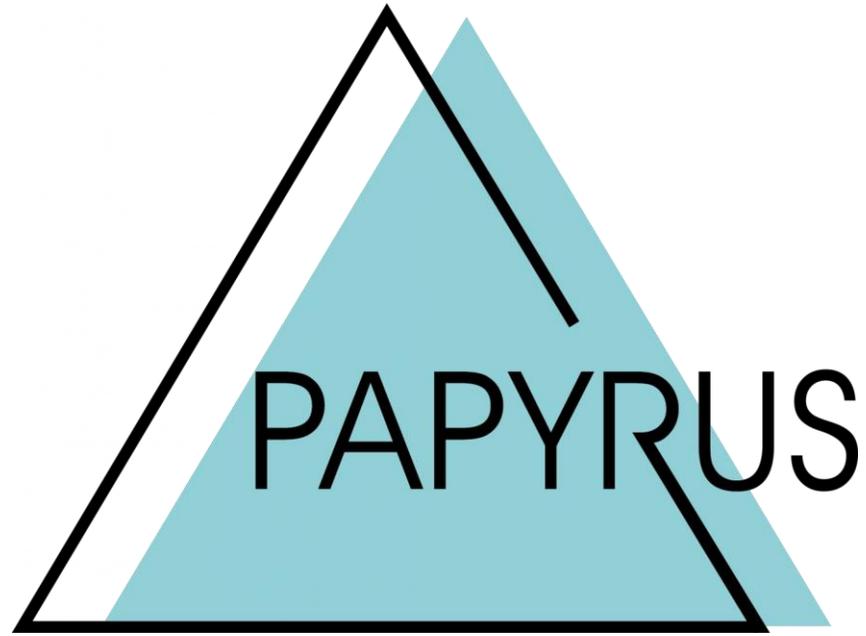


R. Fétick, V. Chambouleyron,
 I. Boudjema, F. Pedreros, E.
 Muslimov, N. Levraud, E. Soria-
 Hernandez, A. Lau, R. Lhoussaine,
 S. Karkar, A. Caillat,
 F. Leroux, M. Massa, M. Lopez,
 M. El Morsy, M. Cissé, F. Madec,
 K. El-Hadi, J-F Sauvage, B. Neichel,
 T. Fusco, J. Schmitt

Provence Adaptive-optics PYramid RUn System

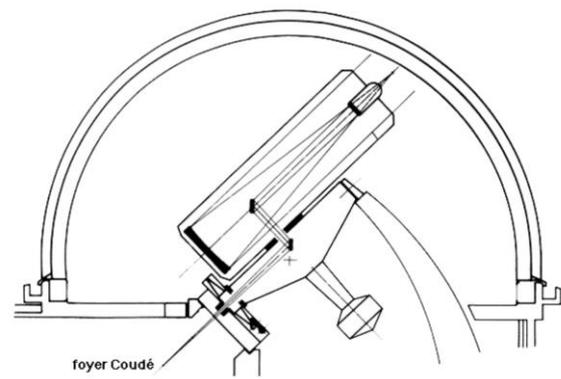
First on-sky results



Olá !

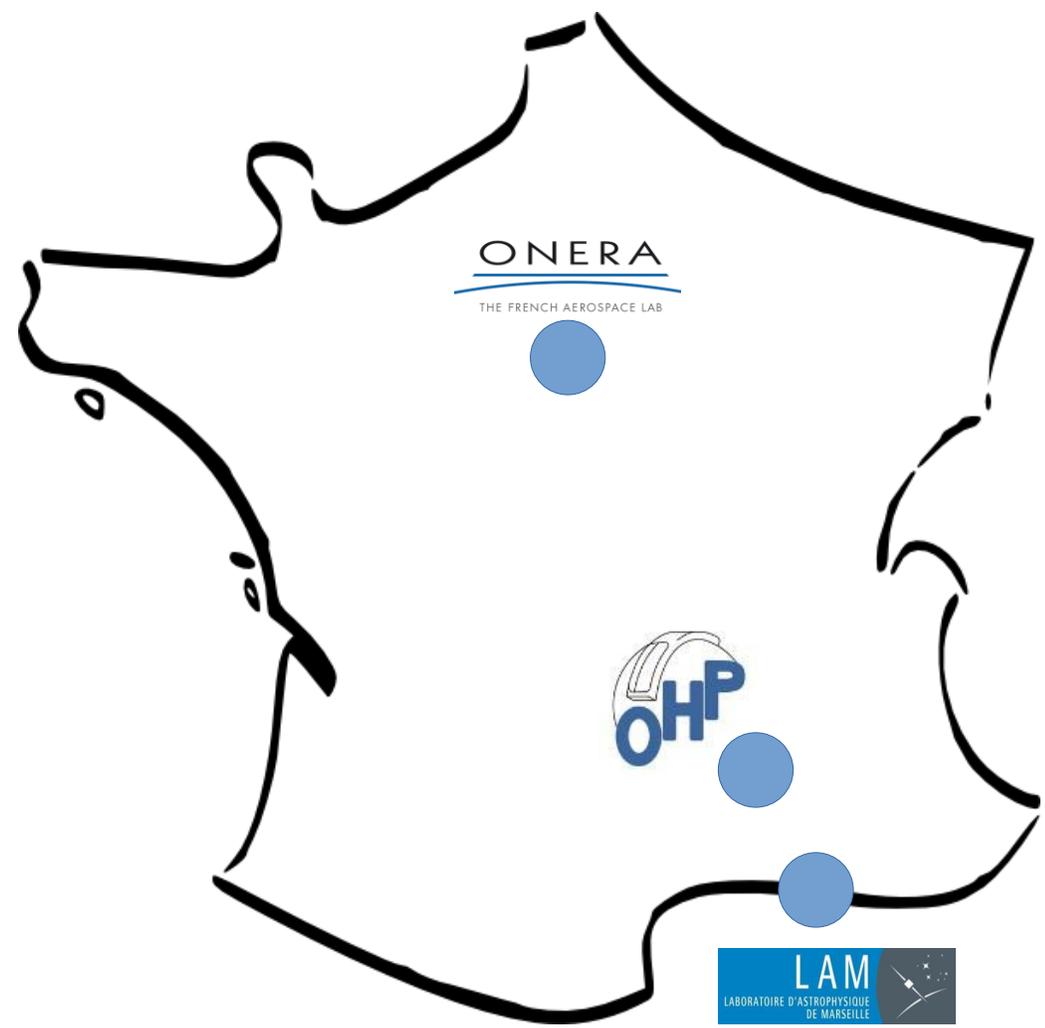
- I. OHP observatory
- II. PAPYRUS bench
- III. First on-sky results
- IV. Future of PAPYRUS

Adaptive optics system on the T-152 at OHP

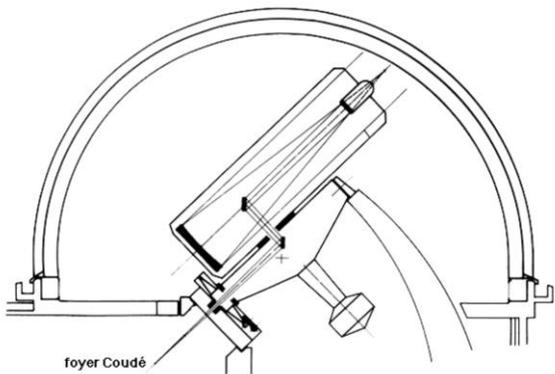


- ### T-152
- Coudé Focus
 - $f/D = 28$
 - Availability = 200 nights / year

- ### OHP
- Median seeing: 2''
 - Windspeed ~ 5 m/s



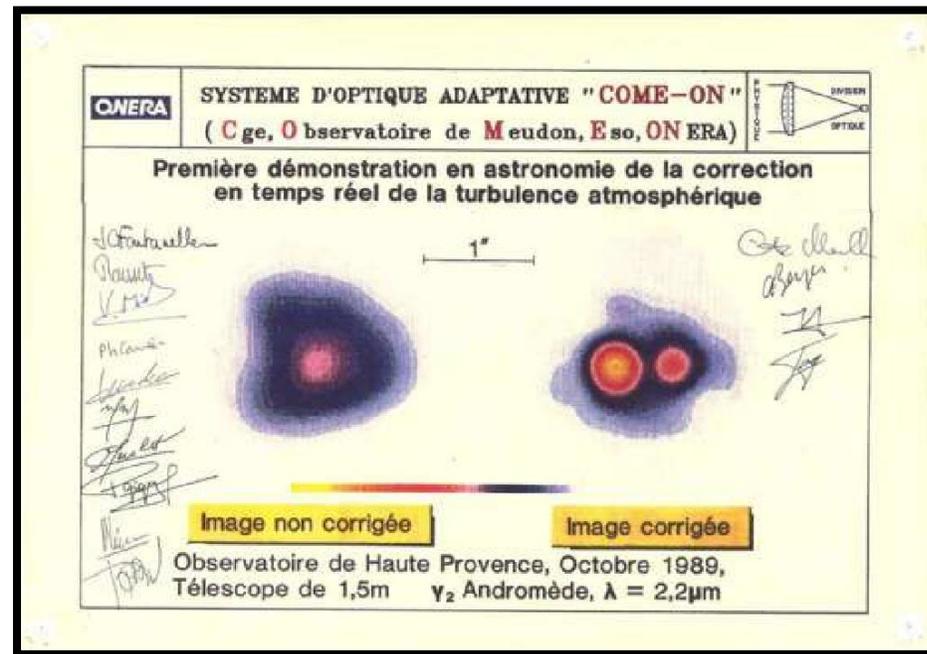
Adaptive optics system on the T-152 at OHP



