Learning from ASTRI-Horn:
how to monitor observation quality using the Variance

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for the ASTRI project

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THE ASTRI PROJECT

An international project (lead by INAF) aimed at the study of **cosmic gamma-rays** up to 300 TeV, through the development of a **new type** of Imaging Atmospheric Cherenkov Telescope (*IACT*) [0].

ASTRI-Horn (2018)

The ASTRI prototype telescope installed on Mt. Etna, in Italy [1].

ASTRI MINI-ARRAY (~2025)

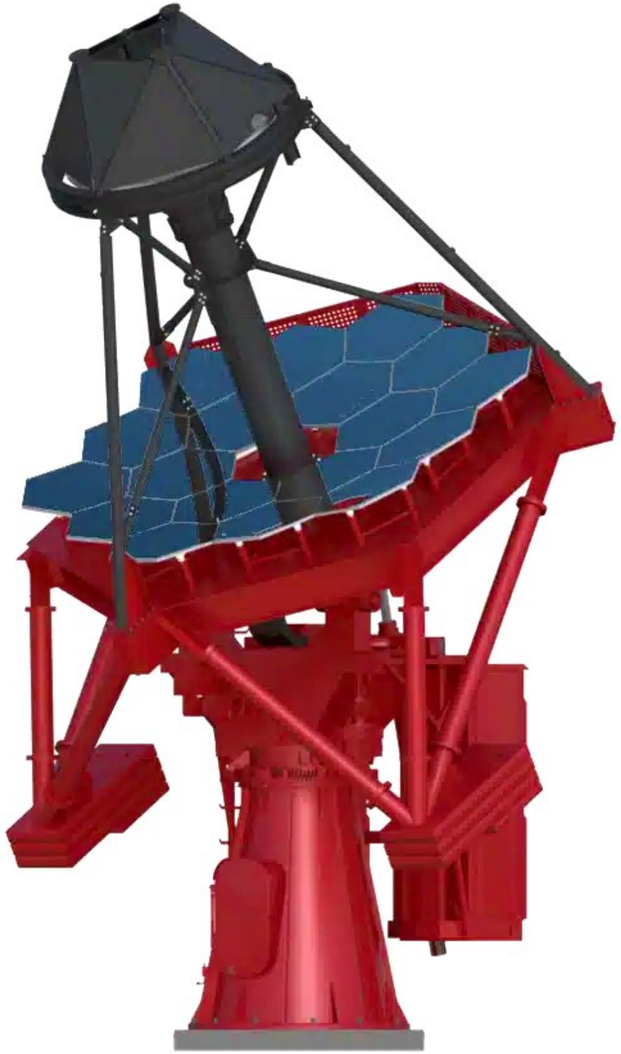
Set of 9 telescopes at the Teide Observatory (Canary Island, Spain) [2].

The ASTRI structure was selected by CTAO for Small Sized Telescopes (SSTs) [3]

(Talk by G. Tagliaferri)

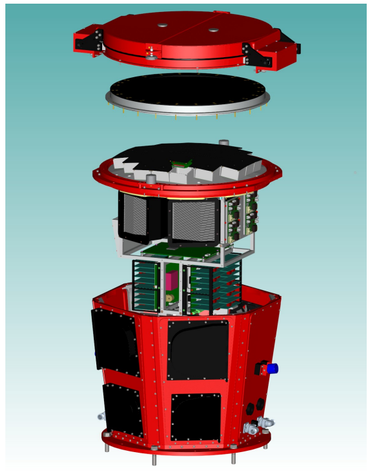
THE ASTRI TELESCOPE

The first IACT in dual-mirror configuration [4], developed end-to-end by the project.



