ASTRI Astrofisica con Specchi a Tecnologia Replicante Italiana

cta cherenkov telescope array

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Universidade de São Paulo
Instituto de Astronomia, Geofisica e Ciencias Atmosferica

MIUR

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

The Cherenkov optics qualification facilities at INAF-OAB laboratories

Nicola La Palombara on behalf of Giorgia Sironi

for the CTA ASTRI Project

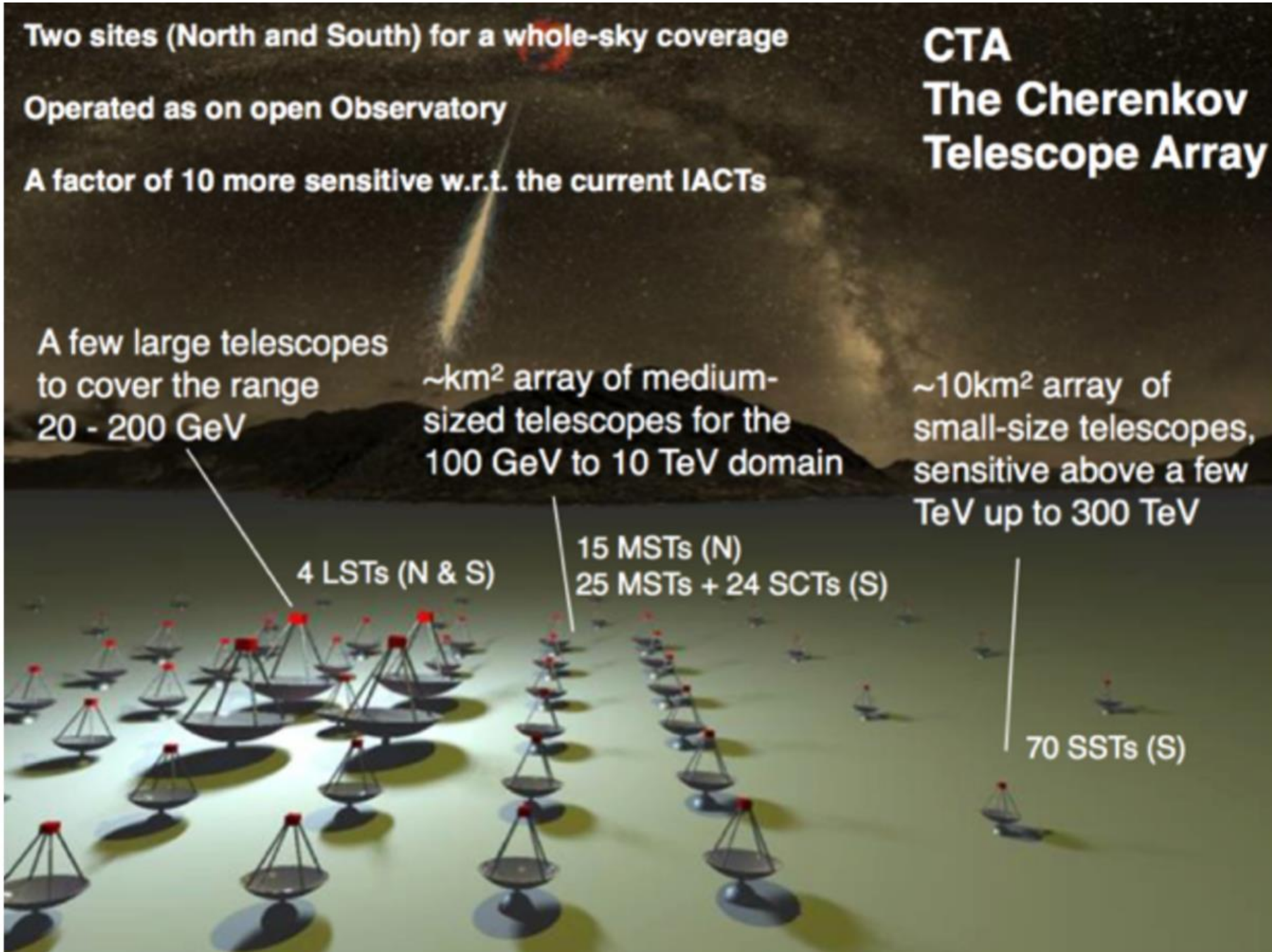
INAF-IASF Milano

This work was conducted in the context of the CTA ASTRI Project

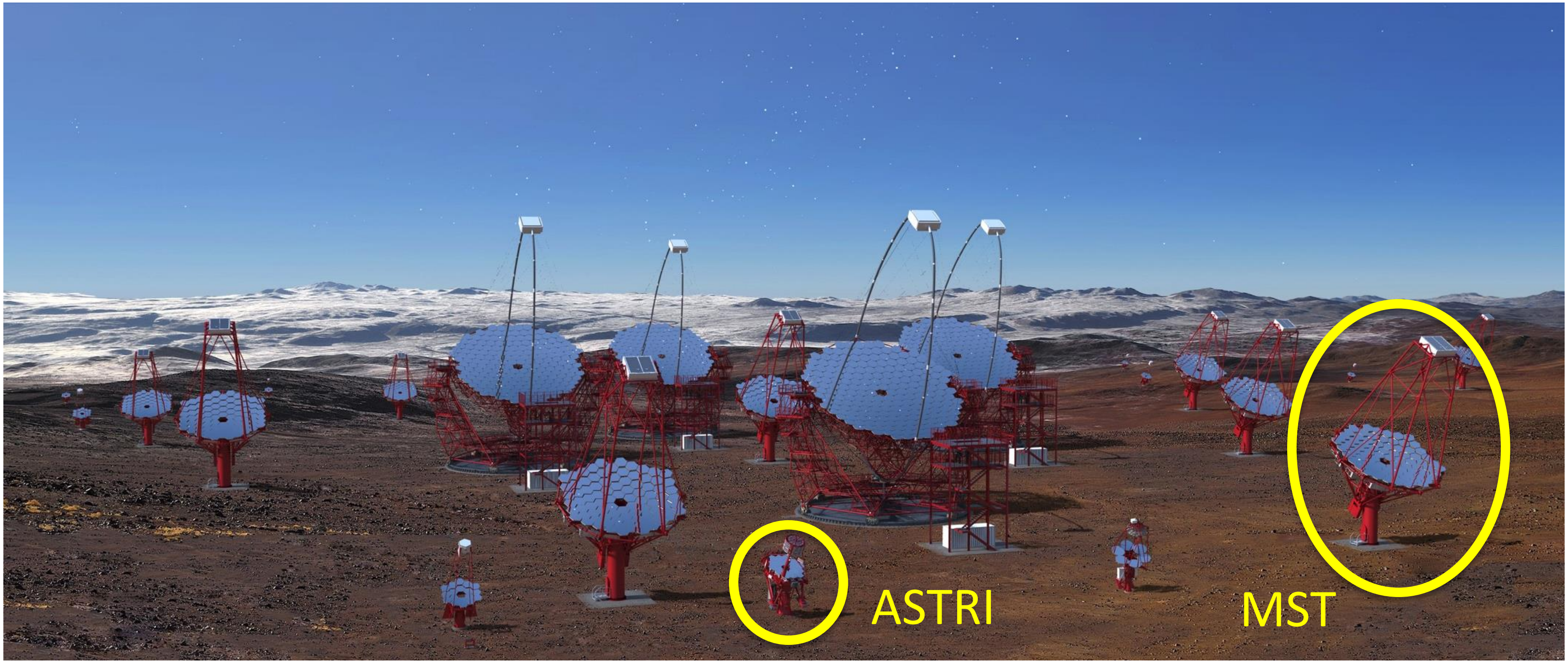
Outline

- The role of @INAF-OAB in the CTA project
- The metrology facilities @INAF-OAB
  - The 2f facility
  - The deflectometry laboratory
  - Possible facilities upgrades
- Conclusion