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 - $f/D = 28$
 - Availability = 200 night / years

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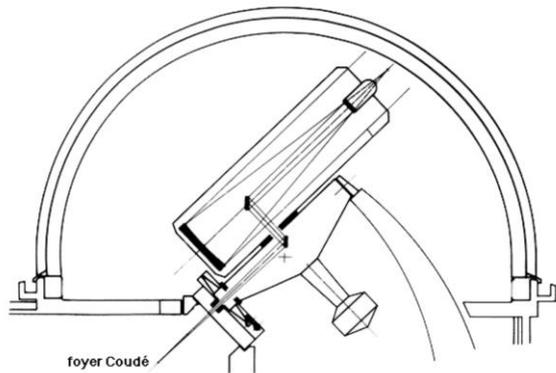
1989 : COME-ON



First astronomical AO corrected images !

19 actuators
5x5 Shack-Hartmann

Adaptive optics system on the T-152 at OHP

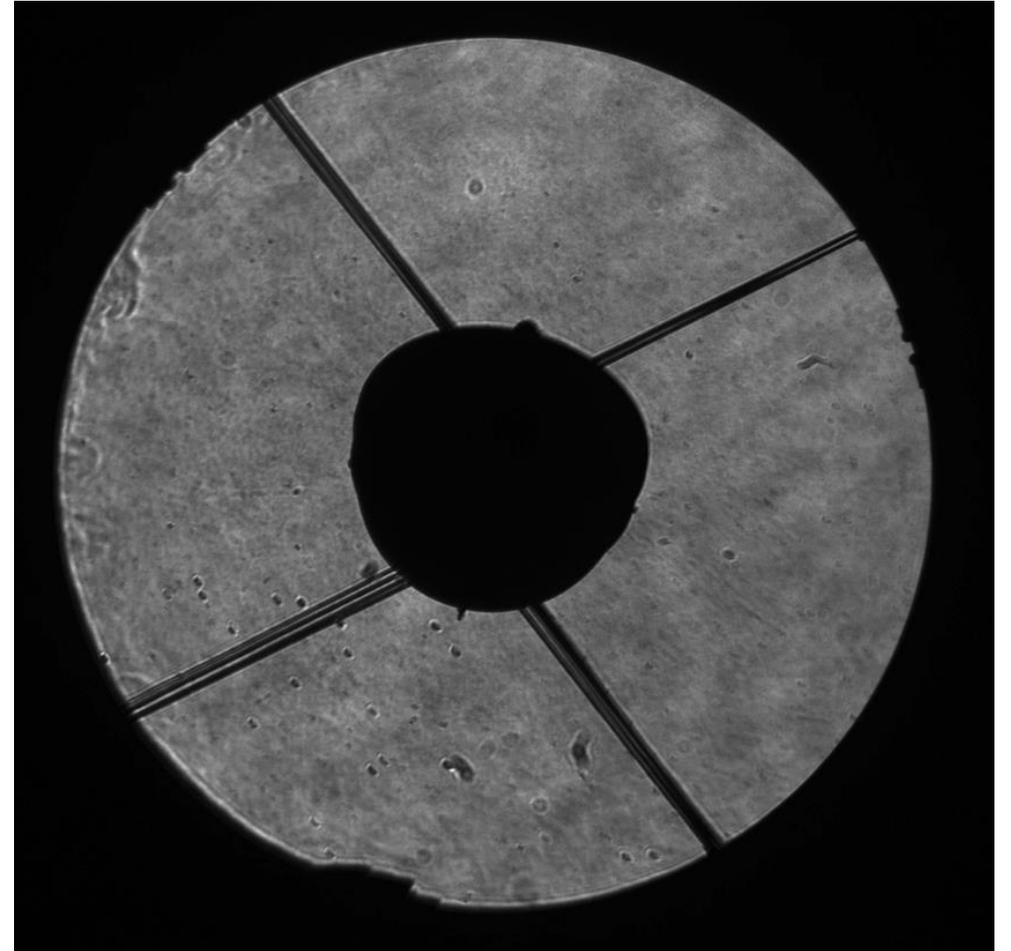


T-152

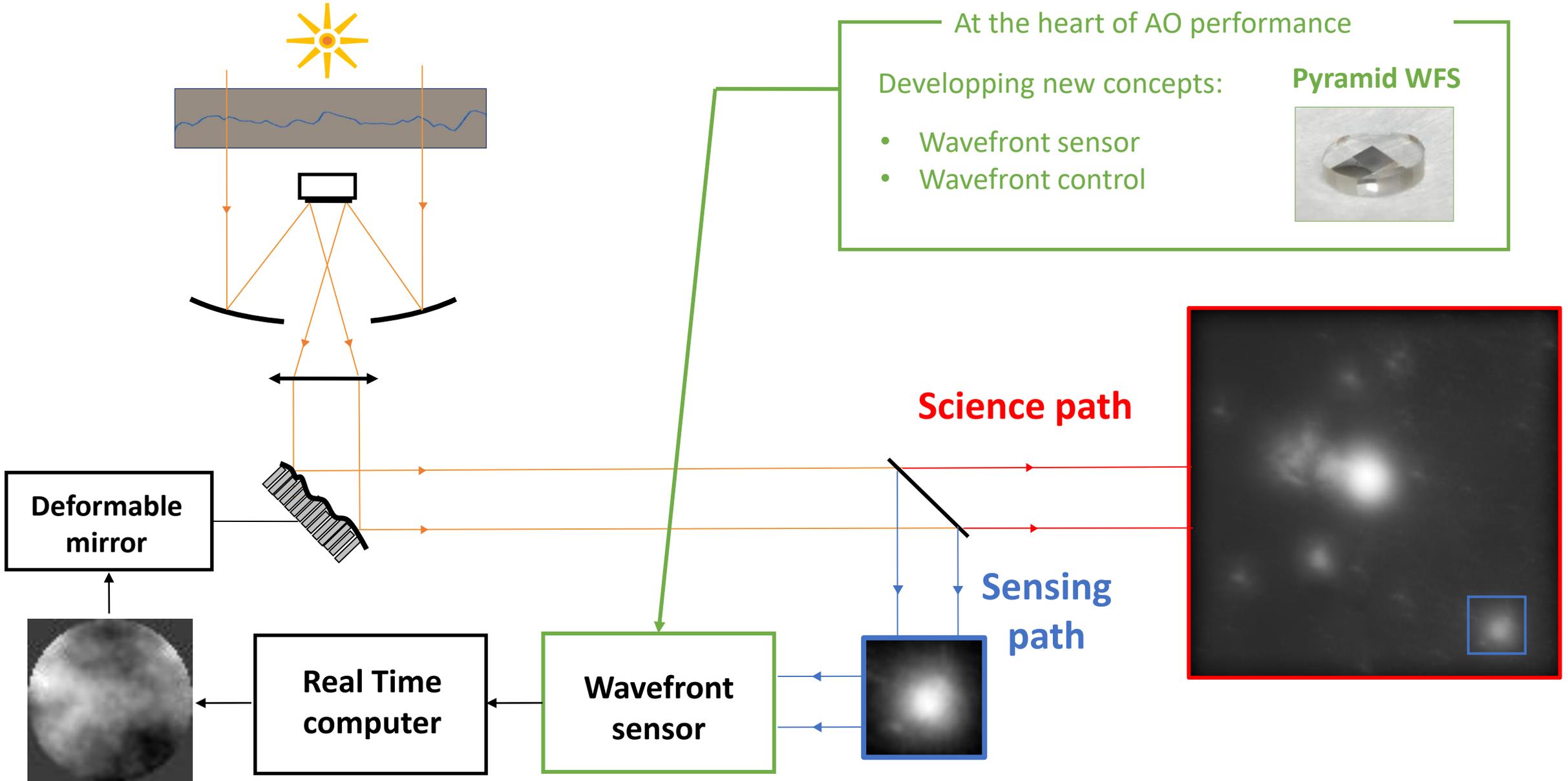
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OHP

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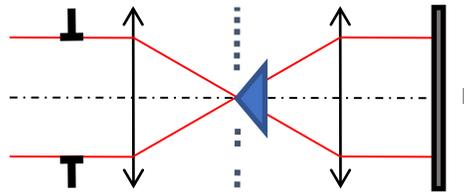
A pyramid wavefront sensor on sky



