ADVANCEMENTS IN ESTIMATING DIFFERENTIAL PISTONS FOR THE EXTREMELY LARGE TELESCOPE USING DEEP LEARNING

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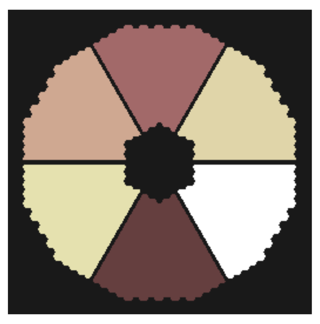
PETALING BASICS

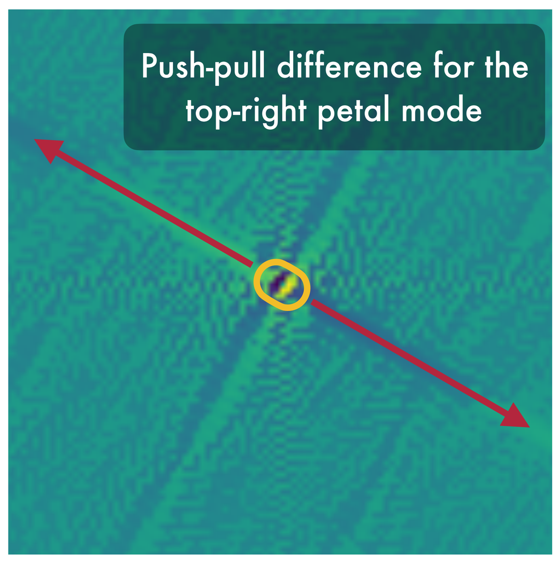
DIFFERENTIAL PISTON (OR PETALING) ARISES FROM VARIOUS SOURCES

e.g. atmosphere, thermal or mechanical effects, control loop properties.

"Petaling is bad for your observations…"

— *a wise scientist* —





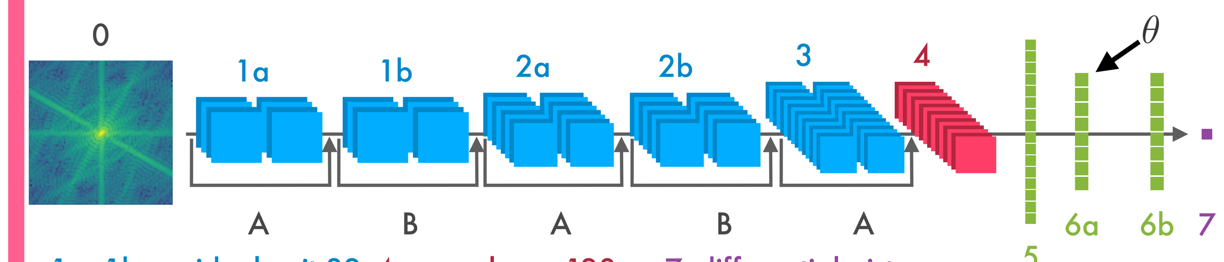
PETALING HAS A DISTINCTIVE PATTERN

Strong effect at low frequencies and ranges along a preferential direction perpendicular to the spider.

NEURAL NETWORK

RESNET ARCHITECTURE

Suited for our image application with a residual unit based architecture. The pupil rotation angle θ is integrated in the first dense layer.



1a, 1b: residual unit 32
2a, 2b: residual unit 64
3: residual unit 128
4: conv. layer 128
5: flatten
6a, 6b: dense layer
7: differential piston
A: conv. cut layer
B: identity cut layer

ONE NETWORK PER DIFFERENTIAL PISTON

Each differential piston has its own personal network as it clearly improve the performances.

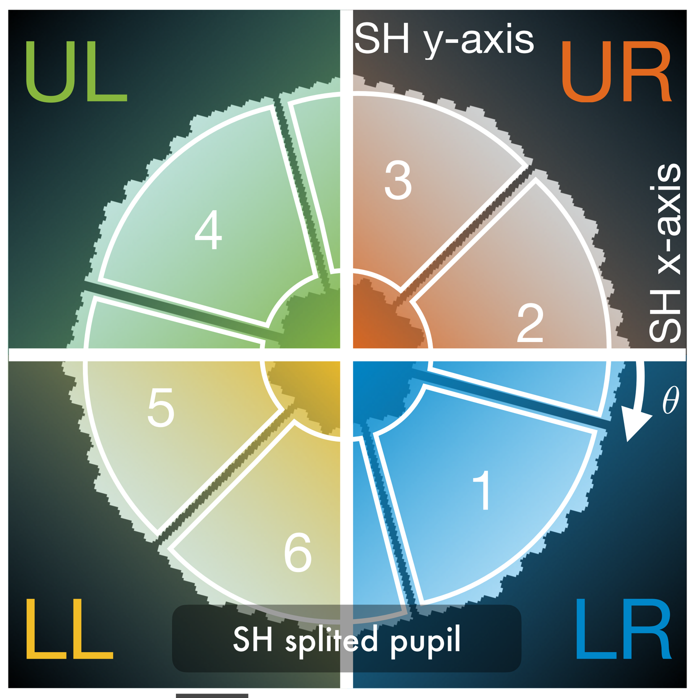
THE MODEL HAS 610K PARAMETERS AND IS TRAINED ON 300K IMAGES

We perform a hyper-parameter search on the scheduler defining the learning rate values for each configuration.