THE OPTICAL SYSTEM

- modified Schwarschild-Couder [5] design (4.3m, *f*/0.5)
- aplanatic and isochronous
- large field of view (FoV, ~11°)
- flat PSF [6] response (~10' D80)



THE CHERENKOV CAMERA

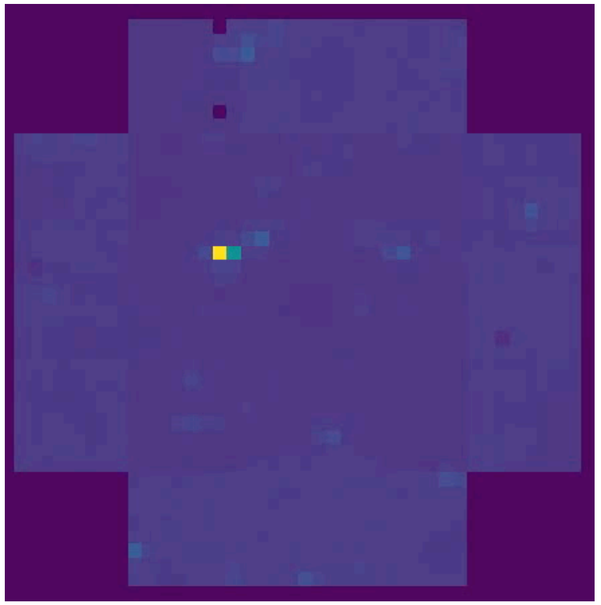
- 37 photo-detection modules [7] (tiles of 8x8 pixels)
- miniaturized silicon photo-multiplier sensors (SiPM, 7mm)
- sky footprint of the pixel ~11'
- impulsive mode for Cherenkov flashes (~few nanoseconds)
- *additional output for the imaging of the night sky background,* ***the so-called VARIANCE method [8]***

THE VARIANCE METHOD

It is a statistical method implemented in the camera backend electronics [9]

- data flow **in parallel to scientific data**
- ~1 sec "integration" for every image
- magnitude limit ~8th B mag

allow us to image the Night Sky Background (NSB).



Tracking run (~1.5h) in the Crab nebula region.

CRUCIAL FOR CALIBRATION AND MONITORING

Unique chance to inspect the FoV during data taking

- same **optical system**
- same **detector** (Cherenkov camera)
- same **sky condition**
- at the same **time**

with respect to *scientific data*.

AFTER ASTRI-HORN, WHAT WE CAN DO NOW FOR THE MINI-ARRAY (AND SST)?

MONITORING - POINTING

Custom astrometry routine (VSTAR) developed for ASTRI [10]

- ~ 2' precision
- ~ 1 Hz rate

The routine runs **automatically**:

- after data-taking at ASTRI-Horn
- **in real-time** at the MiniArray

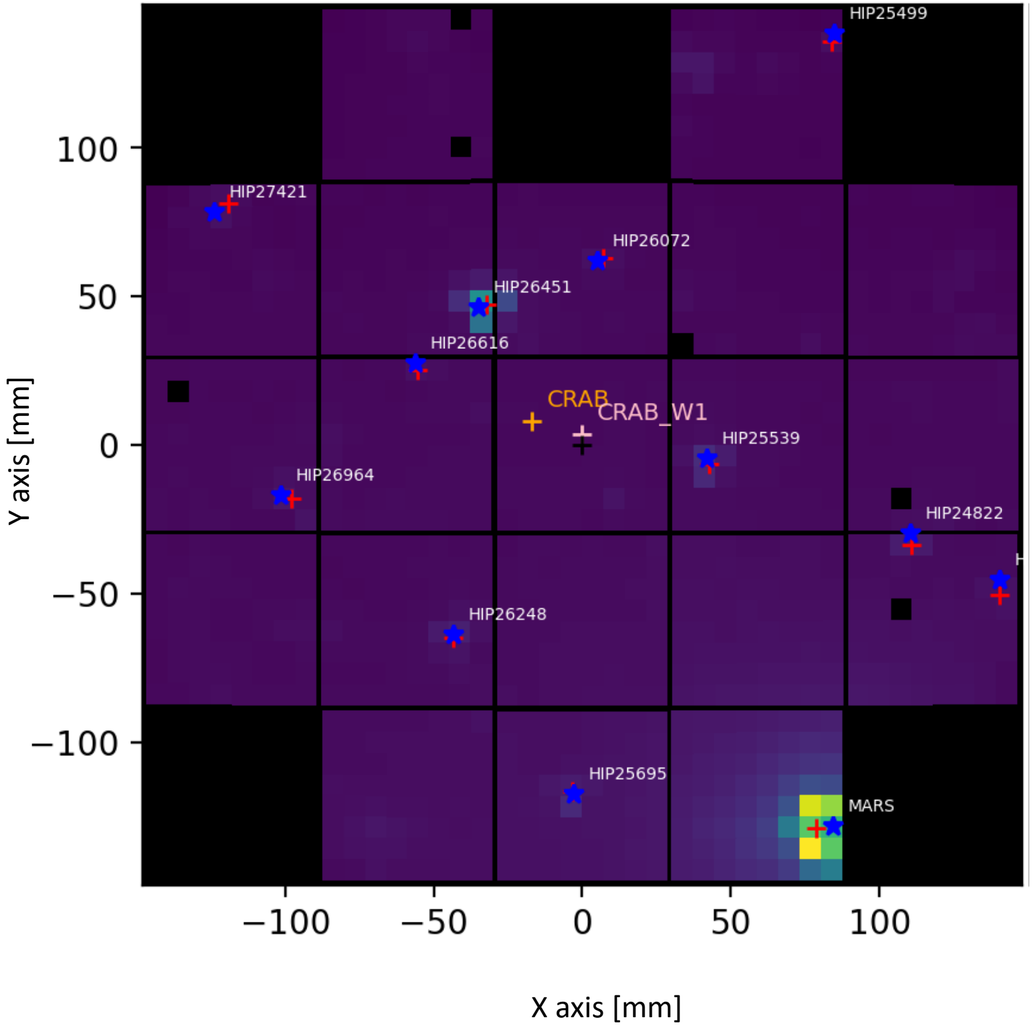
the output is a FITS technical file ("SCITECH").

Enhanced features developed with ASTRI-Horn:

- spot planets in the FoV (crucial for CRAB analysis)
- track the position of any object
- inverse coordinate transformation (WCS-like)

(Talk by S. Crestan)

... and a dedicate WEB user interface!



