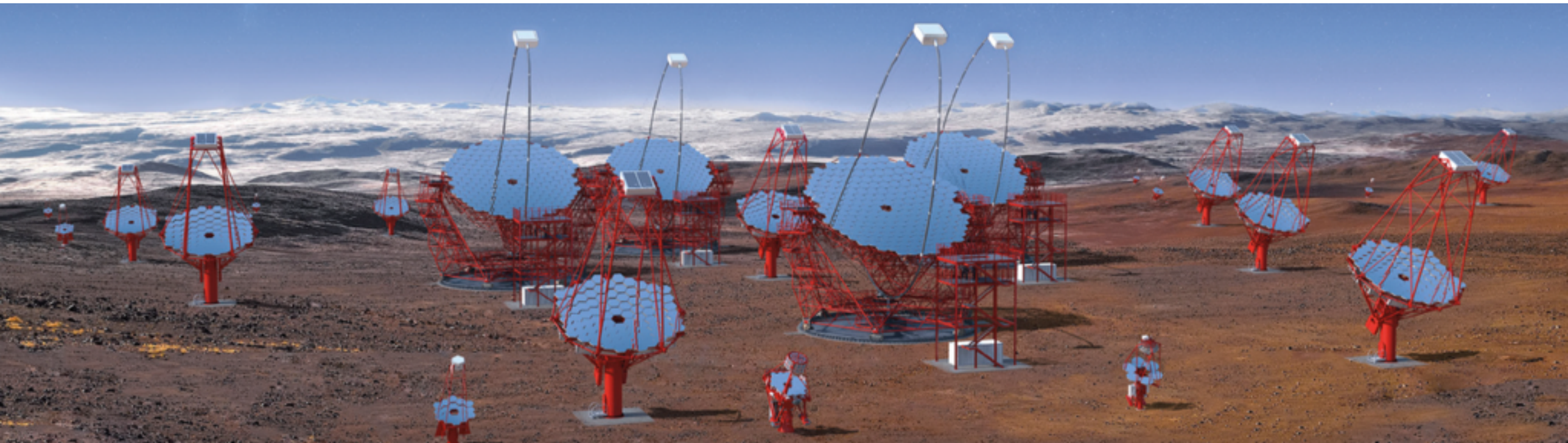
The Cherenkov Telescope Array

Francesco Longo (University and INFN, Trieste)

on behalf of the CTA Transients/MWL Science WG

thanks to F.Schüssler, R.Zanin, G.Ghirlanda, A.Stamerra, A.Carosi



The Cherenkov Telescope Array Consortium

The Cherenkov Telescope Array Consortium

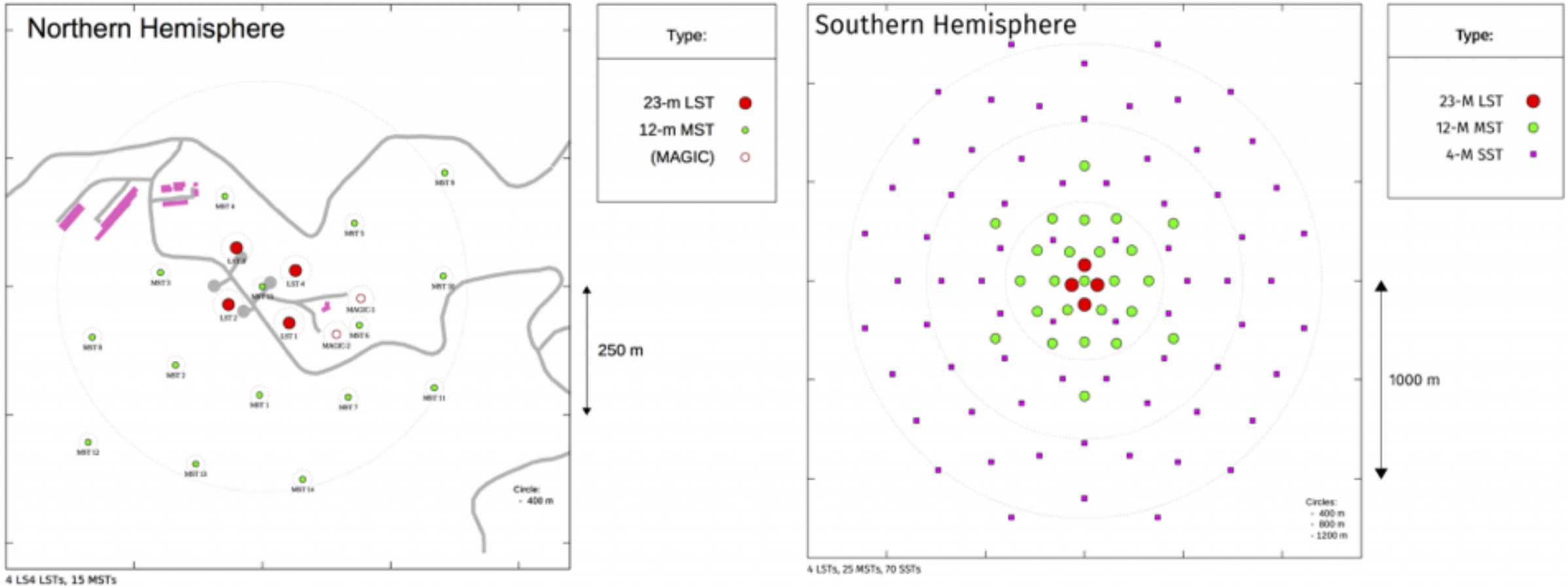
- The CTA Consortium includes 1,500 members from more than 200 institutes in 31 countries.
- The scientists and engineers of the CTA Consortium devised the CTA concept more than a decade ago and have been the driving force behind its design.
- The Consortium has developed and detailed CTA's key science goals (see "Science with the Cherenkov Telescope Array") and will be responsible for the science analysis and publication of scientific results of the Key Science Projects, ensuring that CTA produces legacy data sets and data products for use by the entire community.

