CTA&ASTRI technological activities @ INAF/OAS Bologna and the CTA Science Alert Generation System

OAS VHE meeting, June 8, 2022

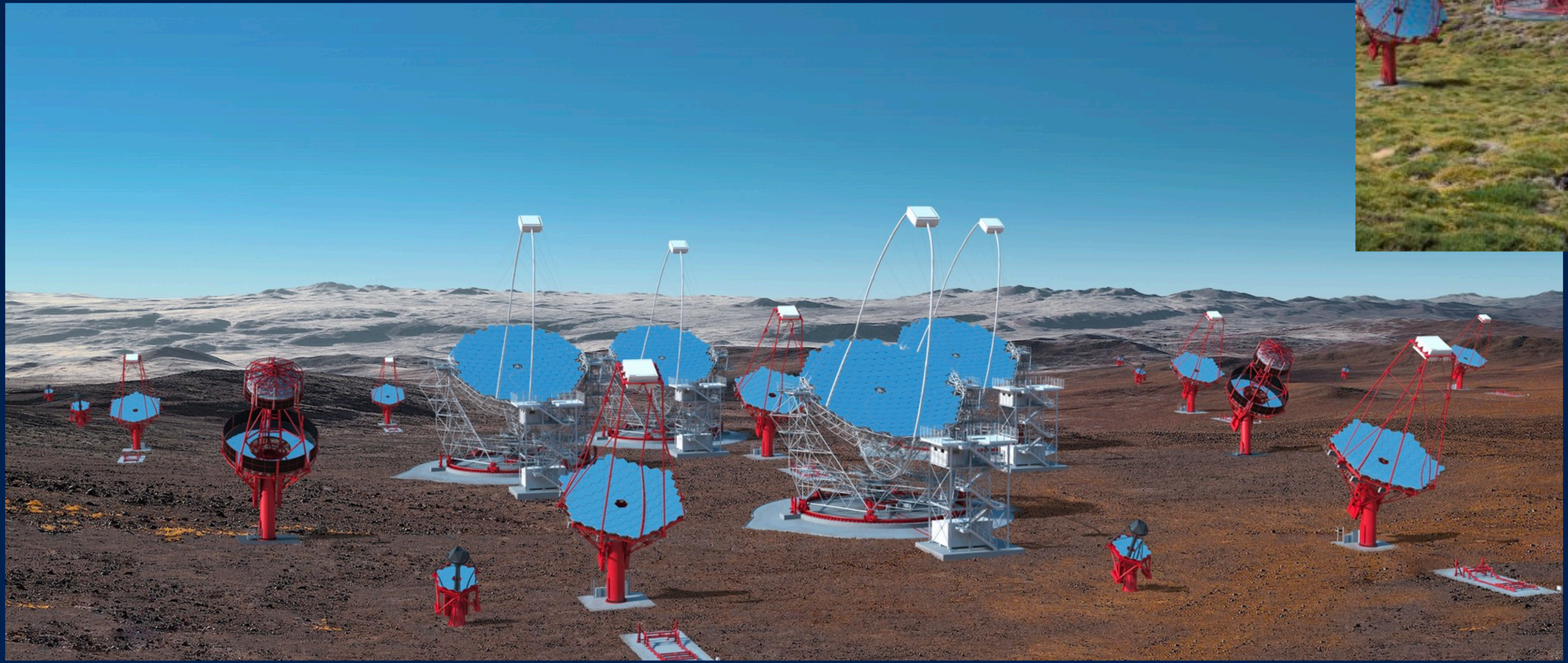
A. Bulgarelli, A. Addis, L. Baroncelli, G. De Cesare, A. Di Piano, V. Conforti, V. Fioretti, F. Gianotti, G. Panebianco, N. Parmiggiani, V. Pastore, F. Russo, A. Tacchini

andrea.bulgarelli@inaf.it

VHE projects

- CTA Observatory (CTAO)
- CTA Consortium (CTAC)
- LST collaboration
- ASTRI Horn collaboration
- ASTRI Mini-Array collaboration

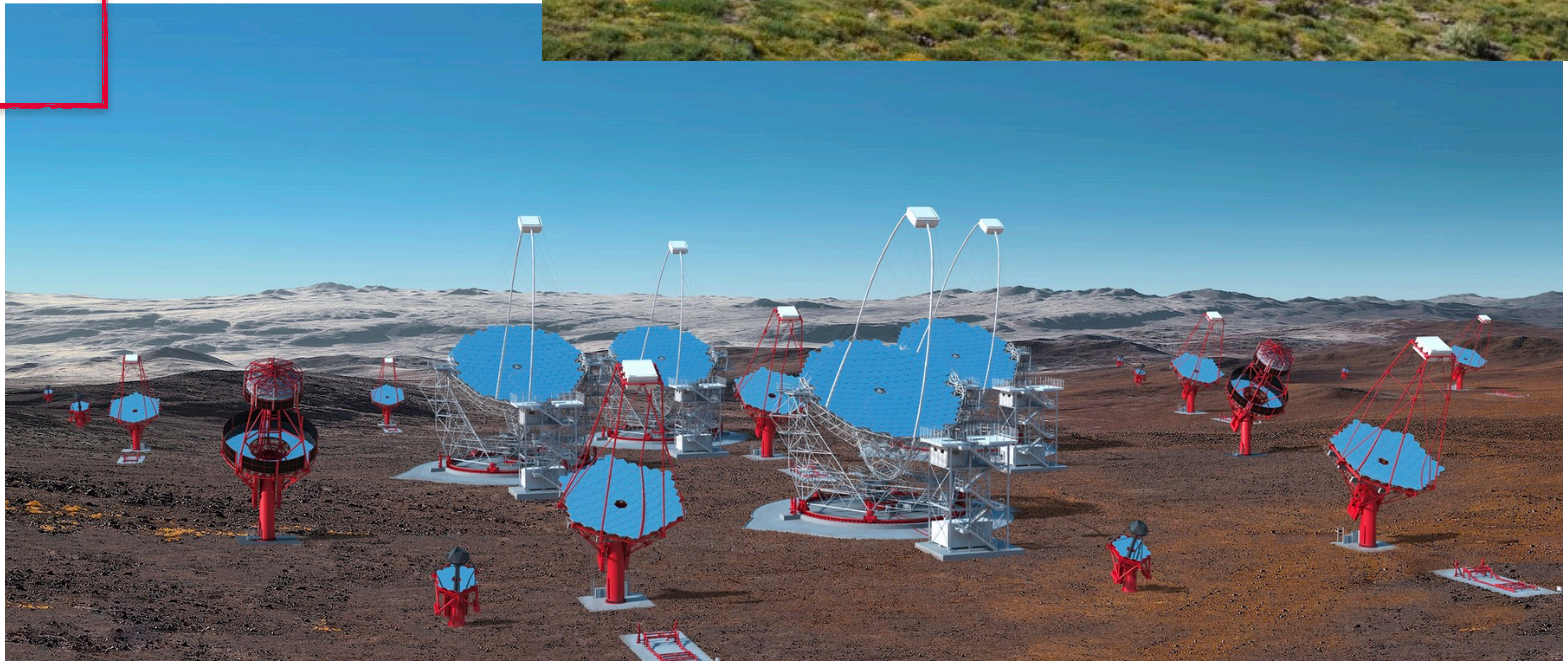
CTA



CTA & ASTRI Technological activities @OAS

- **CTA**
  - CTAO – CTA Science Alert Generation System (a.k.a. Real-Time Analysis)
  - CTAC – GRB/GW working group activities
  - CTAC – Analysis and Simulation Working Group deputy coordinator
  - CTAO – Software Engineering activities
  - – Computing

See Gianotti/Conforti's talk



CTA & ASTRI Technological activities @OAS

cherenkov telescope array

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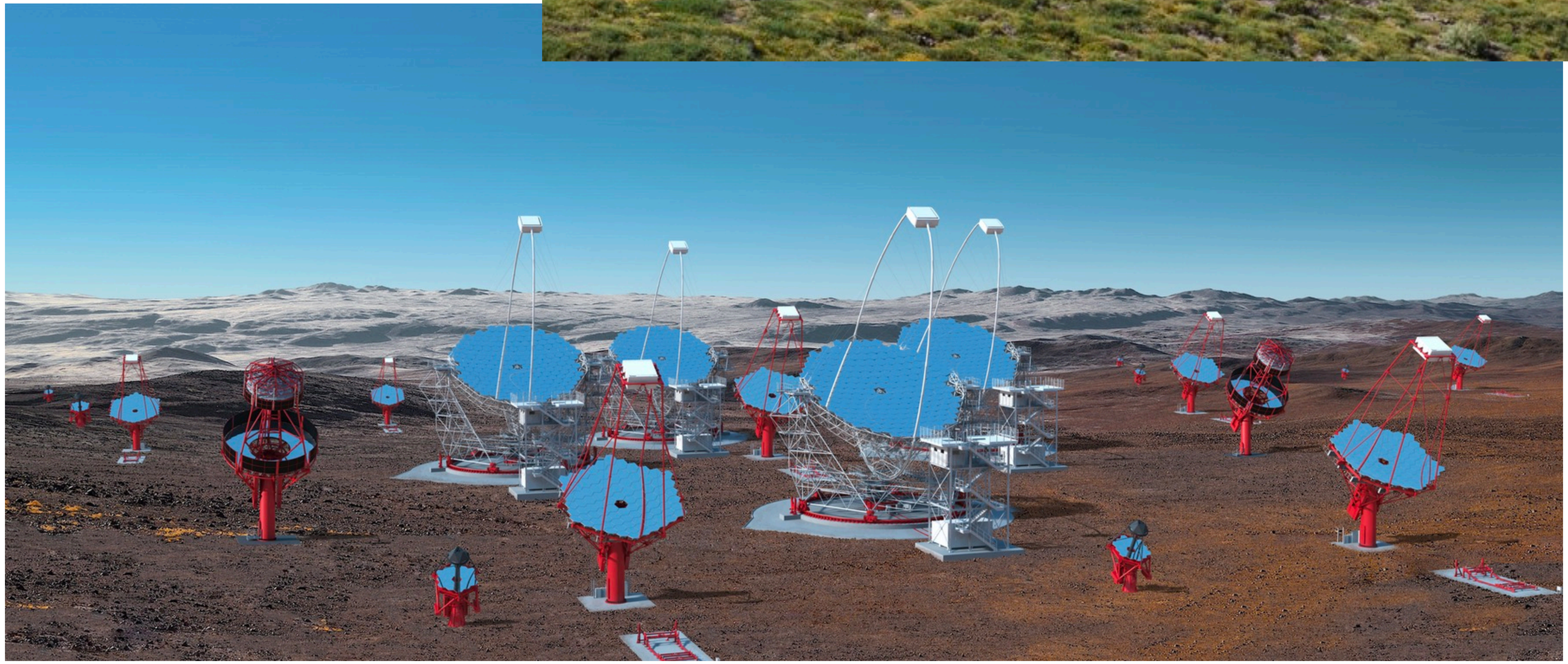
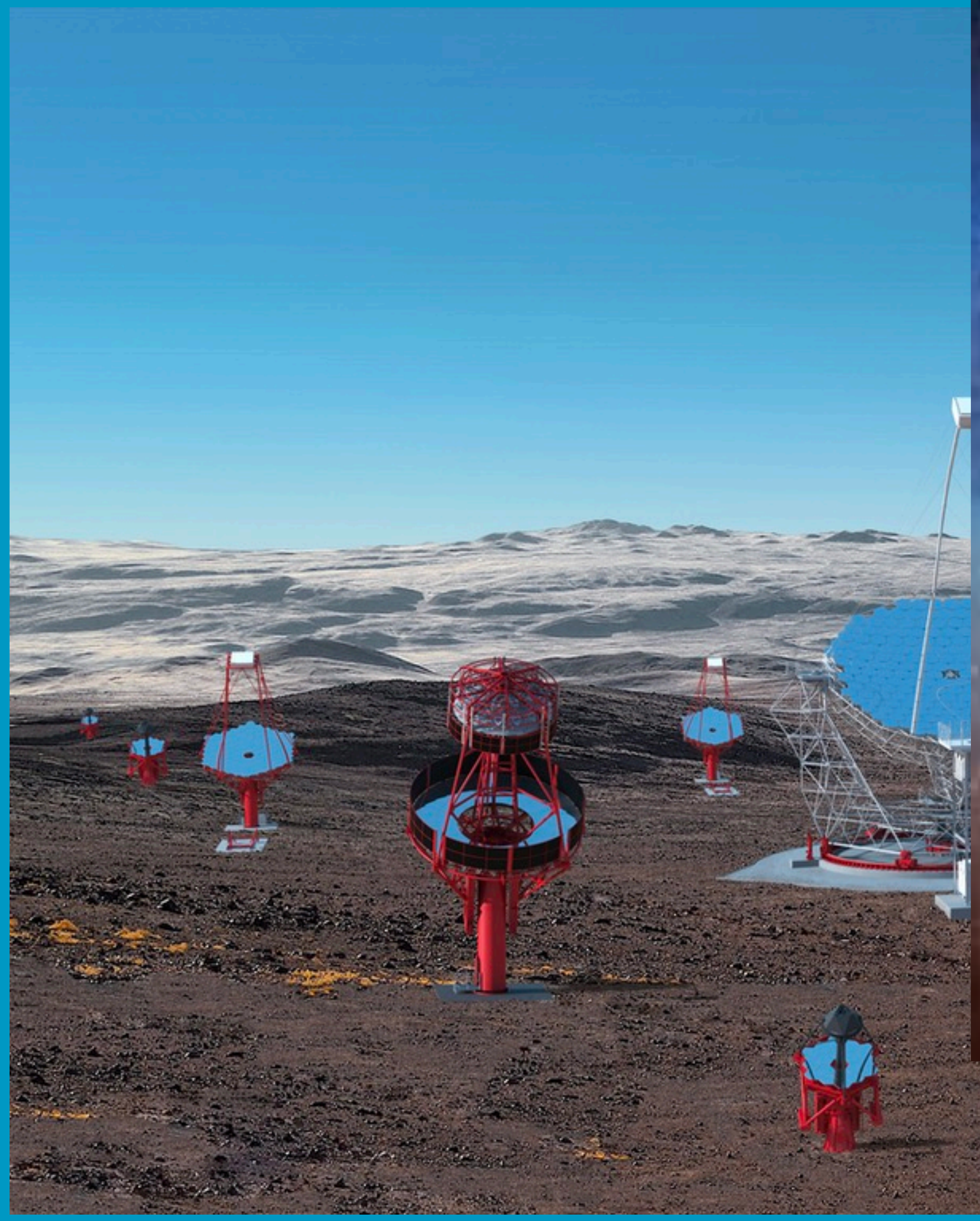
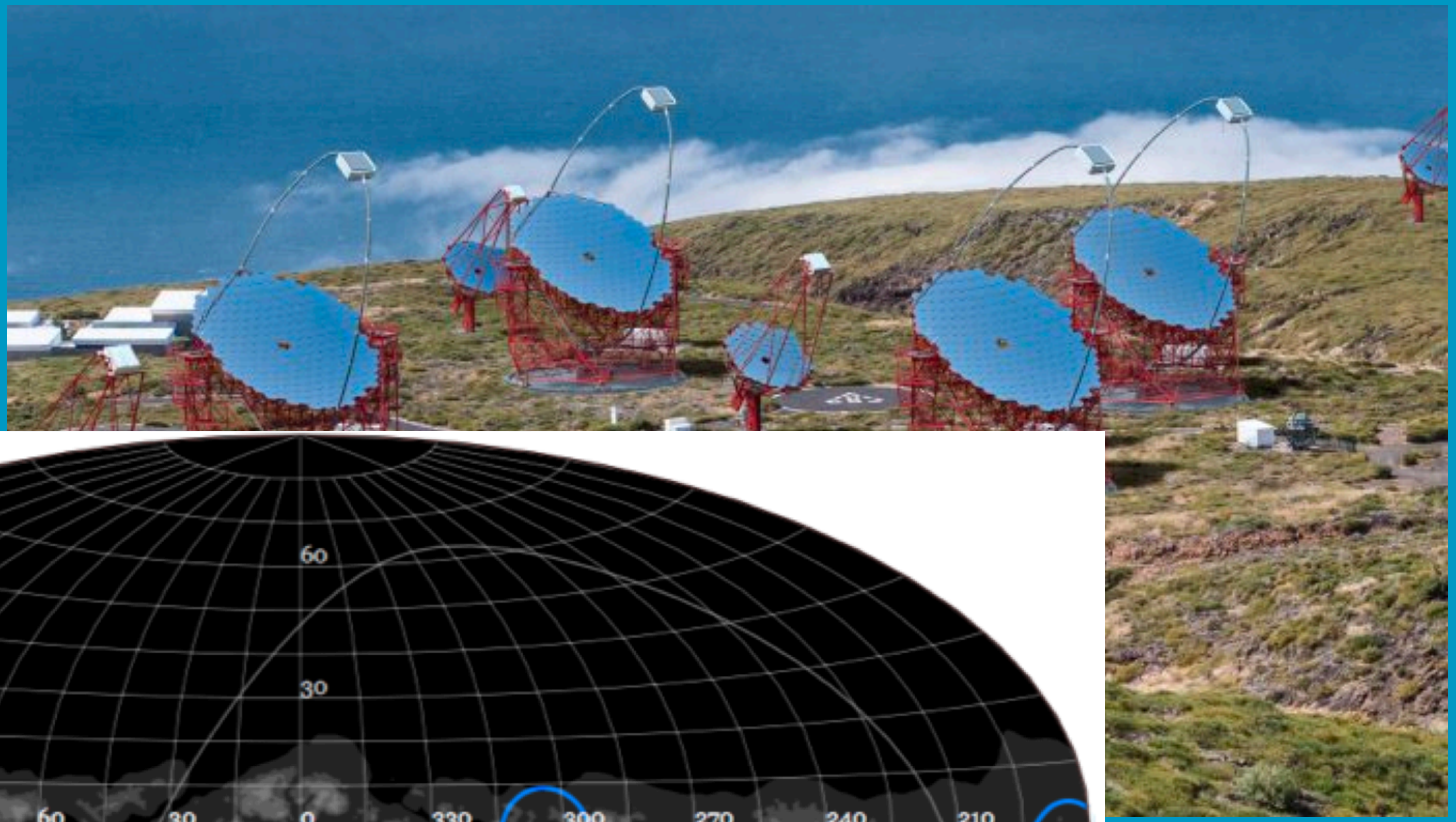
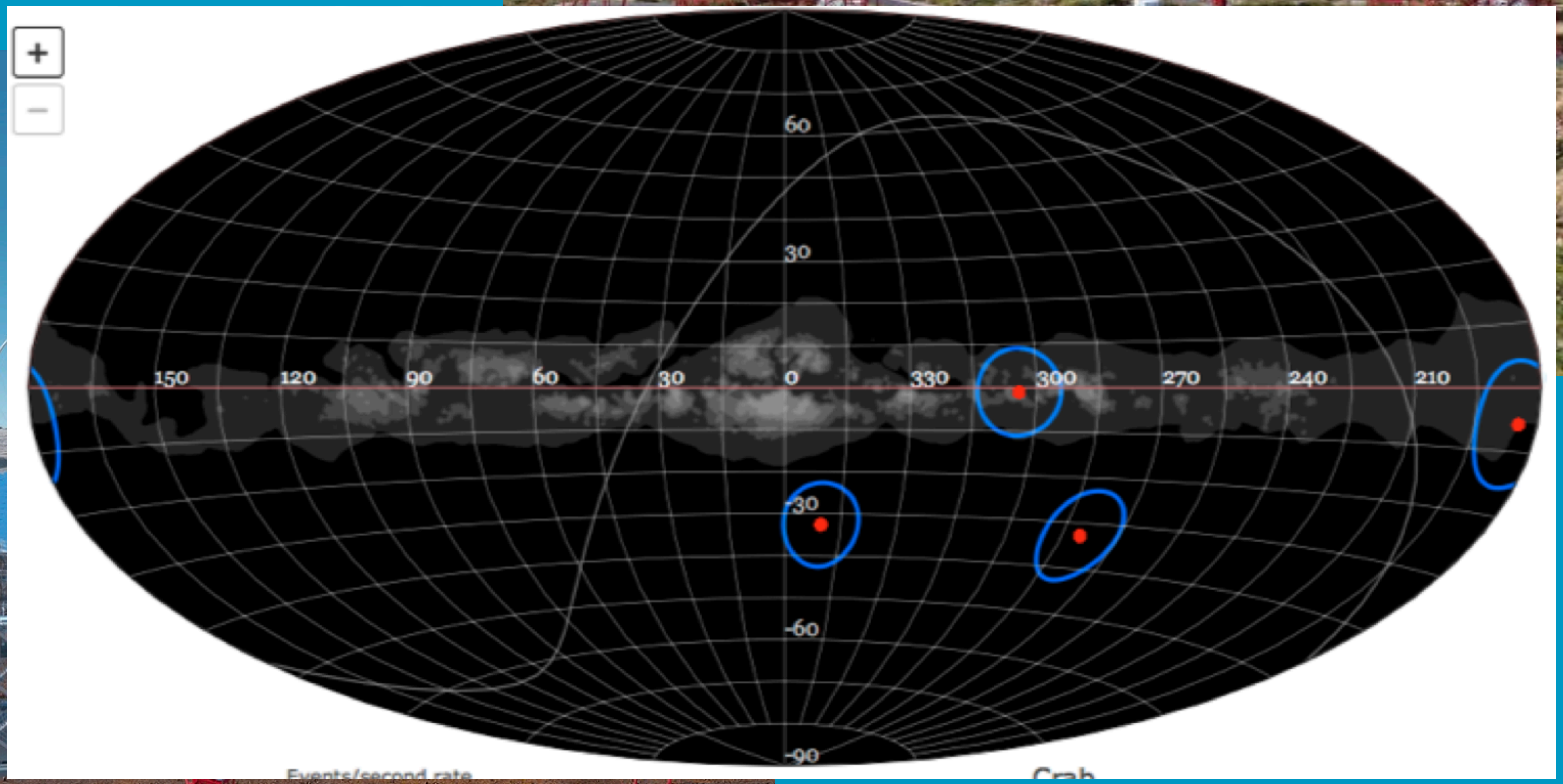
  - Software Engineering activities
  - Computing