Instrumental R&D

- Test and demonstrate AO procedure with on-sky pyramid wavefront sensor
- Test new concepts of wavefront sensing and control

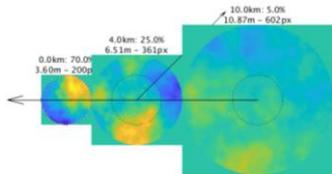
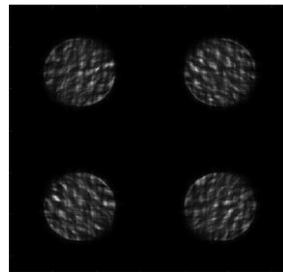
Analytical approach



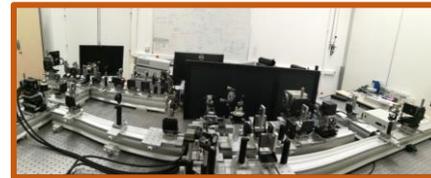
$$I(\phi) = \int_{\mathbb{R}^N} w(\vec{a}) |\mathcal{W}_m [f e^{i\phi} \mathbb{I}_P e^{i\phi_m(\vec{a})}]|^2 d^N \vec{a}$$

2014

Numerical simulations

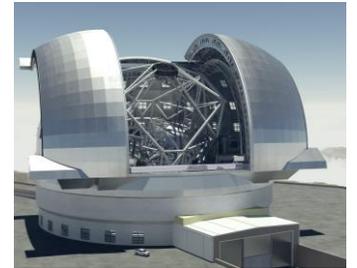
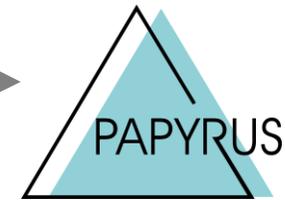


Lab work *LOOPS Bench*



2017

On sky



ELT-HARMONI

2026

Instrumental R&D

- Test and demonstrate AO procedure with on-sky pyramid wavefront sensor
- Test new concepts of wavefront sensing and control

Educational

- Project developed and led by students: Ph.D., interns and Postdocs (kick-off: January 2020)
- Pedagogic purpose: to be used for summer school at OHP

1st pedagogical Pyramid bench in the world

Astronomical

- High angular resolution back at OHP (80 mas in the visible)
- Possibility to add new instruments: coronagraph, spectrometer, etc...

We have some unused components → What can we do ?

AO branch

- DM 17x17 actuators (pitch = $2 \times r_0$ at 635 nm)
- AO freq = 500 Hz (>1.5 kHz with ALPAO RTC)
- Visible broadband WFSing
- Modulated pyramid (first tests at $5 \lambda/D$)
- Mag V < 5-6

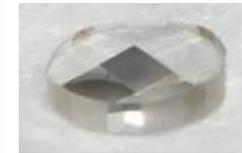
DM 17x17



Fast EMCCD



Pyramid



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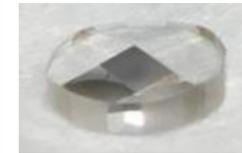
DM 17x17



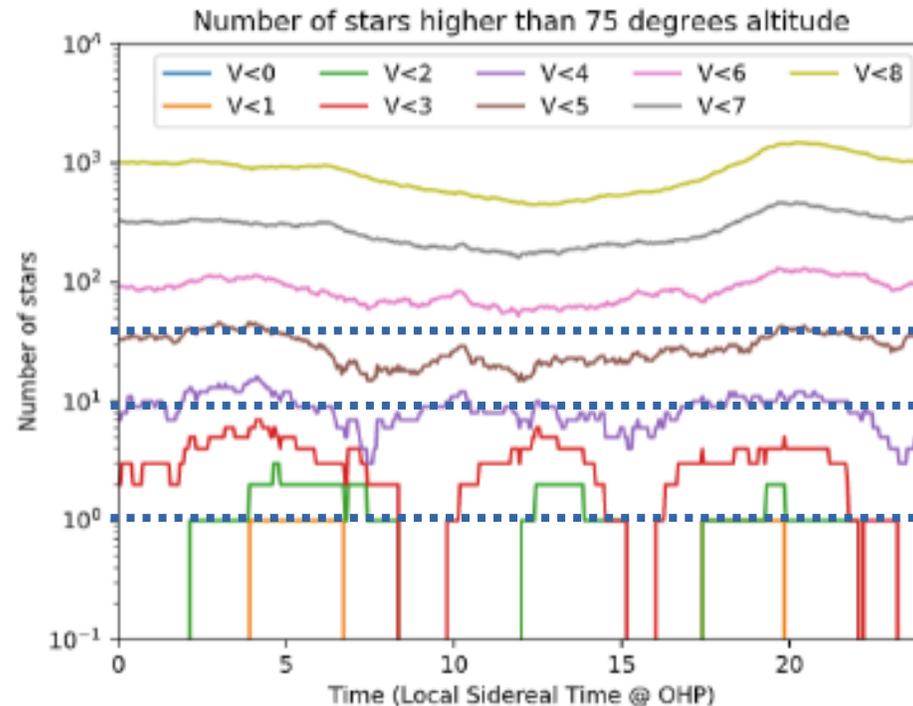
Fast EMCCD



Pyramid



FIRST LIGHT
ADVANCED IMAGERY



On-sky performance

Design prediction (with margins)

Minimum requirement

We have some unused components → What can we do ?

AO branch

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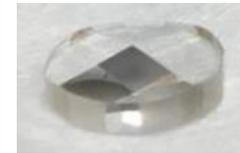
DM 17x17



