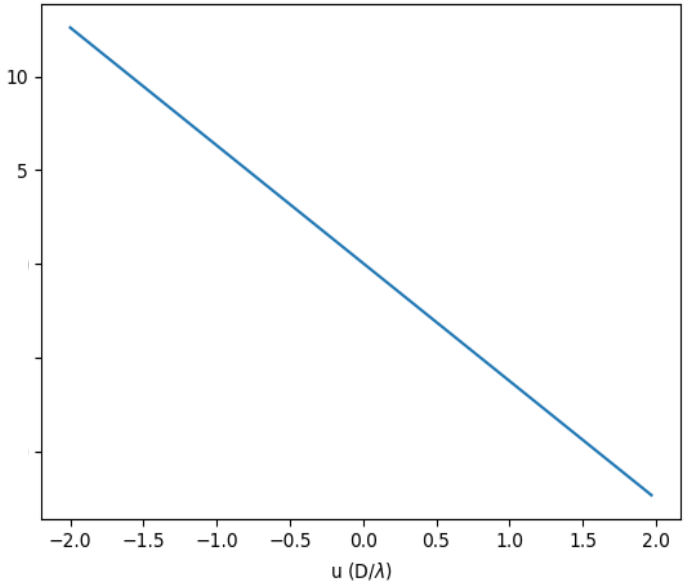


PSF simulation .



Shifted PSF Simulation

- FT of each short exposure.
- Phase difference between two subsequent FT(image).
- Correct from the deduced slope

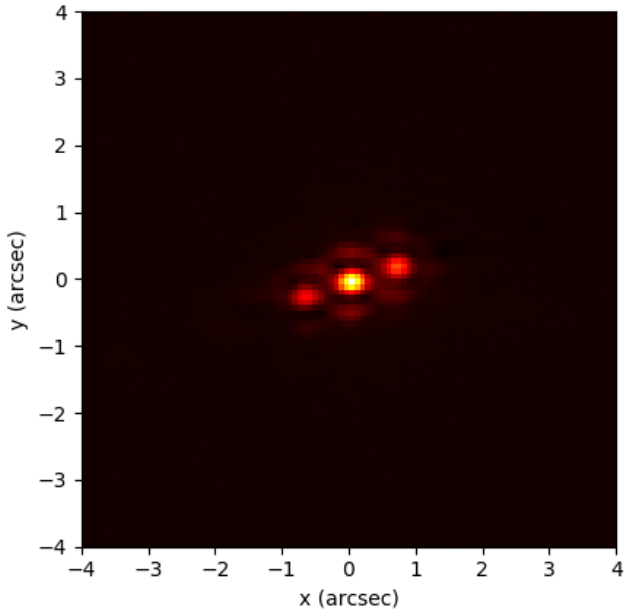


Exemple of phase difference.

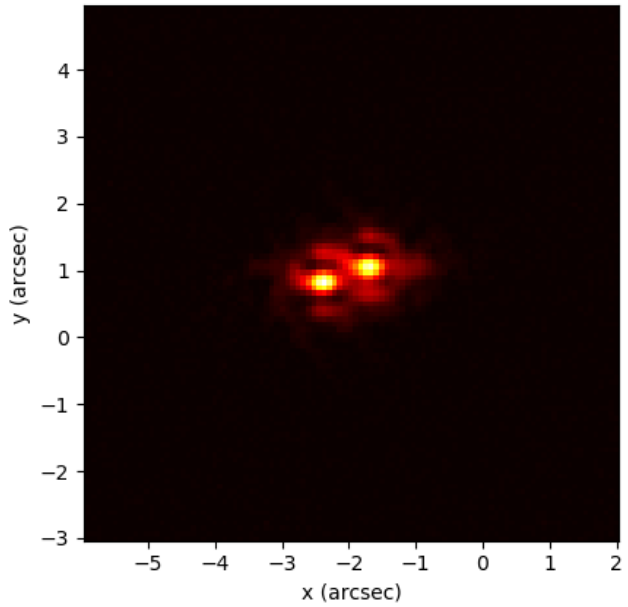
Result on real (uncorrected) data : double star i Boo

We apply this method to an image of the double star i Boo. The sample of short exposure contains 19999 image of 256 pixels x 256 pixels[4].

