cherenkov telescope array

Synergies between CTA and THESEUS

THESEUS workshop, Naples 5-6 October 2017

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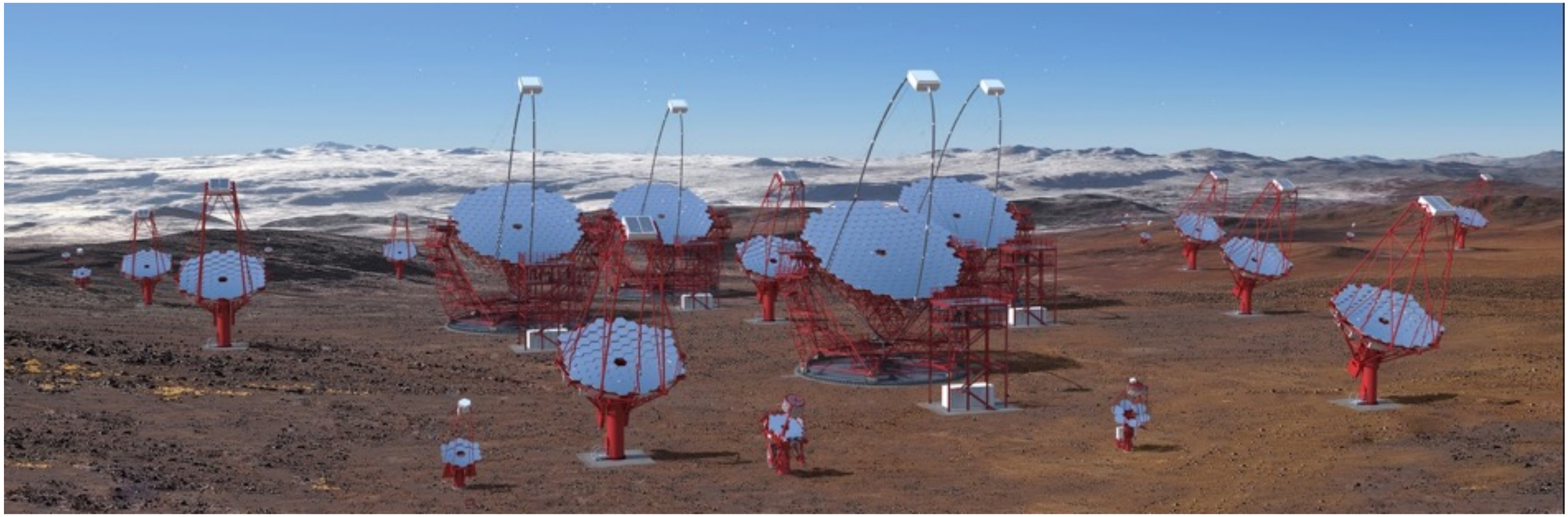
The Cherenkov Telescope Array (CTA)

- **Imaging Atmospheric Cherenkov Telescope (IACT) Array:** observe Cherenkov emission from gamma-ray initiated cascades in the atmosphere