https://www.cta-observatory.org/

The Cherenkov Telescope Array

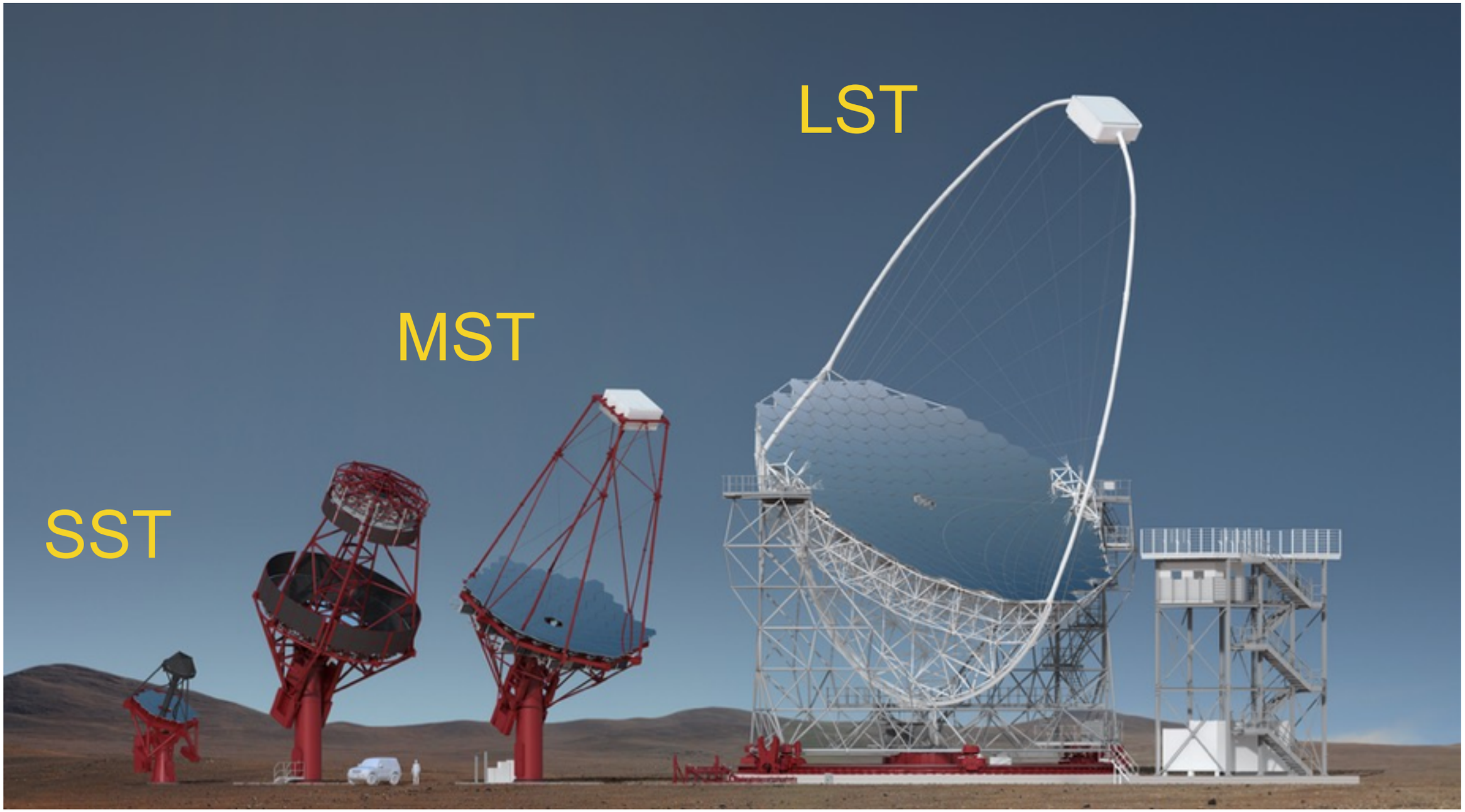
https://www.cta-observatory.org/

The Cherenkov Telescope Array



https://www.cta-observatory.org/

The Cherenkov Telescope Array



https://www.cta-observatory.org/

The Cherenkov Telescope Array

	Large-Sized Telescope (LST)	Medium-Sized Telescope (MST)			Small-Sized Telescope (SST)
		FlashCam	NectarCam	SCT	
Required energy range	20 GeV – 3 TeV	80 GeV – 50 TeV			1 TeV – 300 TeV
Energy range (in which subsystem provides full system sensitivity)	20 GeV – 150 GeV	150 GeV – 5 TeV			5 TeV – 300 TeV
Number of telescopes	4 (South) 4 (North)	25 (South) 15 (North)			70 (South) 0 (North)
Optical design	Parabolic	Modified Davies-Cotton		Schwarzschild-Couder	Schwarzschild-Couder
Primary reflector diameter	23.0 m	11.5 m		9.7 m	4.3 m
Secondary reflector diameter	--	--		5.4 m	1.8 m
Effective mirror area (including shadowing)	370 m^2	88 m^2		41 m^2	8 m^2
Focal length	28 m	16 m		5.6 m	2.15 m
Total weight	103 t	82 t		80 t	19 t
Field of view	4.3 deg	7.5 deg	7.7 deg	7.6 deg	10.5 deg

https://www.cta-observatory.org/

The Cherenkov Telescope Array

	Large-Sized Telescope (LST)	Medium-Sized Telescope (MST)			Small-Sized Telescope (SST)
		FlashCam	NectarCam	SCT	
Number of pixels in Cherenkov camera	1855	1764	1855	11328	2368
Pixel size (imaging)	0.1 deg	0.17 deg	0.17 deg	0.067 deg	0.19 deg
Photodetector type	PMT	PMT	PMT	SiPM	SiPM
Telescope readout event rate (before array trigger for MSTs and SSTs)	>7.0 kHz (after LST array trigger)	>6 kHz	>7.0 kHz	>3.5 kHz	>0.3 kHz
Telescope data rates (readout of all pixels; before array trigger)	24 Gb/s	12 Gb/s			2 Gb/s
Positioning time to any point in the sky (>30₀ elevation)	30 s	90 s			60 s
Pointing precision	<14 arcseconds	<7 arcseconds		<10 arcseconds	<7 arcseconds
Observable sky	Any astrophysical object with elevation > 24 degrees				