The CTA project



INAF-OAB contribution to CTA

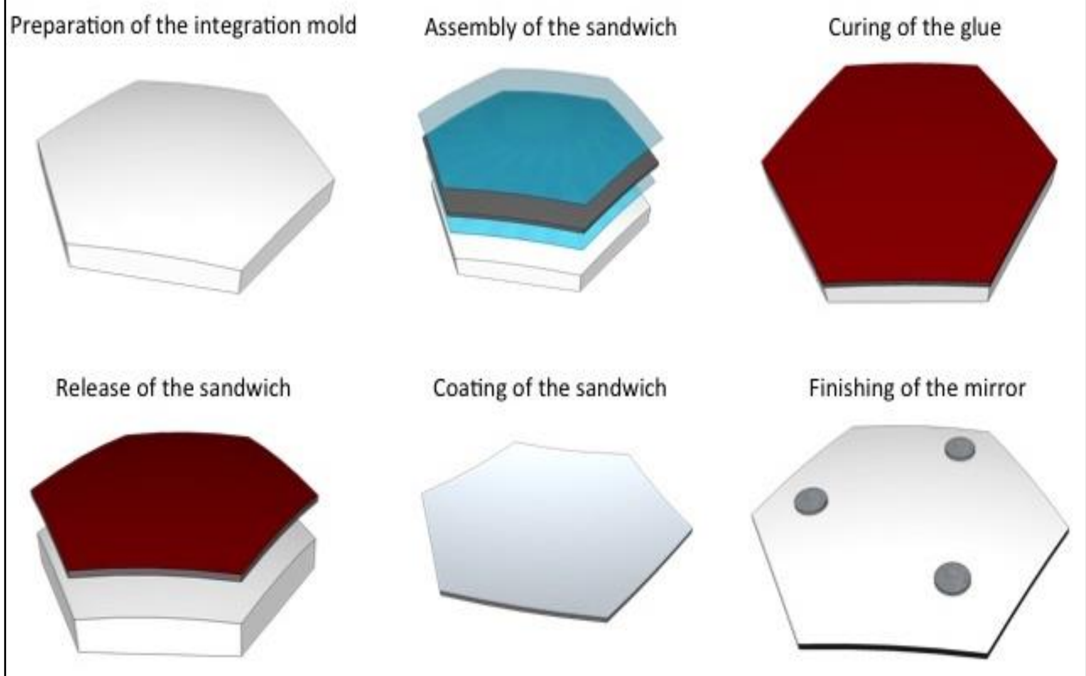


- Small Size Class Telescope (SST):
  - INAF realized the end-to-end ASTRI telescope prototype
  - INAF-OAB is responsible for ASTRI mirrors manufacturing and characterization
- Medium Size Class Telescope (MST): INAF-OAB is providing mirrors as in kind contribution.

Cold slumping

ASTRI and MST mirrors are manufactured by glass cold slumping technology. This technology was developed in synergy by INAF-OAB and Media Lario and successfully used for MAGIC mirrors.

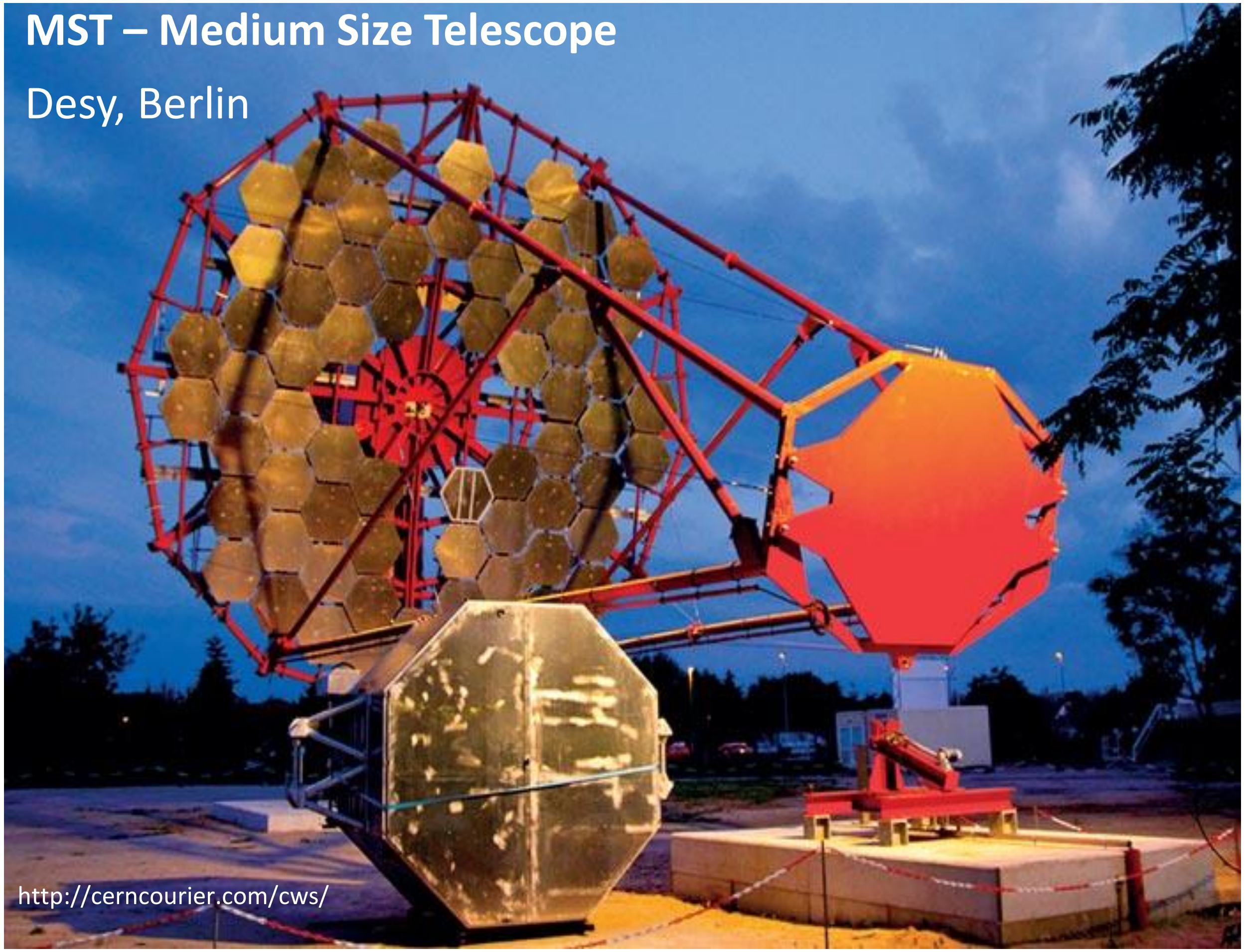
- Based on replica process $\Rightarrow$ suitable for the multiplicity of CTA mirrors
- Lightweight and cost-saving
- Shape error within few microns



Vernani et al. – 7018-32 SPIE Proc. 2008 , Pareschi et al. – 7018-33 SPIE Proc. 2008

2f facility@INAF-OAB

The 2f facility was adopted to measure MST mirrors



Optical configuration: Davies-Cotton

Dish Diameter = 12 m

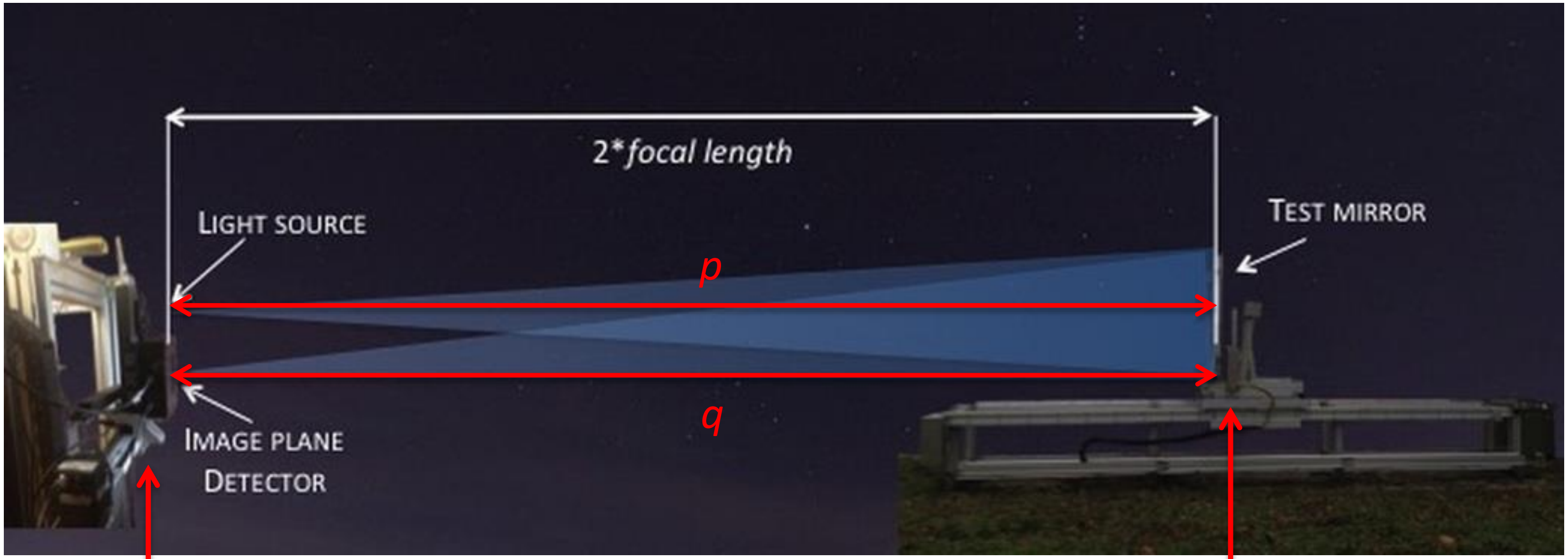
Focal length = 16 m

Mirror = segmented in 84 spherical panels

1 panel = hexagon of 1.2 m side-to-side

Layout of the 2f facility

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q},\ p = q = \mathrm{RoC} \Rightarrow f = \mathrm{RoC}/2$$



http://arxiv.org/abs/1504.02962

Indoor section:

- light source
- CCD camera, mounted on a translation stage

Outdoor section:
stage for mirror support and alignment

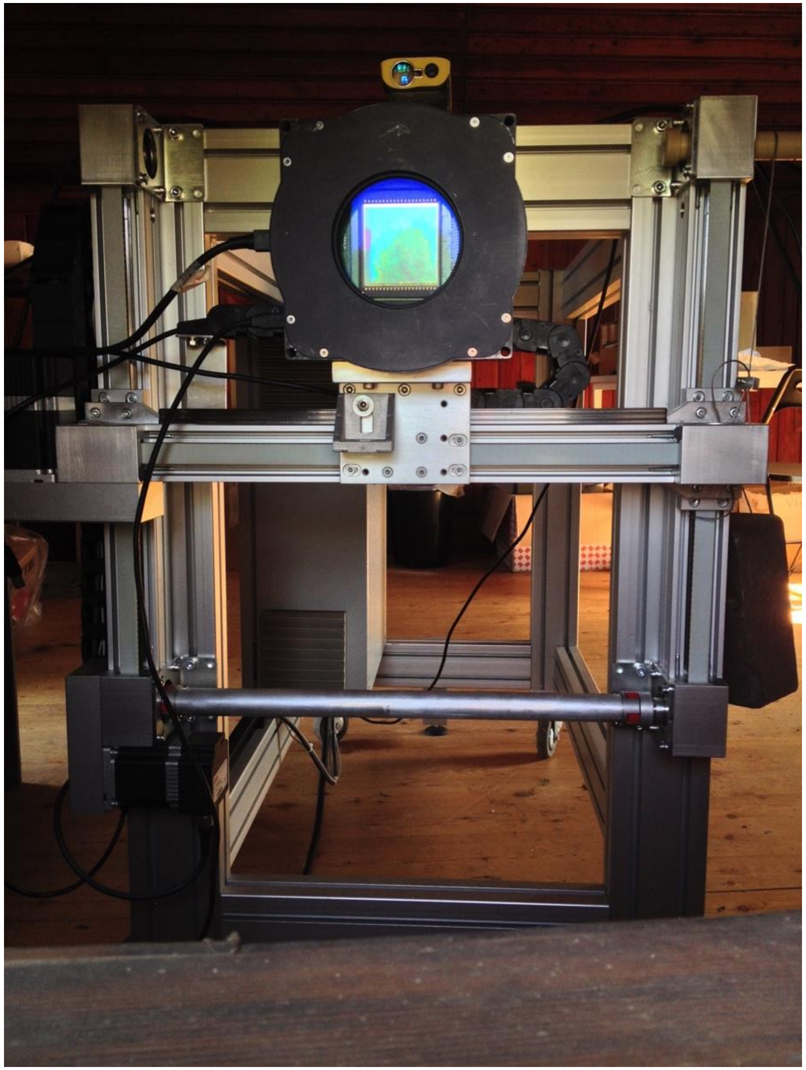
2f facility@INAF-OAB

Outdoor mirror bench:

- Motorized (stepper motor + encoder): tip/tilt for alignment + focus over a wide range (30-36 meters $\Rightarrow$ suitable for both MST and MAGIC mirrors)
- Adaptable for mirrors of different sizes (up to 1.5 m) and weights (up to 45 kg)
- Operated with a Command&Control SW interface on an indoor desktop computer

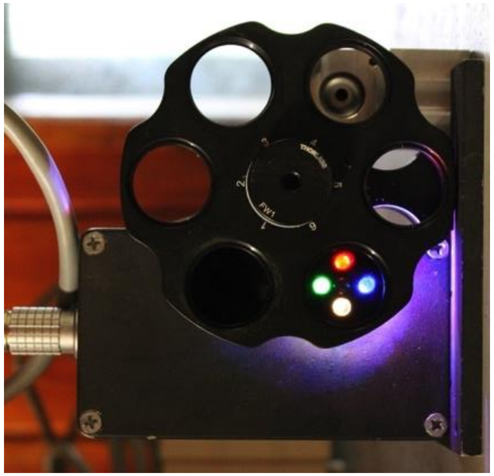
External cabinet + thermocouple for ambient temperature monitoring

2f facility@INAF-OAB



Indoor optical bench:

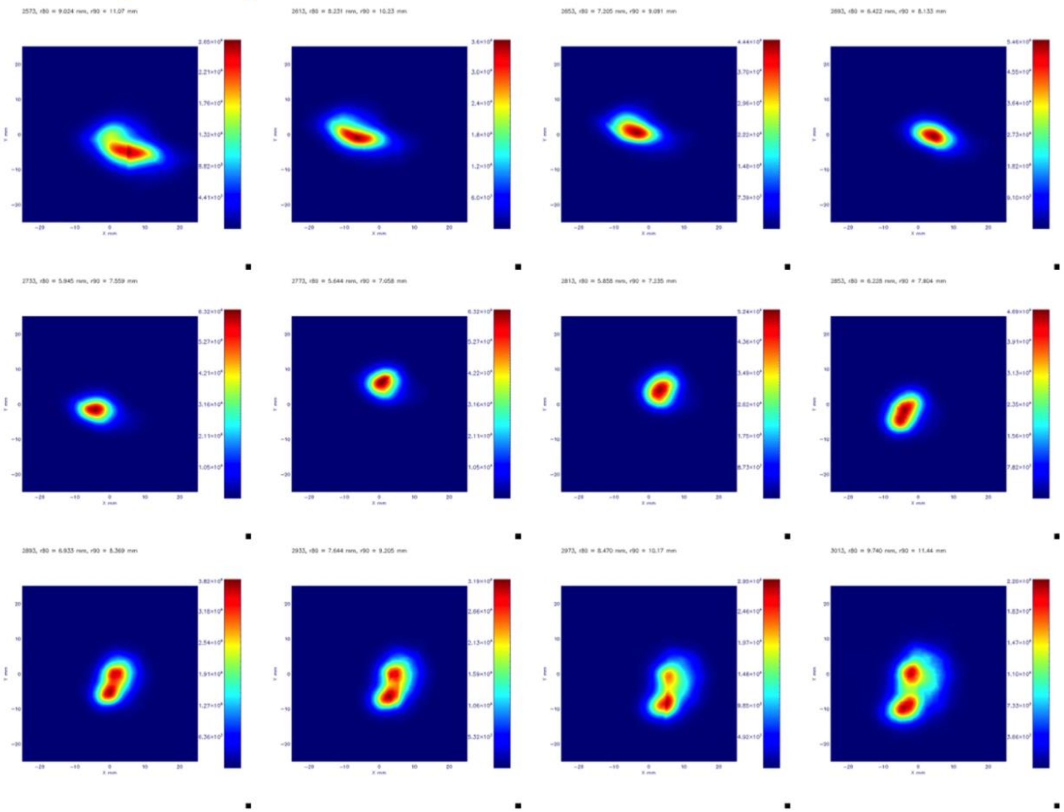
- Motorized x-y stage for focal plane scanning (300x300 mm)
- Finger Lakes CCD camera PL4301 with filter wheel (neutral and band-pass): 2084x2084 px @ 24 μm (49.5x49.5 mm)
- High intensity LED sources (with neutral filters on a filter wheel): white, red (626 nm), green (525 nm) and blue (470 nm)
- Laser meter (accuracy +/- 5 mm over 200 m)

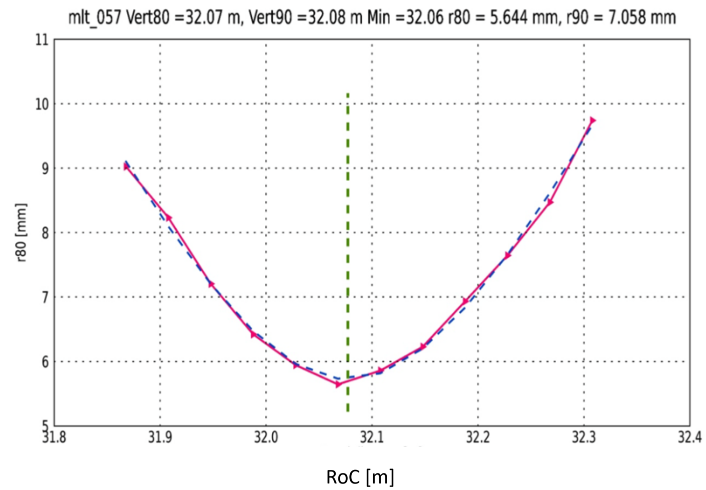


Focal length measurement

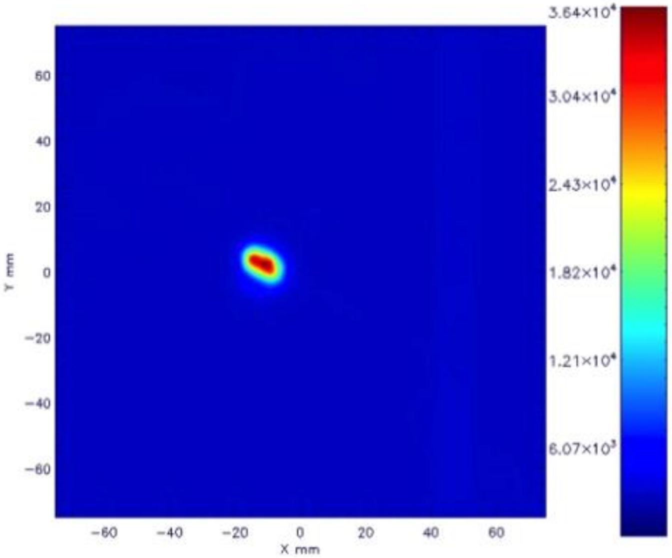
- Image acquisition at different distances
- Measure of the PSF dimension (r80)
- Identification of RoC as distance where the PSF is smaller