CTA Science Alert Generation System: system and workgroup

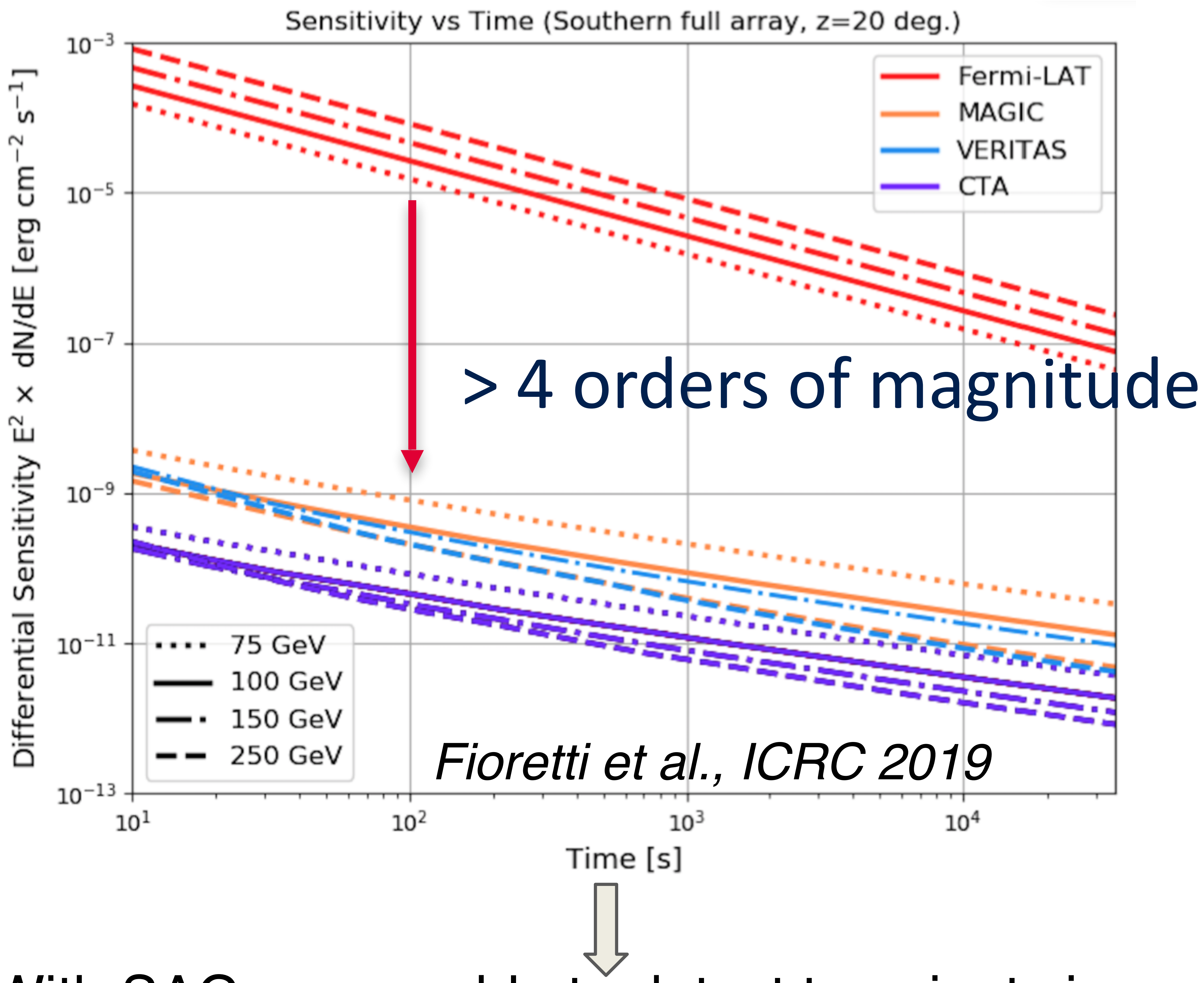






Requirements

- The **SAG** is a **software system** that analyses CTAO data **during the observation**.
- **On-site** with the telescopes.
- The SAG must be capable of **issuing candidate science alerts with a latency of 20s** since data becomes available to ACADA.
- It shall be able to work with different array configurations, ranging from all the telescopes targeting the same object, to the subdivision into a number of independent sub-arrays.
- The SAG must **search for transient** phenomena on different timescales **from 10 seconds to 180 minutes**.
- The **sensitivity** of the analysis is required not to be worse than the one of the final analysis by more than a factor of 2.

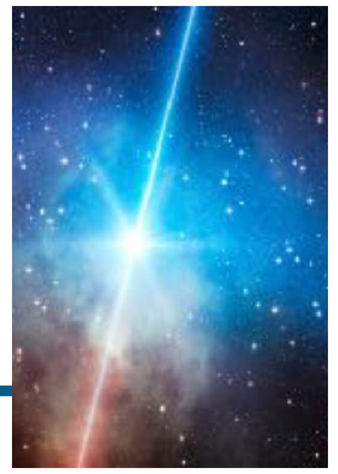


With SAG we are able to detect transients in real-time

The ACADA/SAG is a key system in the context of **multi-messenger** and **multi-wavelength** astronomy.