https://www.cta-observatory.org/

LST-1

https://www.cta-observatory.org/

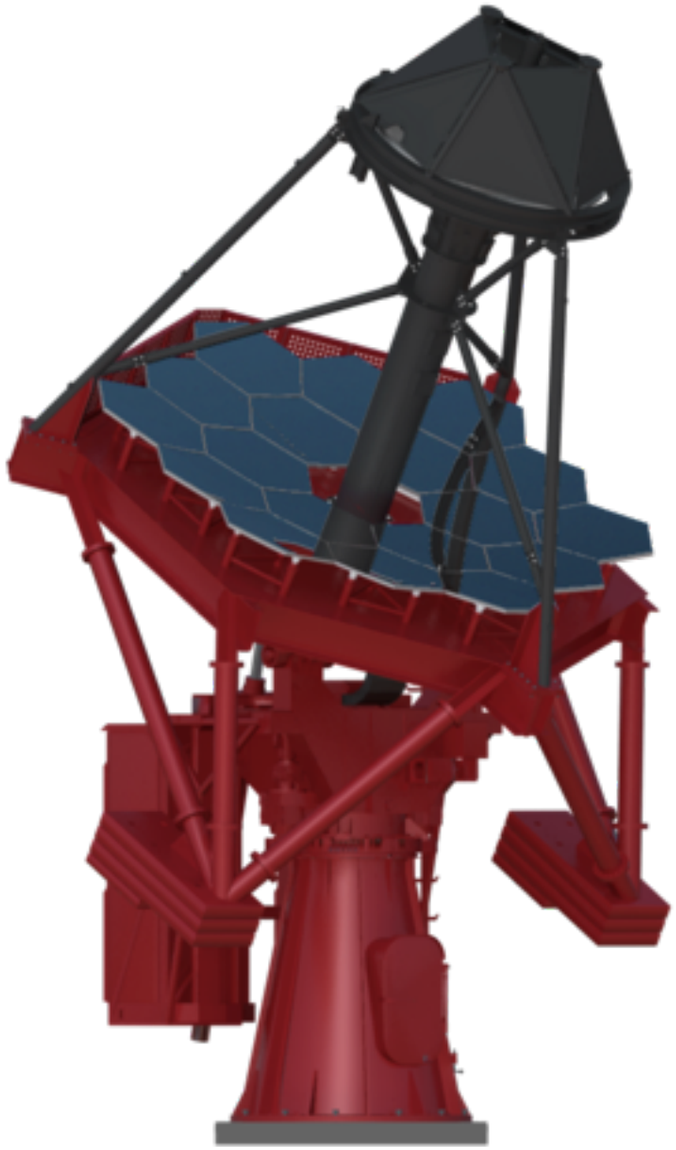
MST

https://www.cta-observatory.org/

MST - SCT

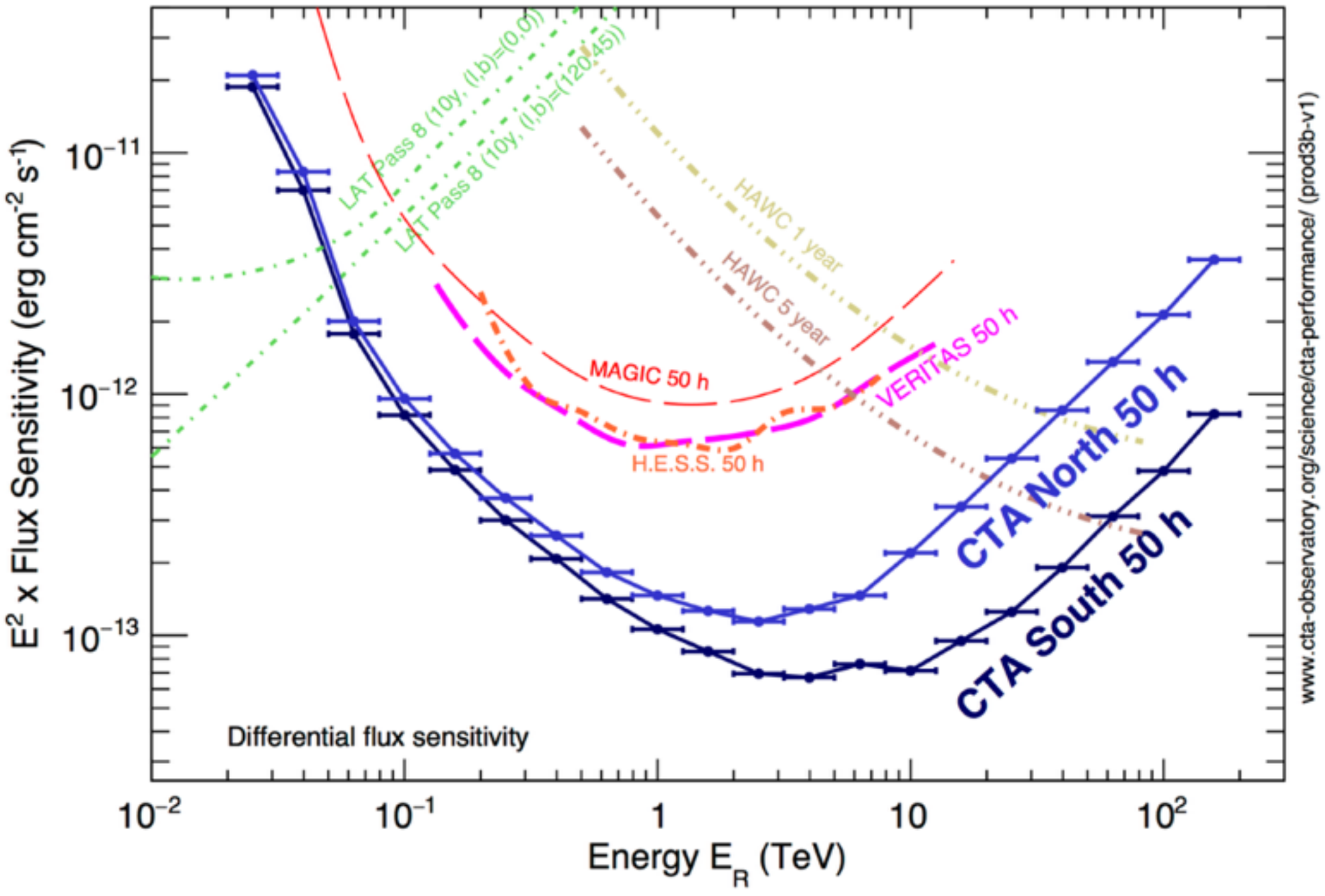
https://www.cta-observatory.org/

SST



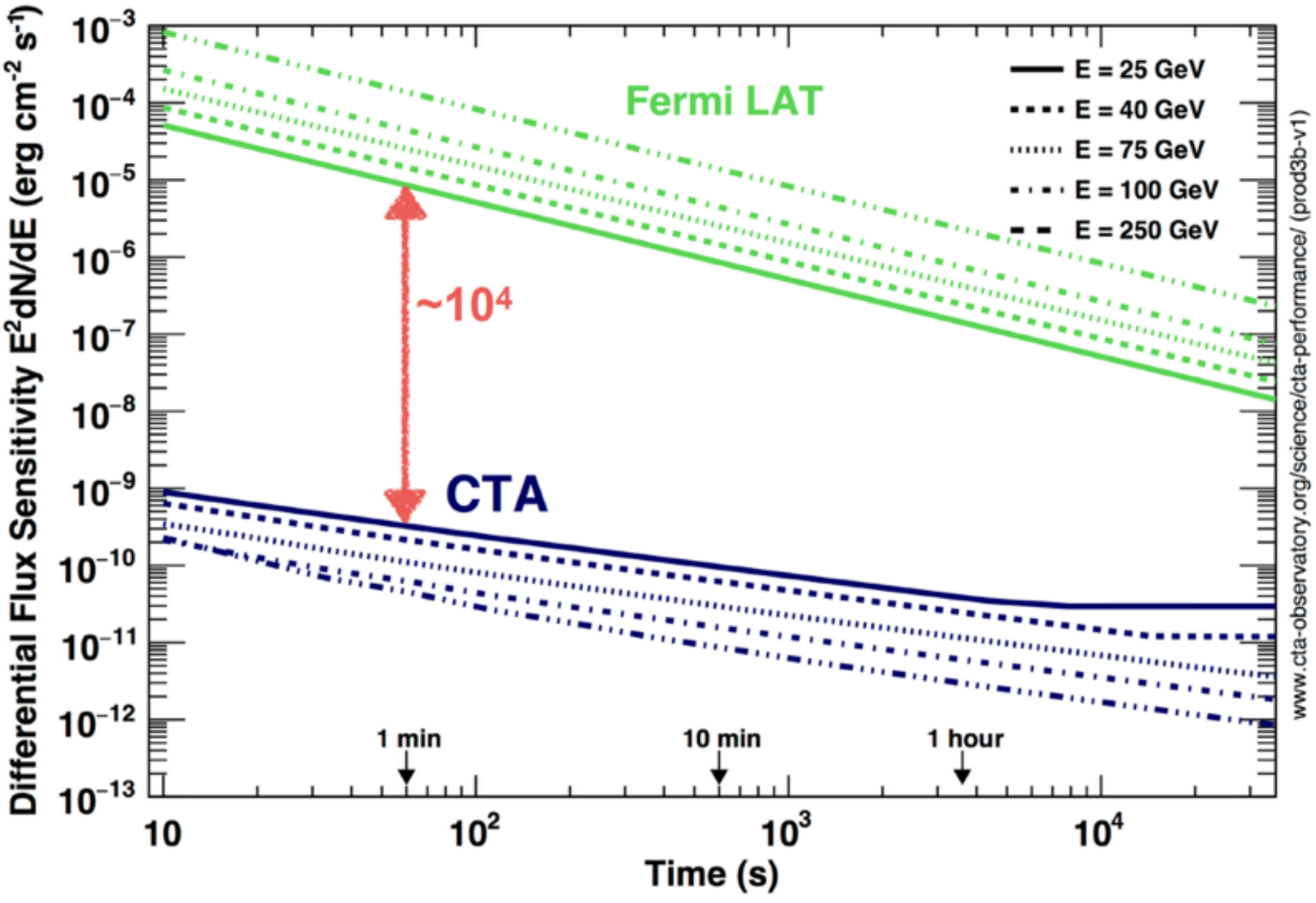
https://www.cta-observatory.org/

The Cherenkov Telescope Array



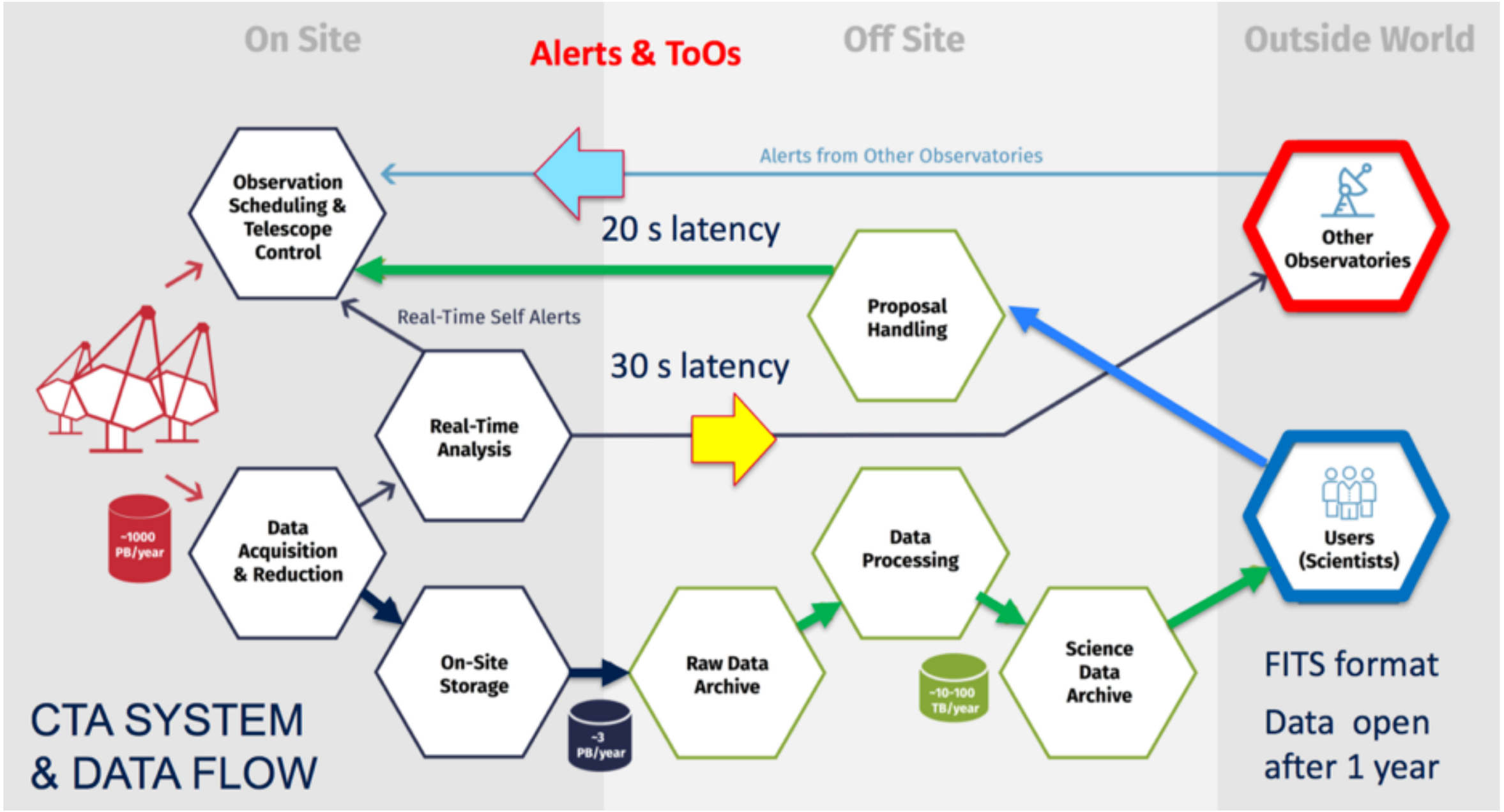
https://www.cta-observatory.org/

The Cherenkov Telescope Array



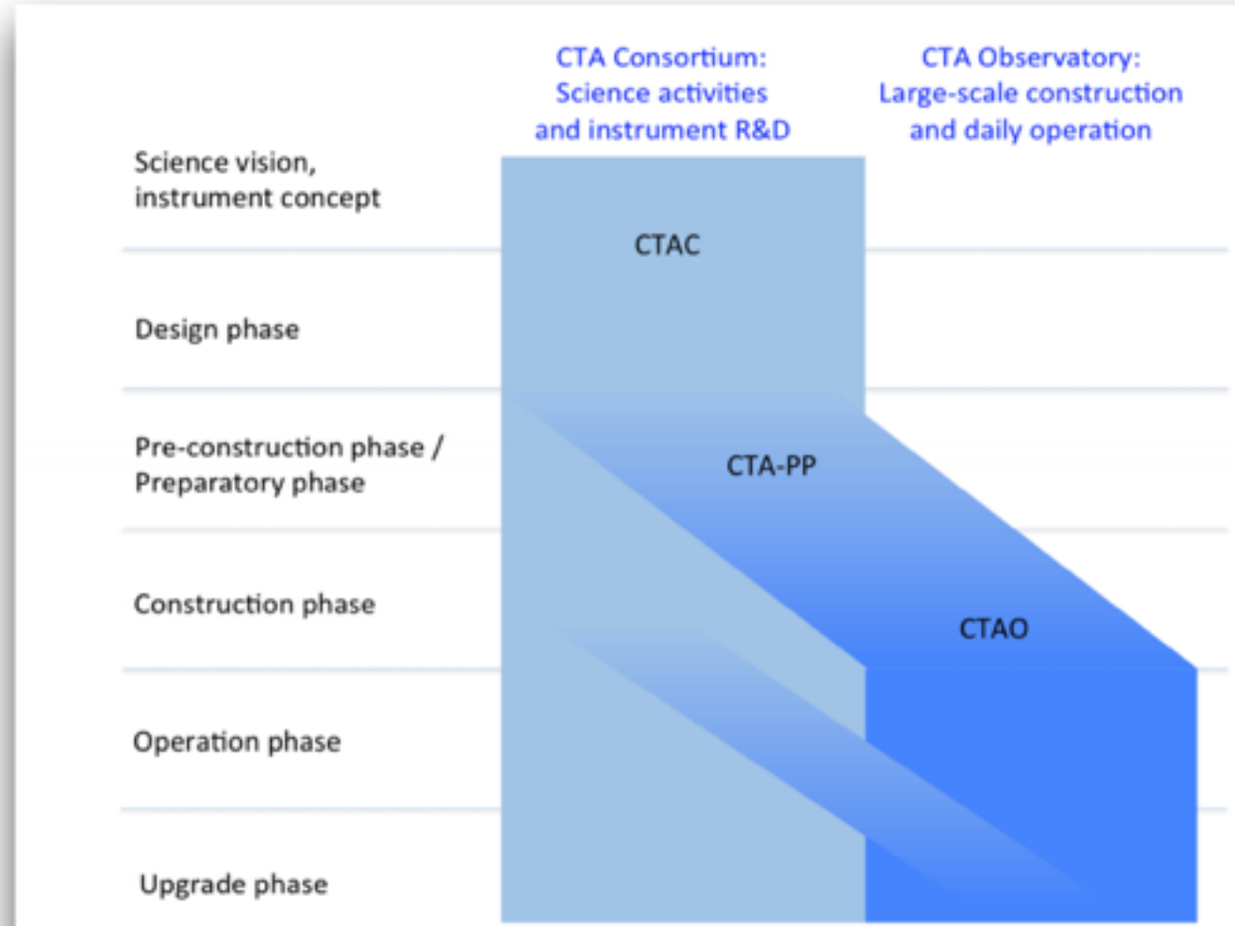
https://www.cta-observatory.org/

Real time alerts with CTA



The Cherenkov Telescope Array