Fast EMCCD



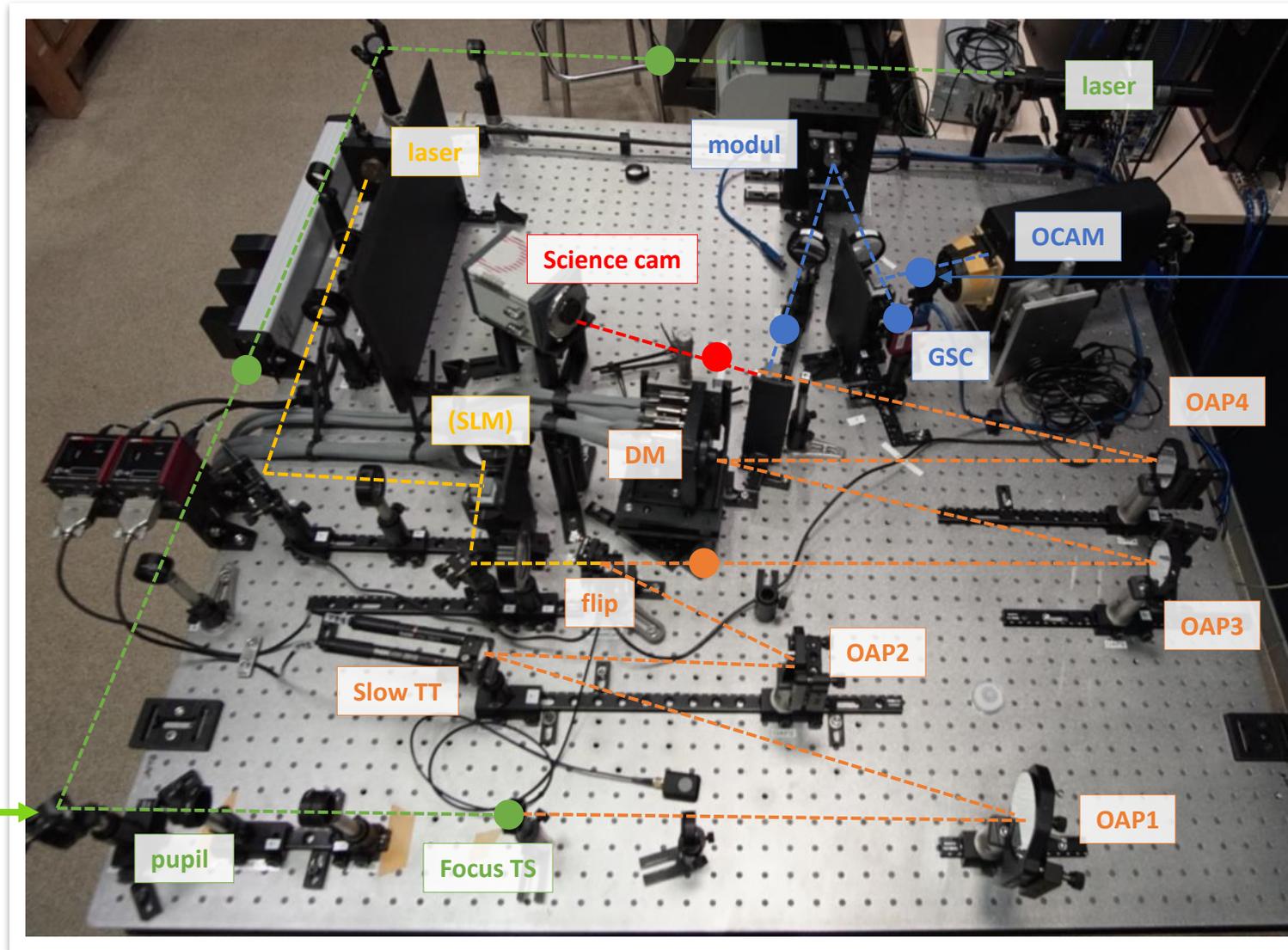
Pyramid



Science branch

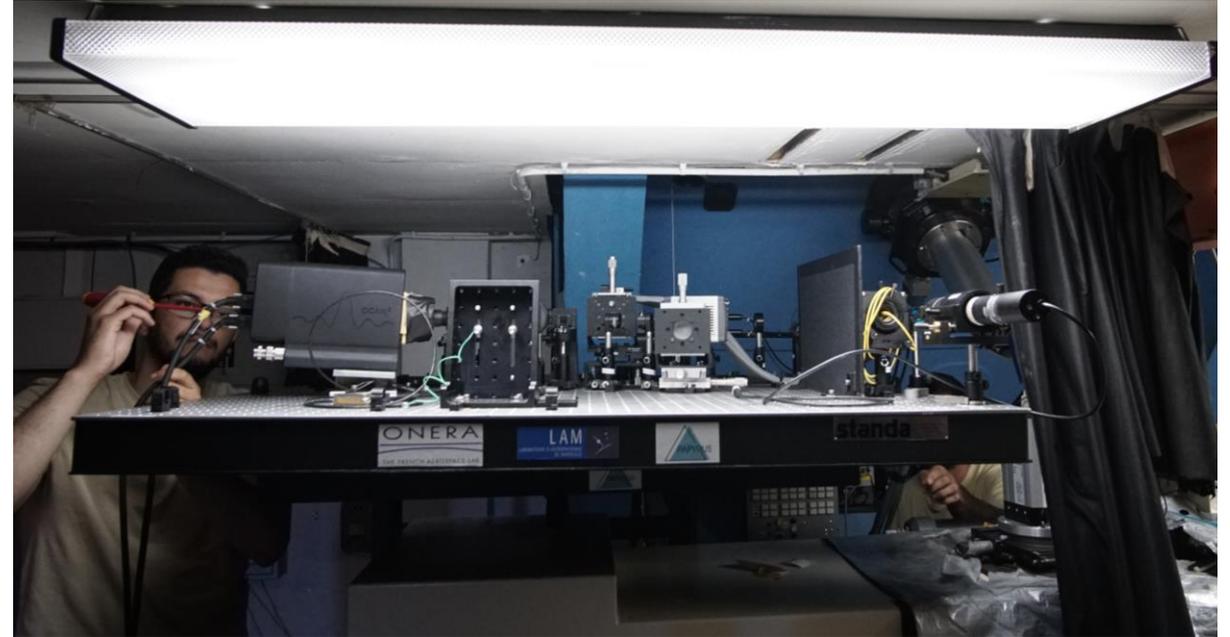
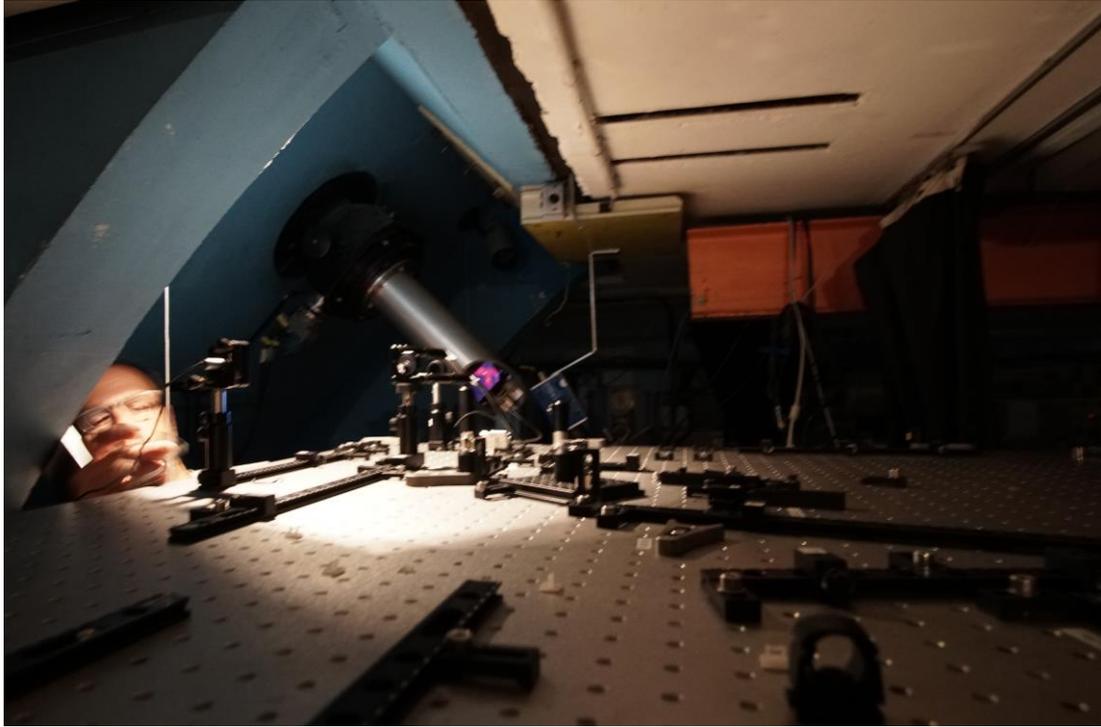
- Visible camera so far (filter = 635 nm)
- Possibility to extend to NIR (mirror based design)

PAPYRUS optical layout

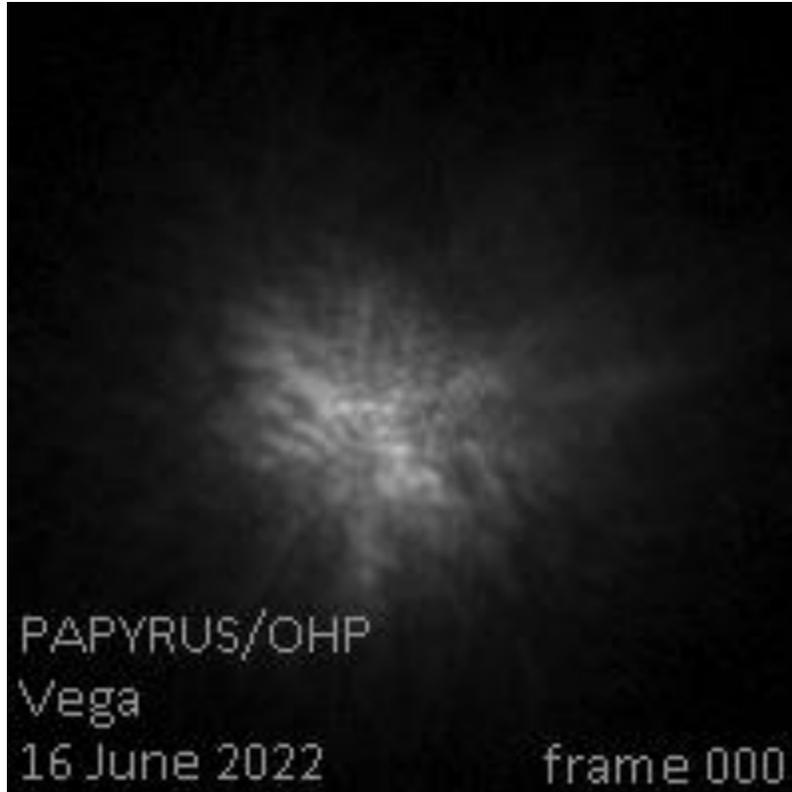


LEGEND

- Telescope simulator
- Common path
- Sensing path
- Science path
- Calibration unit
- Focal point



Strehl Ratio = 0.3%



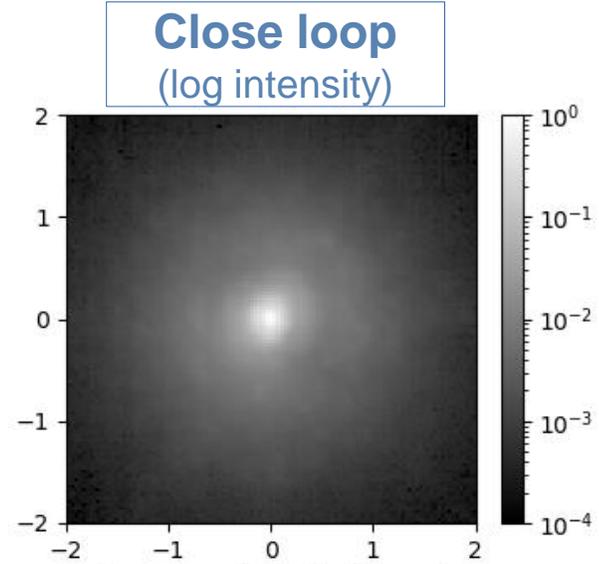
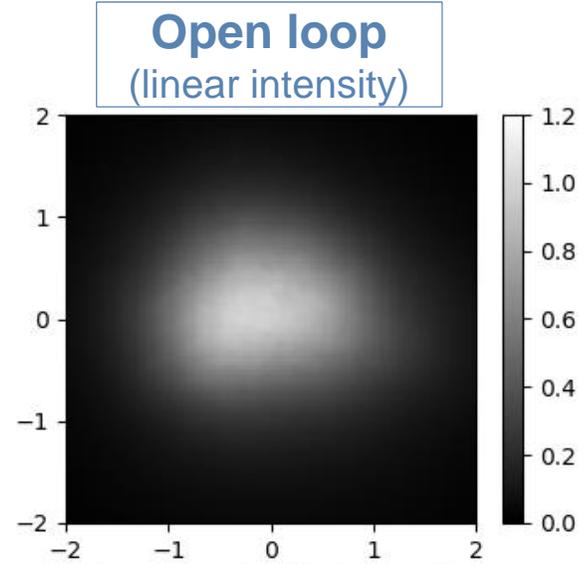
Strehl Ratio = 15%