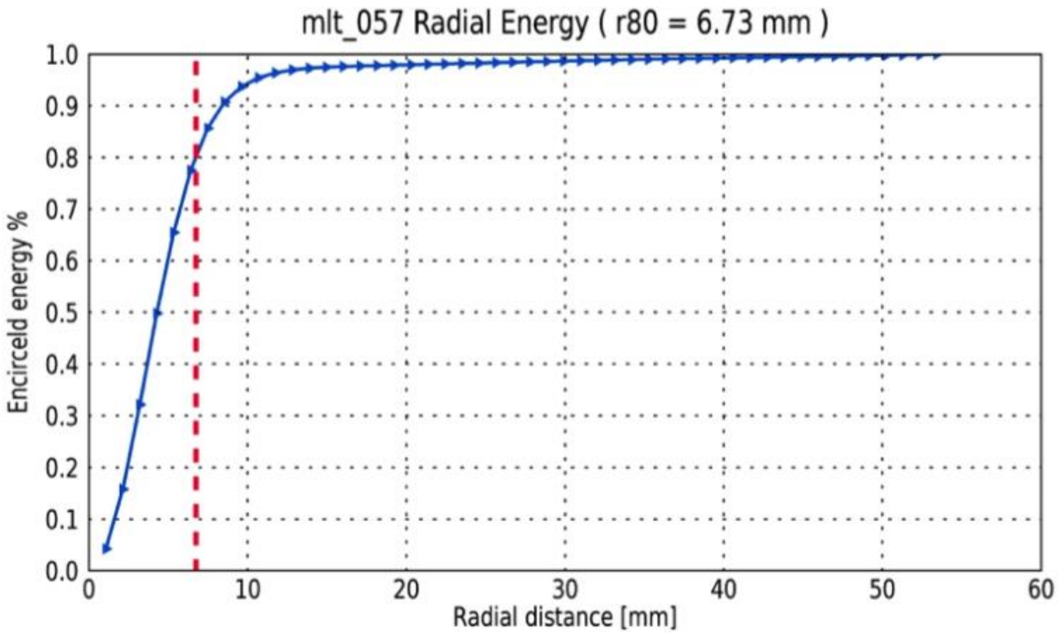
Focal length study





- At nominal focal length
- Mosaic of 3x3 images (15 x 15 cm)
- Calculate the r80

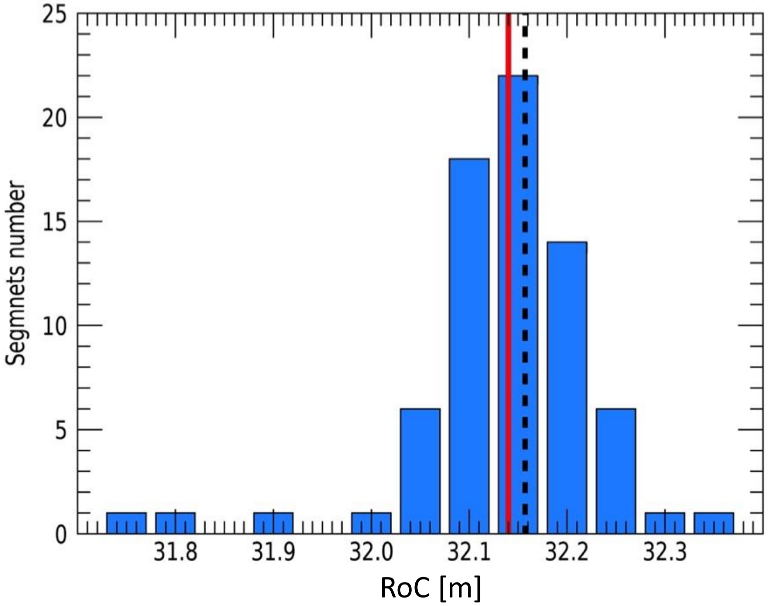


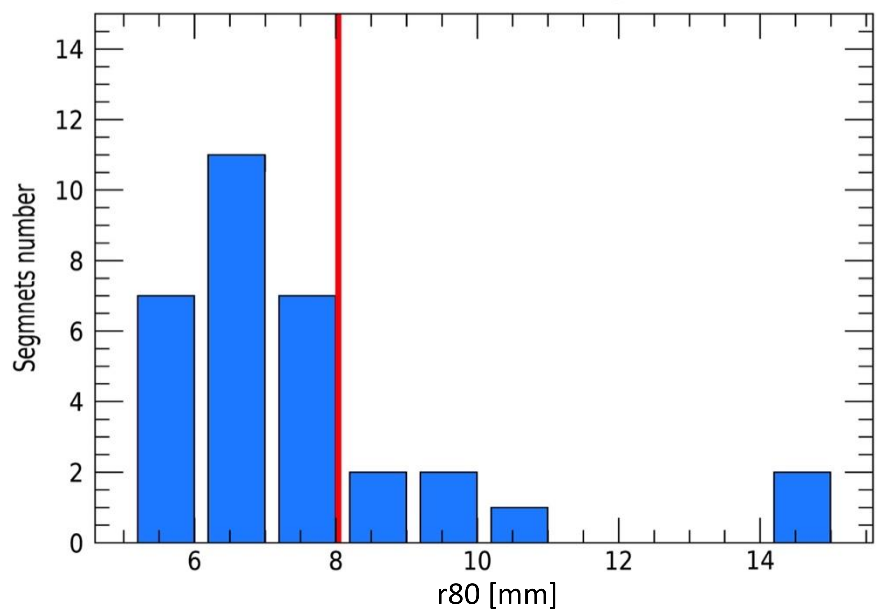


Example: MLT Mirrors@INAF-OAB

Mirror production industrialized by Media Lario Technologies
INAF-OAB is leading the contract and performing independent tests

- Mean RoC: 32.15 m (72 studied mirrors)
- Mean r80 at the nominal RoC: 8.03 mm (32 studied mirrors)





ASTRI SST telescope prototype

- ASTRI telescope is an end-to-end system realized by INAF (Italian National Institute for astrophysics) as prototype for the CTA SST
- The ASTRI telescope is installed at Serra la Nave (Mt. Etna, Sicily)

Dish Diameter = 4 m

Focal length = 2.15 m

Optical configuration: polynomial Schwarzschild-Couder

Primary Mirror = segmented in 18 panels

1 panel = hexagon 85 cm side-to-side

Astrofisica con Specchi a Tecnologia Replicante Italiana

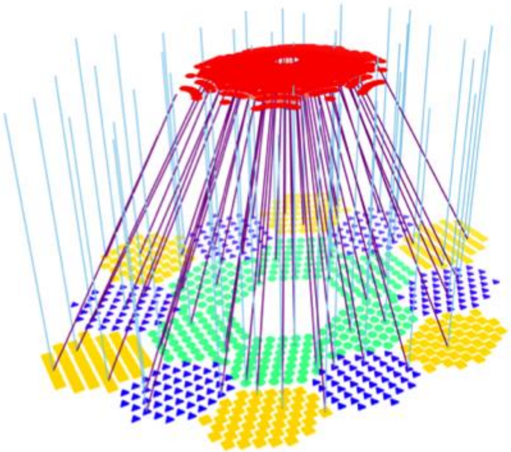
ASTRI is a polynomial Schwarzschild-Couder telescope

The main advantages of the SC design are:

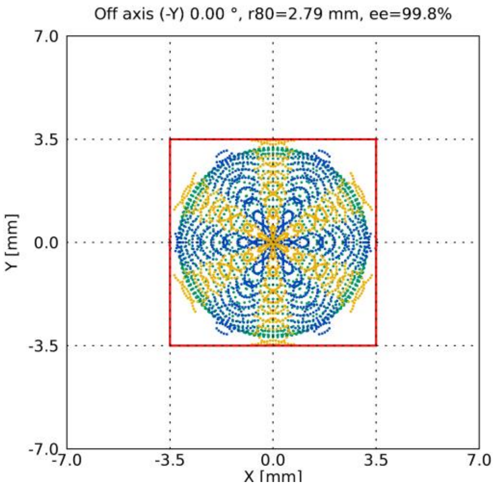
- Double mirror reflection ⇒ shorter focal length
- Better plate scale ⇒ large FOV with a small camera