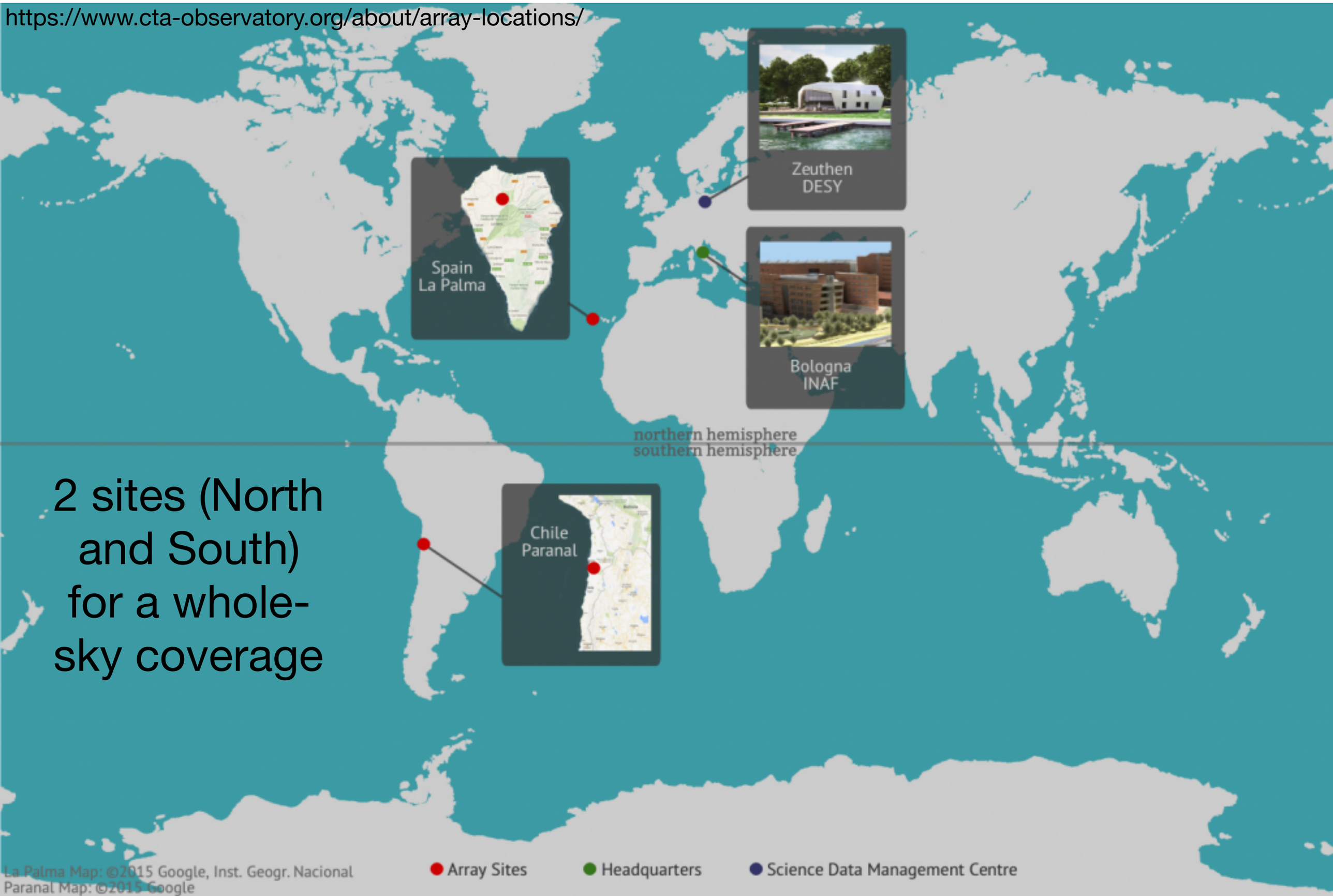
- **Consortium**: 32 countries, ~1400 scientists, ~208 institutes

- **Observatory**: data openly available after proprietary period, GO programmes, ToOs and DDTs



Southern Hemisphere Site Rendering; credit: Gabriel Pérez Diaz, IAC, SMM

The Cherenkov Telescope Array (CTA)