Diameter	1 m
Wavelenght	1650 nm
Sampling	0",078



Lucky imaging reconstruction with a selection of 5 %.



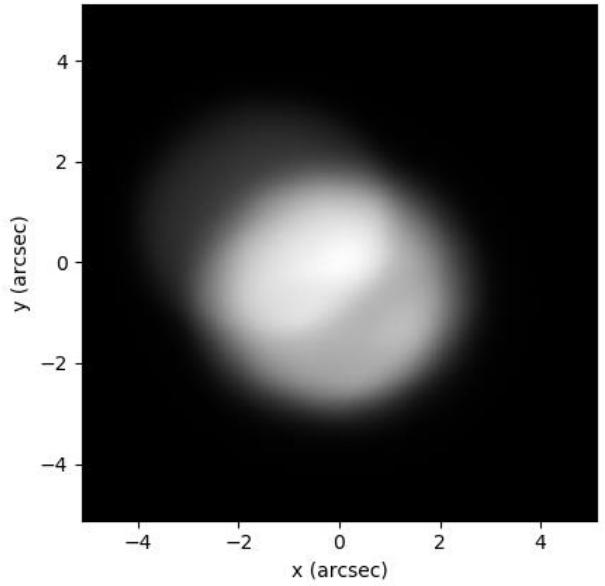
PSE reconstruction with a selection of 5 %.

(4) Aristidi, E., Cottalorda, E., Carbillet, M., Abe, L., & Makki, K. (n.d.).

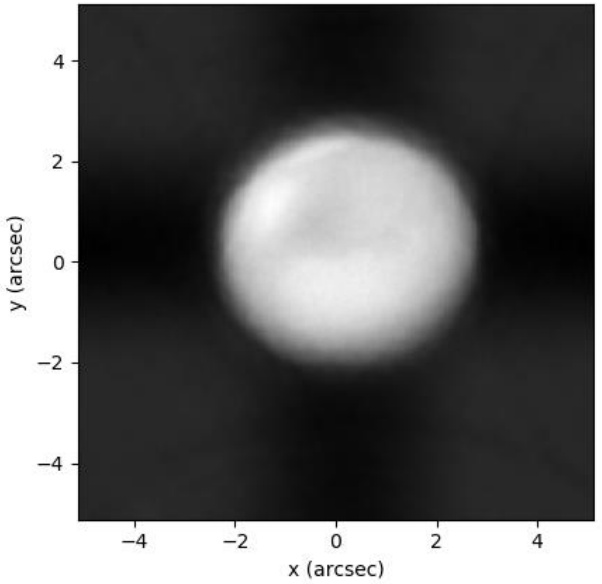
Result on real (uncorrected) data: planet Mars

We apply this method to a set of image of the planet Mars (Ariane Group) . The sample of short exposure contains 1000 images of 640 pixels x 690 pixels.

Diameter	335 cm
Wavelenght	700 nm
Sampling	0",08



Lucky reconstruction of Mars with a selection of 10 %.

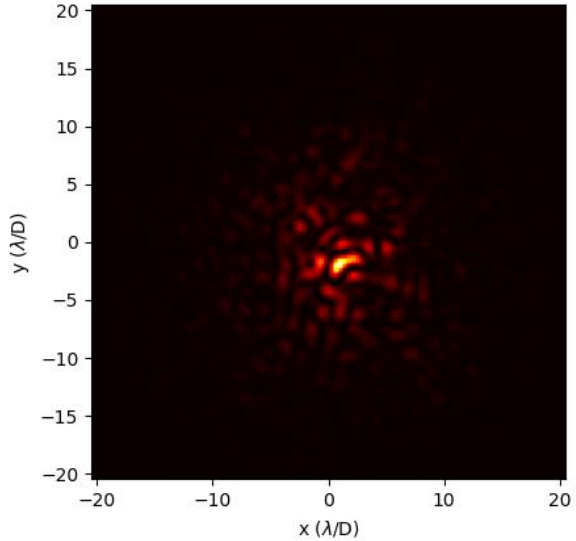


PSE reconstruction of Mars with a selection of 5 %.