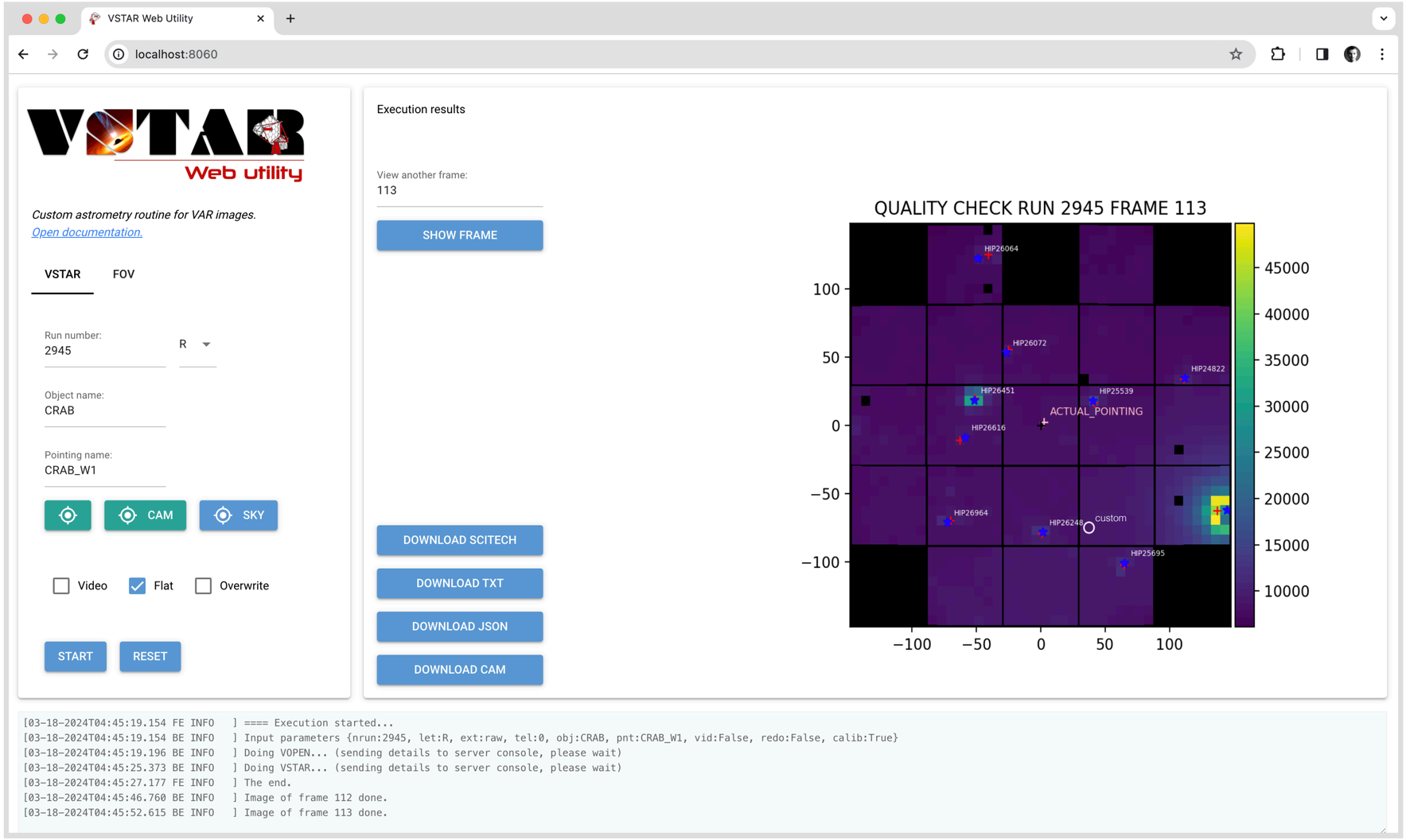
WEB UTILITY FOR VAR ANALYSIS

Dedicated web user interface

- quick look (data taking)
- online analysis

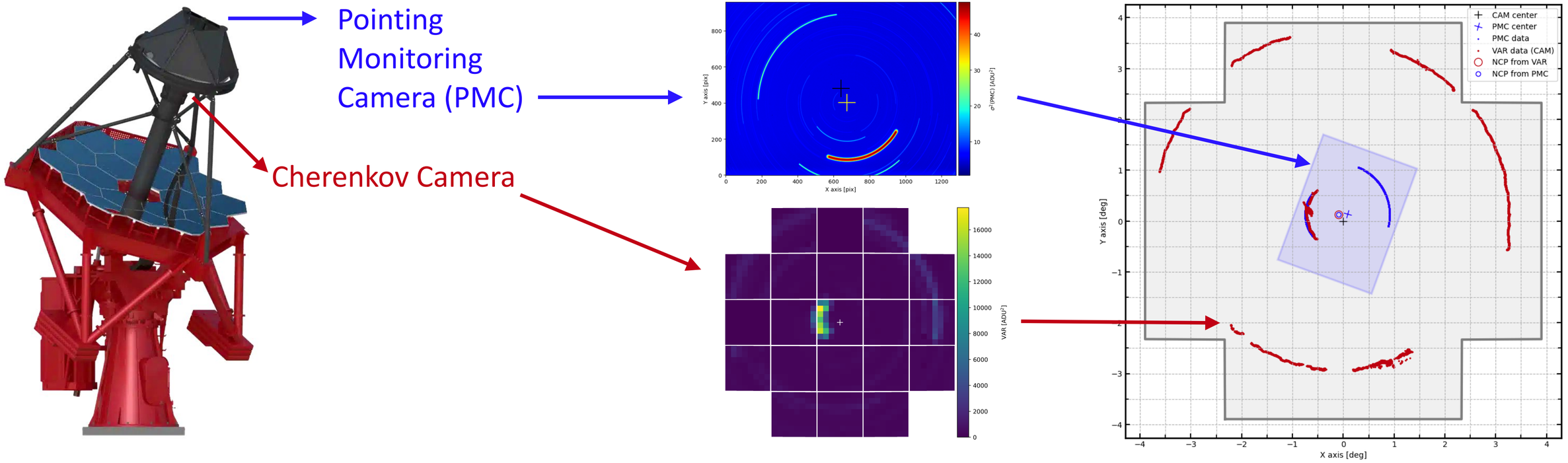
Completely online

- no software installation
- no db access keys
- download outputs



CALIBRATION - CAMERA ALIGNMENT

Mechanical offset - A characterization will improve the accuracy of telescope pointing [11].



The output is the position of the PMC wrt the Cherenkov Camera geometric center (two float numbers).

CALIBRATION - CAMERA ALIGNMENT

ASTRI-1 is almost ready, this calibration will be performed in the next weeks!

(Talk by C. Bigongiari)

North Celestial Pole seen by the ASTRI site in Tenerife.