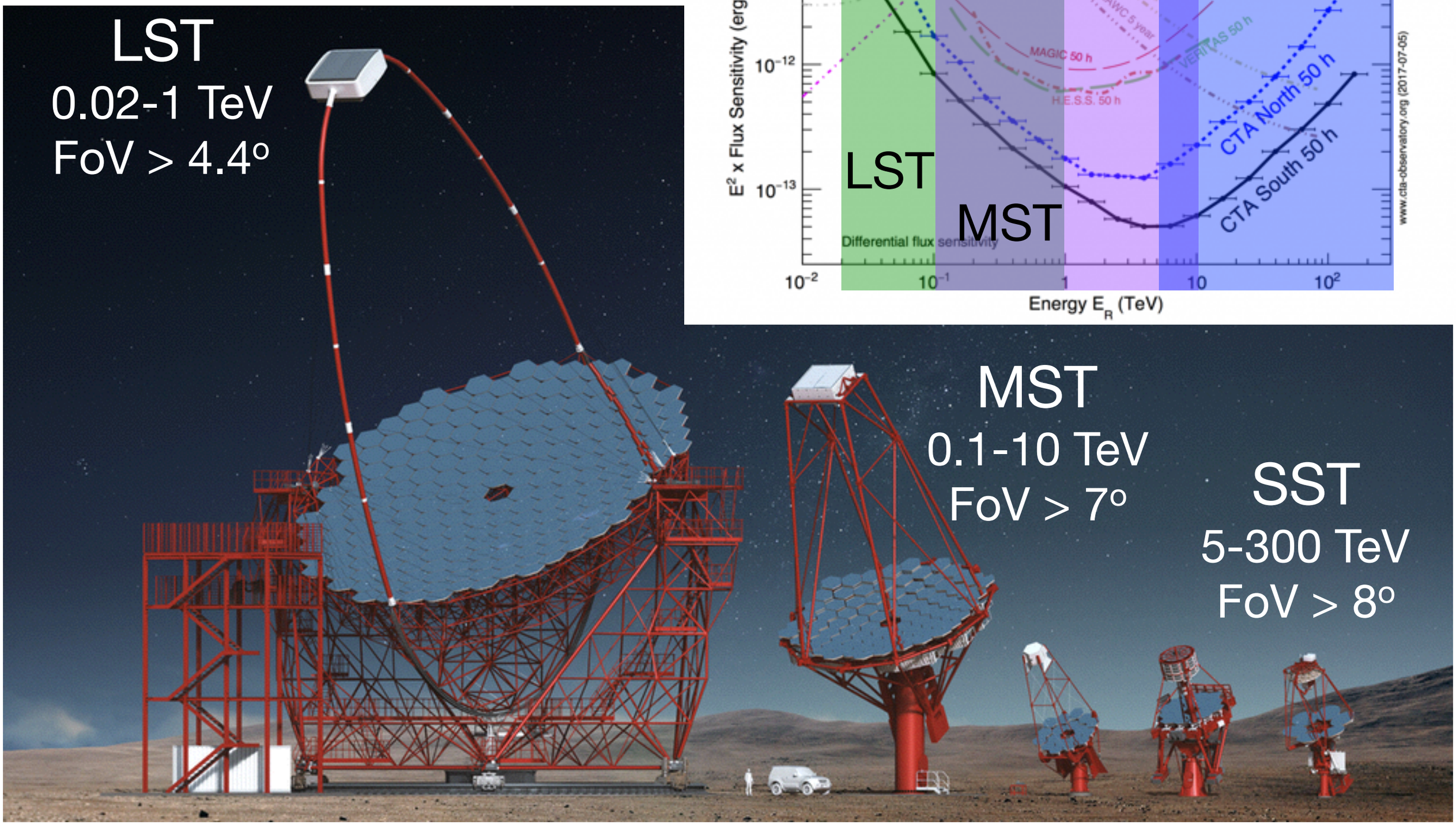


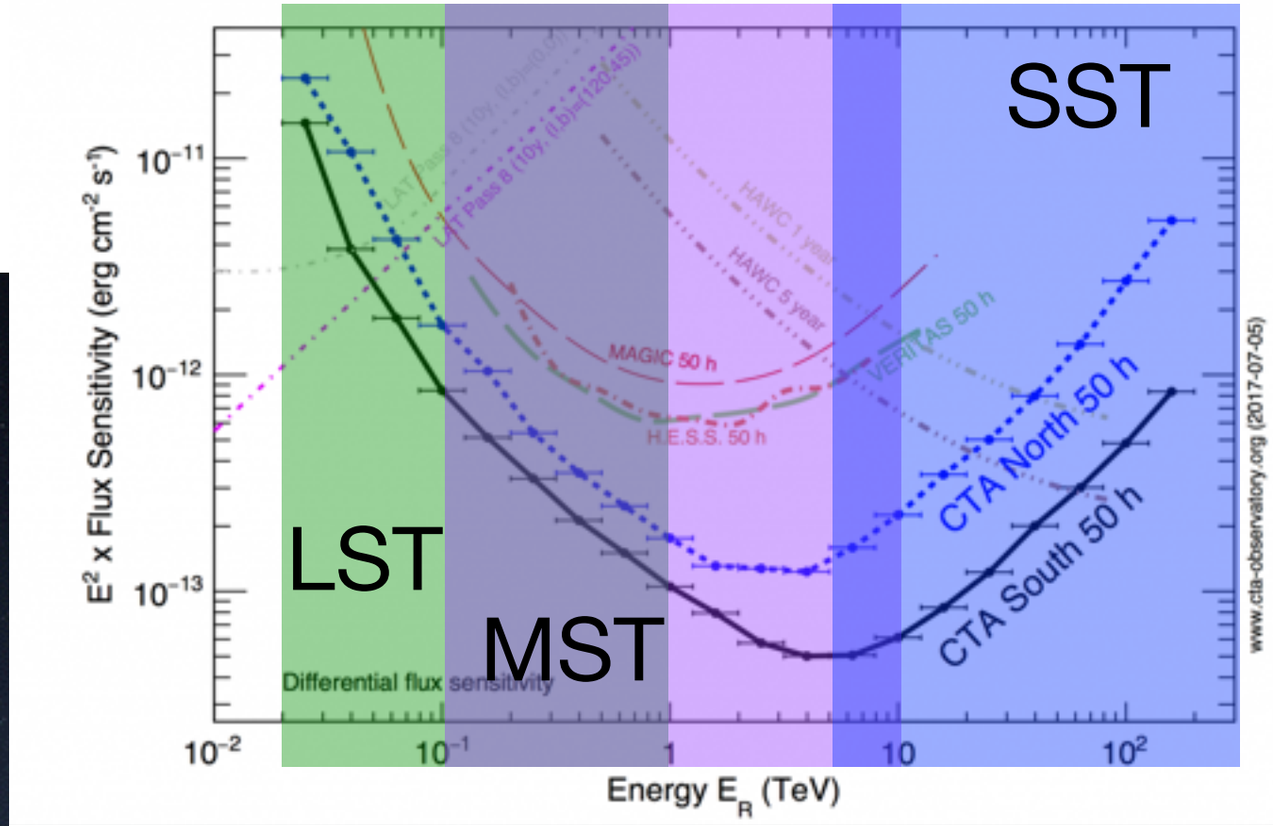
2 sites (North and South) for a whole-sky coverage