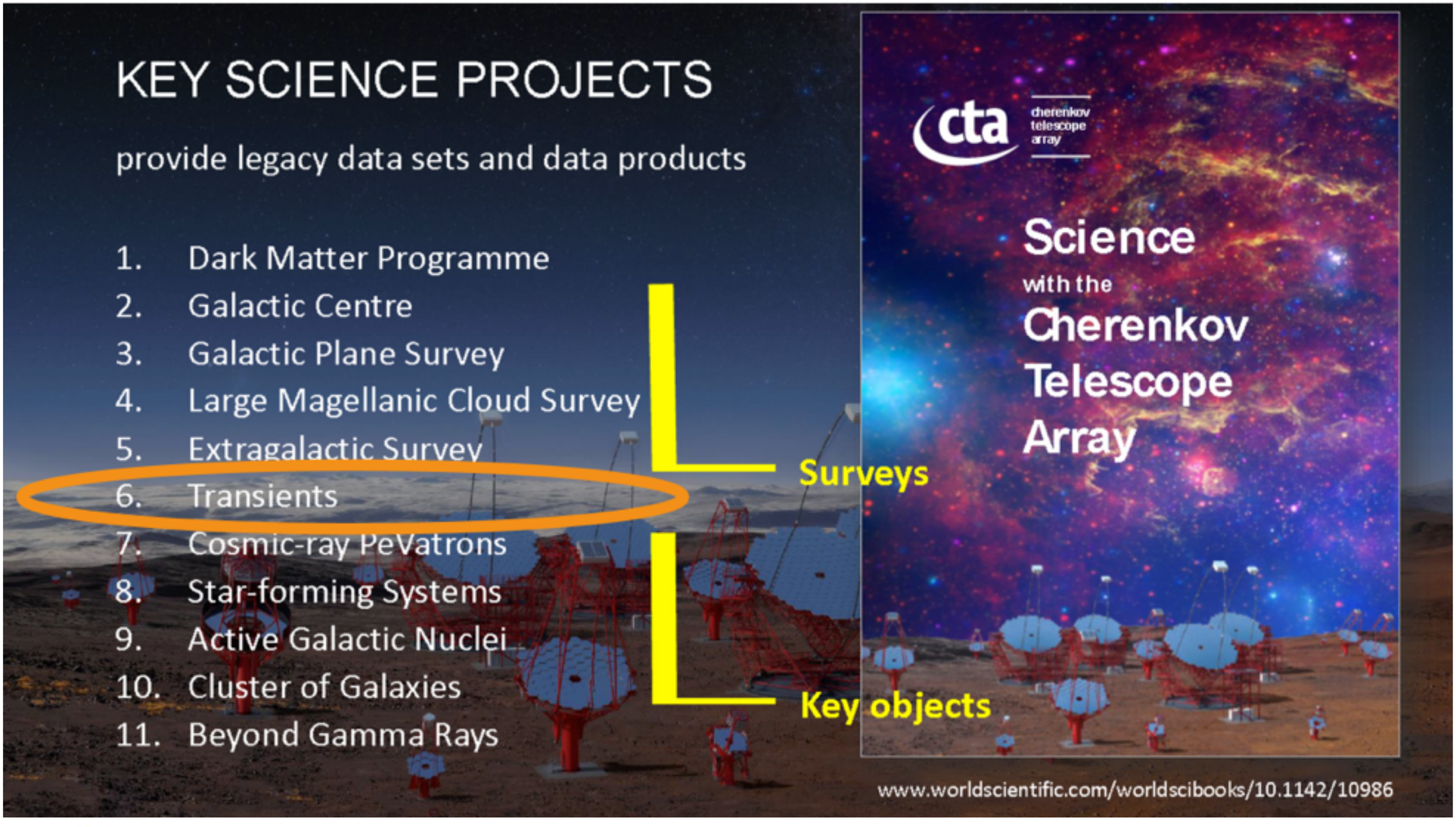
- built and operated by the ”CTA observatory” (CTAO, Bologna)
- in-kind contributions by the ”CTA consortium” (CTAC)
- observation time allocated to the CTA consortium for Key Science projects



- CTA as open observatory
- Regular AOs
- Proposals evaluated by TAC
- Observations carried out in queue mode
- Fully calibrated photon lists and analysis tools provided to observers
- Data open after proprietary period of 1 year

From:
Concept for CTA
construction and operation
WH 2011/12

The key science projects



https://arxiv.org/pdf/1709.07997.pdf

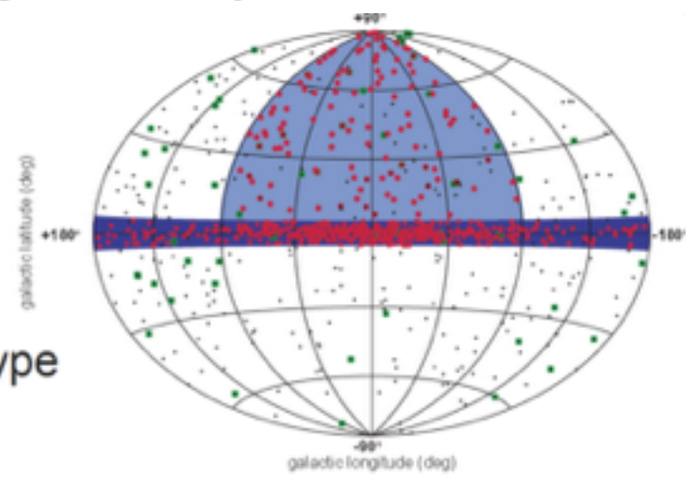
The Key science projects

The CTA Transient program

- Transients are integral part of the CTA "Key Science Projects"
- dedicated Science Working Group "Transients and MWL"
  - Preparation of the first observations (reaction to external ToOs, definition of observation program, preparation of science analysis, etc.)
  - Setup of multi-wavelength/messenger connections
  - Main topics: gamma-ray bursts, gravitational waves, high-energy neutrinos, FRBs, Galactic transients (e.g. microquasars, novae, magnetars, etc.)
- Also: AGN monitoring program + survey of the extragalactic sky + …