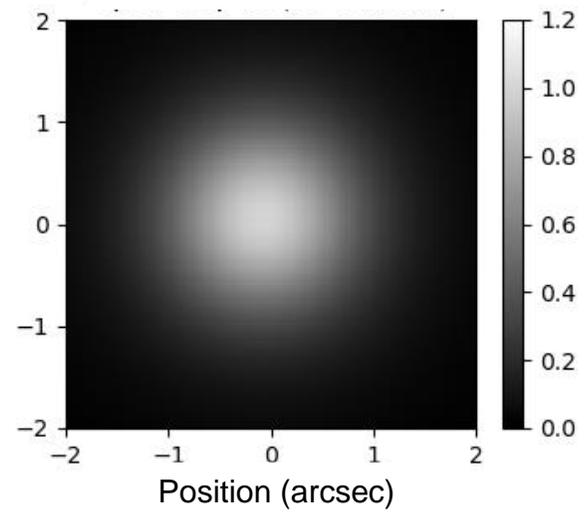
$\lambda = 635 \text{ nm}$
 $\Delta\lambda = 40 \text{ nm}$
Loop freq. = 500 Hz

PSF fitting results

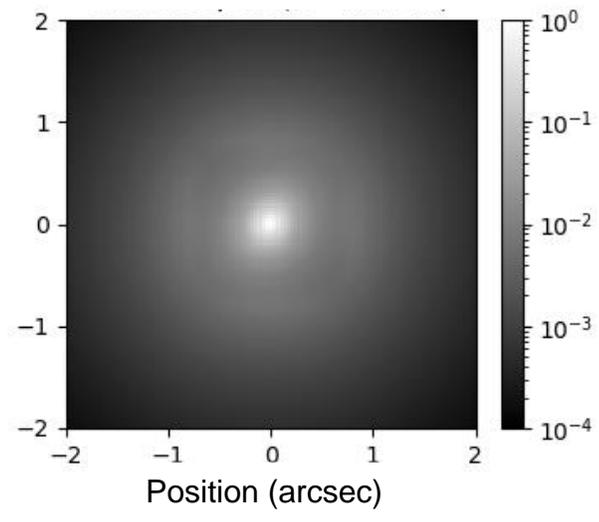
Data



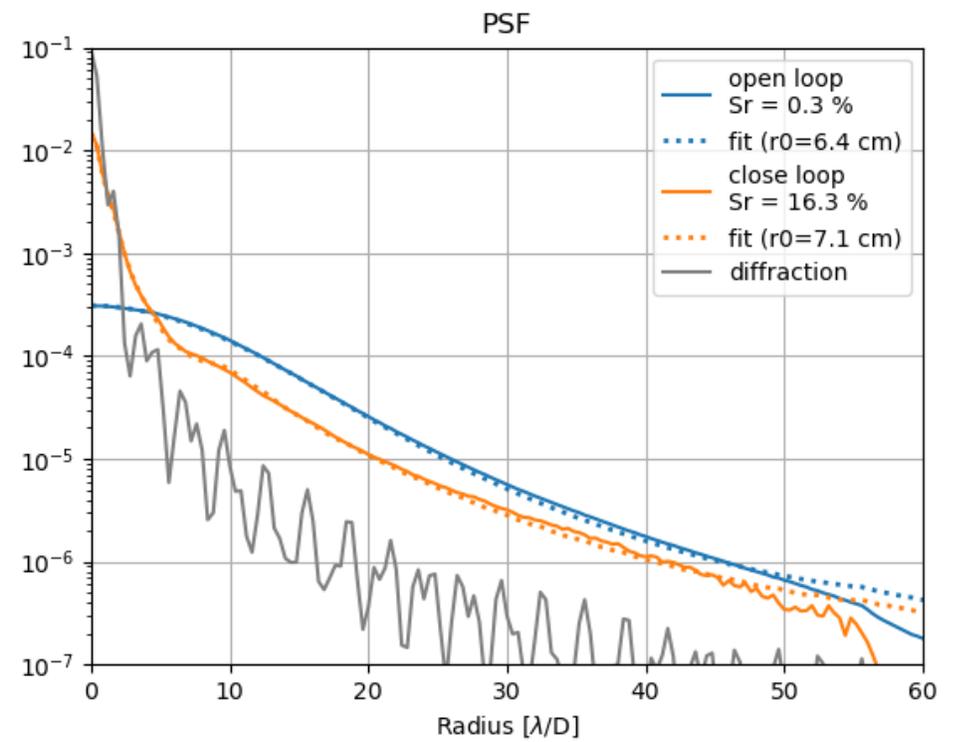
Model fit



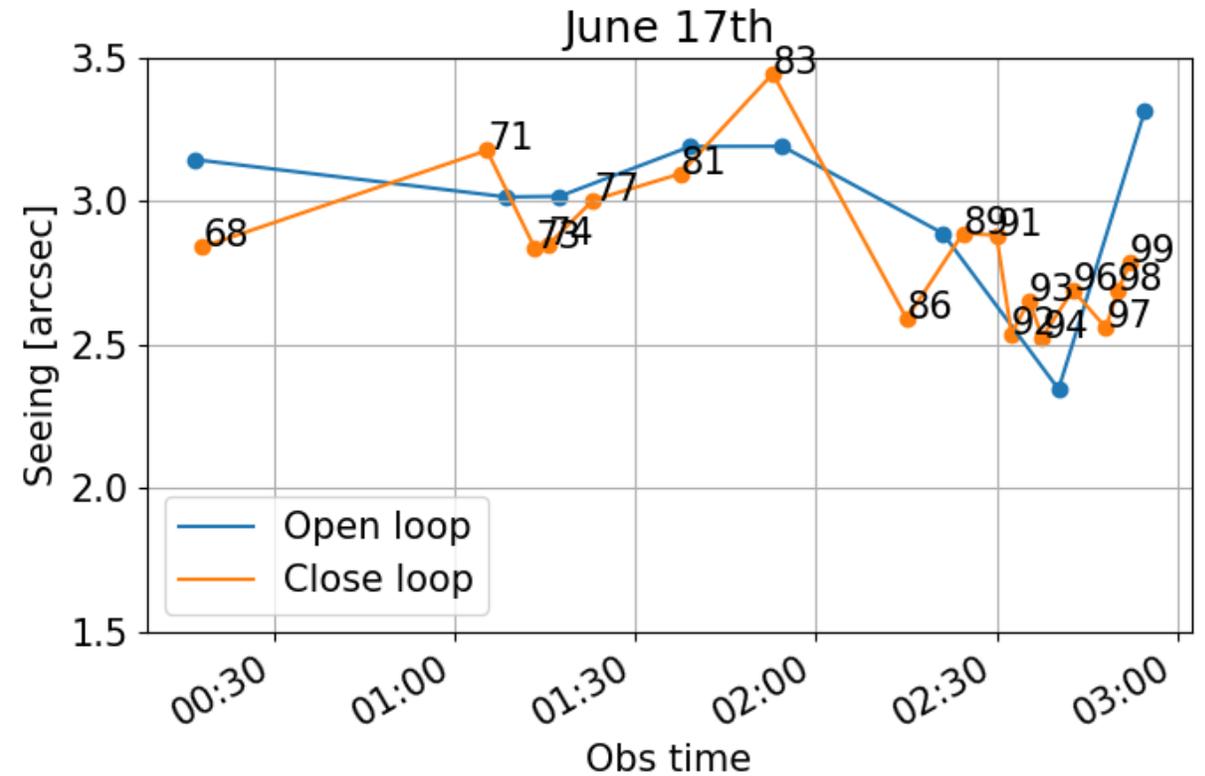
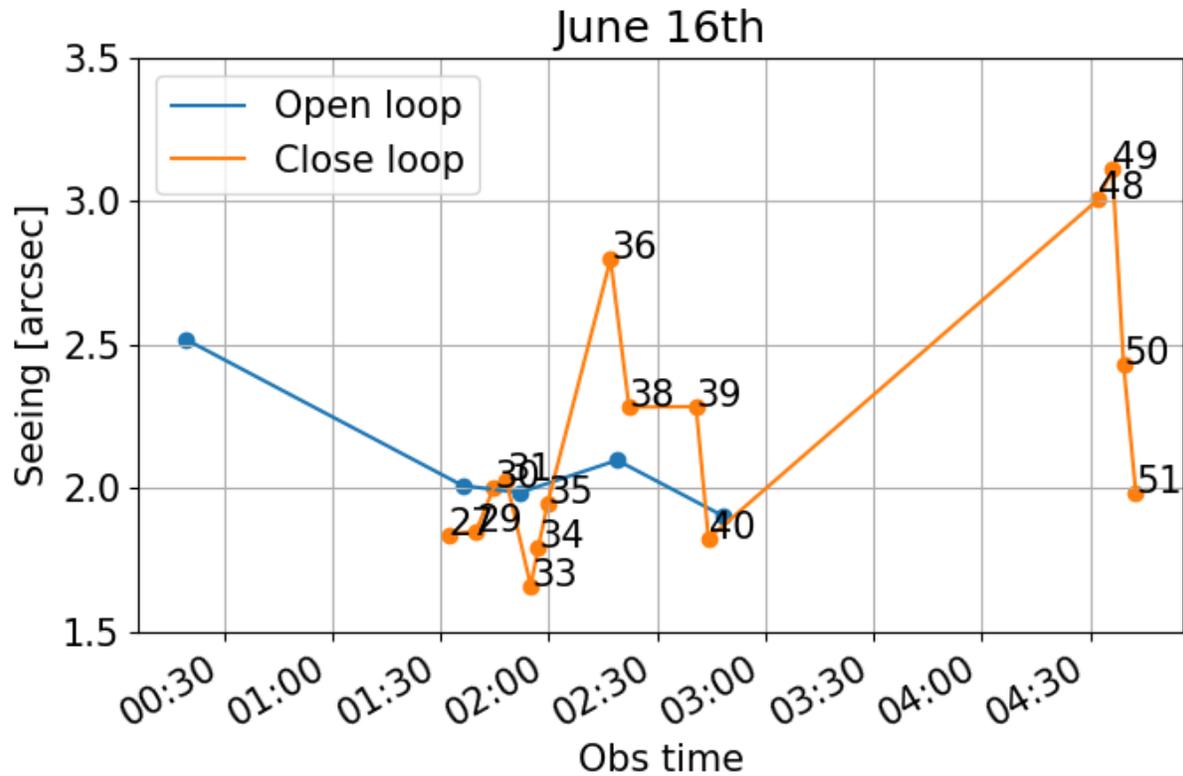
Sr = 0.3 %
r0 = 6.4 cm