The Cherenkov Telescope Array (CTA)

All the systems do not have to point to the same direction

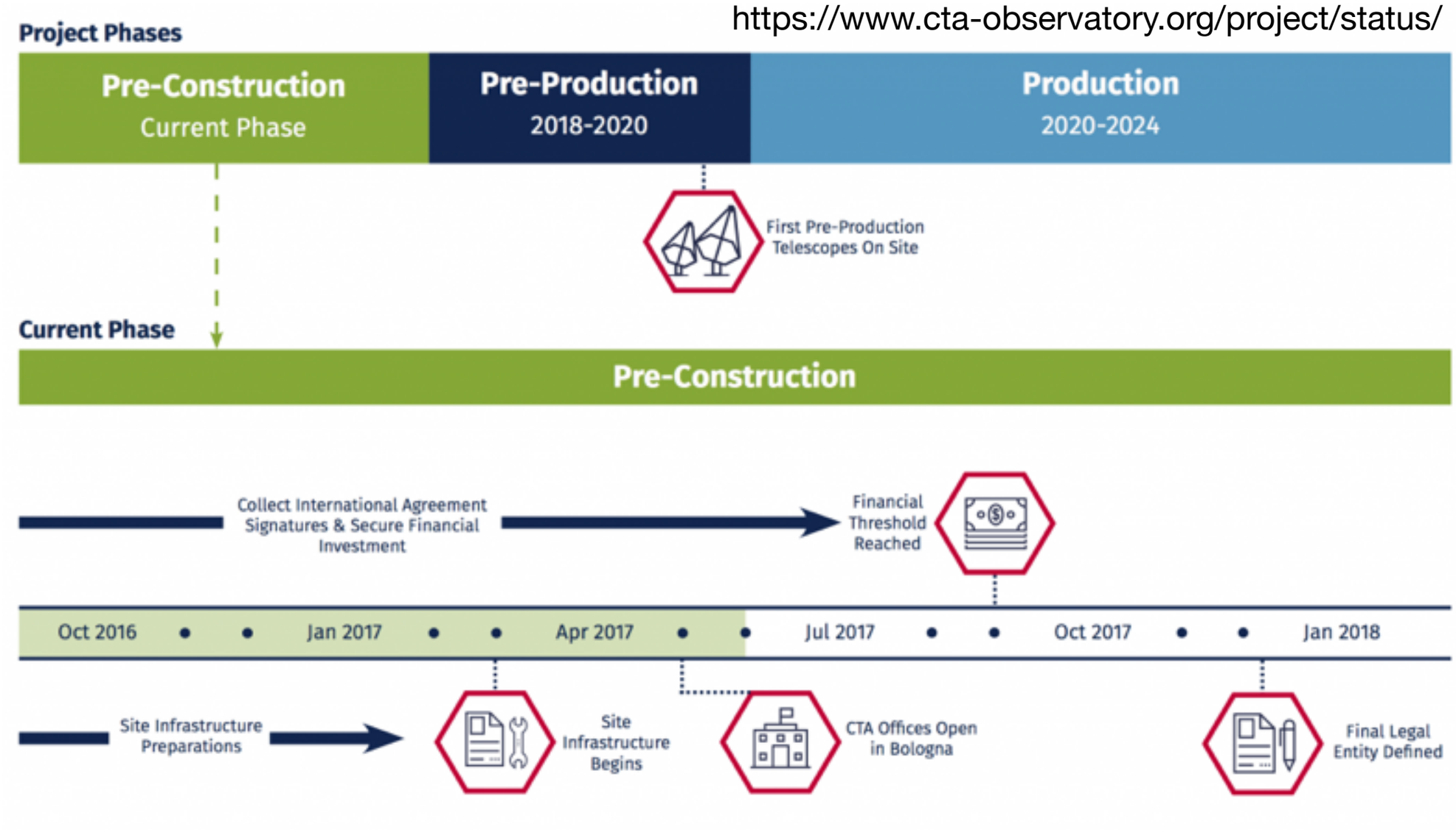
The Cherenkov Telescope Array (CTA)