The main disadvantage is that SC design requires aspheric optics:

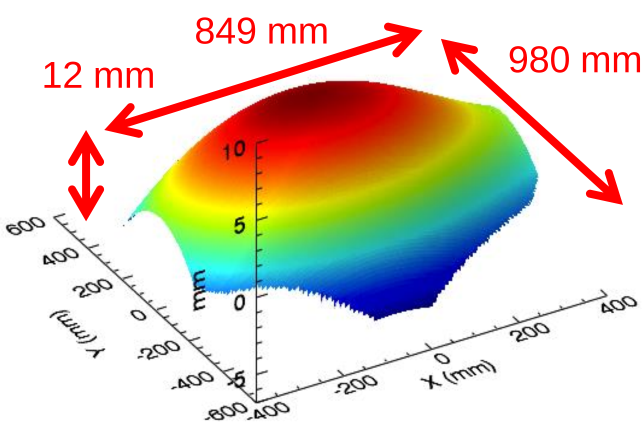
- Segmented aspheric optics ⇒ free-form not focusing panels



Ray-tracing



Photons inside the pixel (7 mm)

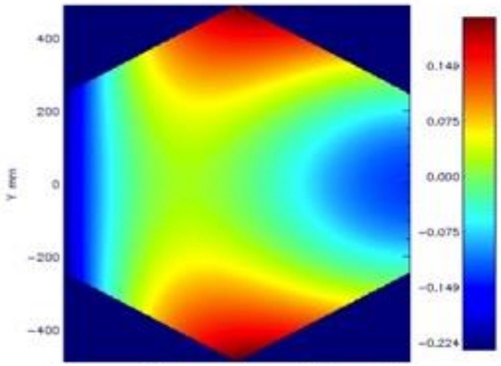


ASTRI primary mirror segment design

Strongly aspheric surfaces:

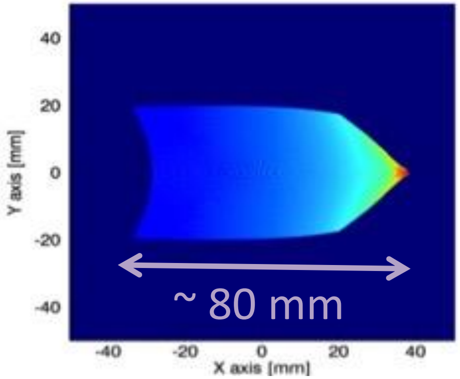
- ➢ Segment residuals wrt best fit sphere
- ➢ Very large best focus images ⇒ 2f test not possible