Sr = 16 %
r0 = 7.1 cm



PSF fitting results

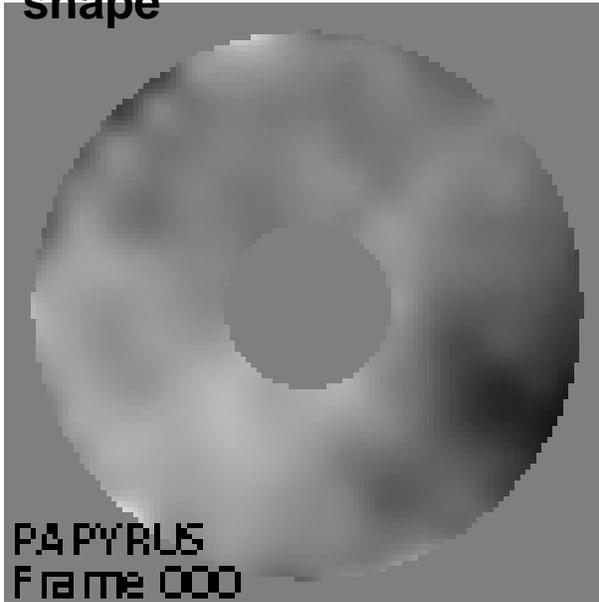


- Correct agreement between OL and CL fitting
- PSF fitting : $1.5'' < \text{seeing} < 3''$
- IRIS seeing monitor : $1'' < \text{seeing} < 1.5''$
- Mismatch \rightarrow different estimation method, T152 induced turbulence

DM shape : **work in progress**



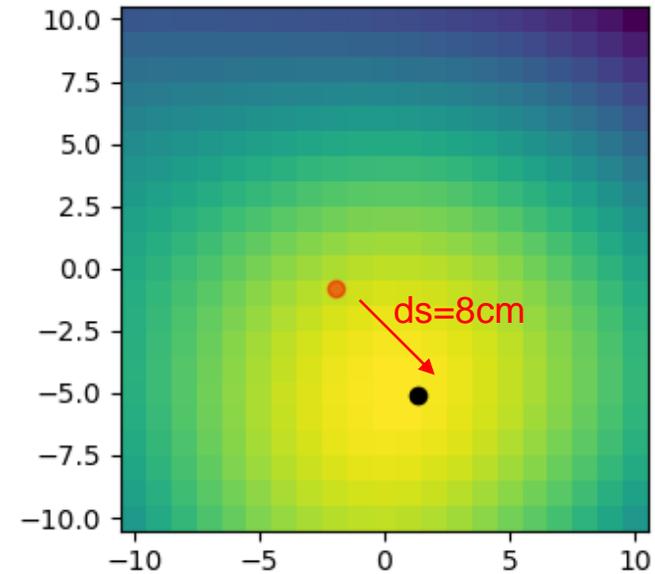
**DM reconstructed
shape**



Correl(frame[i], frame[i+15])