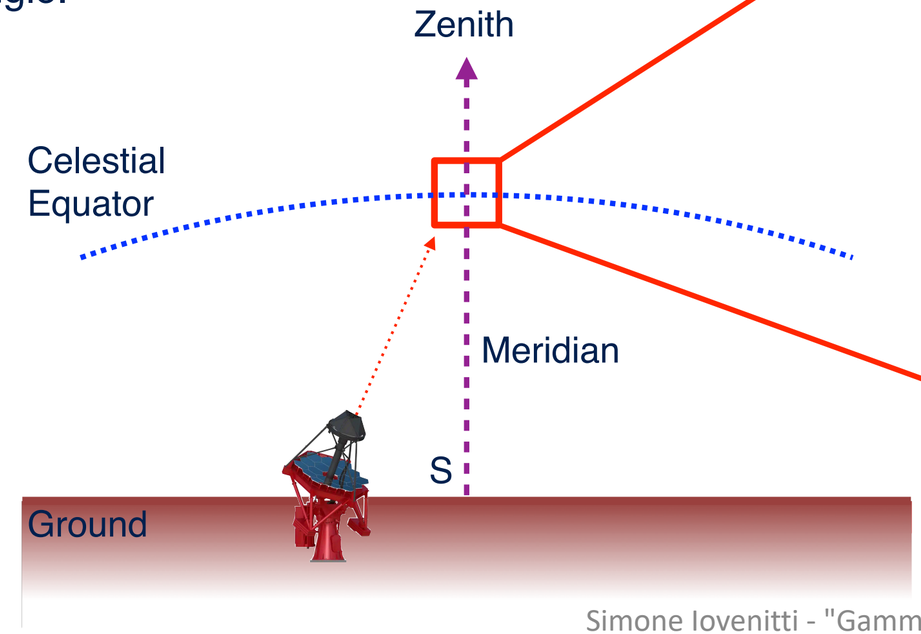
CALIBRATION - CAMERA ROTATION

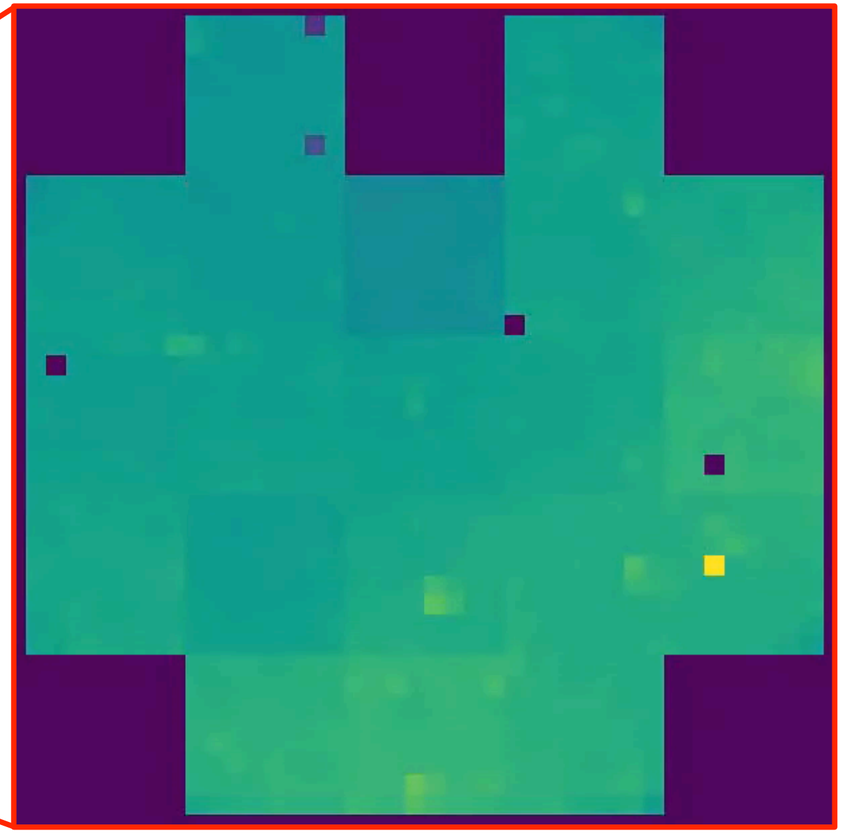
The **rotation angle** of the camera is zero, by design.

With the Variance, we can characterize it with **astrometry techniques**:

- pointing at local zenith on the celestial equator
- telescope in **staring mode**

the average slope of the stars in the FoV is the camera rotation angle.





Real ASTRI-Horn data, unpublished.

MONITORING - BACKGROUND LEVEL

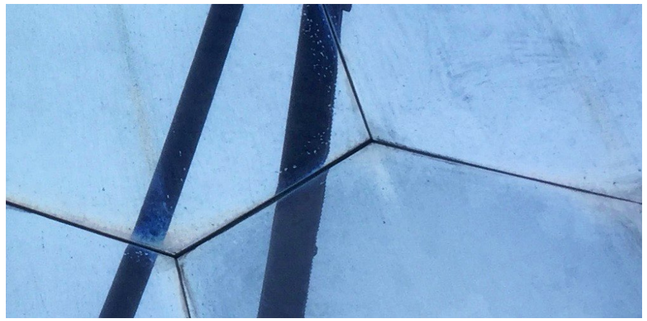
The NSB level may affect the **quality of Cherenkov data**

- bright stars may contaminate the shower image
- a high background may introduce spurious triggers