CTA Real-Time Analysis: Workflow

cherenkov telescope array



sag-reco

LAPP

Data reconstruction

INAF

sag-dq

INAF

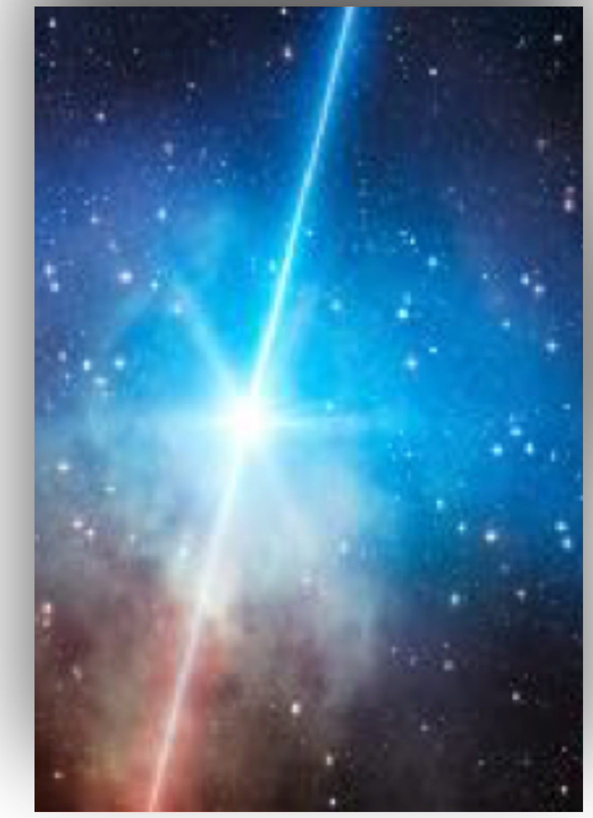
sag-sci

Check the status of the observation

Data quality monitoring

Science monitoring

To provide a scientific feedback during the observation

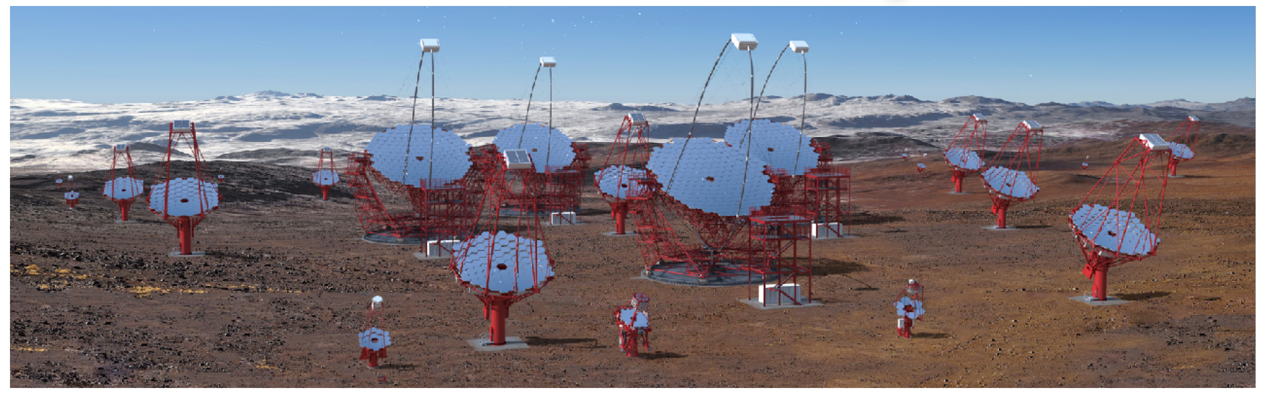


Generate science alerts

sag-sci

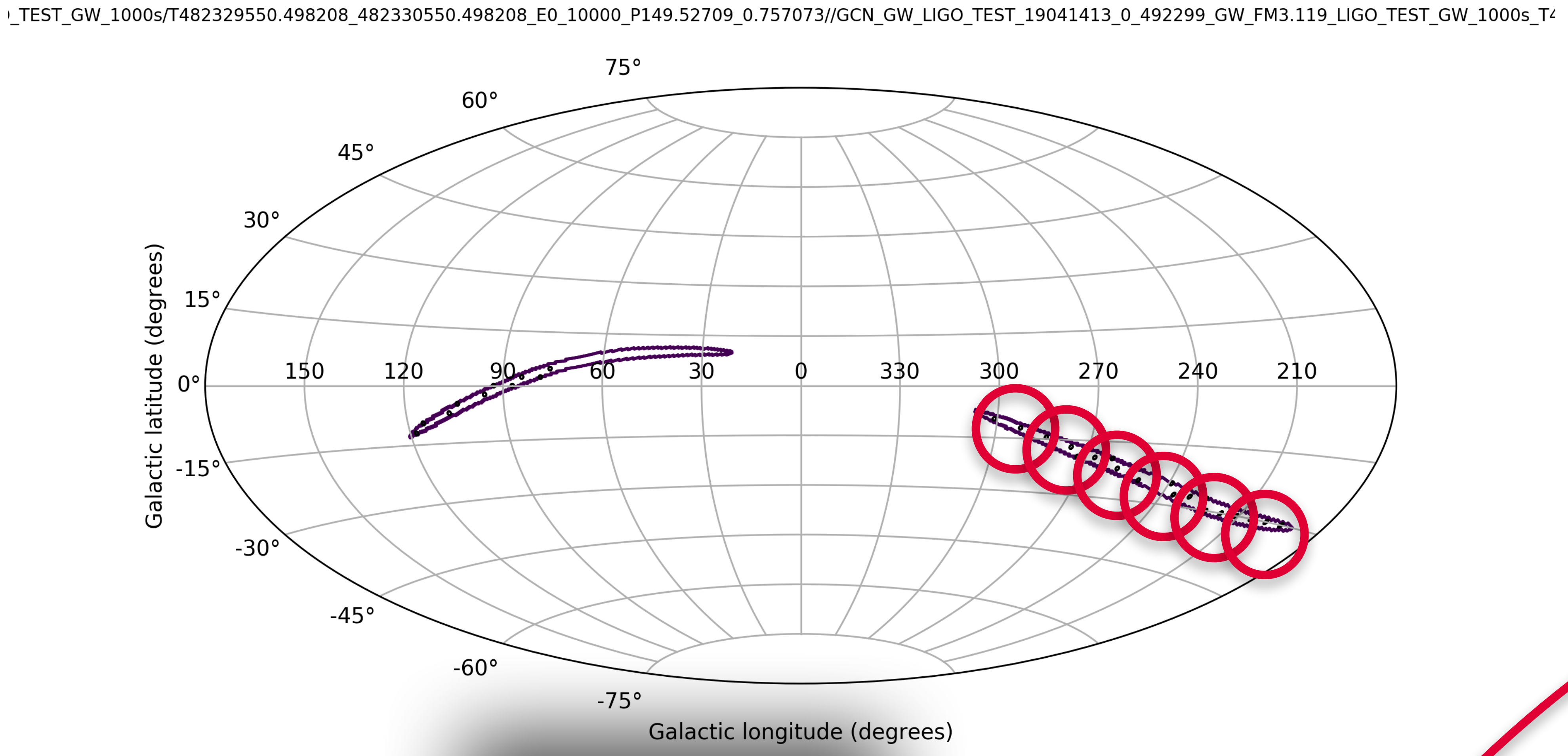
INAF

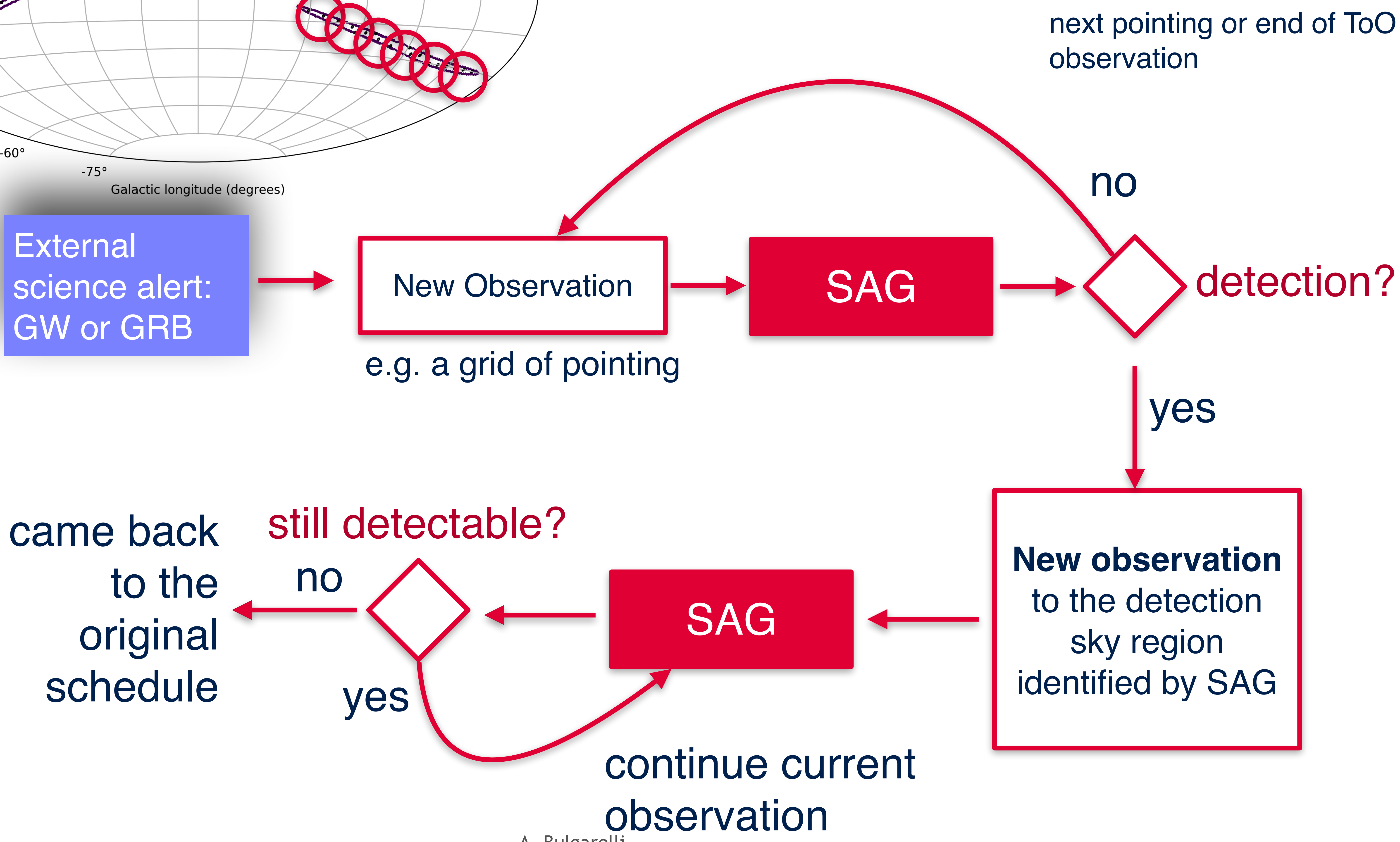
To provide feedbacks during observation to **external** (from other observatories) **science alerts**, to change the observation strategy



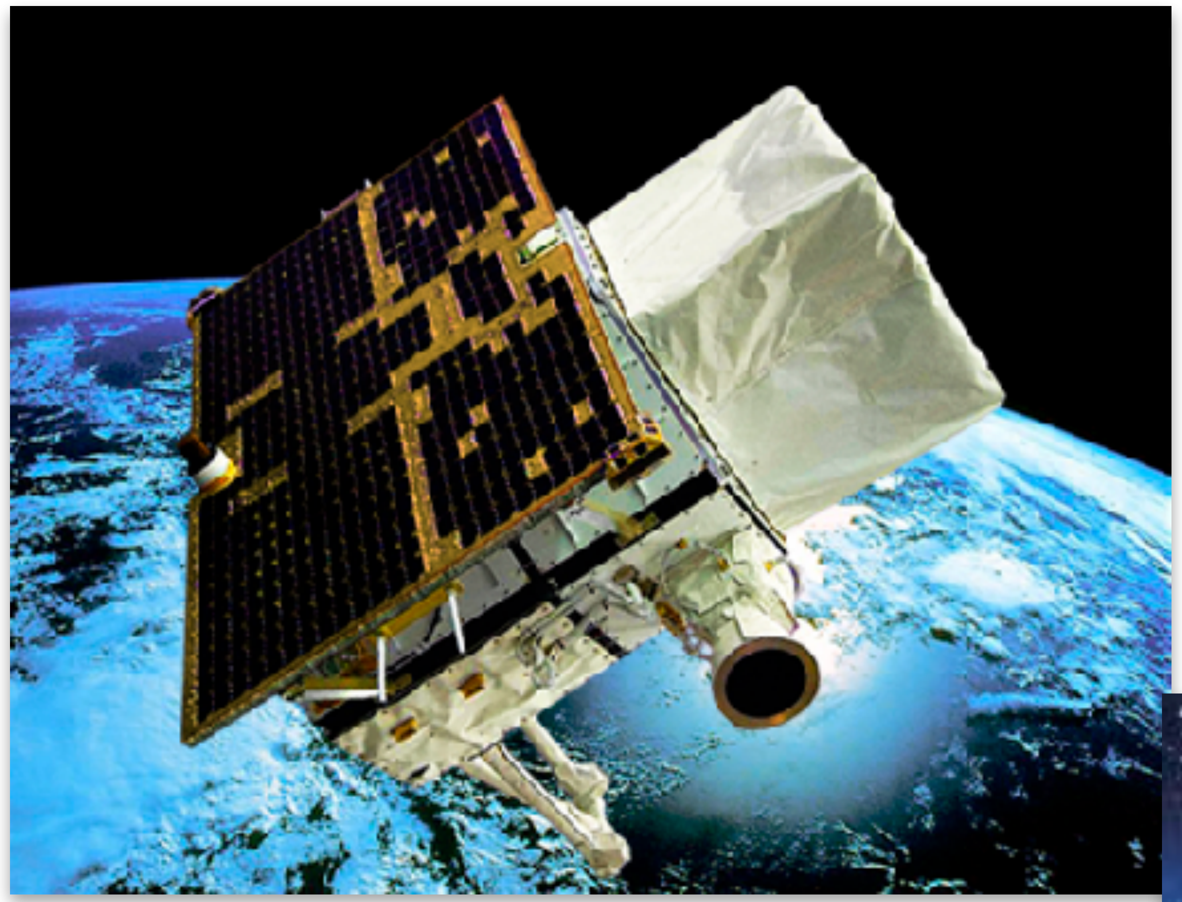
To alert the astrophysical community immediately

CTA SAG/Real-Time Analysis: Change of the observation strategies in real-time



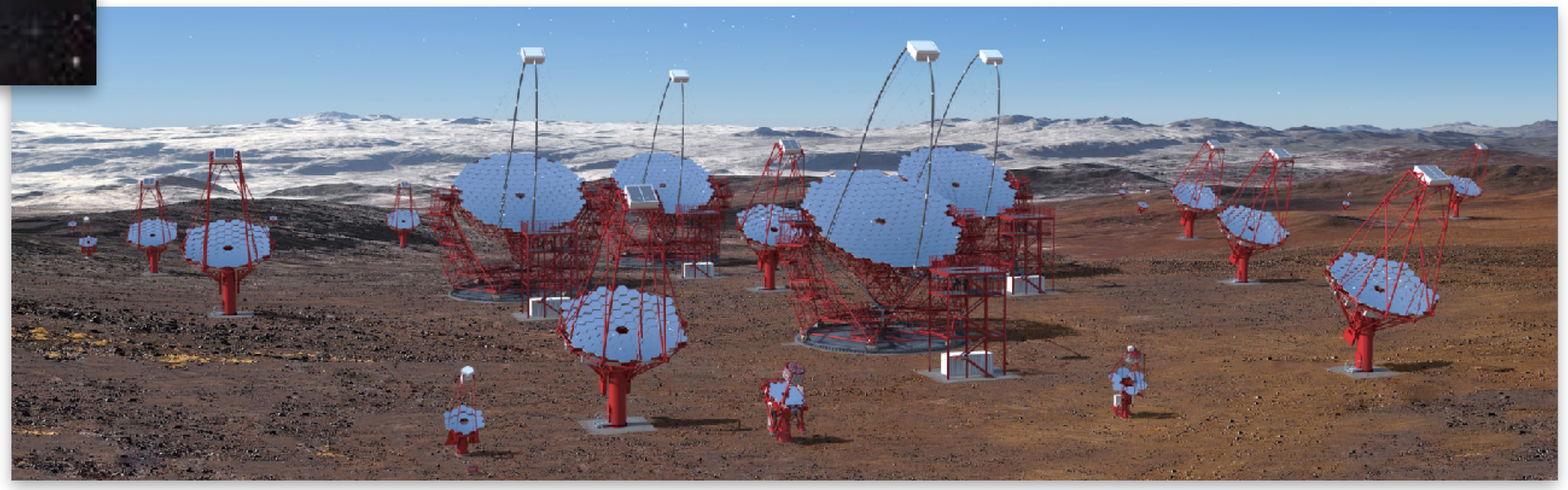


The Real-Time Analysis: Current systems and prototypes



AGILE satellite

LST1 @ La Palma



CTA

ACADA Technical Coordination Committee
- ACADA Coordinator (I. Oya, Chair)
- ACADA Systems Engineer (E. Antolini)
- ACADA Lead Developer (D. Niese)
- RM&CC Coordinator (D. Melkumyan DESY)
- HMI Coordinator (I. Sadeh DESY)
- ADH Coordinator (E. Lyard University of Geneva)
- SAG Coordinator (A. Bulgarelli INAF)
- STS Coordinator (R. Vallés IEEC/CSIC)
- TH Coordinator (K. Egberts U. Potsdam, rep. DESY)
- MON Coordinator (A. Costa, INAF)
- AAS Coordinator (A. Costa, INAF)
- CDB Coordinator (TBD)
- REP Coordinator (TBD)

ACADA Project Office Personnel

ACADA Coordinator: Igor Oya
Deputy Coordinator: Bernhard Lopez

ACADA Systems Engineer: <<vacant>>

ACADA Lead Developer: D. Neise

ACADA Oversight Committee
- S. Schlenstedt (PO, Chair)
- D. Berge (DESY)
- M. Cappi (INAF)
- R. Walter (U. Geneva)
- F. Cassol (IN2P3)
- J. Colome (ICE/CSIC)
- J. Hinton (MPIK)
- B. Rudak (CAMK Torun)
- NN (Configuration and Reporting Contributor)
- I. Oya (Ex Officio)

ACADA Configuration Control Board
- ACADA Deputy Coordinator (B. Lopez, Chair)
- ACADA Release Manager (V. Conforti)
- Project Librarian (<<vacant>>)
- Sub-task Coordinators (depending on the change)

Sub-system Developers

Resource Manager and Central Control
Coordinator: D. Melkumyan (DESY)

Team (DESY):
- D. Melkumyan
- T. Schmidt
- T. Murach
- S. Sah
- J. Vesel
- R. Fernandez

Human Machine Interface
Coordinator: I Sadeh (DESY)

Team (DESY):
- I. Sadeh
- D. Lebout (INRIA)
- E. Pietriga (INRIA)

Transients Handler
Coordinator(U. Potsdam): K. Egberts

Team (DESY/U. Potsdam):
- C. Steppa
- K. Egberts
- E. de Oña

Array Data Handler
Coordinator: E. Lyard (U. Geneva)

Cherenkov Cam. and Aux. Inst. Data Handling, ADH Integration and Testing (UniGeneva)
- E. Lyard
- J. Jurysek
- S. Fukami
- C. Armand
- A. Tramacere
- M. Schefer

Software Array Trigger (CAMK)
- A. Muraczewski
- V. Bashley

Data Volume Reduction (MPIK):
- F. Werner
- S. Sailer

Short-term Scheduler
Coordinator: R. Vallés (ICE/CSIC)

Team (ICE/CSIC):
- J. Colome
- N. Nakhjiri
- R. Vallés
- P. García

Reporting
Coordinator: NN

Team (NN)

Configuration (DESY)
Coordinator: NN

- D. Kostunin (DESY)

Science Alert Generation Pipeline
Coordinator: A. Bulgarelli (INAF)

Low-level Reco Pipeline, Param Ext. Lib (LAPP):
- S. Caroff
- P. Aubert
- E. Garcia
- T. Vuillaume

High-Level Reco Pipeline, Data Quality (INAF):
- A. Bulgarelli
- N. Parmiggiani
- V. Fioretti
- G. De Cesare
- L. Baroncelli
- A. Addis
- A. Di Piano
- G. Panebianco

Monitoring & Logging
Coordinator: A. Costa (INAF)

Coordinator: A. Costa (INAF)

Common Team (INAF):
- A. Costa
- P. Bruno
- S. Germani (U. Perugia)
- F. Incardona
- K. Munari

AIV and Development Infrastructure Team
- Release Manager: V. Conforti (INAF)
- System Integrator: H. Gasparyan (DESY)
- System Admin: P. Bolle + H. Hees (DESY)
- Cross-cutting: SW Developer: <<vacant>>
- Standard Devel Env: T. Schmidt (DESY)
- Project Librarian: <<vacant>>

Use Case Teams

(changing composition per use case integration)