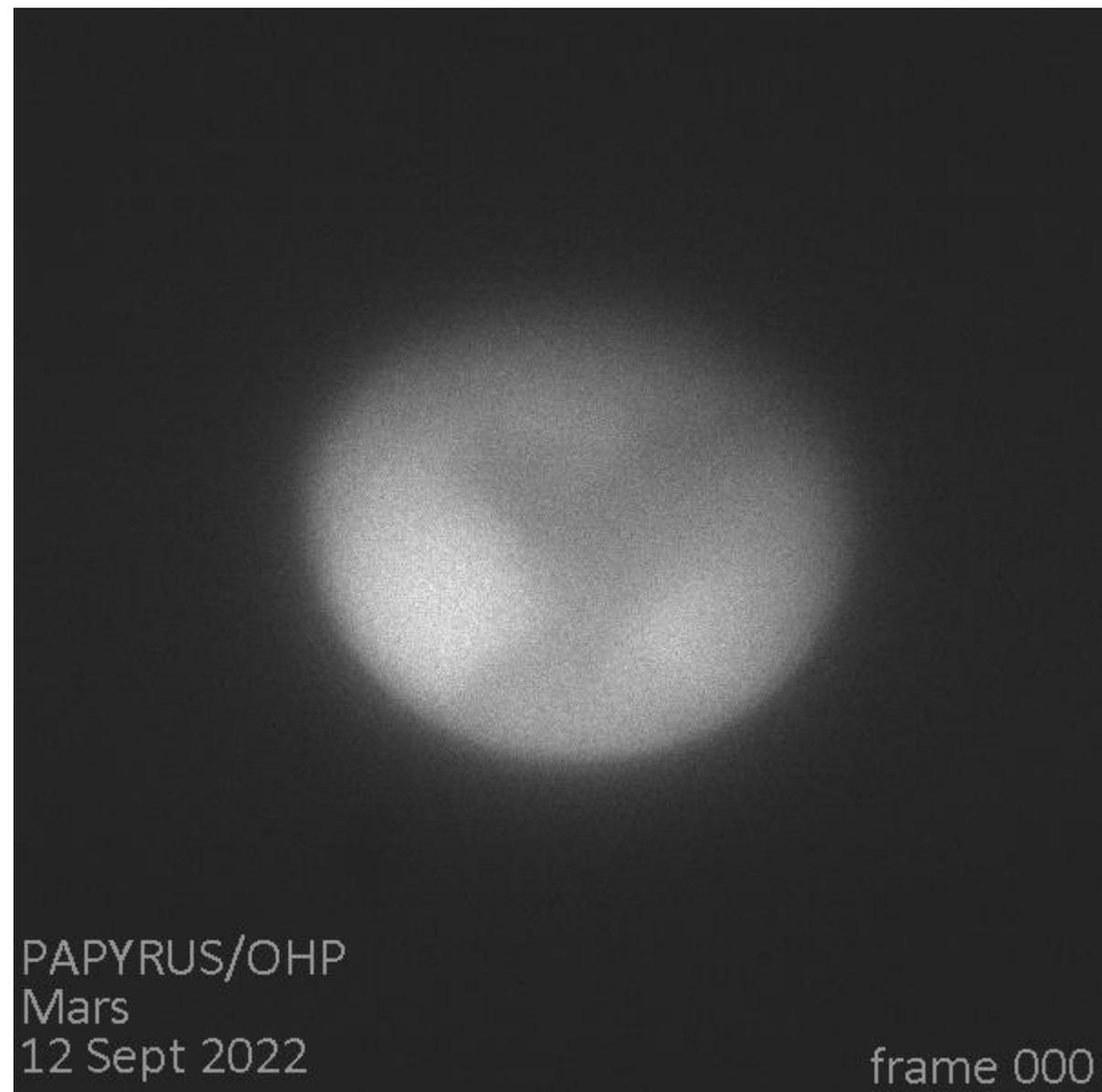
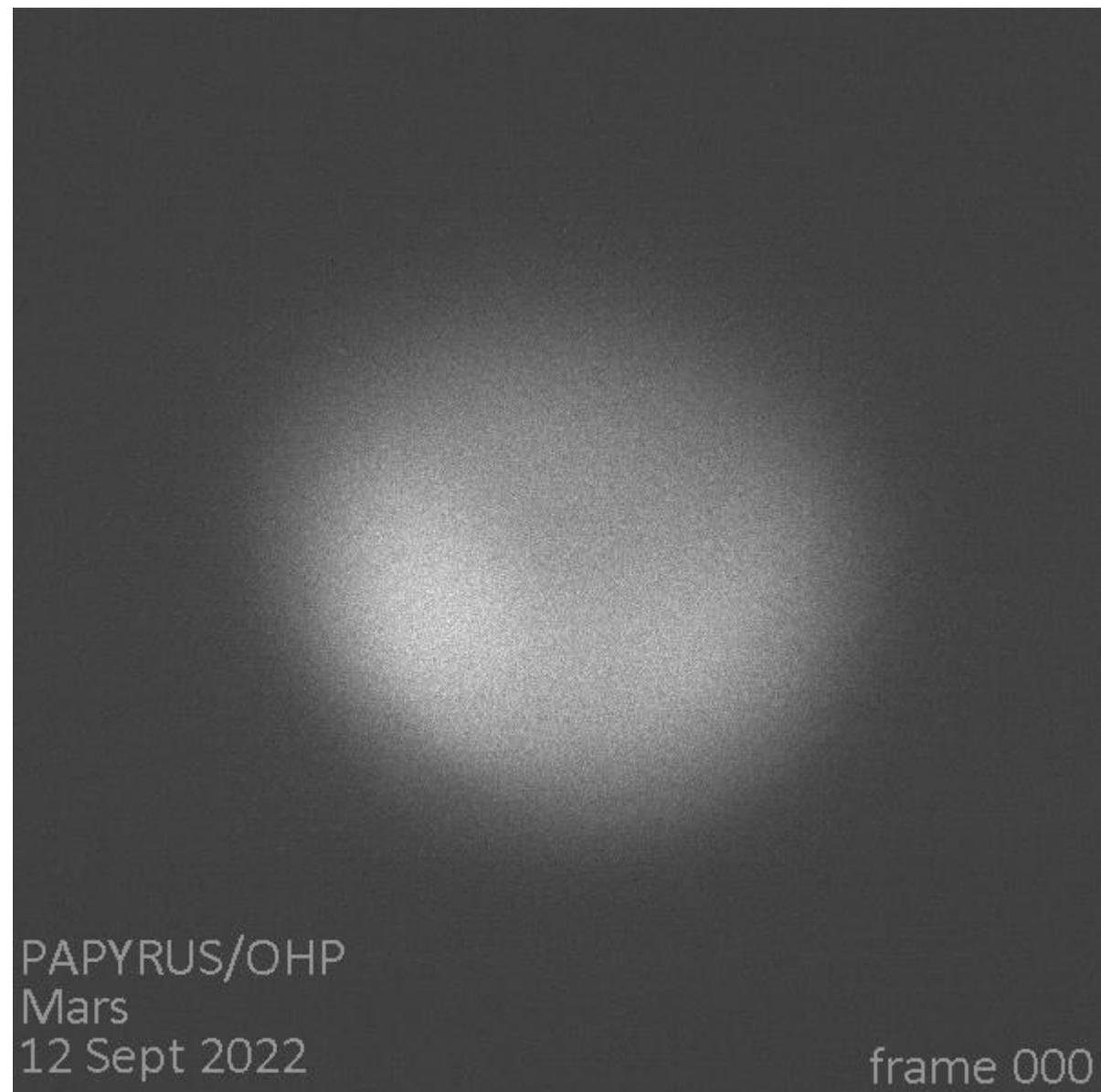
$dt=(15 \text{ frames})/(500\text{Hz}) = 30 \text{ ms}$

Phase correlation
15 frame shift

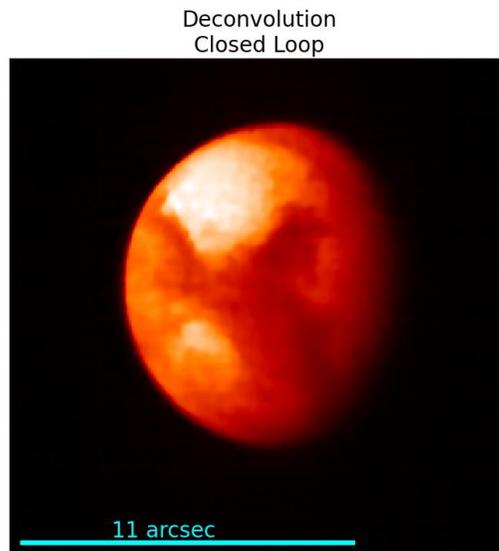
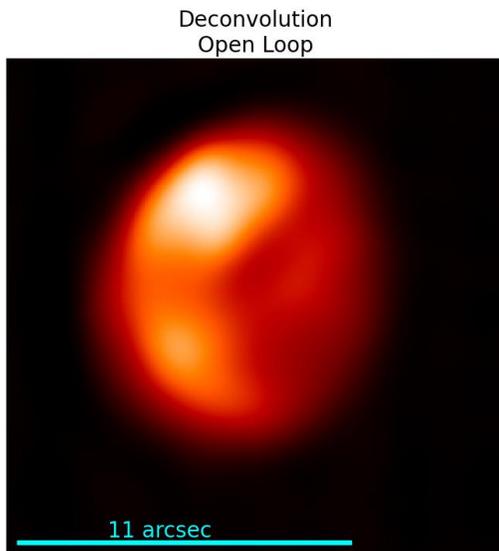
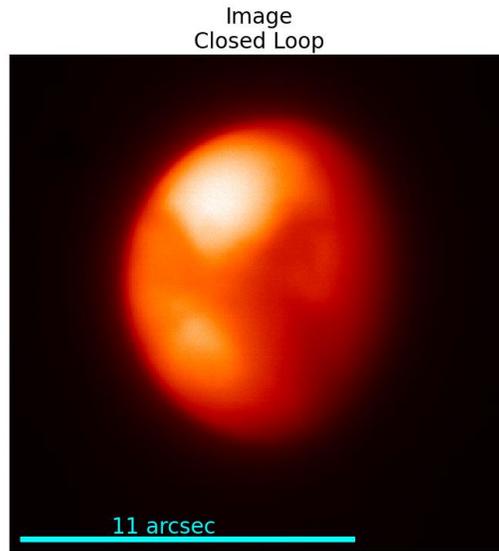
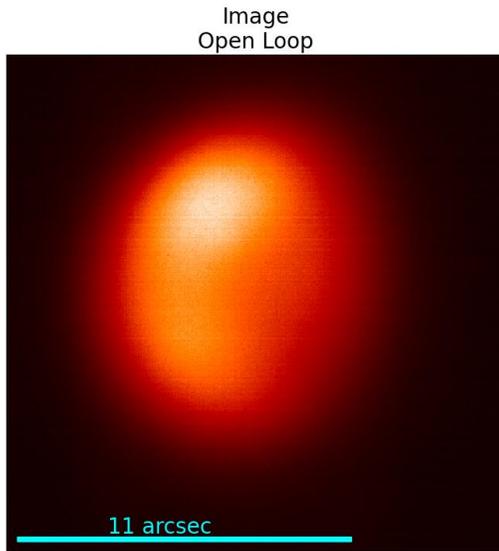