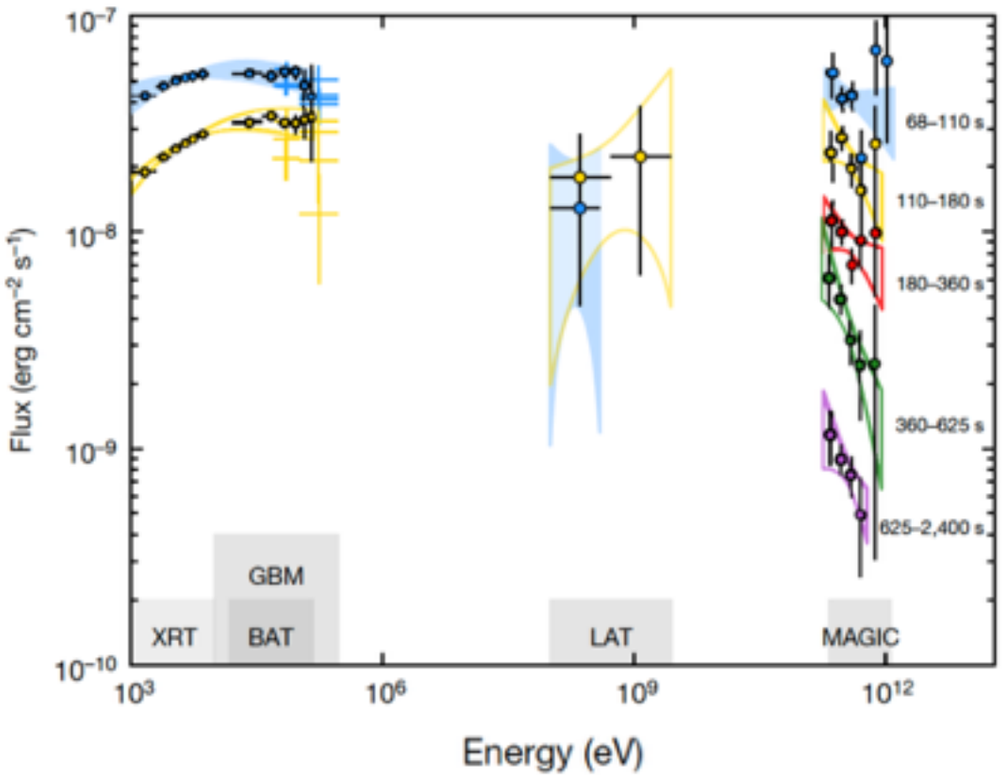
CTA surveys

- CTA will cover large portions of the sky
  - large telescope FoV: 4 - 10deg depending on telescope type
  - may be increased by divergent pointing
- important survey programs (Galactic + Extragalactic)



GRB in the TeV energy range

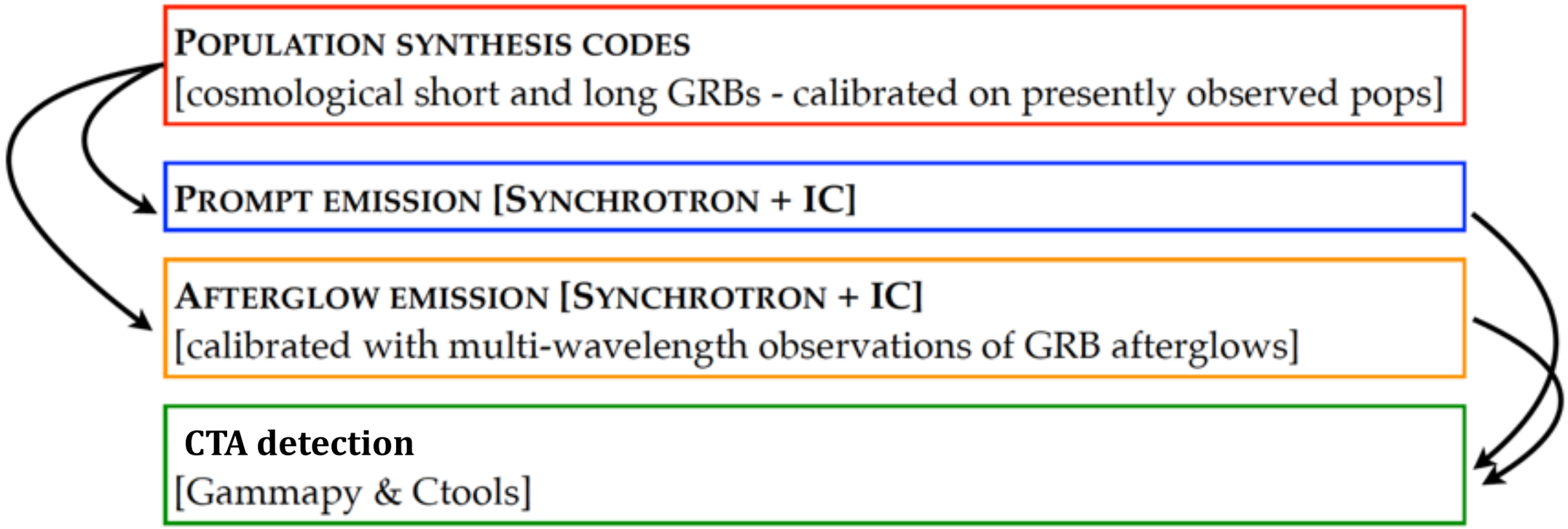
- Important program with strong links to most other topics (GW!, neutrinos?, etc.)
- Recent breakthroughs:
  - GRB180720B: >100GeV emission 10h after the burst (H.E.S.S., *Nature* **575,** 464–467 (2019))
  - GRB190114C: >300GeV emission 50s after the burst (MAGIC, *Nature* **575,** 459 (2019))
  - GRB190829A: VHE detection after 4h (ATEL #13052)



MAGIC collab. et al., *Nature* **575,** 459 (2019)

GRB with CTA

- Detailed study to assess the potential of the CTA GRB program
- Core input: GRB population by G. Ghirlanda et al.



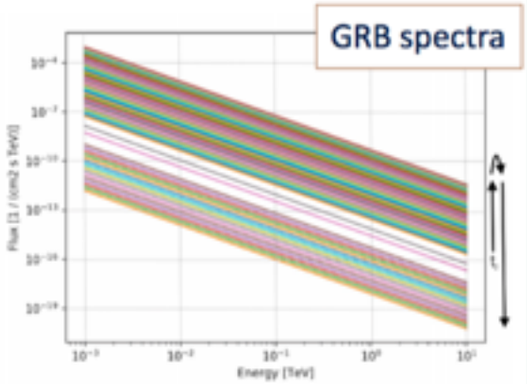
M.G. Bernardini et al. (CTA), PoS(ICRC2019)598

GW with CTA

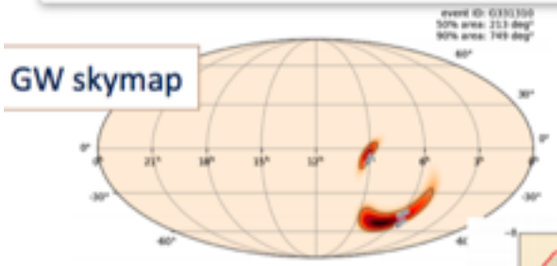
Simulation of BNS mergers and GW signal in local universe