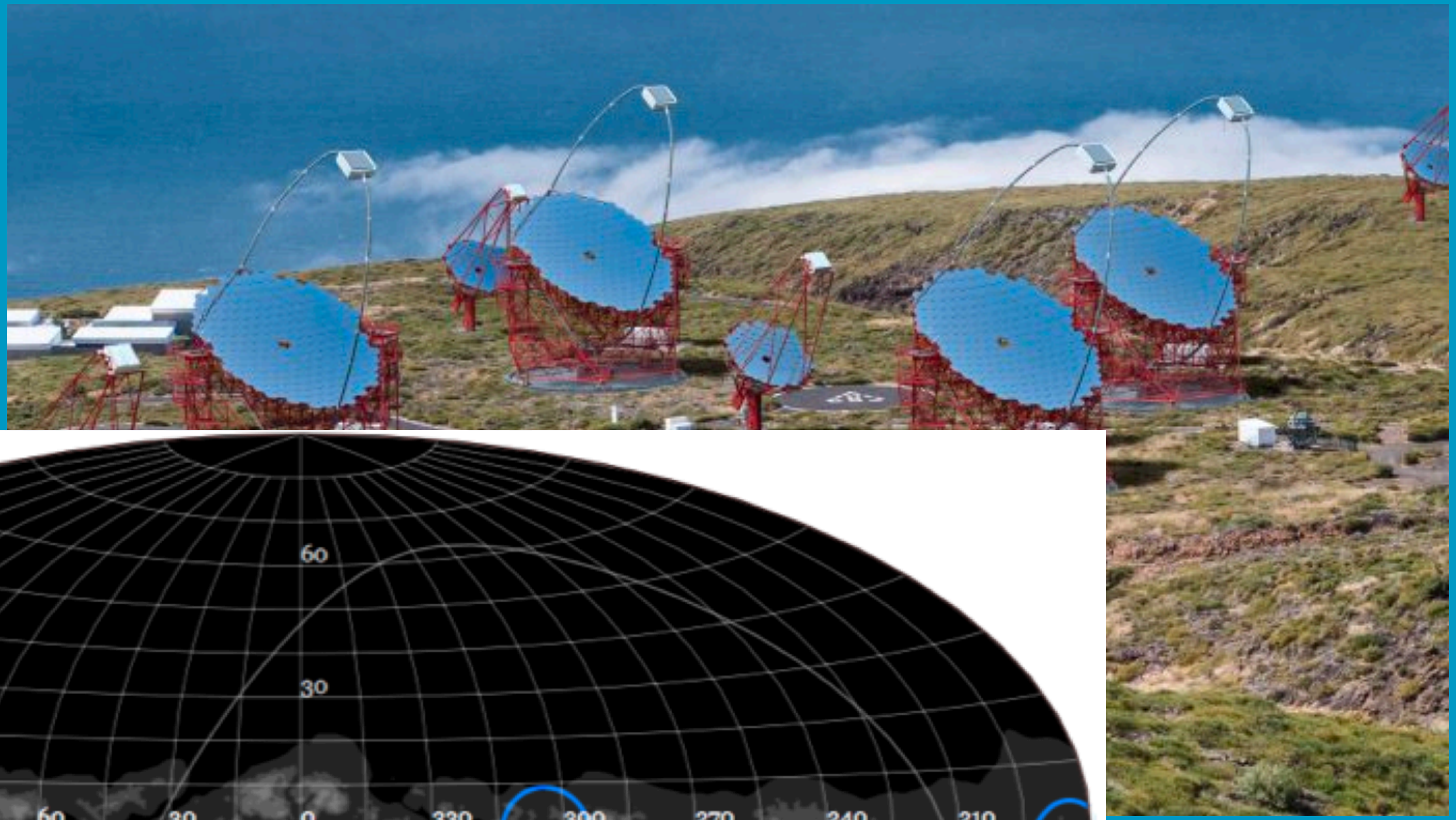
ACADA Org Chart, V 5, Rev. d (2022-05-12)
Author: I. Oya

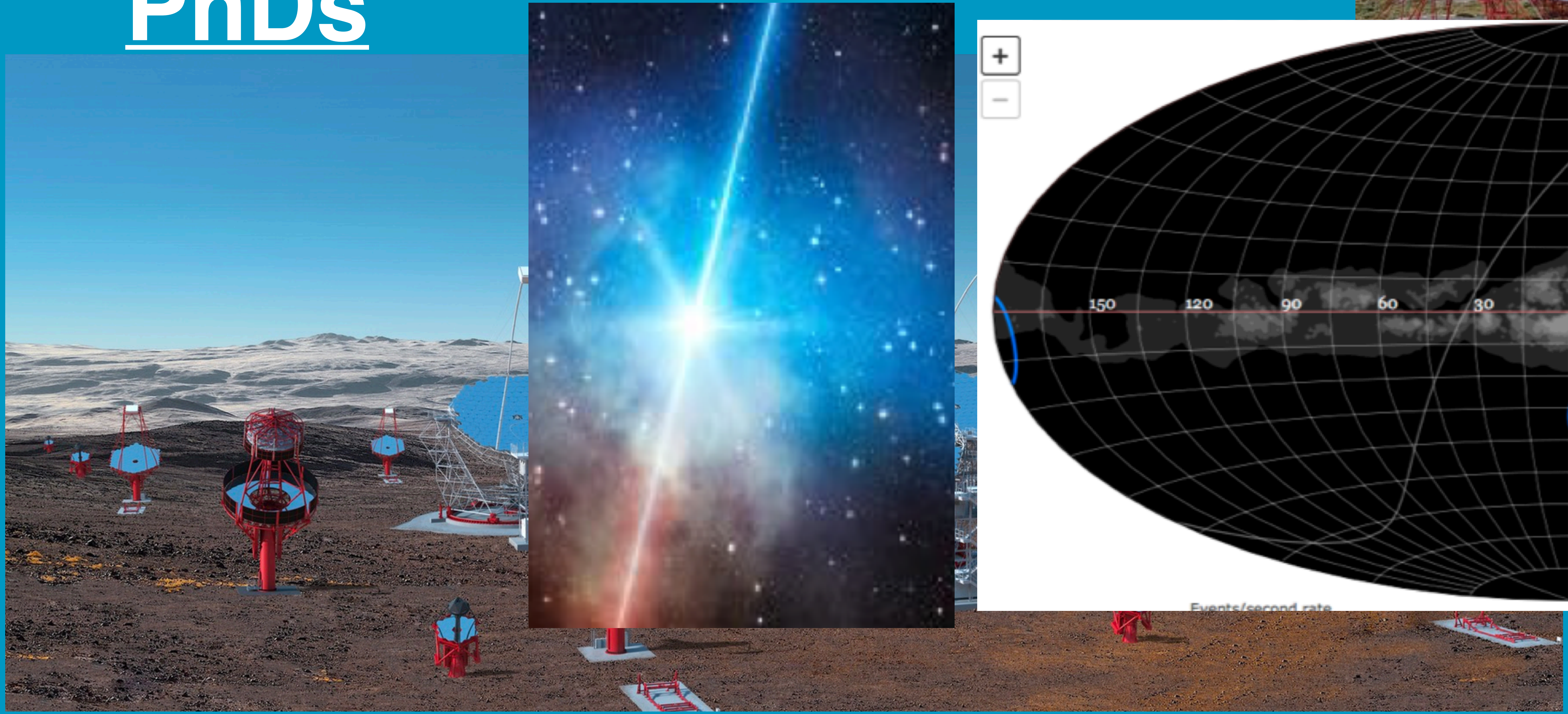
SAG contribution

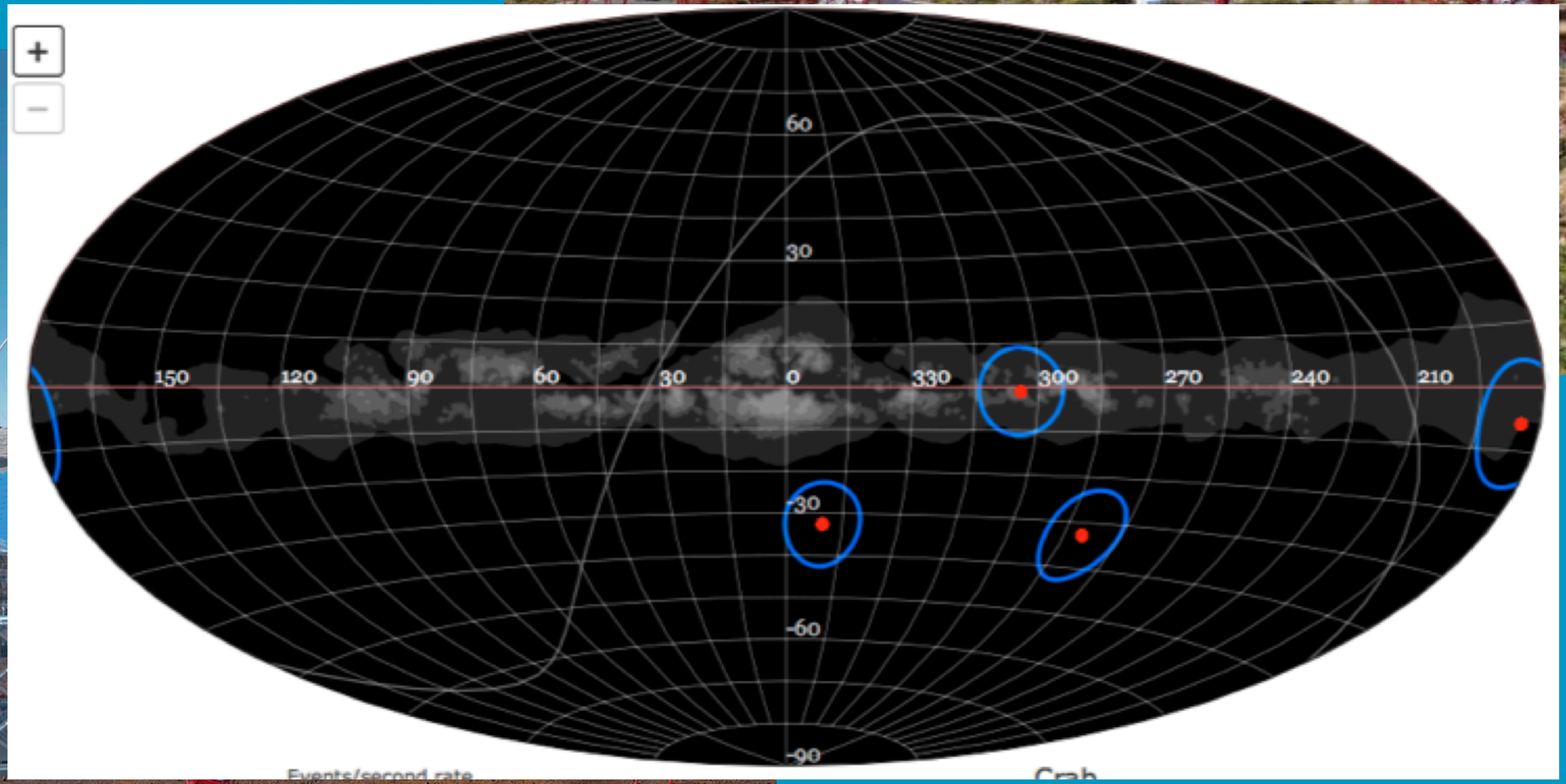
- SAG developed in the context of the ACADA WG as CTAO In-Kind contribution
  - 3 FTEy for 5 years = 15 FTE
    - A. Bulgarelli (coordinator)
    - N. Parmiggiani (AdR, sag-sci responsible, sag responsible for verification procedure, ACADA database selection group leader)
    - L. Baroncelli (PhD student on Data Science and Computation @ UNIBO, sag supervisor responsible, software integration leader, sag-dq responsible, LST member)
    - A. Di Piano (PhD student @UNIMORE on machine learning, LST member, development of SAG algorithms, sag responsible for GRB and GW WGs)
    - G. Panebianco (PhD student @DIFA, simulation of light curves, atmospheric variability studies for CTA, gammapy)
    - A. Addis (sag-dq responsible for LST)
    - G. De Cesare (sag-sci test leader)
    - V. Fioretti (short-term sensitivity, IRFs, data challenge)

cherenkov telescope array

CTA Science Alert Generation System: PhDs







Atmospheric variability studies for CTA (G. Panebianco)

Current goal: understand how atmospheric variability affects the reconstruction process of IACT data.
Long term goal: implement corrections for atmospheric effects in SAG pipelines.

What have we understood so far?

Atmospheric effects are due to

Short-term absorbers (local clouds over one or more telescopes)

Trigger rates have high fluctuations, their variance increases wrt cloudless sky.

Long-term absorbers (cloud layers, aerosol)

Cherenkov photons are more absorbed and scattered wrt cloudless sky.

SAG-DQ should be alerted if trigger rate variance is high!

Open questions

- In H.E.S.S. a trigger rates std >3% is due to local clouds. How much in CTA?
- How should we act on the data?

SAG-RECO should implement corrections for cloudy sky.

Cloud layers effects

- Detection rate of Cherenkov photons and effective collection area decrease, thus energy threshold increases.
- Shower images are distorted. High-energy showers appear as lower energy shower.
- Reconstructed energy has a bias.

Open questions: corrections for cloud layers proposed by IACT community

1. Train Random Forests for reconstruction with «cloudy» simulated data.
2. Train Random Forests with «cloudless» data, then apply empirical corrections on the reconstructed energy and the source flux. Different methods for LSTs, MSTs, SSTs.

Transient light curve simulator with Gammapy for CTA and COSI (G. Panebianco)

Current goal: setup a simulator of light curves (GRBs, AGNs, other transients) given a source model (spectral+temporal) and a set of IRFs.
Long term goal: create a dataset of simulated light curves that can be used to train ML algorithms to detect transients.

Current task: setup the simulator and reproduce a GRB (i.e. GRB 120323A) as detected by Fermi-GBM.

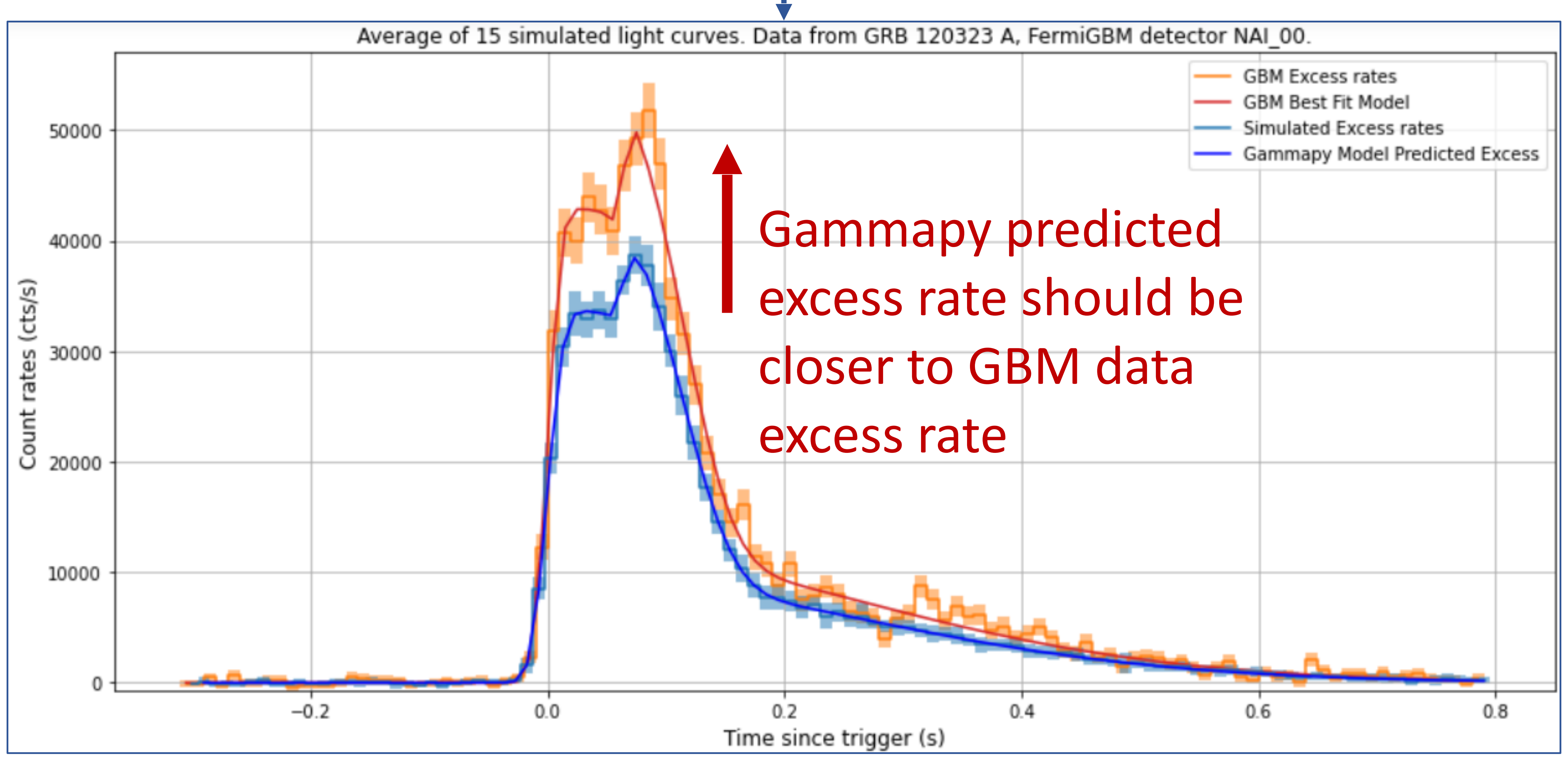
- **Background rates: OK**, GBM Data reproduced.
- **Temporal shape: OK**, GBM Data reproduced.
- **Spectral shape: OK**, GBM Data reproduced.
- **Excess rate: NOT OK**, predicted ≈18% systematically lower than GBM Data. Something wrong with IRF normalization? Or spectral parameter choice?