SQM, UVSiPM, ASC: auxiliary instrument for NSB monitoring

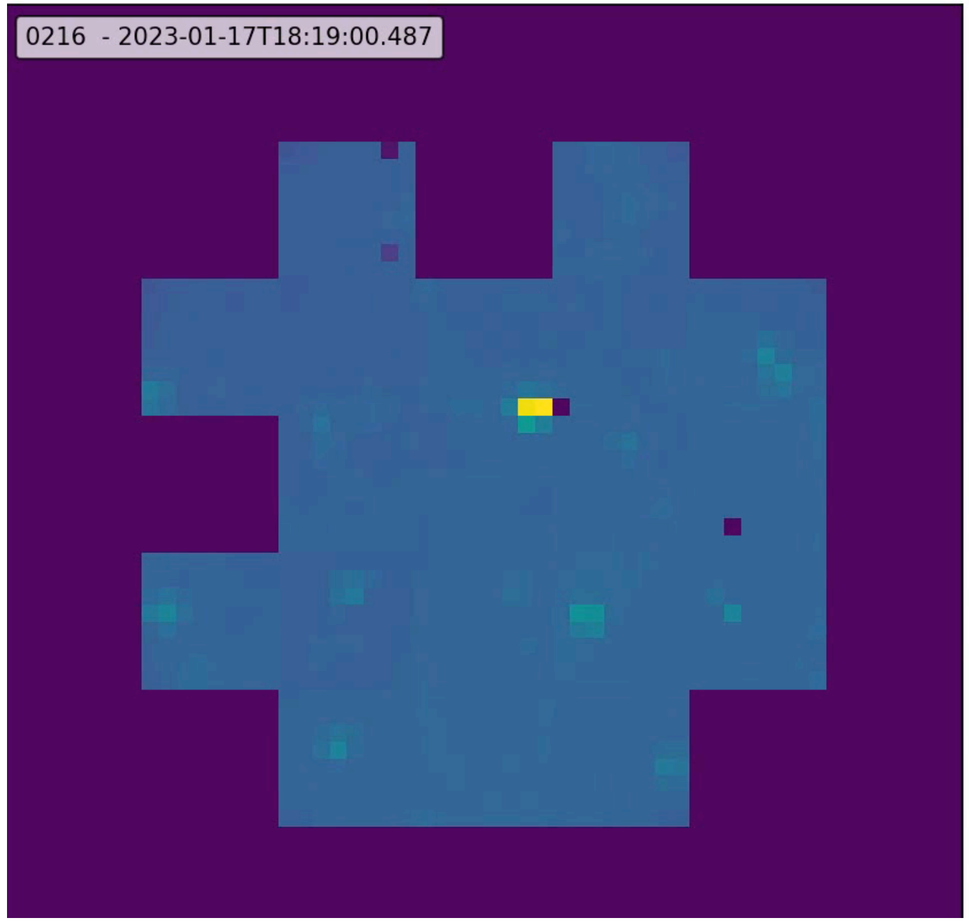
- **good match** with independent estimations from VAR data

(Poster by T. Mineo)



IACT mirrors suffer from fast degradation.

The average NSB level in VAR data allow us to monitor the **degradation of mirror reflectivity** in time.

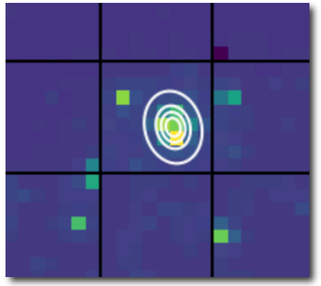


Real ASTRI-Horn VAR data.

MONITORING - THE PSF

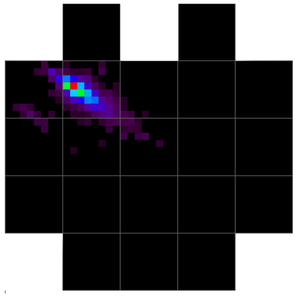
The optical PSF is composed (18 segments) using a **removable optical camera**.

VAR is the only access to the status of the optical system during acquisition.