Corona 1

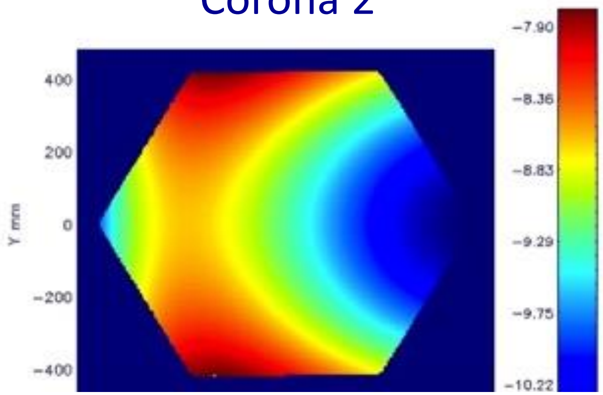


PV 4.5 mm - Rms 800 µm

RoC = 8.6 m

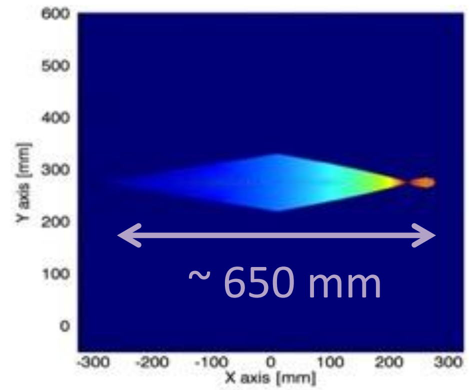


Corona 2

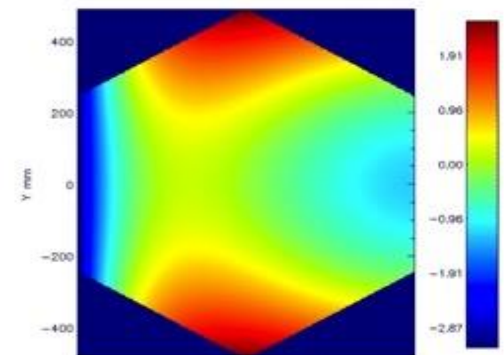


PV 2.8 mm – Rms 670 µm

RoC = 9.8 m

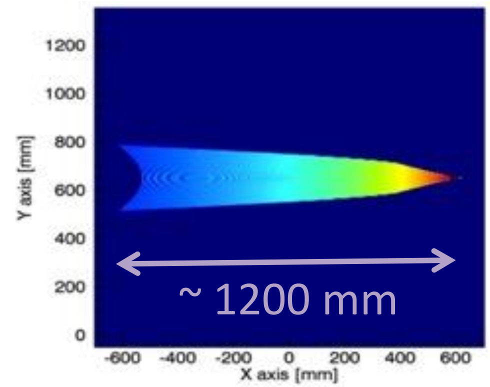


Corona 3



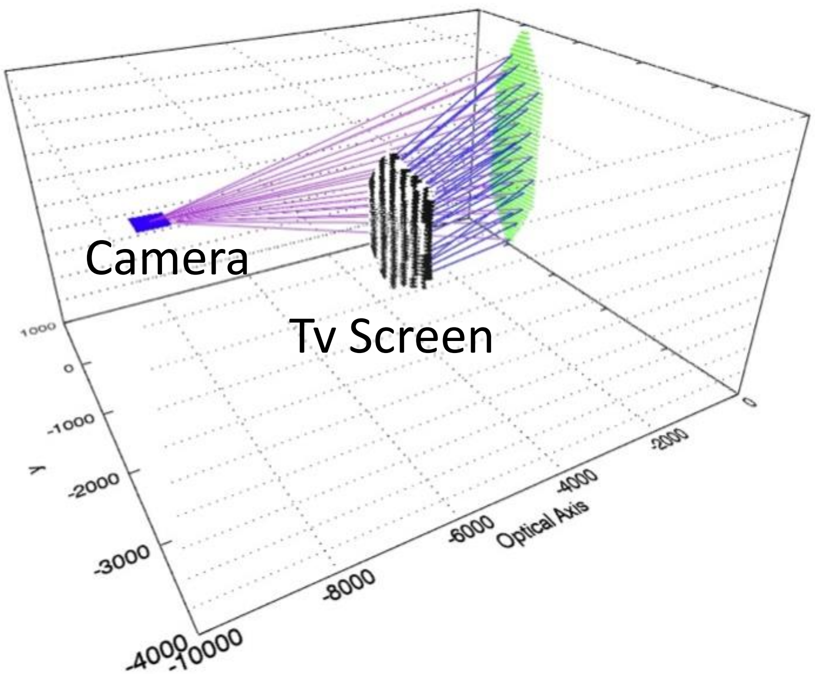
PV 5.7 mm – Rms 972 µm

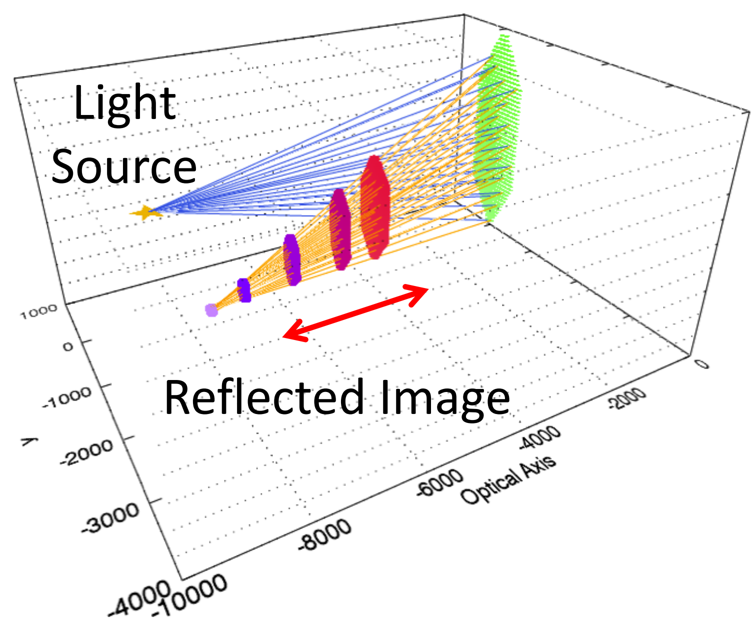
RoC = 11.7 m



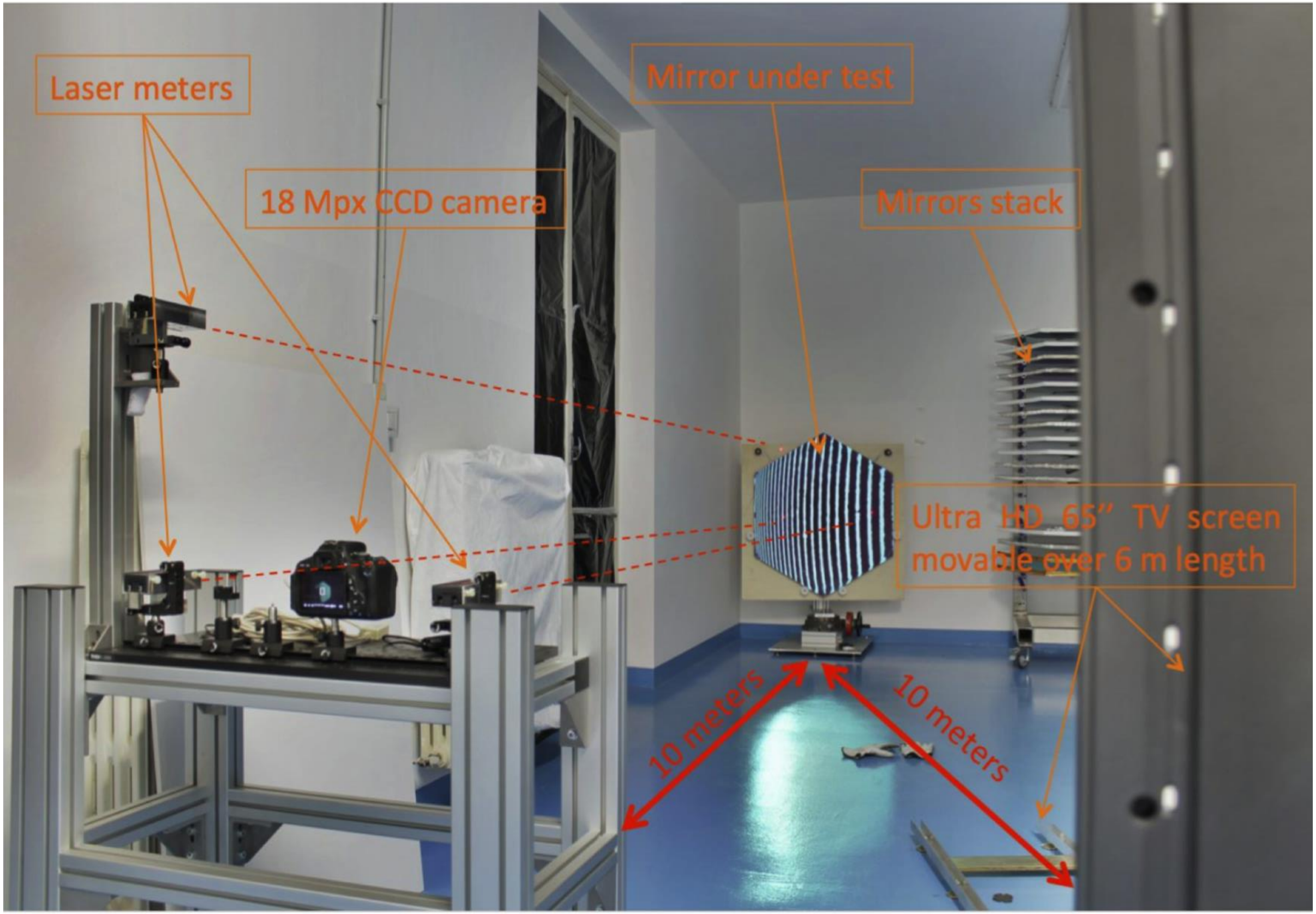
Deflectometry test:

- Illuminate the mirror with a defined pattern and observe the distorsions after its reflection
- Calculate normal vectors to the reflecting surface
- Make the ray-tracing simulation in the acquisition configuration
- Compare really reflected images with the simulated ones





ASTRI Deflectometry lab

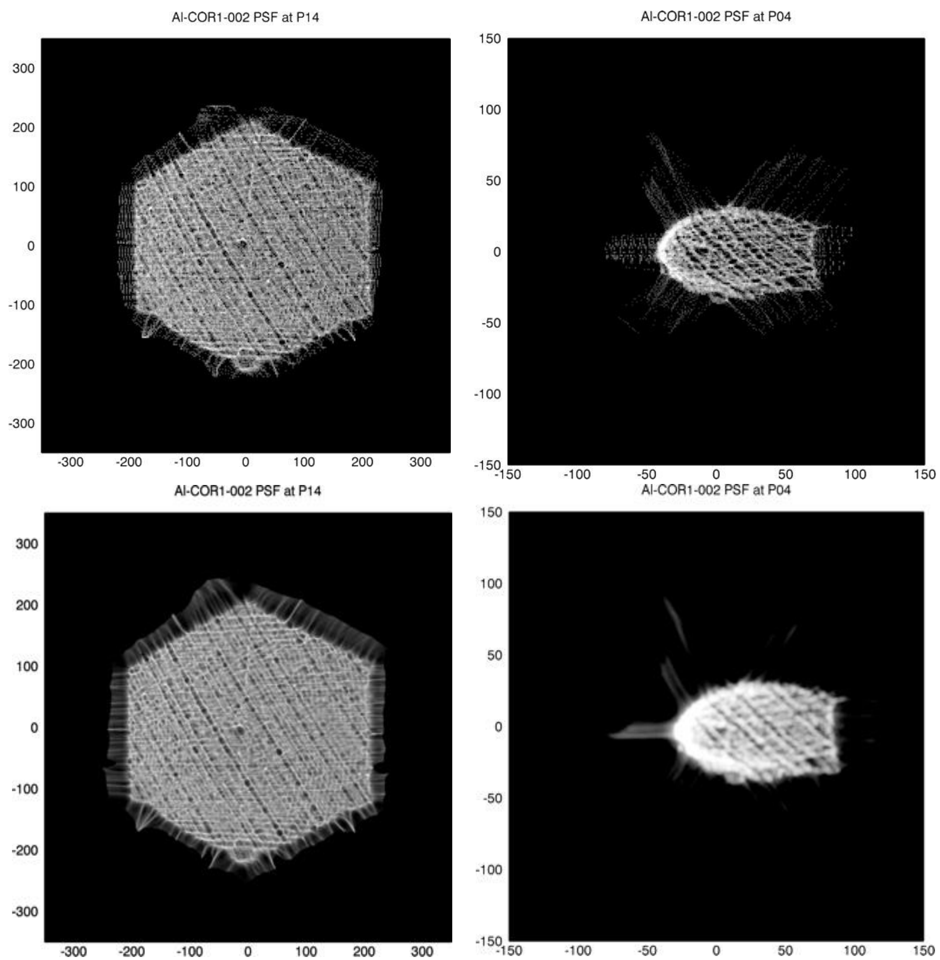


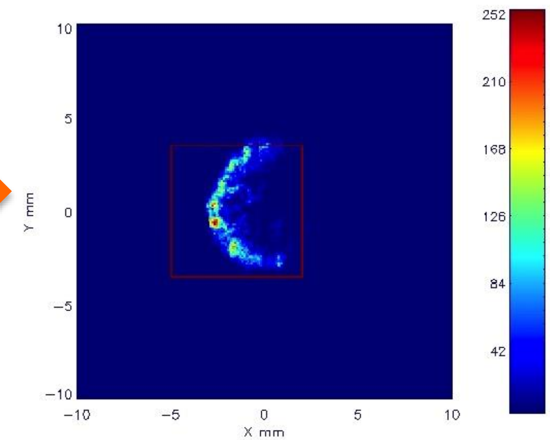
Validation by comparison of:

- Images simulated by ray-tracing of the measured surface
- Pictures acquired in direct illumination

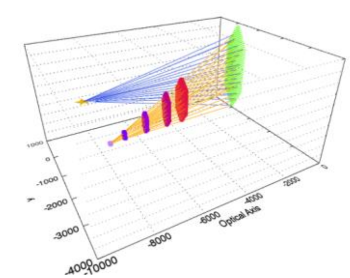
Ray-tracing Simulations @different distances