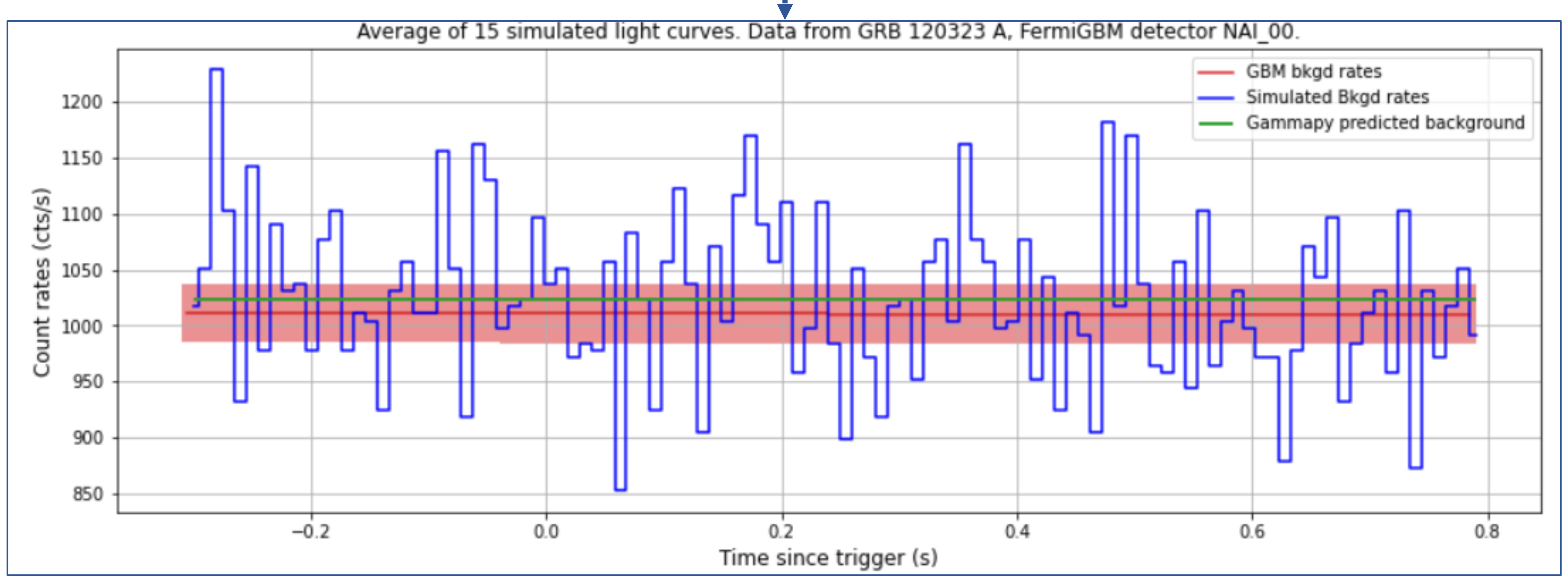
GBM IRFs
(from GBM archive)

Spectral and temporal model
(from GBM Data fit)

Gammapy simulator

- Background rates prediction + simulation
- Excess rates prediction + simulation

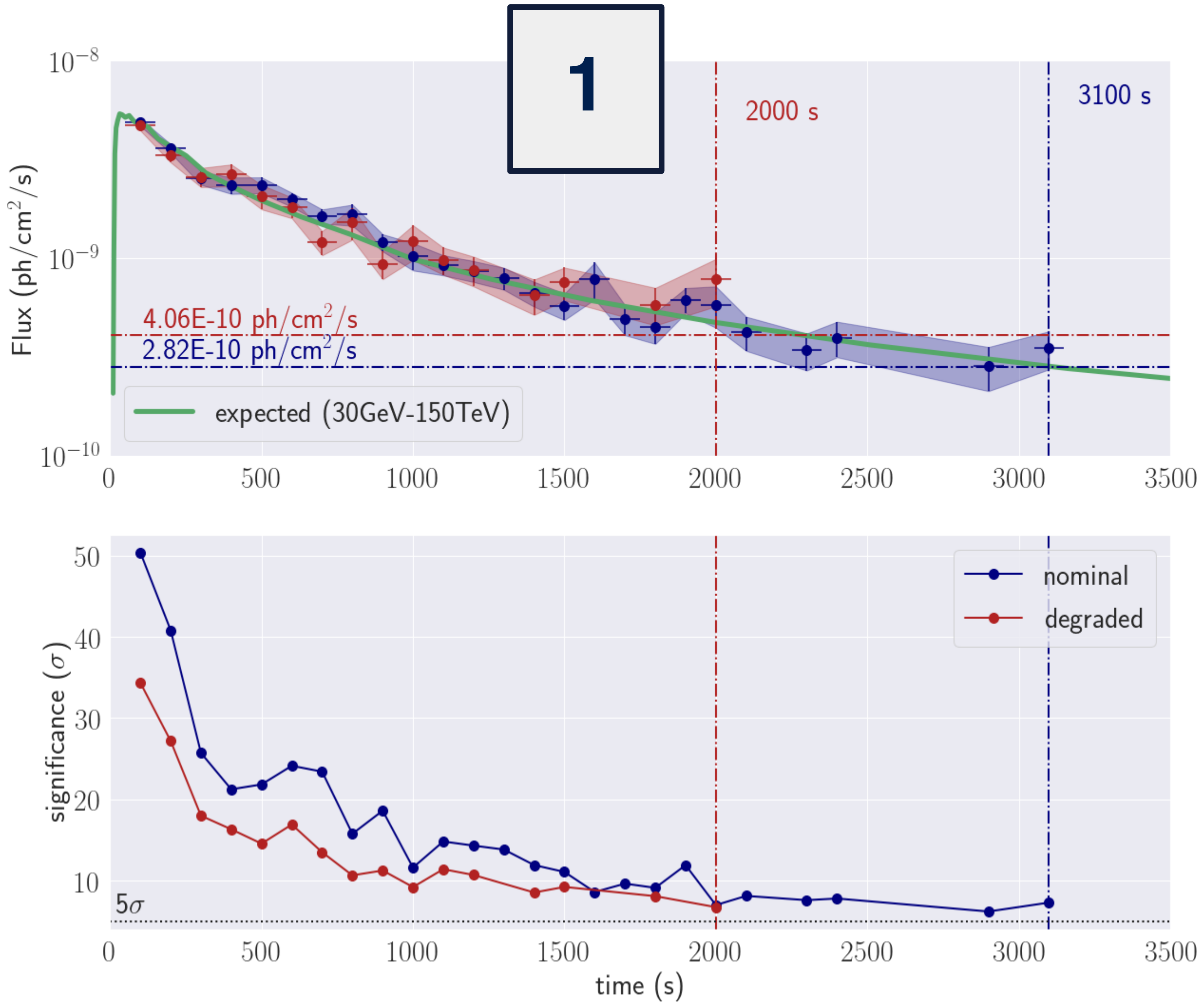


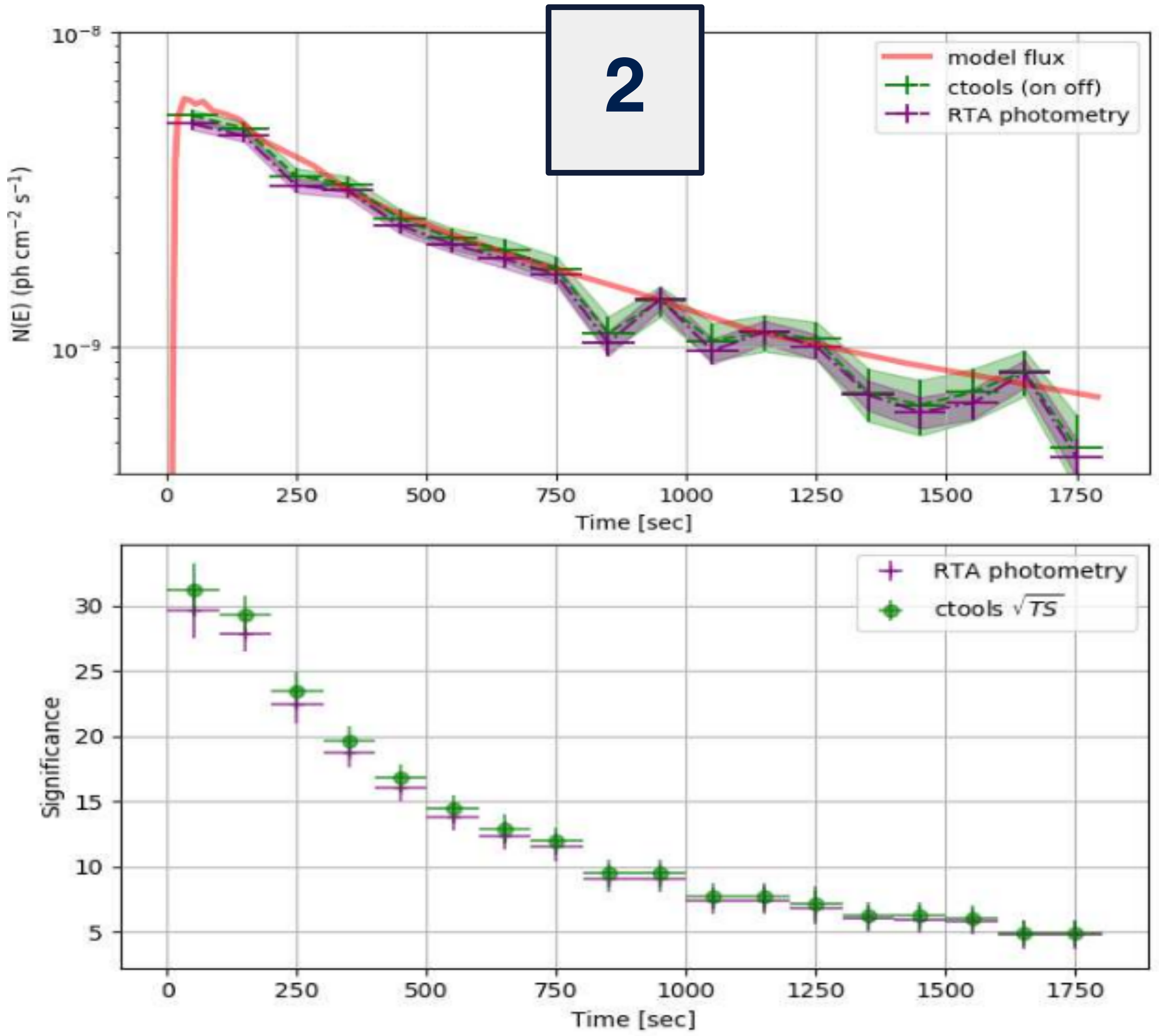


Thesis works

1. Blind-search + full-FoV maximum likelihood pipeline with ctools software package for externally alerted follow-ups (A. Di Piano thesis)

2. RTA Photometry tool pipeline (reflected/wobble methods) for targeted observations + comparison with ctools on/off analysis (S. Tampieri thesis)





Leonardo Baroncelli PhD main activities

cherenkov telescope array

- Design and development of an online anomaly detection system for science alert generation, based on deep learning, in the context of the CTA Observatory.

Nicolò Parmiggiani PhD Main Activities

- Desing and Development of the **RTApipe framework** to implement real-time analysis pipelines for ground and space based gamma-ray observatories in the multi-messenger and multi-wavelenght context.

> Parmiggiani, N. et al., "The RTApipe framework for the gamma-ray real-time analysis software development", Astronomy and Computing, Volume 39, April 2022. DOI: https://doi.org/10.1016/j.ascom.2022.100570

- Development of **Deep Learning models** to detect Gamma-ray Bursts in the AGILE space mission data acquired by the GRID instrument.

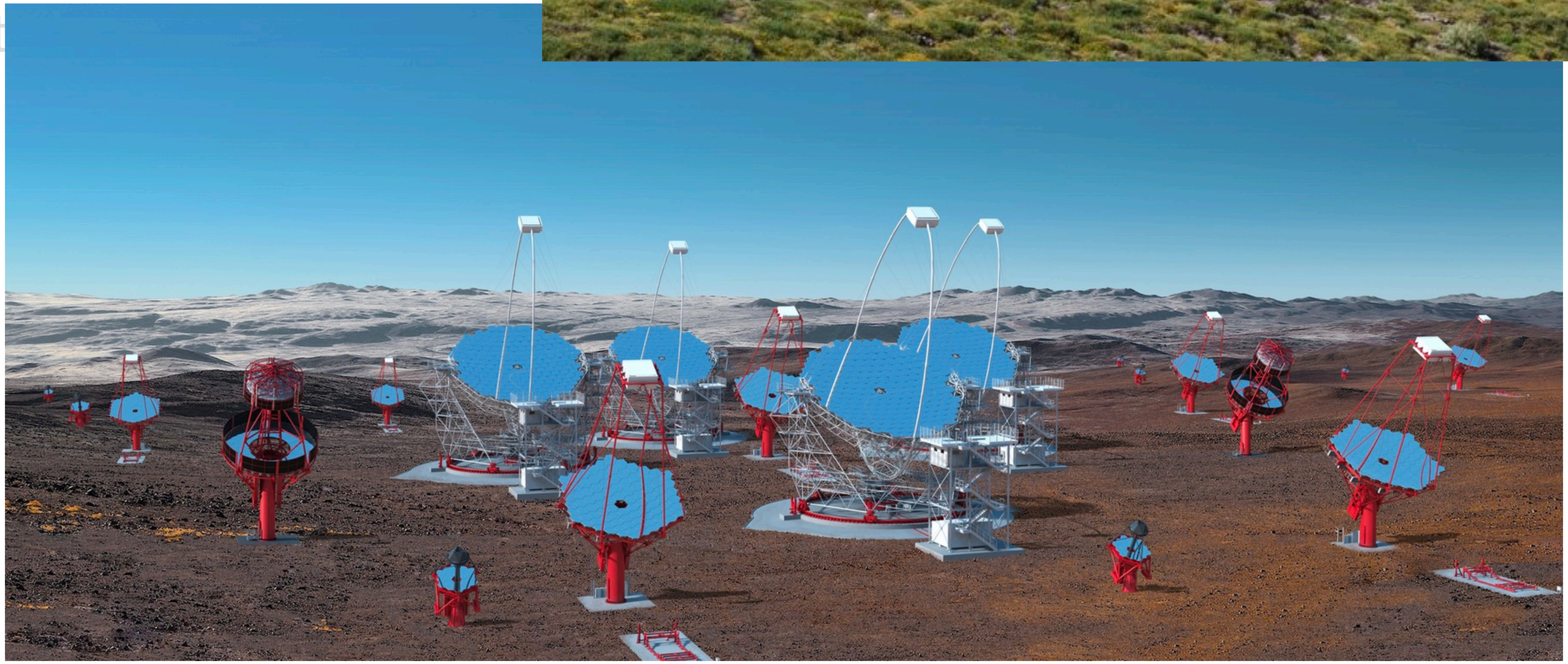
> Parmiggiani, N. et al, Astrophysical Journal, 914, 67, 2021.