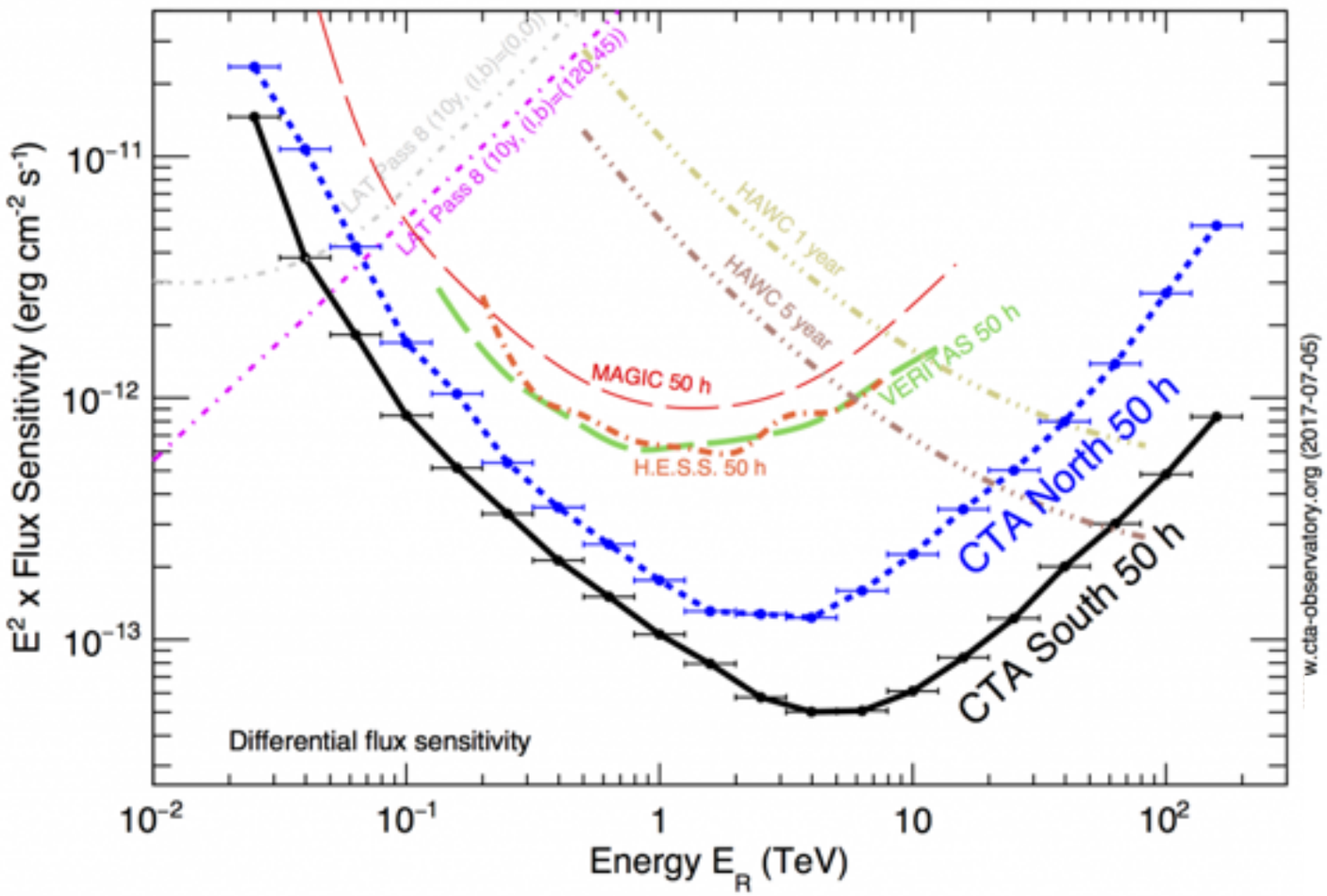
Schedule

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

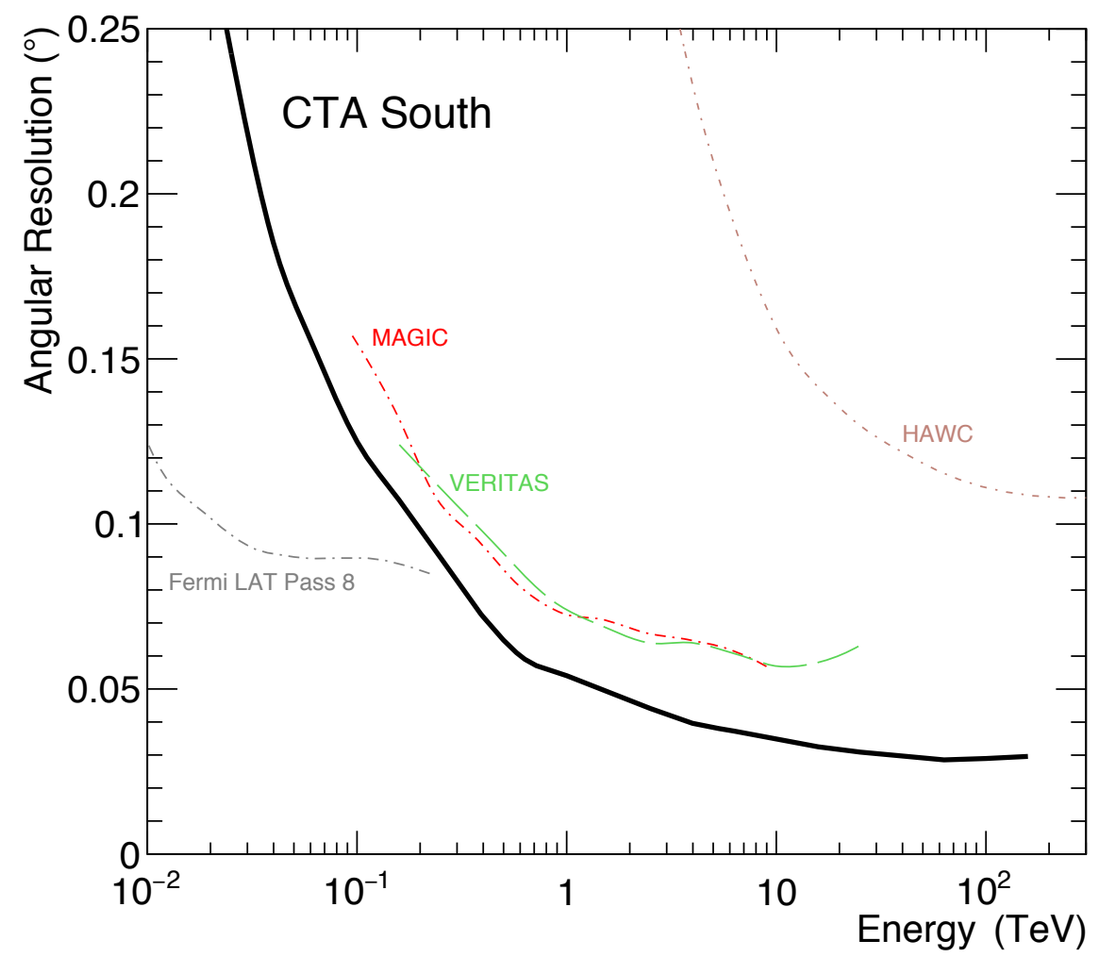


- construction already started in 2017
- construction period of ~6 years
- initial science with partial arrays possible before the end of construction

CTA expected performances



- **~ 5-10 more sensitive** than the current IACTs
- **broader energy coverage** (20 GeV-300 TeV)



- **better angular resolution** (~3 arcmin at ~ 1 TeV)

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

CTA science themes

- **Cosmic particle acceleration** (origin, acceleration site and feedback on star formation and galaxy evolution)
- **Probing extreme environment** (processes at the vicinity of NSs and BHs, relativistic jets, winds and explosions)
- **Exploring frontiers in Physics** (dark matter, Lorentz invariance violation)

The CTA consortium, ArXiV:1709.07997

Key Science projects (KSPs)

Science themes