PHILOSOPHY

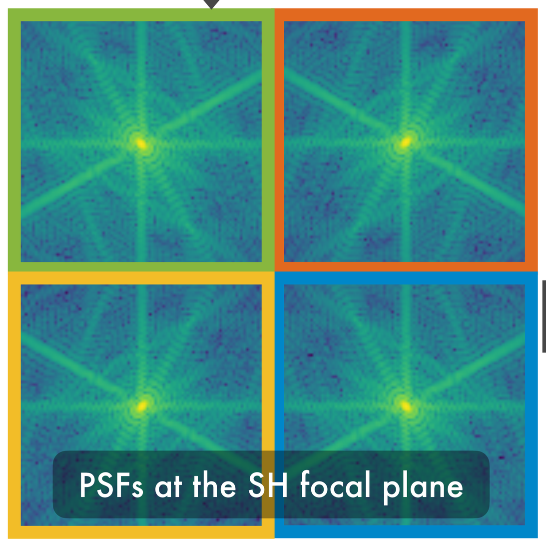
WE MEASURE DIFFERENTIAL PISTON FROM FOCAL PLANE IMAGES

Harmoni will integrate a 2x2 Shack-Hartmann WFS dedicated to the measure of low-order aberrations. The PSF produce by the sensor contains information on the differential piston.



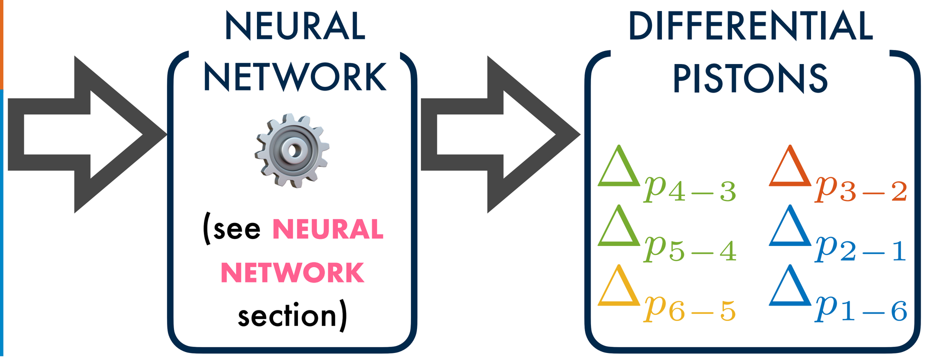
WE TRAIN NEURAL NETWORKS TO ESTIMATE PISTON FROM THESE PSF

Each of the four sub-apertures produces a PSF that encodes the information on differential piston. The network learns the relation between the differential piston value and the PSF.



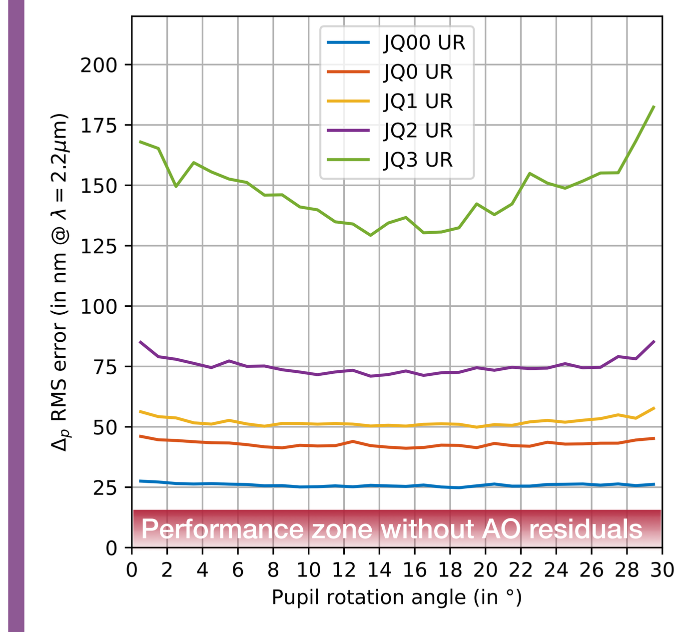
THE SYMMETRIES OF THE PUPIL REDUCE THE CASES TO BE TESTED

We only have to study the two upper sub pupils UL and UR.



RESULTS

Our previous study (Chauvet *et al.* 23) demonstrated that the network achieves high performances (RMSE < 10nm @ 2.2µm) when using single frames containing only turbulence residuals.