> Parmiggiani, N., Italian National Prize for Artificial Intelligence and Big Data research, WMF and IFAB 2021. Media INAF

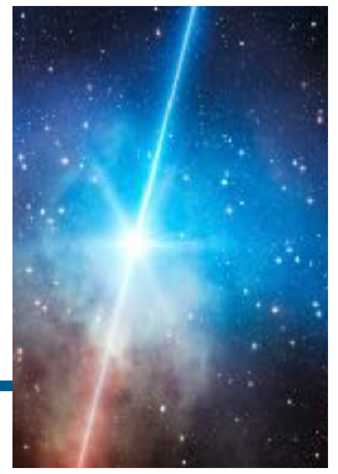
- Development of real-time analysis pipelines for the AGILE space missions to perform the follow up of external science alerts and maintainance of the hardware systems.

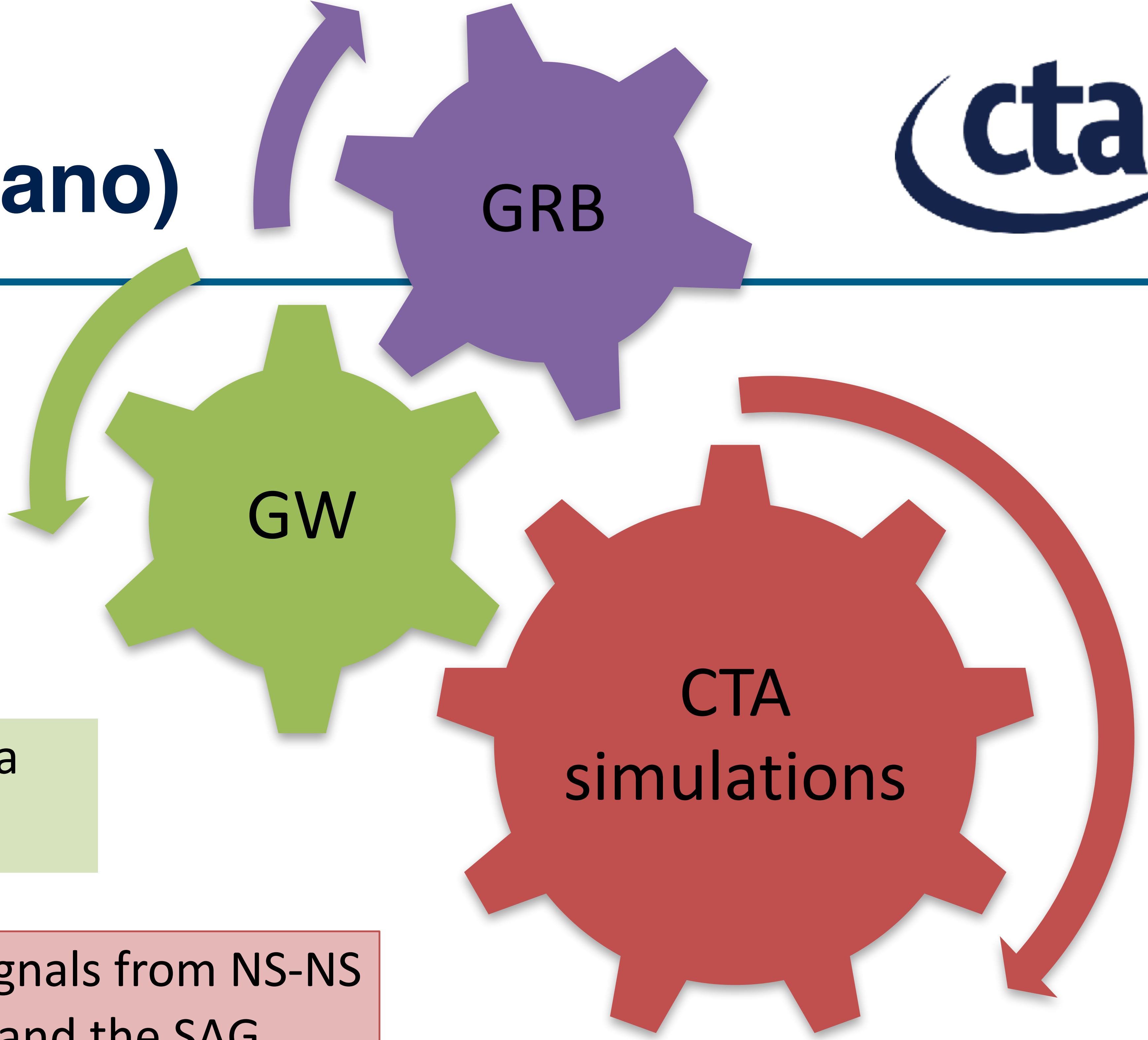
CTA & ASTRI Technological activities @OAS

- **CTA**
  - CTA Science Alert Generation System (a.k.a. Real-Time Analysis)
  - **GRB/GW working group activities** (A. Di Piano)
  - Analysis and Simulation Working Group deputy coordinator
  - Software Engineering activit
  - Computing



Transient SWG: GRB and GW (A. Di Piano)

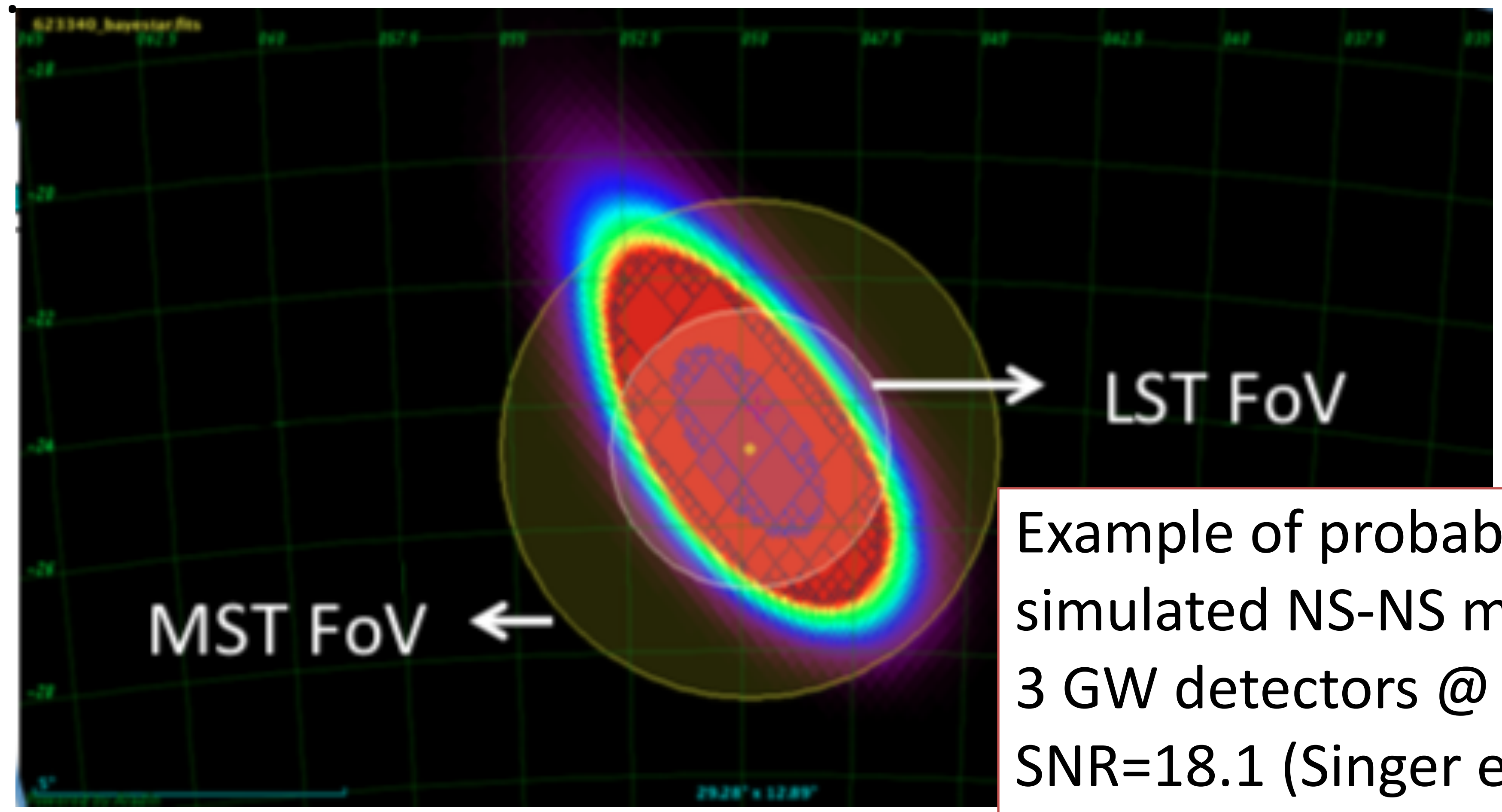




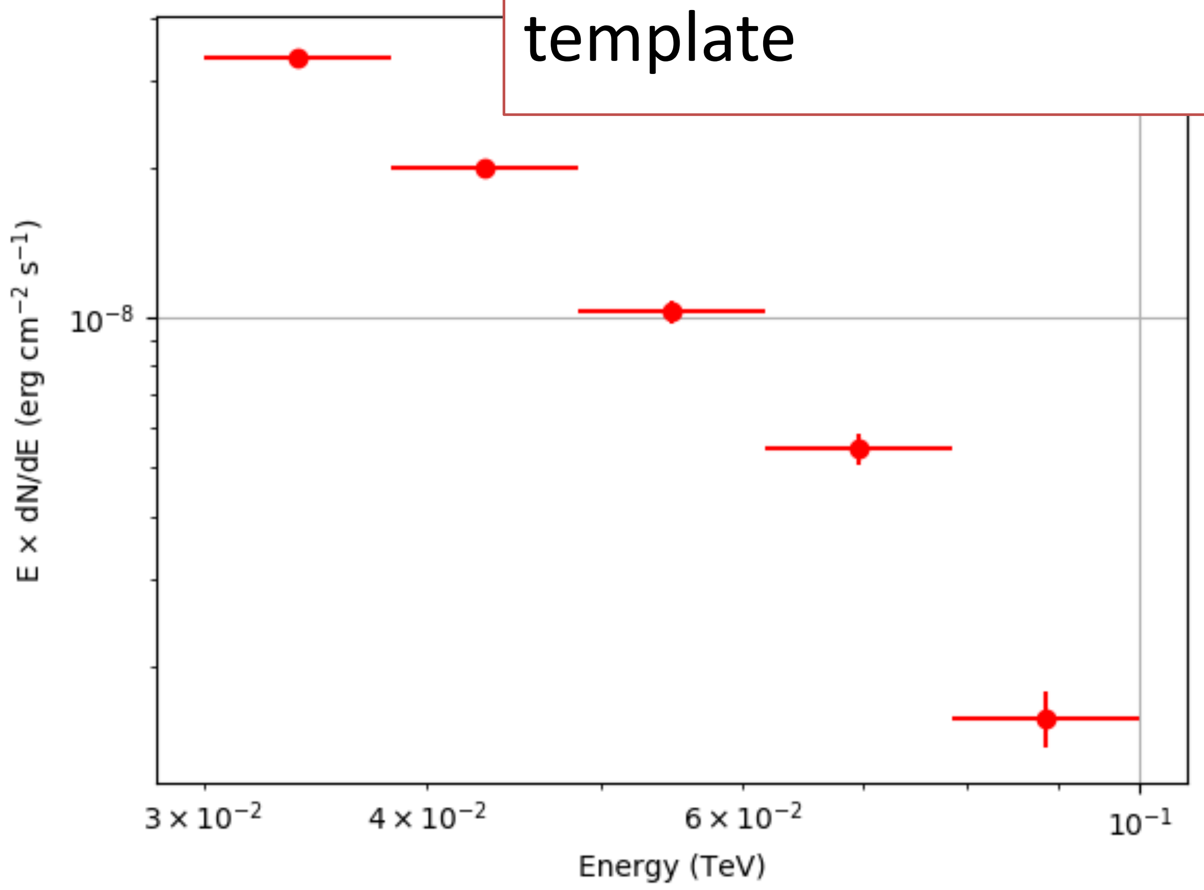
Fermi/LAT and MAGIC detection have shown that GRB emit up to TeV energy domain (e.g. GRB 190114C, GCN 23701, Mirozyan et al. 2019)

GW 170817 / GRB 170817 has definitively associated Gamma Ray Bursts to NS-NS mergers (Abbott et al. 2017)

We simulate CTA observations of realistic electromagnetic signals from NS-NS mergers, in strong synergy with the GRB and GW CTA teams and the SAG team at OAS-INAF. **Development of the visibility tools**



Example of probability skymap of a simulated NS-NS merger detected with 3 GW detectors @ 54 Mpc, i=8°, SNR=18.1 (Singer et al. 2015). CTA FoV covers 98% of total probability



Example of a simulated spectrum using the Fermi/LAST GRB080916 template

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cherenkov telescope array

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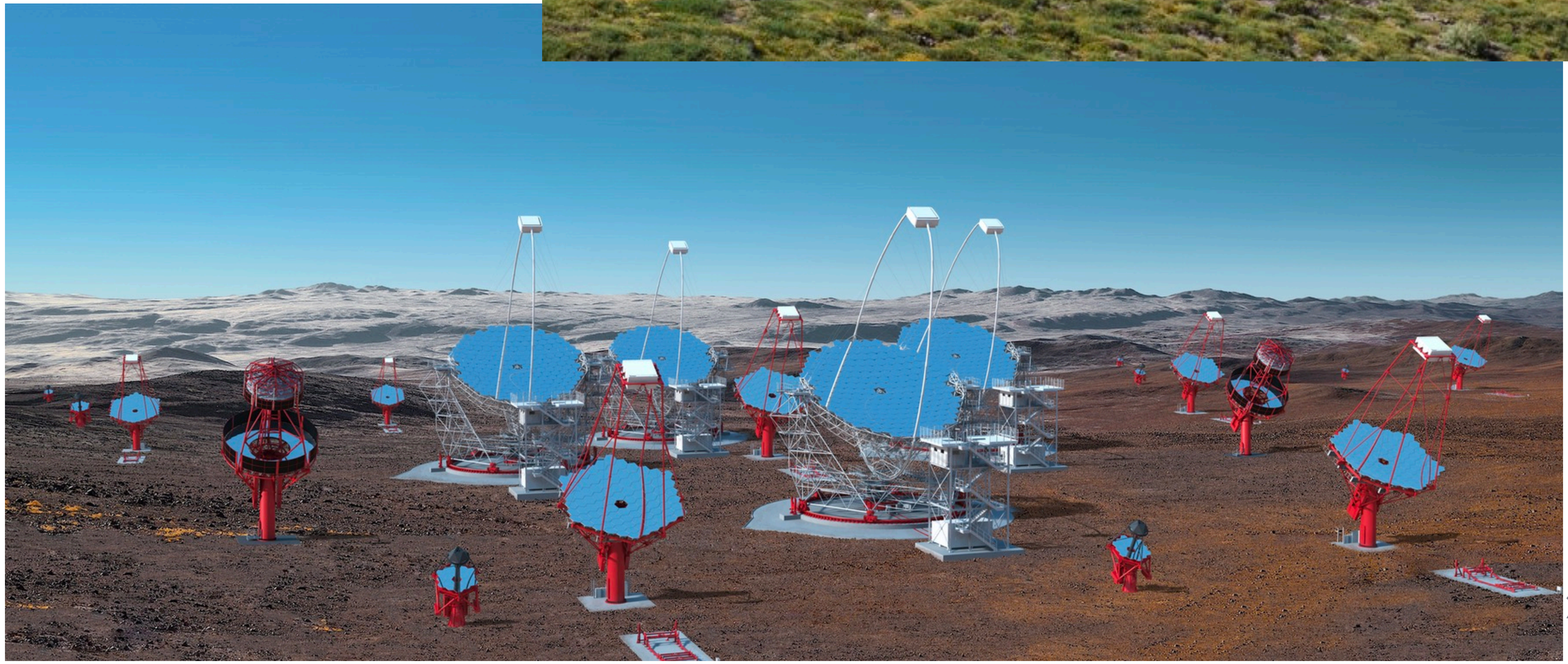