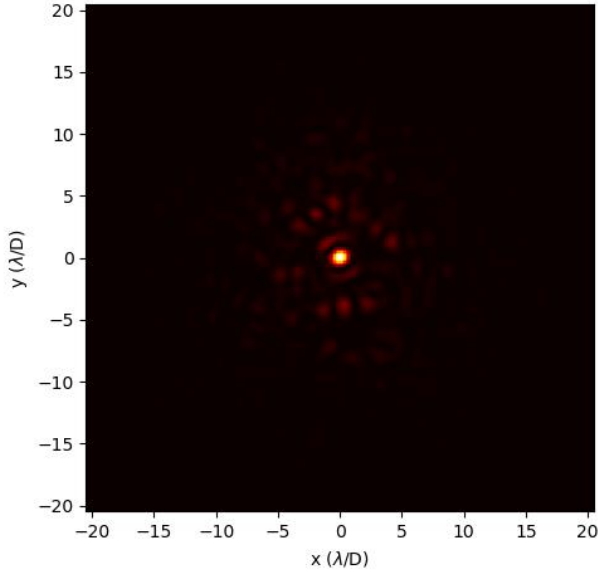
Simulation with AO correction :

Data simulated with CAOS[5] and different level of AO correction, Strehl ratios ≈ 0.024, , 0.036, 0.059, 0.075, 0.095, 0.106, 0.170, 0,205.

Diameter	1,54 m
Wavelenght	700 nm
Sampling	0",015
r0	5 cm
L0	25 m



Simulated post-AO PSF with a Strehl ratio of 2,4%

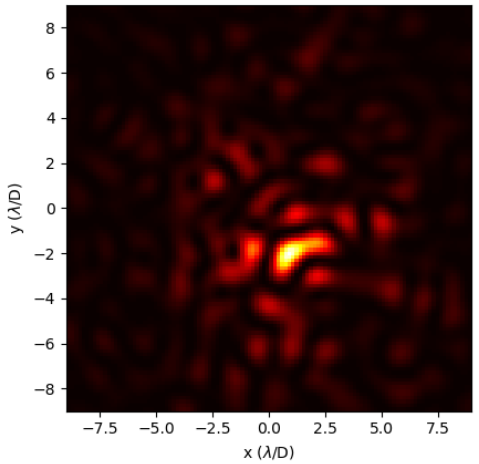


Simulated post-AO PSF with a Strehl ratio of 20,5%

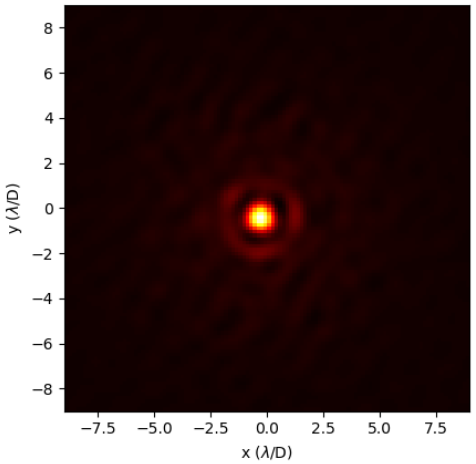
(5) Carbillet, M., Vérinaud, C., Femenía, B., Riccardi, A., & Fini, L. (2005).