Theme		Question	Dark Matter Programme	Galactic Centre Survey	Galactic Plane Survey	LMC Survey	Extra-galactic Survey	Transients	Cosmic Ray PeVatrons	Star-forming Systems	Active Galactic Nuclei	Galaxy Clusters
Understanding the Origin and Role of Relativistic Cosmic Particles	1.1	What are the sites of high-energy particle acceleration in the universe?		✔	✔✔	✔✔	✔✔	✔✔	✔	✔	✔	✔✔
	1.2	What are the mechanisms for cosmic particle acceleration?		✔	✔	✔		✔✔	✔✔	✔	✔✔	✔
	1.3	What role do accelerated particles play in feedback on star formation and galaxy evolution?		✔		✔				✔✔	✔	✔
Probing Extreme Environments	2.1	What physical processes are at work close to neutron stars and black holes?		✔	✔	✔			✔✔		✔✔	
	2.2	What are the characteristics of relativistic jets, winds and explosions?		✔	✔	✔	✔	✔✔	✔✔		✔✔	
	2.3	How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?					✔	✔			✔✔	
Exploring Frontiers in Physics	3.1	What is the nature of Dark Matter? How is it distributed?	✔✔	✔✔		✔						✔
	3.2	Are there quantum gravitational effects on photon propagation?						✔✔	✔		✔✔	
	3.3	Do Axion-like particles exist?					✔	✔			✔✔	