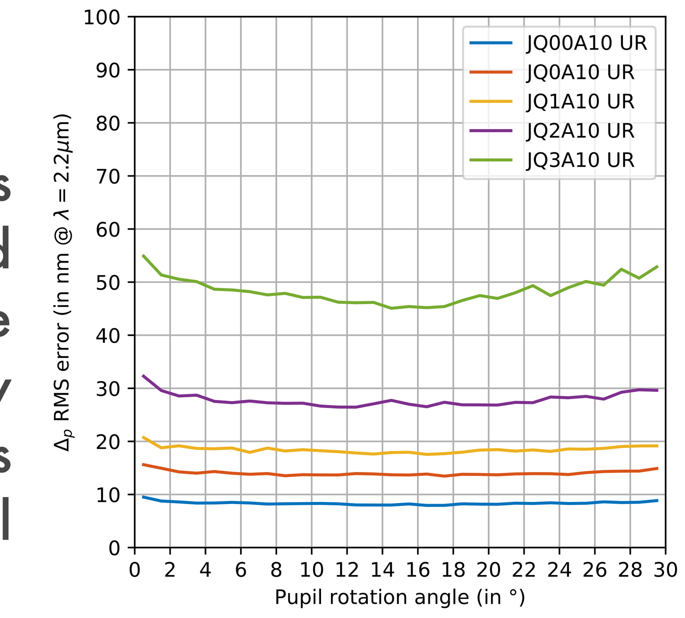


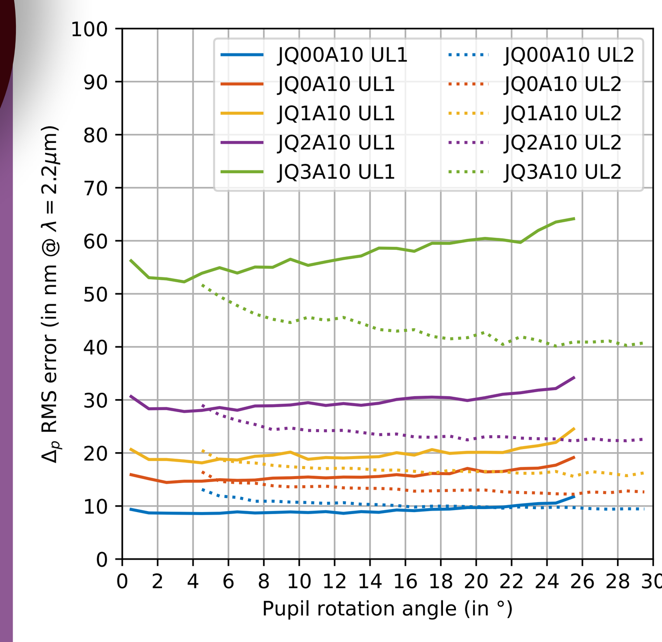
AO RESIDUALS SIGNIFICANTLY DEGRADE PERFORMANCES

Introducing AO residuals (e.g., fitting errors or temporal errors) into the simulation leads to a decline in performance on single frames.

AVERAGING RESTORE PERFORMANCES

Averaging the results across 10 images (uncorrelated realizations of the turbulence) significantly improves the network's performance over all conditions.





UL TYPES SUB PUPILS PERFORMANCE

Differential piston estimation is in the same range as the UR case. Anisotropy in the PSD causes the asymmetry between the UL1 and UL2 cases.

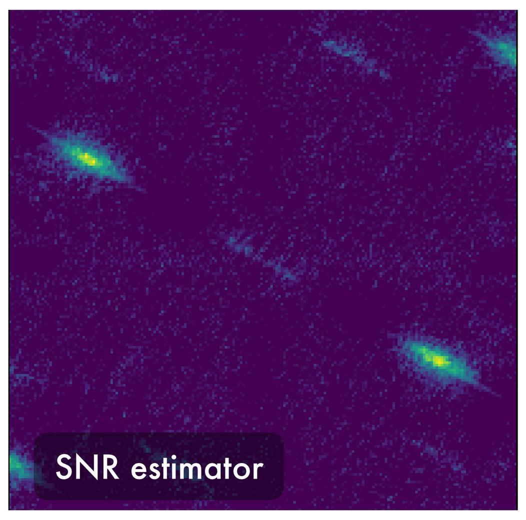
TURBULENCE PROFILES MEMENTO

Name	Strehl ratio	Seeing	NGS zenith	Comments
JQ00	98% (K-band)	0.432" (V-band)	0"	Unrealistic profile
JQ0	75%	0.432"	30"	Unrealistic profile
JQ1	50%	0.432"	70"	Good conditions profile
JQ2	25%	0.568"	110"	Intermediate conditions profile
JQ3	10%	1.042"	60"	Bad conditions profile

IN THE FUTURE

TAKING A STEP FURTHER TOWARD REAL WORLD APPLICATION

We will include noise, polychromatism and use correlated turbulence phase screens in the coming simulations.



BUILDING MORE INSIGHTS ON THE IMAGE FORMATION PROCESS

We will try to better understand the behavior of the speckles created by the petaling to propose ameliorations to our algorithm.

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