ASWG deputy coordinator

- CTA short-term sensitivity WGs leader (V. Fioretti)

- ASWG deputy coordinator:
  - forum for exchange on analysis topics beyond the core pipeline development;
  - Instrument Response Functions (IRFs): testing, data model/ format discussion, interpolation;
  - Performance investigations (e.g. ctapipe / protopipe analysis)
  - Participation in the SDC technical committee

LST

CTA & ASTRI Technological activities @OAS

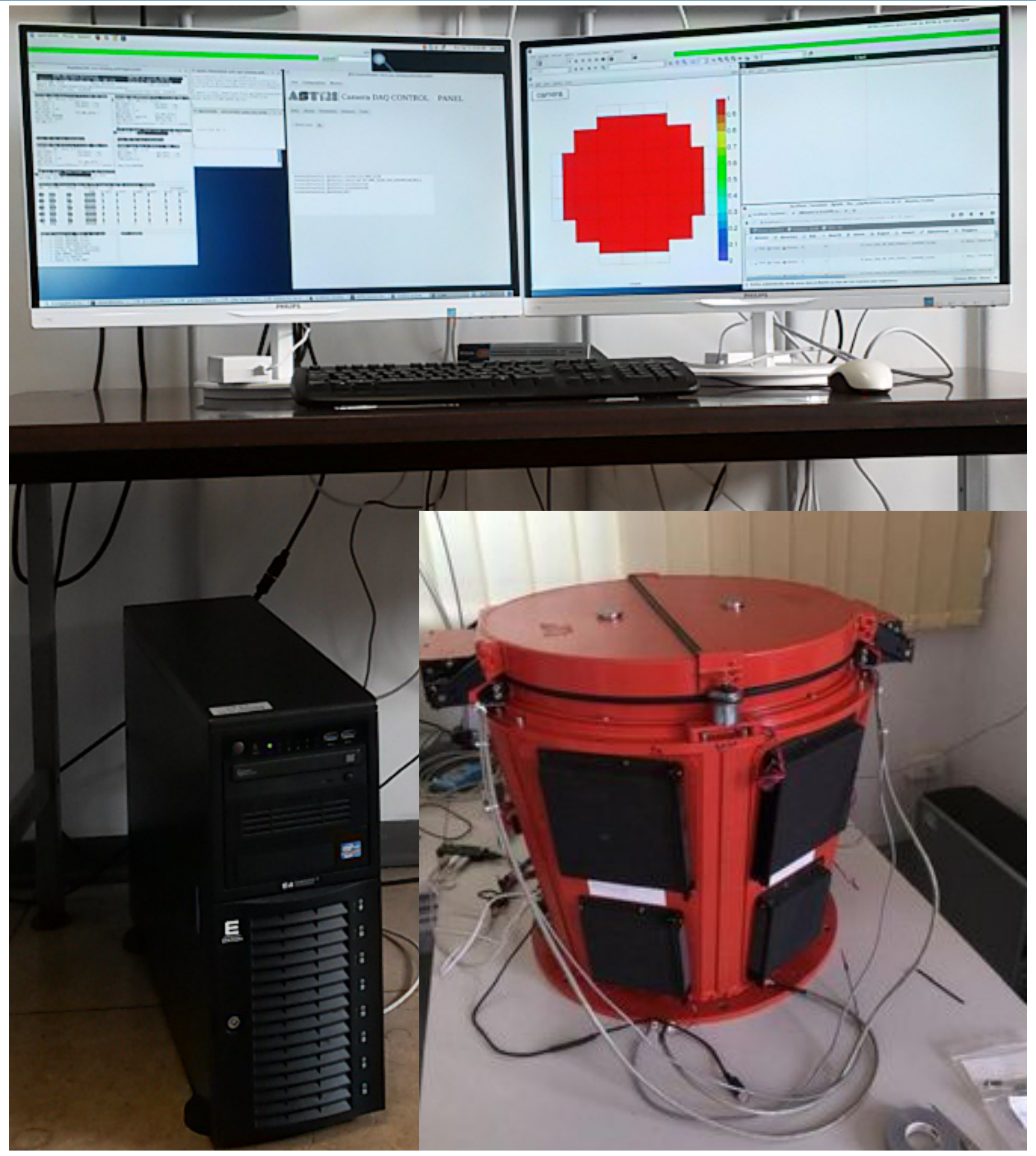
- **LST**
  - Real-Time Analysis
  - On-site Shifter activities (Baroncelli’s shift in 2021, Di Piano’s shift in 2022)

See Di Piano’s talk

ASTRI Mini-Array

ASTRI Horn

CTA & ASTRI Technological activities @OAS



- **ASTRI Horn** (M. Trifoglio, F. Gianotti, V. Conforti, V. Fioretti, F. Russo, A. Bulgarelli, N. Parmiggiani)**:**
  - Software for Development and test
    - Camera development and testing through an Instrument Workstation
    - Active Mirror Control
    - Software Development and Testing infrastructure
  - Software for Operations
    - Data stream Acquisition, pre-processing and storage
    - Engineering quick-look
    - Operator Control Room
  - ICT responsibility
  - Development of a prototype of automated science analysis

Mini-Array

ASTRI Mini-Array

CTA & ASTRI Technological activities @OAS

- **ASTRI Mini-Array**
  - Deputy Software coordinator
  - Responsibility of the on-site software for control, monitoring and data acquisition (a.k.a. SCADA)
  - Responsibility and development of the SCADA subsystems:
    - Telescope Control System
    - On-Line Observation Quality System
    - Array Data Acquisition System
  - Responsible of the on-site ICT
  - Integration and deployment test bed
  - Software engineering activities and members of the software engineering team

  - Interface Manager
  - Responsibility of software in the ASTRI Data Center
    - Automated scientific analysis pipeline
    - Cherenkov Camera Preprocessing

CTA & ASTRI Technological activities @OAS

Mini-Array

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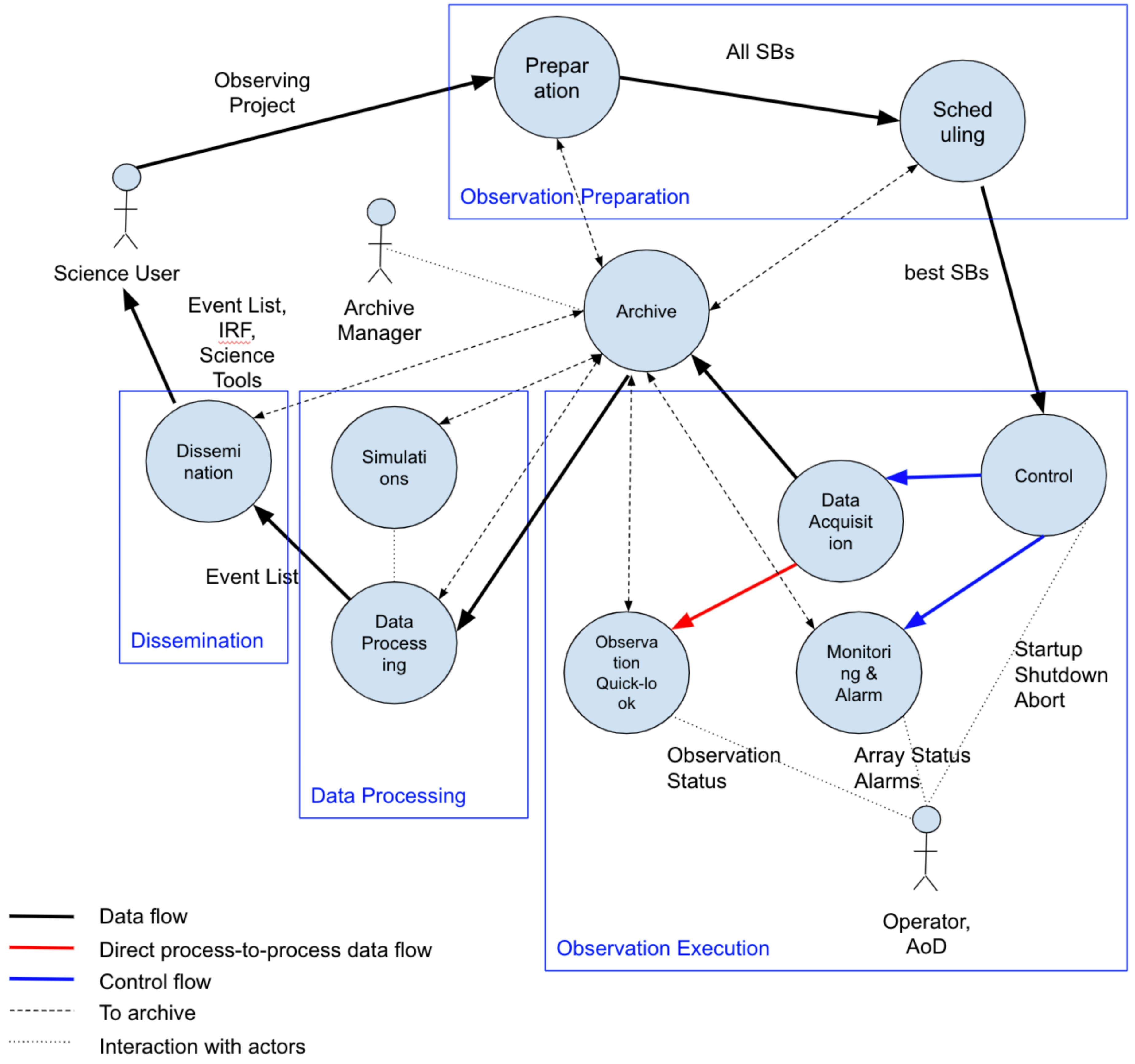
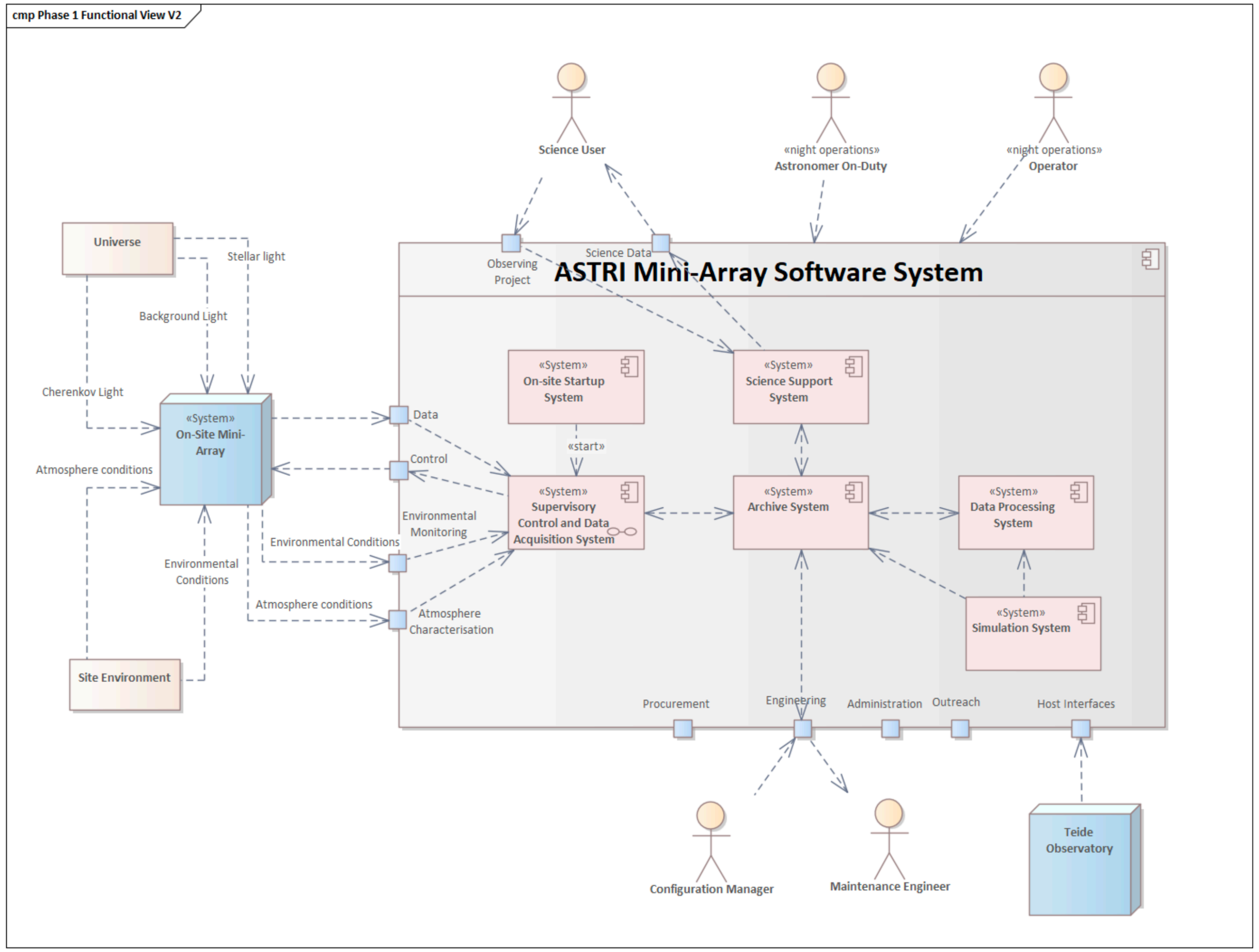
ASTRI Mini-Array Software system

- Software system engineering documents

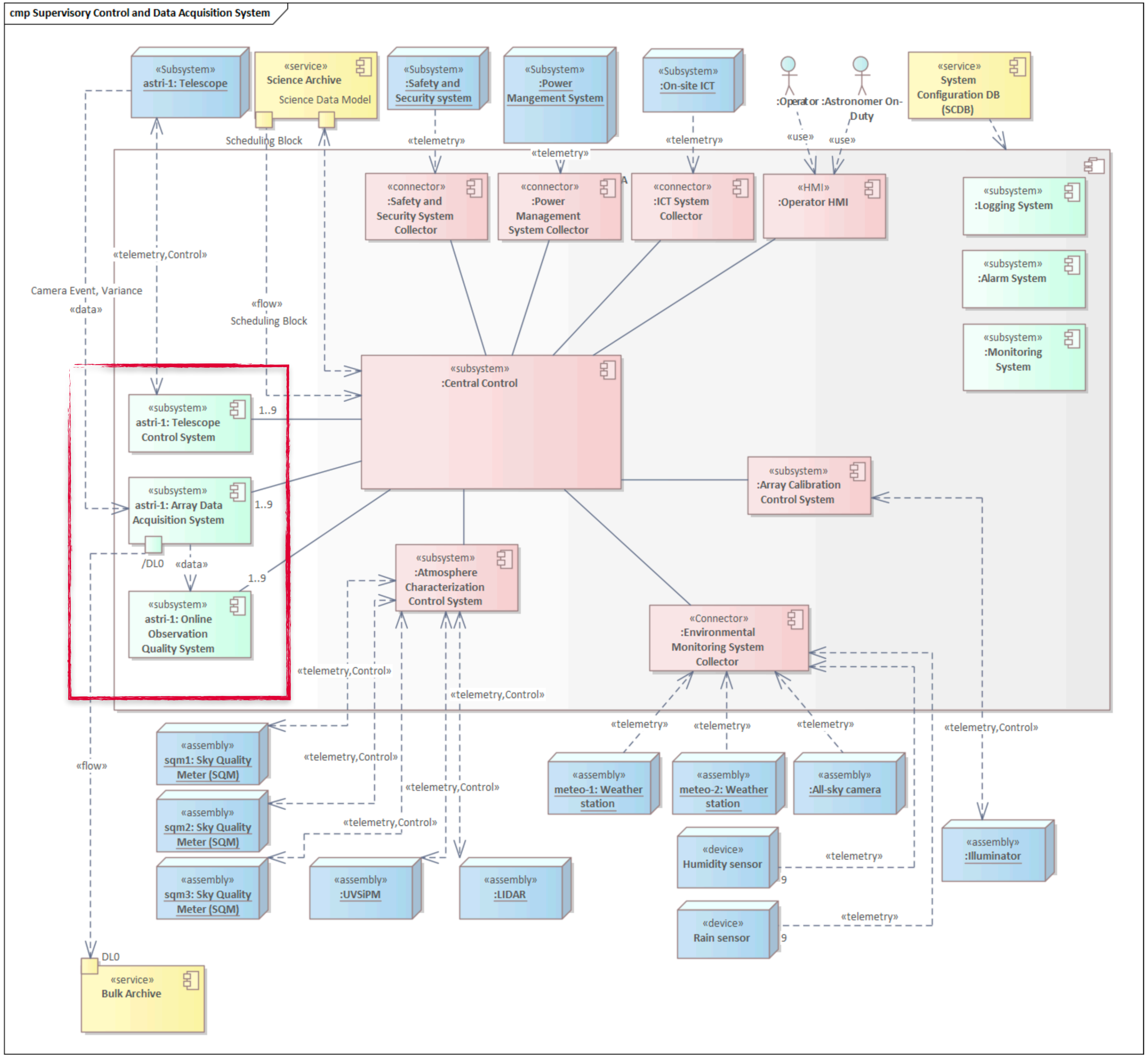




ASTRI Mini-Array SCADA

- **SCADA** is an on-site software system controlling all the operations carried out at the MA site.
    - SCADA has a **Central Control System** which interfaces and communicates with all ASTRI MA subsystems and their dedicated software installed at the site.
    - SCADA is responsible for the execution of the observations and shall normally perform the operations in an automated way but is supervised by the **Operator** located in one of the ASTRI Control rooms.
    - SCADA shall collect scientific data provided by the scientific instruments, logging, monitoring, alarms provided by the ASTRI MA subsystems and provide online observation quality information to the **Operator** in order to assess the quality of data during the acquisition.