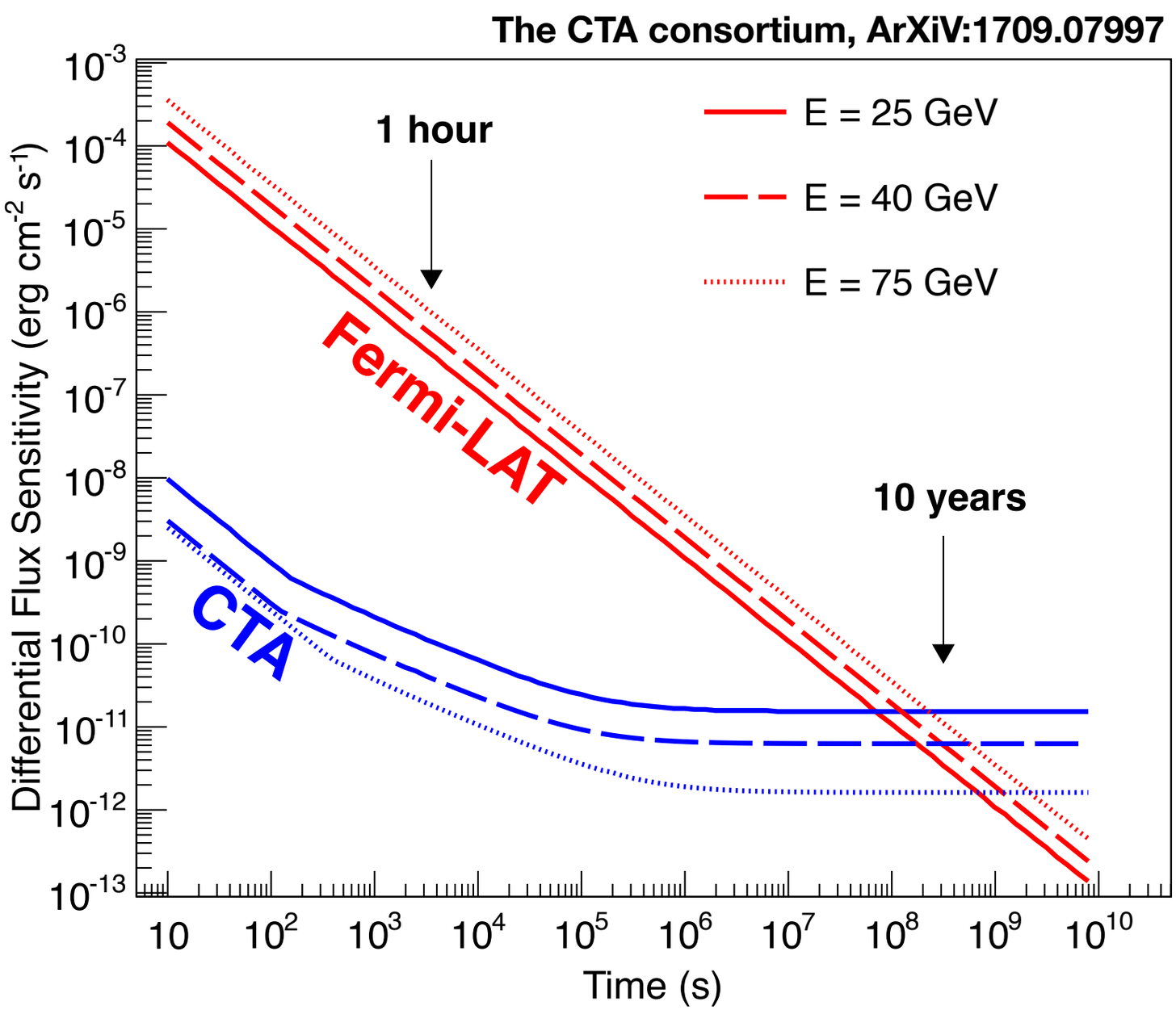
The transient sky with CTA

- **rapid response to external alerts**, and to deliver alerts to other observatories
- wide FoV+unprecedented sensitivity: **serendipitous detection of transient** (low-latency real-time analysis pipeline to detect gamma-ray events and issue an alert within 60s)

➡**characterise different classes of transients:**

- GRBs
- multimessenger (MM) transients
- TDEs, SN shock breakouts, FRBs
- AGN flares
- galactic transients (microquasars, PWN flares, novae, magnetars, X-ray binaries, …)

The transient sky with CTA



- **improved sensitivity** for short timescales w.r.t. Fermi-LAT in the range of overlap
- **limited FoV** compared to Fermi-LAT
  - ➡**prompt reaction** to external triggers is critical
  - ➡**fast repointing**: <20s for LSTs and 60s for MSTs and SSTs to and from the obs. sky
  - ➡**divergent pointing and tiling observations** (under study)

The Transients key science project

- a programme responding to a broad range of multi-wavelength and multi-messenger alerts
- rapid feedback to a wide scientific community (selected information communicated in the form of GCNs, Astronomer's Telegrams, IAU circulars)
- specific strategies will be put in place for different classes of transients (for more detailed guidelines see "Science with the CTA", ArXiV:1709.07997)