Real image @different distances



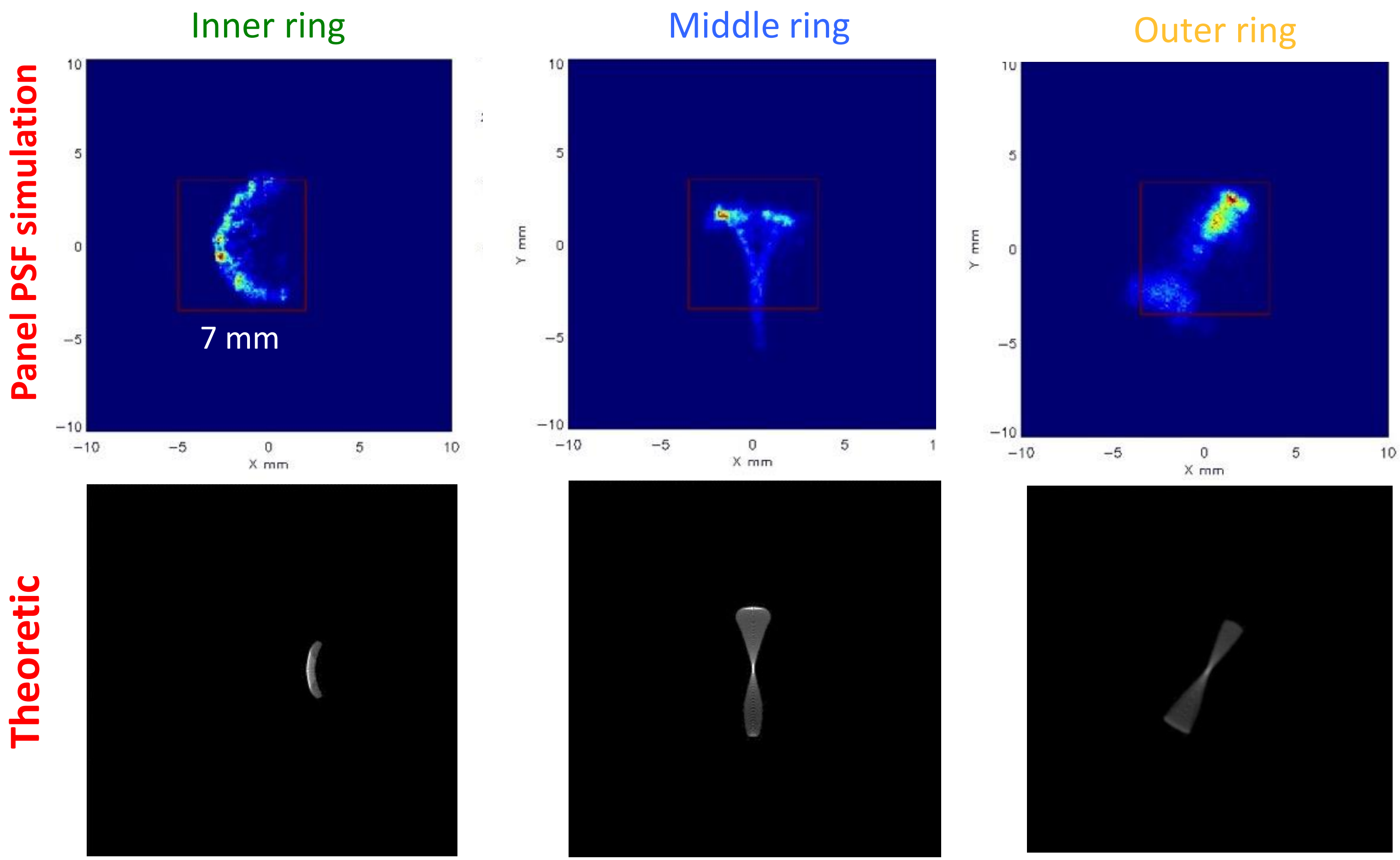


Ray-tracing Simulations @telescope focal plane



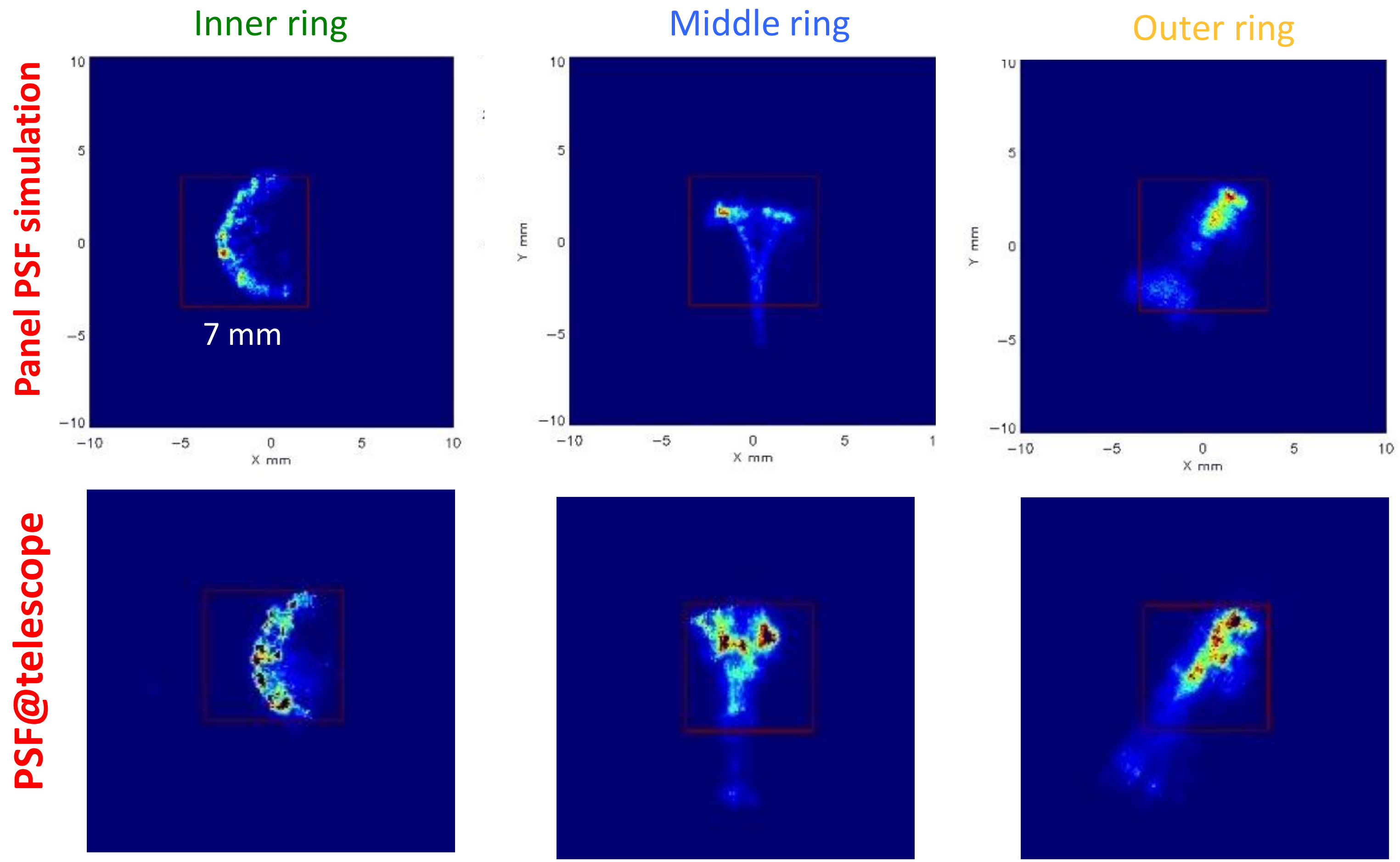
All ASTRI M1 segments were characterized only by means of INAF-OAB deflectometry facility.

- To evaluate the mirrors quality we compared the simulated PSF with the expected theoretical PSFs



All ASTRI M1 segments were characterized only by means of INAF-OAB deflectometry facility.