$$V = dt/ds = 2.7 \text{ m/s}$$

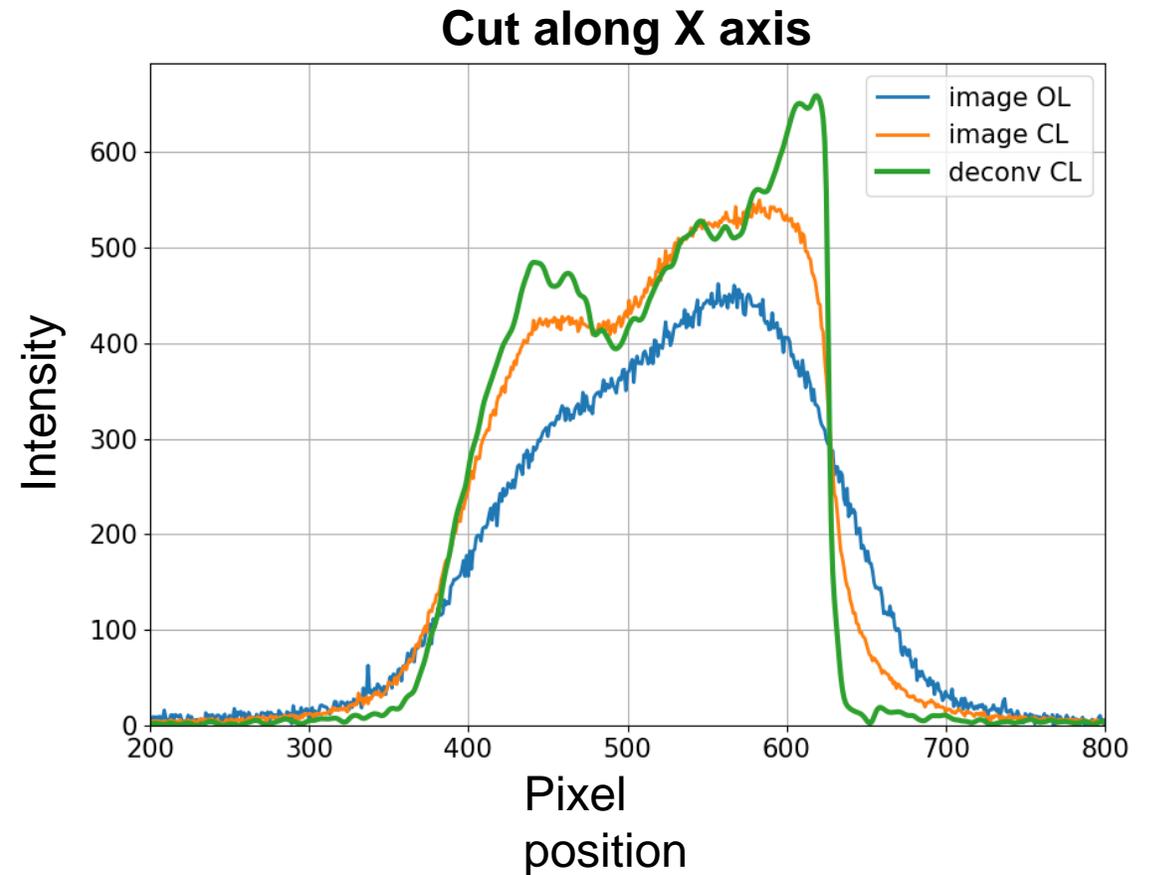
Closing the pyramid on Mars



Closing the pyramid on Mars



- Extended object : 120 MD
- Seeing $\sim 2.6''$
- Sr $\sim 5\%$ (at 635 nm)
- Applications to solar system observations



Next Steps

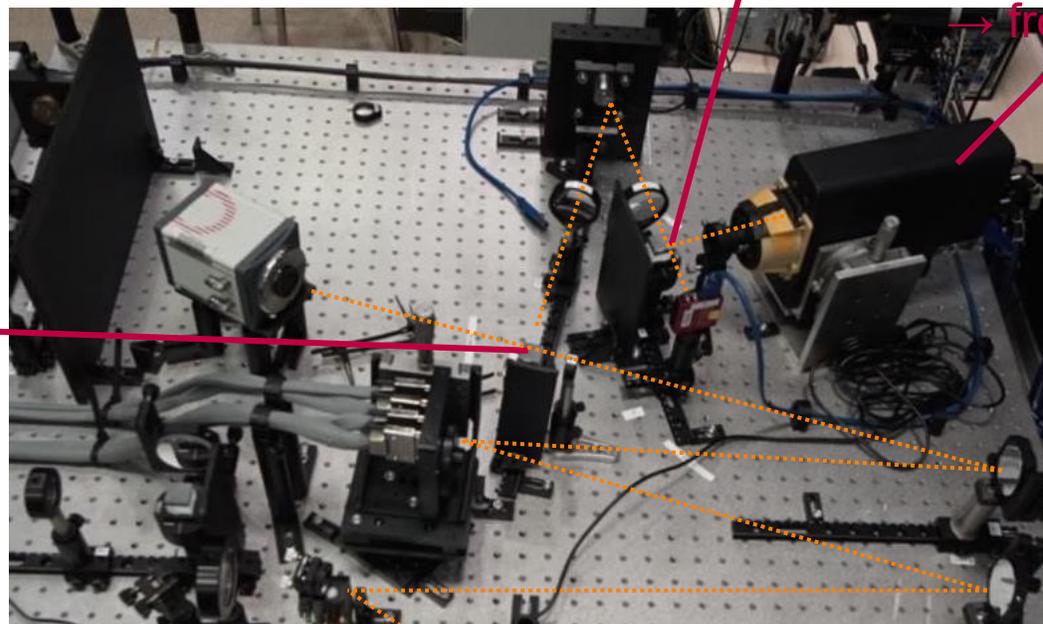
Short-term : commissioning

- Improve and characterize performances
 - Kill the temporal error (ALPAO RTC)
 - Improve SNR on OCAM
 - Comparison with simulations
 - Push performance on extended objects
- Test the bench with IR camera

OCAM/GSC beam-splitter
→ splitting ratio ?

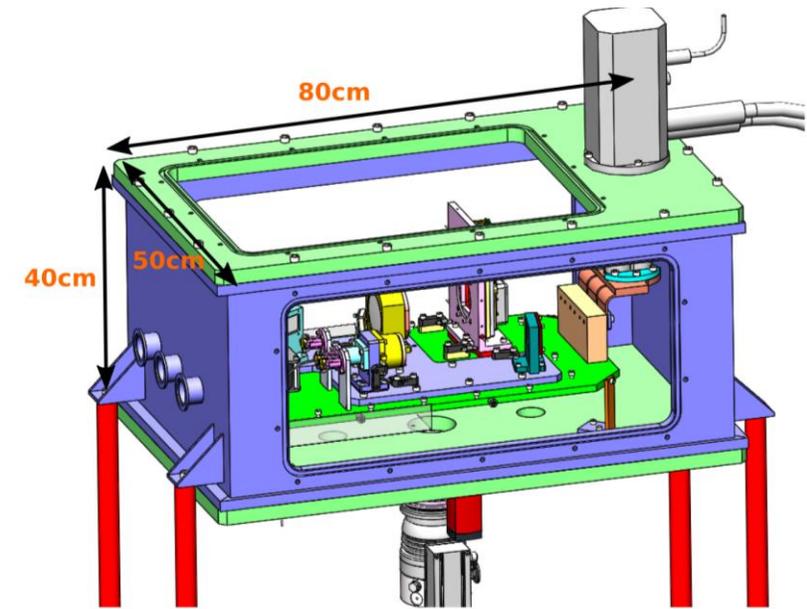
OCAM EMCCD
gain
→ from 300 to 1000

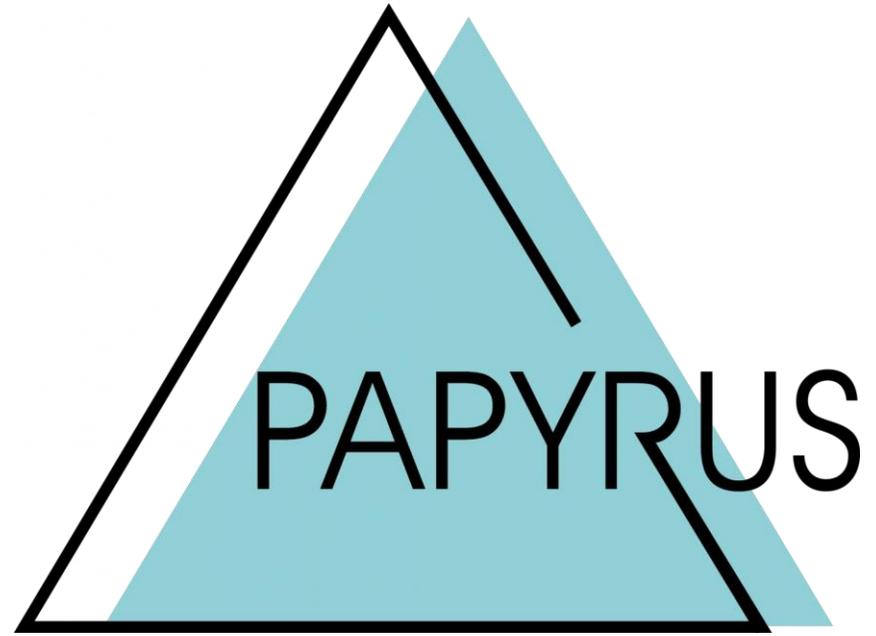
WFS/science beam-splitter
→ visible/IR dichroic



Long-term : objectives

- Test WFS control algorithms
 - pyramid and petalling (N. Levraud)
- Test innovant WFS techniques
 - 2nd stage double Zernike (M. Cissé)
- Welcome science instruments
 - VIPA portative fiber spectrometer (IPAG)
 - R=100 000
 - Band H and K
 - Fiber injection module to build





Obrigado !