Comparaison with Image Synthesis Based on Fourier Amplitude Selection (ISFAS)[6] :

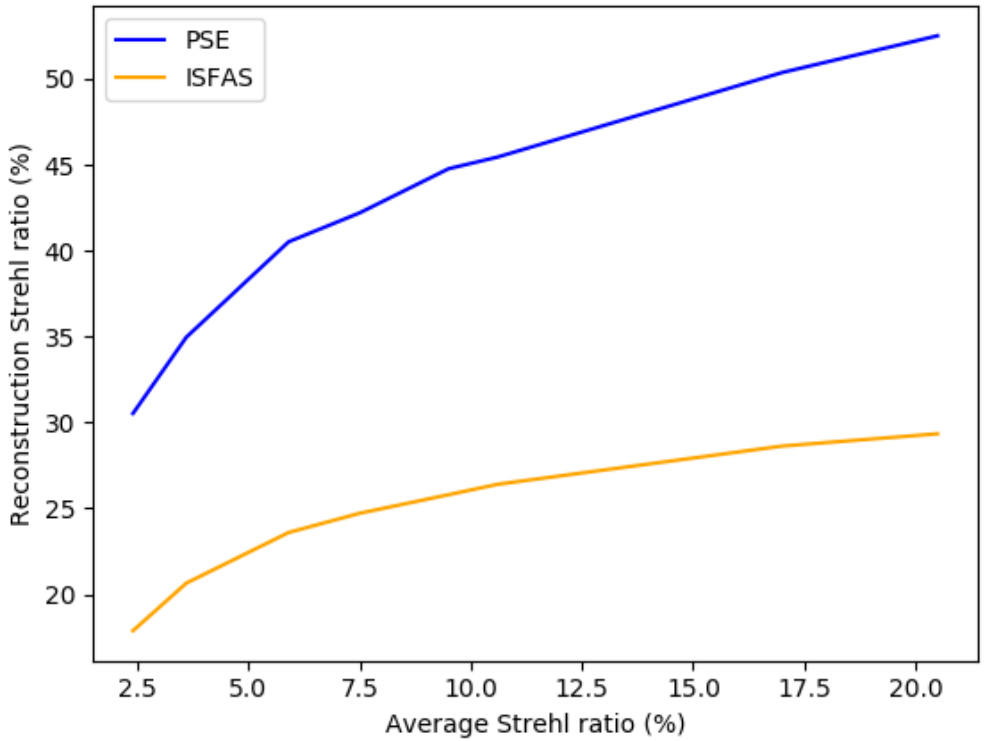
We compare the PSE method with one of the most advance Lucky technique ISFAS. For this we compute for the reconstruction the Strehl ratio :



PSF short exposure post OA with a Strehl ratio of 2,5%



PSE Reconstruction of PSF with a selection of 10%, with a Strehl ratio of 30%



Strehl ratio of the reconstruction for the two methods, with a selection rate of 10%

(6) Garrel, V., Guyon, O., & Baudoz, P. (2012).

thank you for listening to me, if you have any questions, you are welcome

References

(1) Fried, D. L. (1978). Probability of Getting a Lucky Short-Exposure Image Through Turbulence. *J Opt Soc Am*

(2) Baldwin, J. E., Tubbs, R. ., Cox, G. ., Mackay, C. D., Wilson, R. W., & Andersen, M. . (2001). Difraction-limited 800 nm imaging with the 2.56 m Nordic Optical Telescope. *Astronomy and Astrophysics*

(3) Cottalorda, E., Aristidi, E., Carbillet, M., Guinard, M., & Vourc, S. (2020). Power Spectrum Extended Method. *Draft Article*

(4) Aristidi, E., Cottalorda, E., Carbillet, M., Abe, L., & Makki, K. (n.d.). The power spectrum extended technique applied to images of binary stars in the infrared. *SPIE Conference*.

(5) Carbillet, M., Vérinaud, C., Femenía, B., Riccardi, A., & Fini, L. (2005). Modelling astronomical adaptive optics - I. The software package CAOS. *Monthly Notices of the Royal Astronomical Society*.

(6) Garrel, V., Guyon, O., & Baudoz, P. (2012). A Highly Efficient Lucky Imaging Algorithm: Image Synthesis Based on Fourier Amplitude Selection. *Publications of the Astronomical Society of the Pacific*,