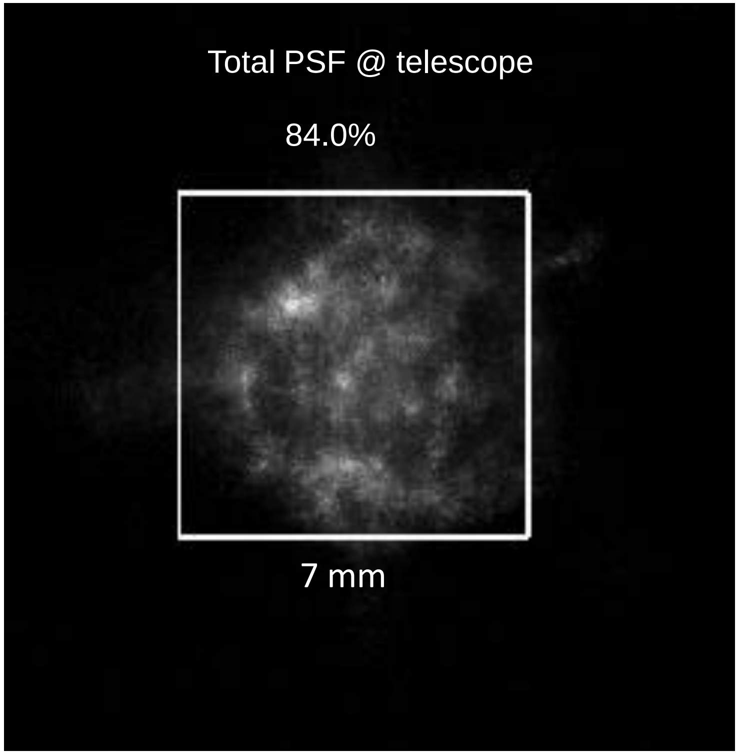
- To evaluate the test reliability we compared the simulated PSF with the PSF directly measured at the telescope focal plane



ASTRI optical quality

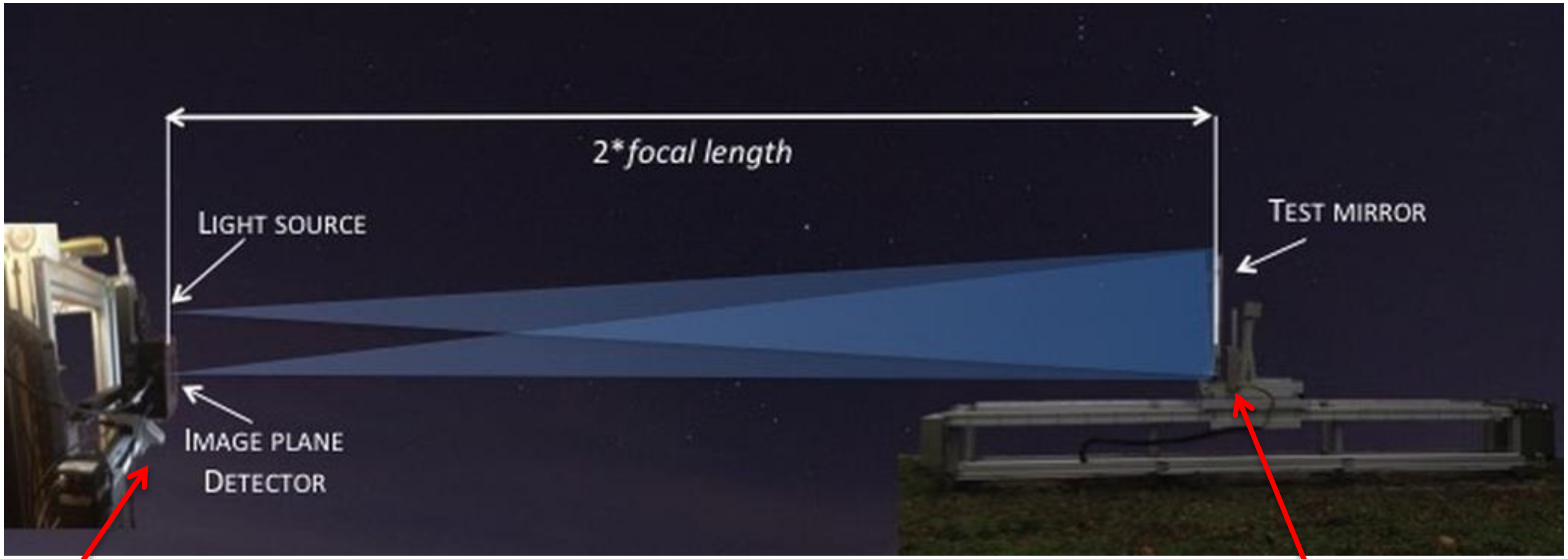
All ASTRI M1 segments were characterized only by means of INAF-OAB deflectometry facility.

The final obtained PSF of the ASTRI telescope, measured observing Polaris, results to be fully compliant with the requirement to concentrate the 80 % of the source light in the pixel of the focal-plane camera.



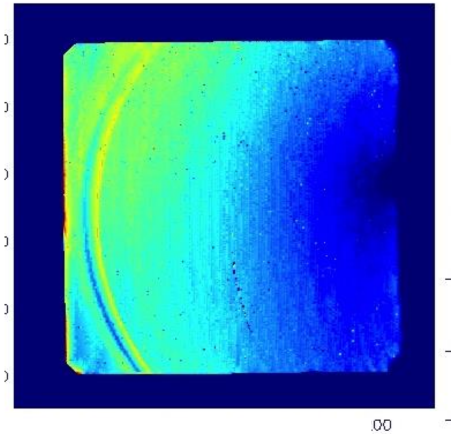
Facilities possible upgrade

Direct measure of mirror surface: http://arxiv.org/abs/1504.02962



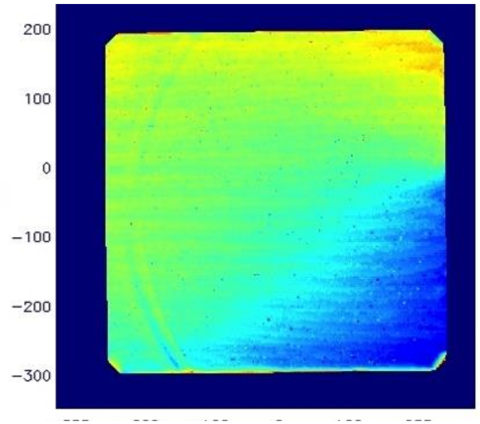
Facilities possible upgrade

X slope error



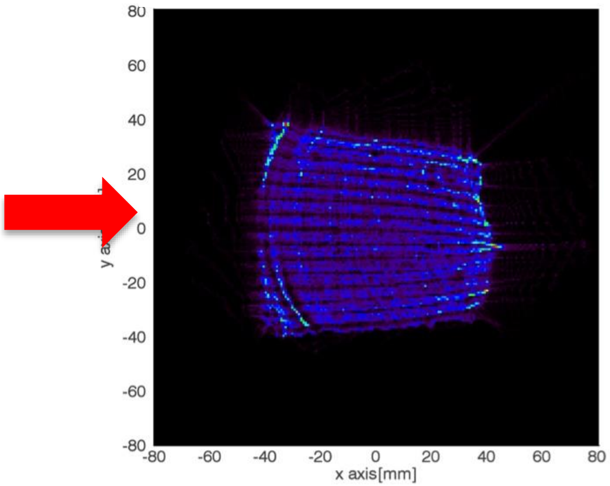
rms = 0.1’’

Y slope error

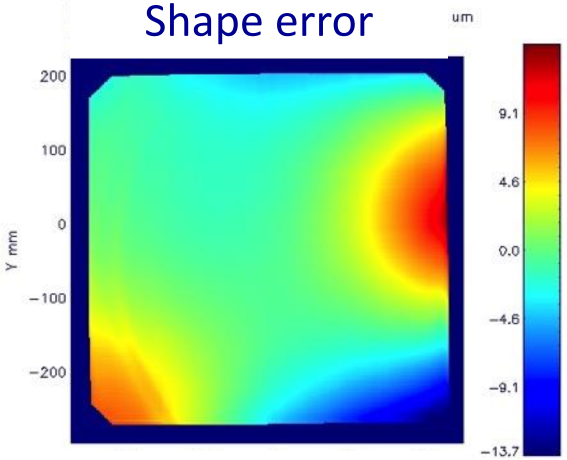


rms = 0.2’’

RT Simulation



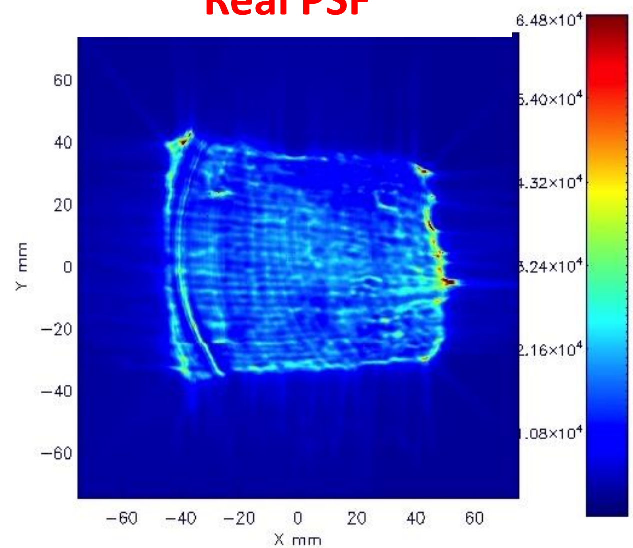
Shape error



rms = 3.5 µm

It is promising, we will go on working on it!

Real PSF



Conclusions

- The 2f and the deflectometry facilities @ INAF-OAB are reliable tools to measure spherical and aspheric mirrors
- They can be used to characterize in an independent way the SST and MST mirrors
- They can be used to monitor the mirror replica process applied by industries during the production phase of CTA

PSFs simulations

Ray-tracing PSF simulation of the measured optic slope errors allowed us to

- Determine the best reciprocal position of the single M1 panels’ PSFs
- Foresee the optical quality of the telescope