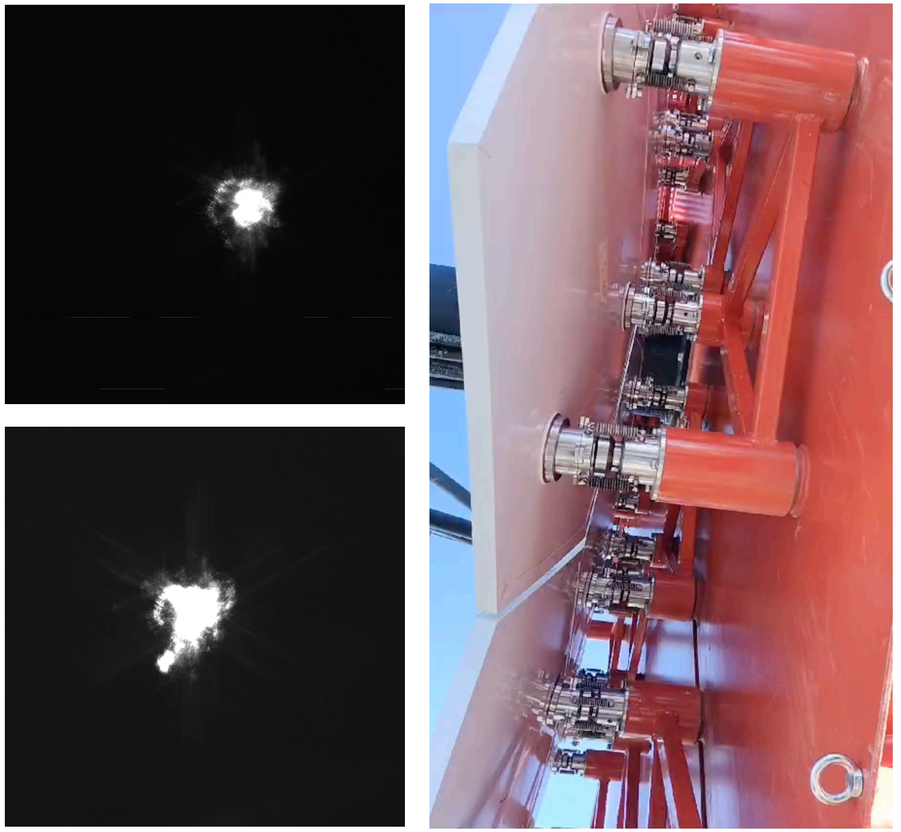
Size of the focal spot

- best focus with **M2 piston** (window refraction)
- constant in time (or slow varying)



Ghost images

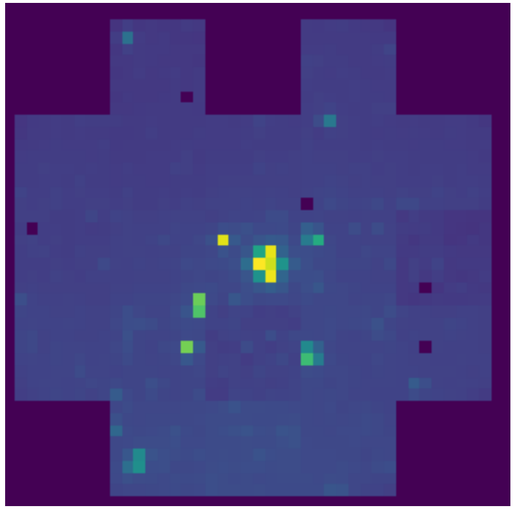
- *ice* or *wind gusts* may dis-align segments
- visible effects on shower images
- can be prevented with VAR analysis



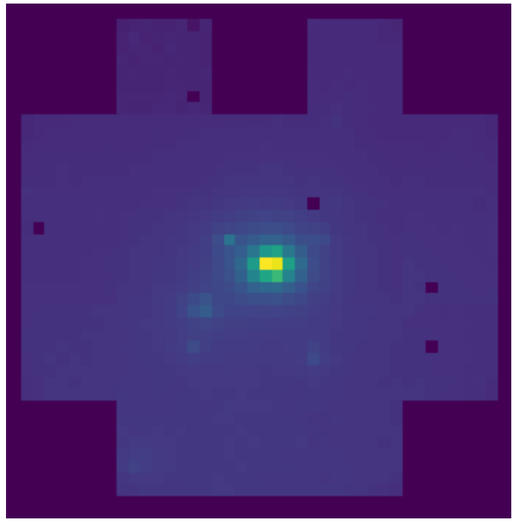
Real-case of a primary mirror segment displaced after the alignment procedure.

OTHER APPLICATIONS

- ☑ Optimization of optical parameters in Monte Carlo productions
  - local NSB characterization
  - optical vignetting
  - filter cutoff (red stars intensity)
- ☑ Alert for bright lights in the FoV
  - transients, airplanes, satellites, car flashes, etc...
- ☑ Independent check of weather conditions...
- ☐ Pointing model with the Cherenkov camera



ASTRI-Horn Variance image of the Vega region.



Same as above but during a foggy and humid night.

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