- Green: INAF
  - Red box: OAS
- Red: industrial contract
- Operator HMI: University of Geneve



CTA & ASTRI Technological activities @OAS

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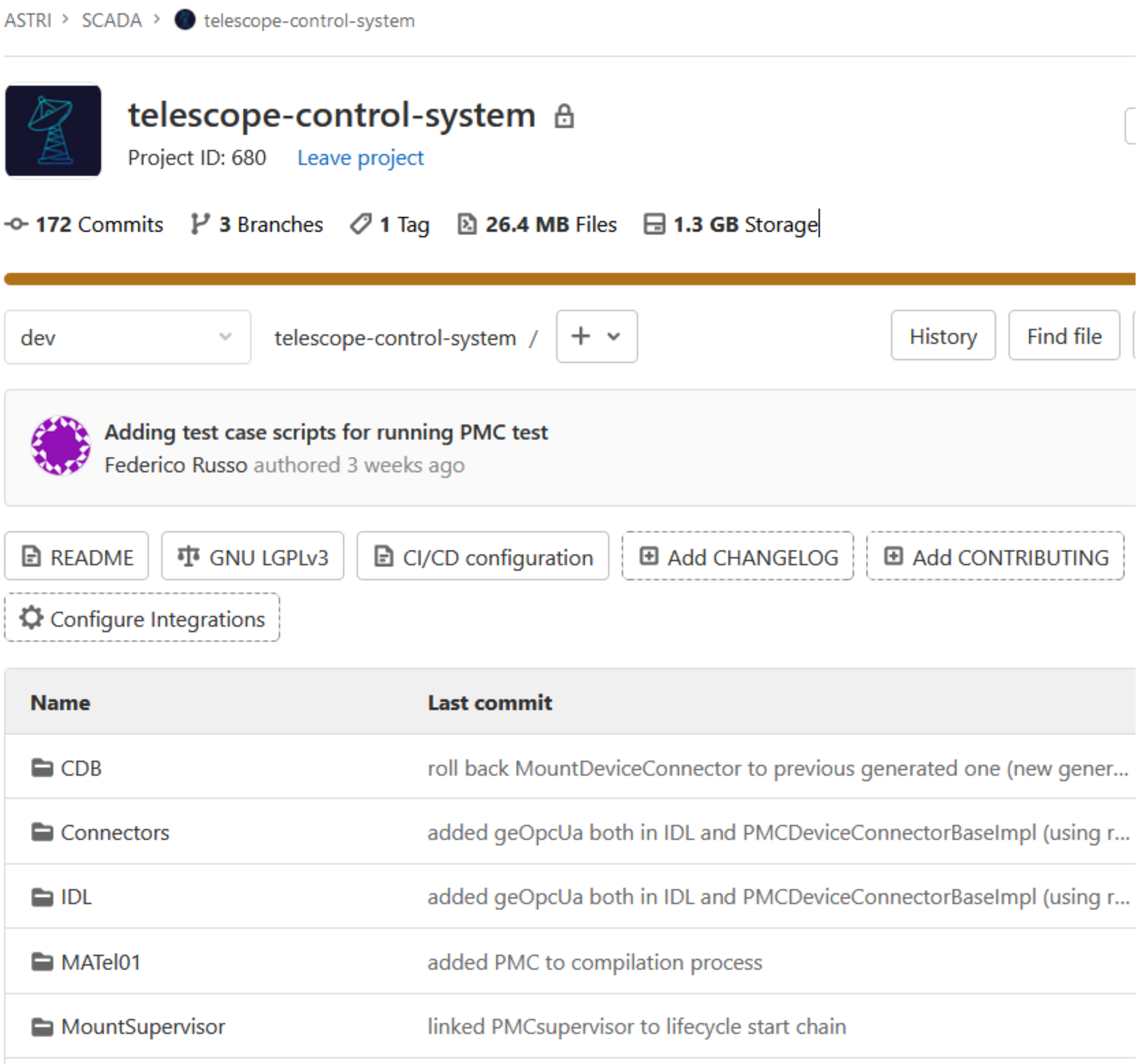
  - Cherenkov Camera Preprocessing (V. Conforti)

See Parmiggiani's talk

See Conforti's talk

Telescope Control System (TCS)

ASTRI Mini-Array



TCS: control of monitor of a single telescope and Cherenkov camera. Used also for testing activities.

The actual status of the TCS is progressively growing following the Use Cases document.

The current progress includes:

- Management of high level commands and implementation of the workflow **from the highest interface**, represented by the SCADA Central Control (which is now simulated by Junits) **to the lowest interface**, represented by Local Control Software (which is now simulated by opc-ua simulator).

  I.E. command for tracking, pointing, jogging motion, parking, requests for telescope assemblies state change etc.

- Implementation for Cherenkov Camera high level commands: I.E. Put online the Camera LCS, Stop the Camera LCS, Perform Camera Calibration and Perform a Cherenkov Observation.

- Centralized management for errors, alarms and logging.

- Hardware monitoring.

- Script for automatic execution for on site tests (I.E. automatic execution for stress test pointing AZ/EL…).

Teide Observatory test activities with TCS

2.1.2 Test di inizializzazione sistemi da TCS

TEST ID:	**EIE-200**
TEST NAME:	**Accensione PLC e verifica esecuzione cambi di stato preliminari TelescopeHealthAndSafety**
TEST OBJECTIVES:	• Controllare la comunicazione server OPC-UA dei PLC con i client OPC-UA del tcs. • Controllare lo stato iniziale dei PLC se quella prevista. • Controllare esecuzione di cambio di stato per TelescopeHealthAndSafety LCS.

TEST ID:	**EIE-201**
TEST NAME:	**Accensione PLC e verifica esecuzione cambi di stato preliminari Mount LCS**
TEST OBJECTIVES:	• Controllare la comunicazione server OPC-UA dei PLC con i client OPC-UA del tcs. • Controllare lo stato iniziale dei PLC se quella prevista. • Controllare funzionamento comando di accensione corrente per la Mount da parte della TelescopeHealthAndSafety. • Controllare esecuzione di cambio di stato per Mount LCS.

TEST ID:	**EIE-202**
TEST NAME:	**Stop durante procedura inizializzazione encoder**
TEST OBJECTIVES:	• Controllare la comunicazione server OPC-UA dei PLC con i client OPC-UA del tcs. • Controllare lo stato iniziale dei PLC se quella prevista. • Controllare funzionamento comando di accensione corrente per la Mount da parte della TelescopeHealthAndSafety. • Controllare esecuzione di cambio di stato per Mount LCS e TelescopeHealthAndSafety LCS.

TEST ID:	**EIE-203**
TEST NAME:	**Accensione PLC e verifica esecuzione cambi di stato preliminari da posizione fuori parcheggio**
TEST OBJECTIVES:	• Controllare la comunicazione server OPC-UA dei PLC con i client OPC-UA del tcs. • Controllare lo stato iniziale dei PLC se quella prevista. • Controllare funzionamento comando di accensione corrente per la Mount da parte della TelescopeHealthAndSafety. • Controllare esecuzione di cambio di stato per Mount LCS e TelescopeHealthAndSafety LCS da posizione fuori parcheggio.

TEST ID:	**EIE-204**
TEST NAME:	**fungo di emergenza durante movimentazione di inizializzazione encoder**
TEST OBJECTIVES:	• Controllare il funzionamento del fungo di emergenza durante la movimentazione di inizializzazione encoder. • Controllare la ripresa di funzionamento del sistema dopo il disingaggio del fungo di emergenza.

TEST ID:	**EIE-201**
TEST NAME:	**Accensione PLC e verifica esecuzione cambi di stato preliminari Mount LCS**
TEST OBJECTIVES:	• Controllare la comunicazione server OPC-UA dei PLC con i client OPC-UA del tcs. • Controllare lo stato iniziale dei PLC se quella prevista. • Controllare funzionamento comando di accensione corrente per la Mount da parte della TelescopeHealthAndSafety. • Controllare esecuzione di cambio di stato per Mount LCS.
TEST DESCRIPTION:	1. Eseguire **TelescopeHealthAndSafetyDeviceConnector.TCUON()** 2. Controllare se il Mount risponde al ping entro 180 secondi. 3. Utilizzare l'object Esplorer per attivare la raccolta log per Mount. o In alternativa aggiungere all'object explorer il monitoraggio sugli stati della Mount. 4. Controllare se lo stato della MountDeviceConnector sia **LOADED** 5. Eseguire **MountDeviceConnector.GO_STANDBY()** 6. Controllare se lo stato della MountDeviceConnector cambi in **STANDBY** in un tempo inferiore a 250 secondi (TBD). 7. Eseguire **MountDeviceConnector.GO_ONLINE()** 8. Controllare se lo stato della MountDeviceConnector cambi in **ONLINE** in un tempo inferiore a 160 secondi (TBD). 9. Controllare se l'encoder AZ si sia inizializzato correttamente. (GET_TCU_AZENCINITEN(new LongHolder()) == **true**) Tabella riferimento associazioni stati e valore ritornato: (see table below)
TEST CONFIGURATION:	**Mount LCS, TelescopeHealthAndSafety LCS e TCS.**
PRE-REQUIREMENTS:	• Eseguito il test EIE2 • Mount LCS, TelescopeHealthAndSafety LCS e TCS sono collegati. • TelescopeHealthAndSafety é in running nello stato iniziale (no altre operazioni sono state eseguite). • TCS é running. • Il telescopio é nella posizione di parcheggio.
TOOLS/FACILITIES:	• ACS, Object esplorer, PLCs.
MANPOWER:	

Tabella riferimento associazioni stati e valore ritornato:

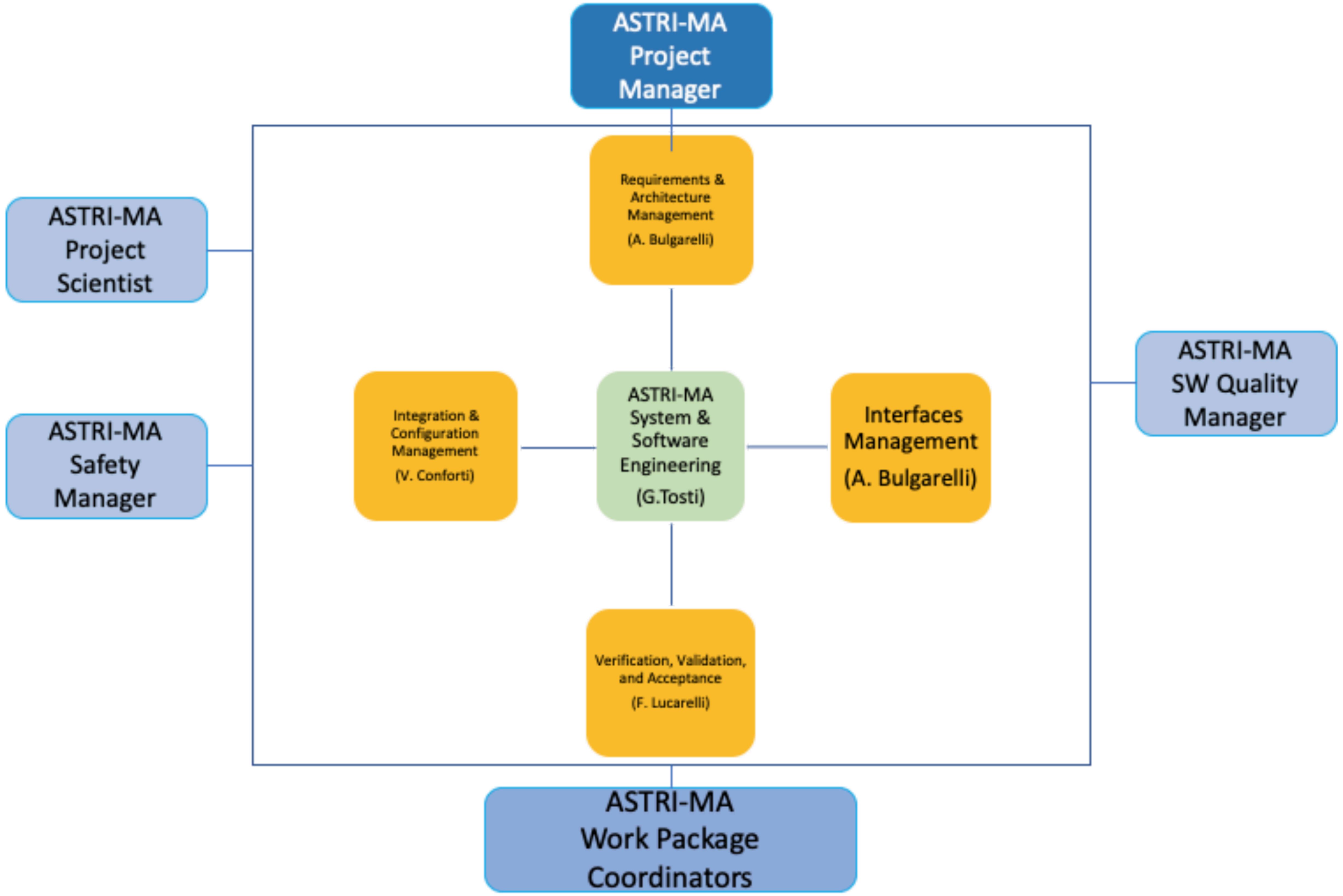
	Mount
LOADED	0
STANDBY	1
ONLINE IDLE	2
ONLINE SLEW	3
ONLINE TRACK	4
ONLINE	N/A
CALIBRATION	5
MAINTENANCE	6
FAULT	7

CTA & ASTRI Technological activities @OAS

ASTRI Mini-Array

- **ASTRI Mini-Array**
  - Deputy Software coordinator
  - Responsibility of the on-site software for control, monitoring and data acquisition (a.k.a. SCADA)
  - Responsibility and development of the SCADA subsystems:
    - Telescope Control System
    - On-Line Observation Quality System
    - Array Data Acquisition System
  - Responsible of the on-site ICT (F. Gianotti)
  - Integration and deployment test bed (F. Gianotti, V. Conforti)
  - Software engineering activities and members of the software engineering team
    - Release Manager (V. Conforti)
    - Software Quality Assurance (V. Conforti)
    - Requirement, Architecture, Interfaces (A. Bulgarelli)

See Gianotti/Conforti's talk



Conclusions

- Participation in CTA Consortium PHYS WGs
- Deputy coordination of CTAC/ASWG
- Software engineering activities and responsibilities
- ICT activities responsibilities
- Shifters on LST
- Software development and responsibilities on
  - telescope and array control system
  - data acquisition and preprocessing
  - data quality status
  - scientific analysis pipelines for science monitoring and gamma-ray transient detection
    - 3 PhDs
    - 1 AdR

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cta cherenkov telescope array

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