Synthetic GW-GRBs Phenomenological model of VHE emission, from short-GRB

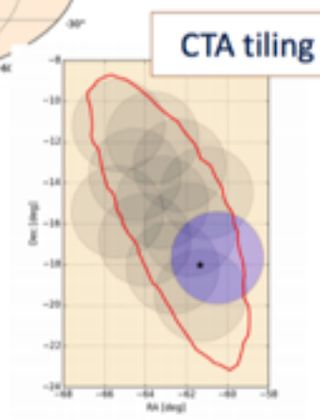
GRB spectra



GW skymap

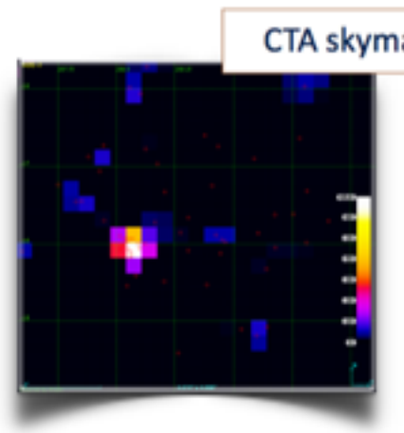


CTA tiling



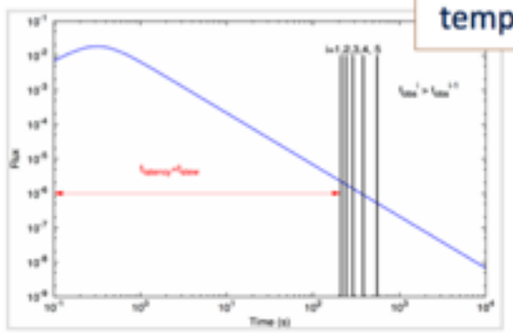
Observation optimisation and scheduler CTA observing strategy

CTA skymap



Simulation of CTA response (set of IRFs) *gammapy, ctools*

temporal scan



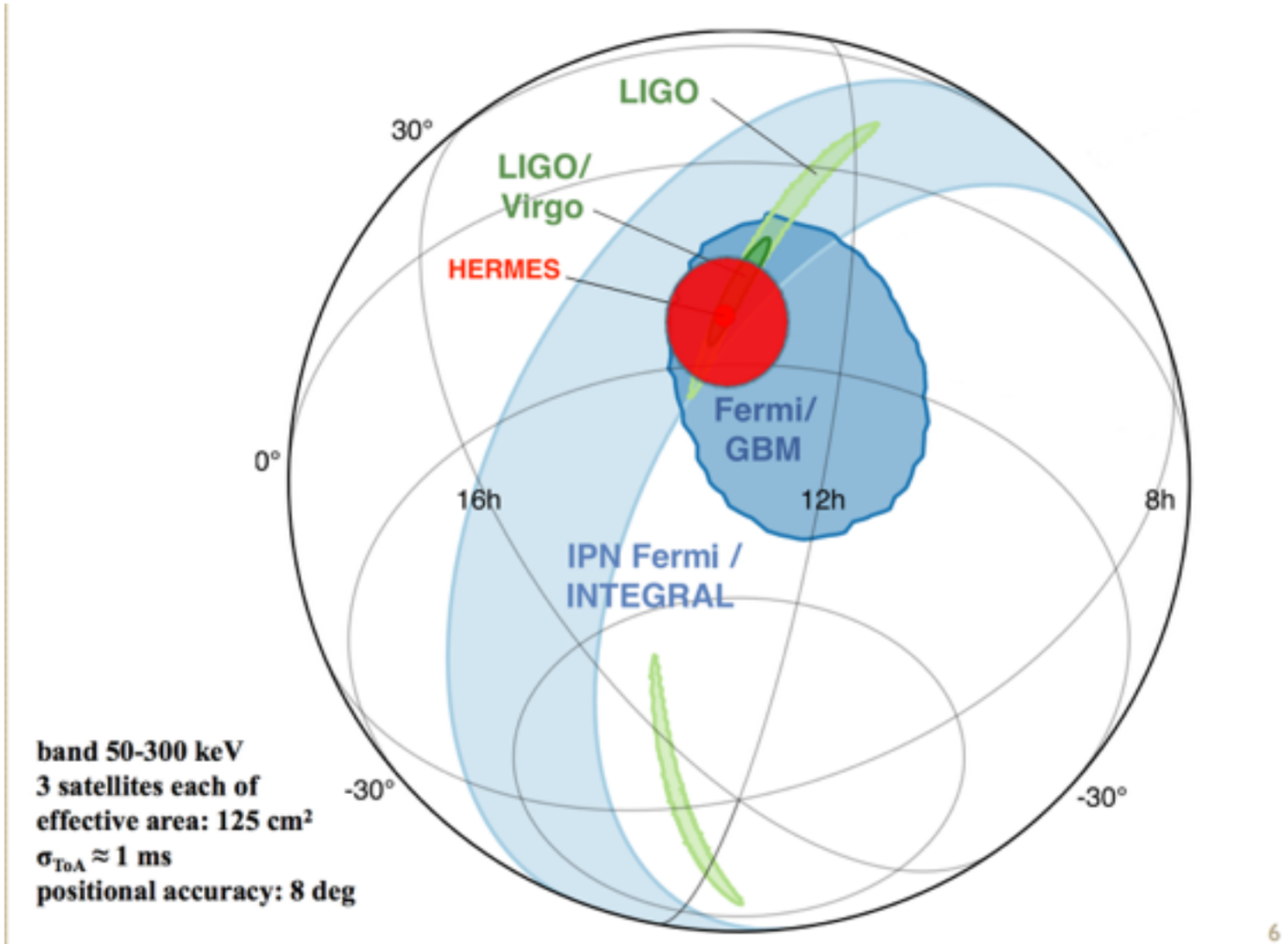
Expected Results and CTA prospects

- ✓ Joint GW-CTA detection rates and coverage
- ✓ Optimal observation strategies

M. Seglar-Arroyo et al. (CTA) PoS(ICRC2019)790

GRB, GW EM counterparts with HERMES and CTA

- Localisation
  - Need to have a better localisation wrt to GW detectors —> HERMES might help !

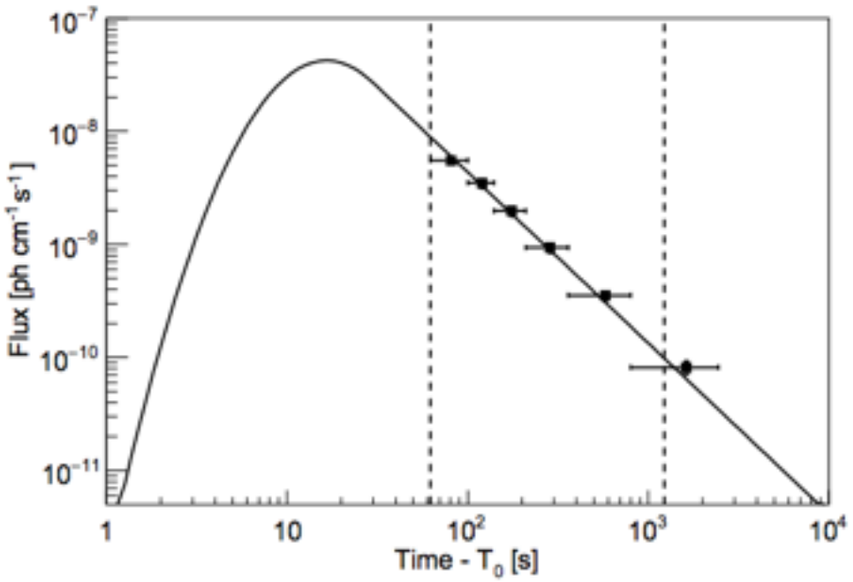


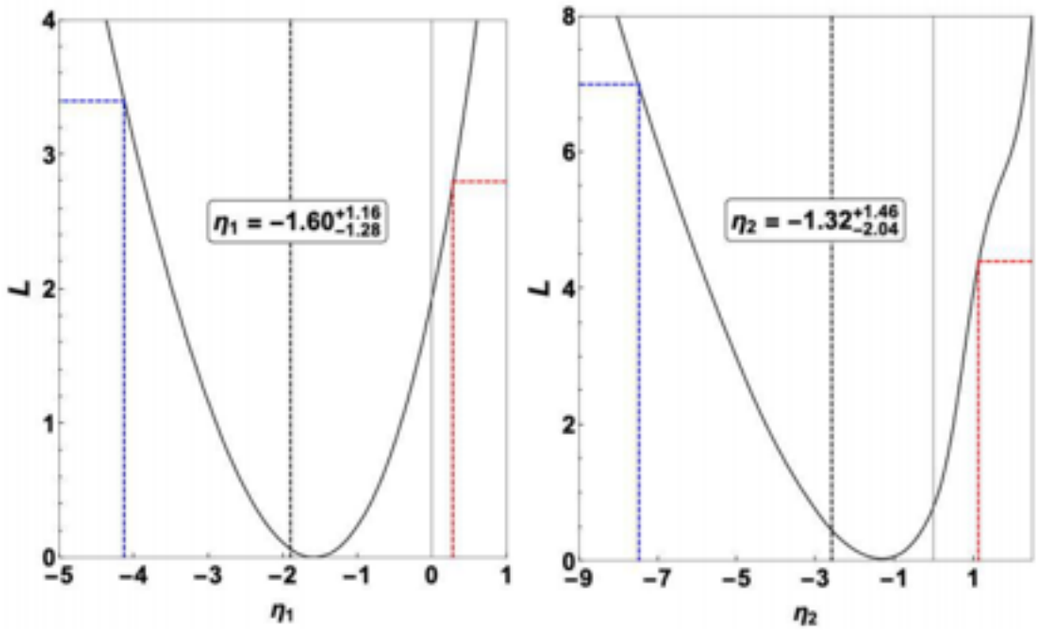
Sanna et al. COSPAR 2019

GRB, GW EM counterparts with HERMES and CTA

- Quantum gravity studies with GRB
  - Larger “level arm” for Energy study of QG with GRBs.

Bounds on Lorentz Invariance Violation from MAGIC Observation of GRB 190114C





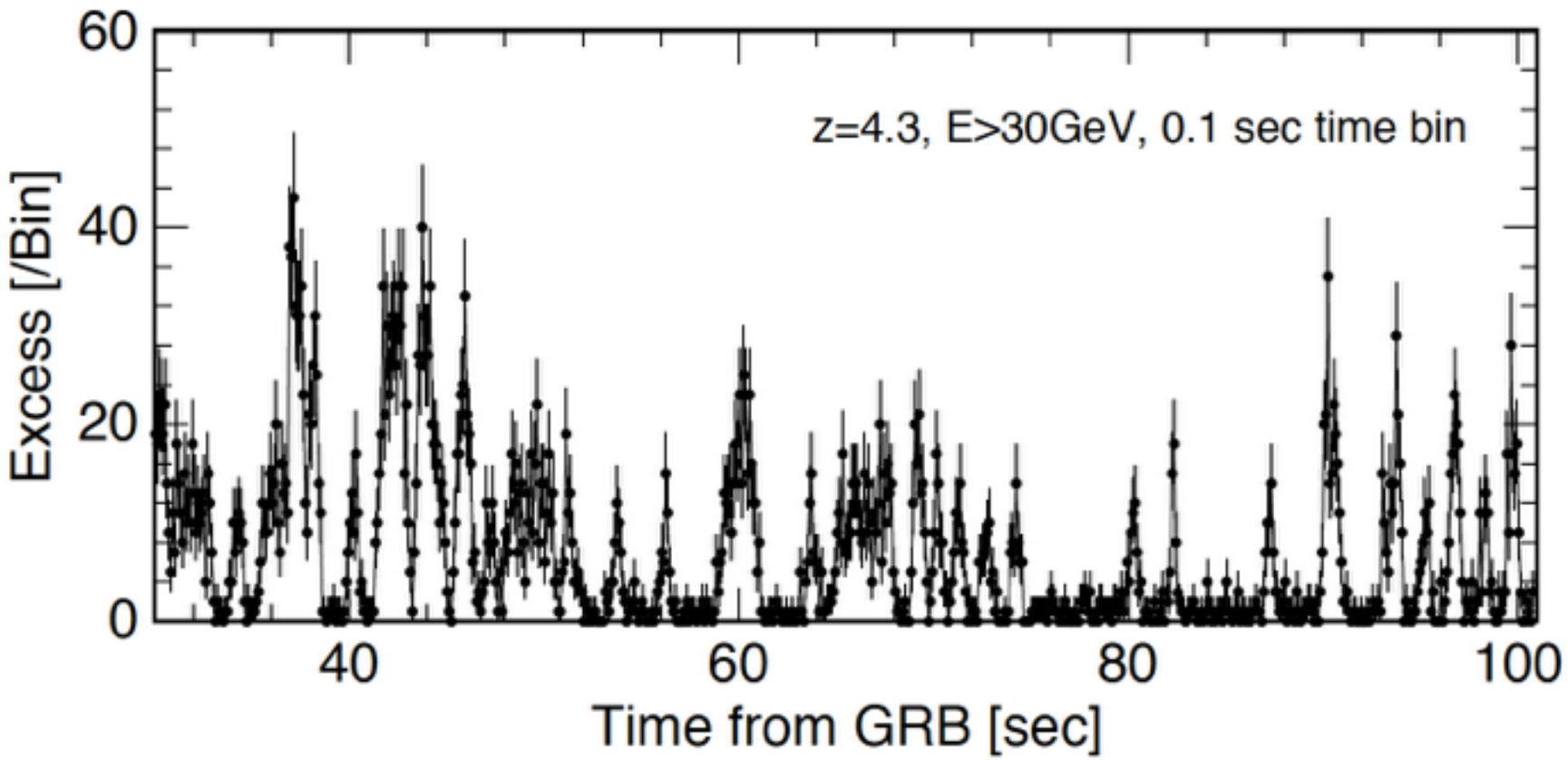
ABSTRACT

On January 14, 2019, the Major Atmospheric Gamma Imaging Cherenkov telescopes detected GRB 190114C above 0.2 TeV, recording the most energetic photons ever observed from a gamma-ray burst. We use this unique observation to probe an energy dependence of the speed of light in vacuo for photons as predicted by several quantum gravity models. Based on a set of assumptions on the possible intrinsic spectral and temporal evolution, we obtain competitive lower limits on the quadratic leading order of speed of light modification.

V. A. Acciari et al. (MAGIC Collaboration), 2020

GRB, GW EM counterparts with HERMES and CTA

- GRB studies with HERMES and CTA
  - Temporal structure of the Prompt Phase
  - What is the temporal structure of the prompt phase at TeV energies?
  - Input from spectral modeling at X-ray energies



https://arxiv.org/pdf/1709.07997.pdf

Conclusions

- MWL/MM input necessary for most CTA science cases
  - X-ray domain crucial for interpretations/modelling
- Key Science Projects: significant dataset of the VHE sky (e.g. surveys)
  - Transients
    - Alerts to CTA on a large range of objects/sources (GRBs!) => CTA reaction O(30s)!
    - Public alerts from CTA on transient emission from known and unknown sources
    - Real-time analysis => alert emission with O(30s)
- CTA will be an observatory
  - A lot of opportunities for joint programs + ToOs