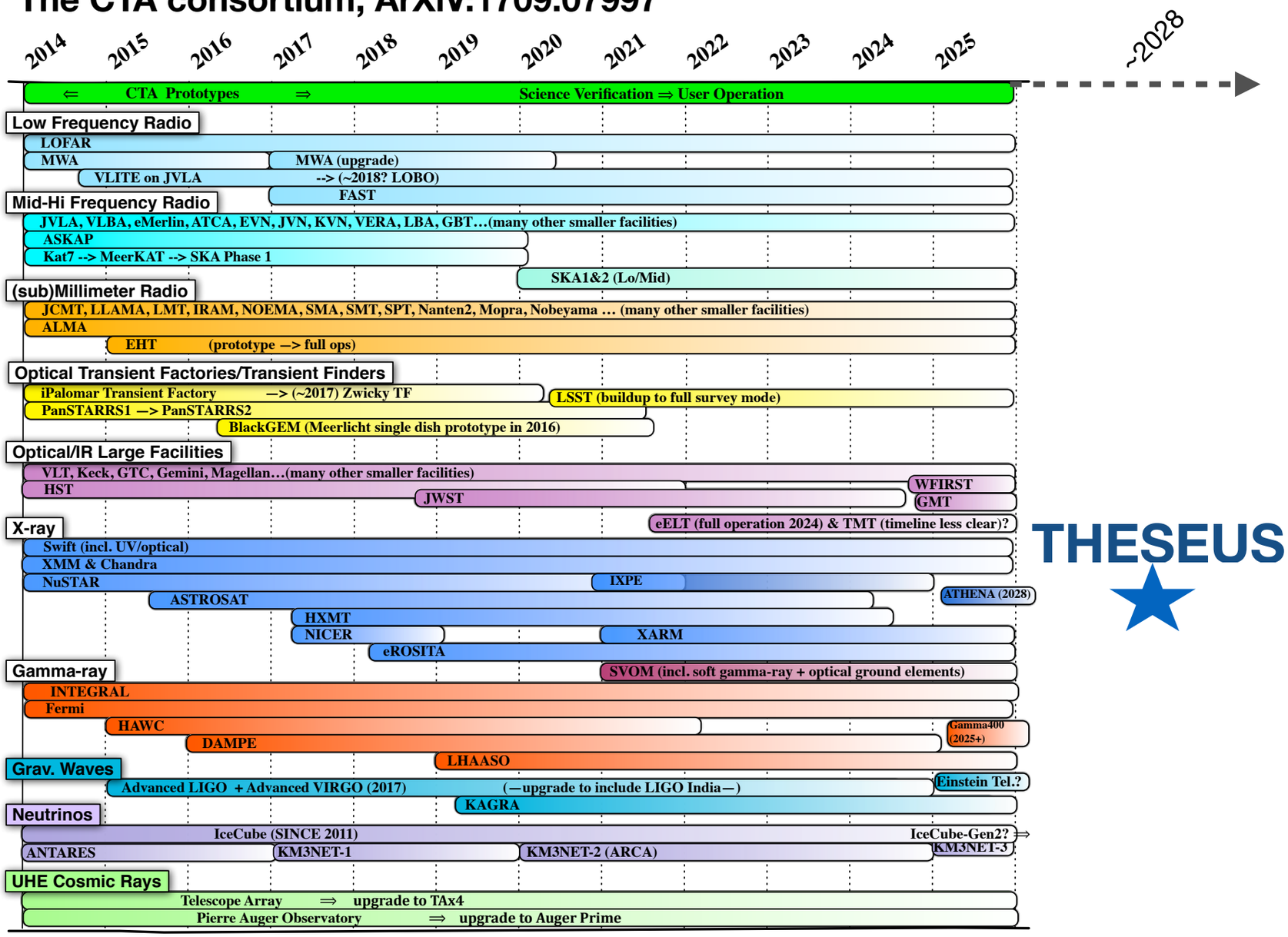
Proposed max obs. time for follow-up targets in the Transients KSP

		Observation times (h yr^{-1} $site^{-1}$)			
Priority	Target class	Early phase	Years 1–2	Years 3–10	Years 1–10
1	GW transients	20	5	5	
2	HE neutrino transients	20	5	5	
3	Serendipitous VHE transients	100	25	25	
4	GRBs	50	50	50	
5	X-ray/optical/radio transients	50	10	10	
6	Galactic transients	150	30	0(?)	
	Total per site (h yr^{-1} $site^{-1}$)	390	125	95	
	Total both sites (h yr^{-1})	780	250	190	
	Total in different CTA phases (h)	1560	500	1520	2020

The CTA consortium, ArXiV:1709.07997

Synergies with THESEUS

The CTA consortium, ArXiV:1709.07997



THESEUS

THESEUS will provide:

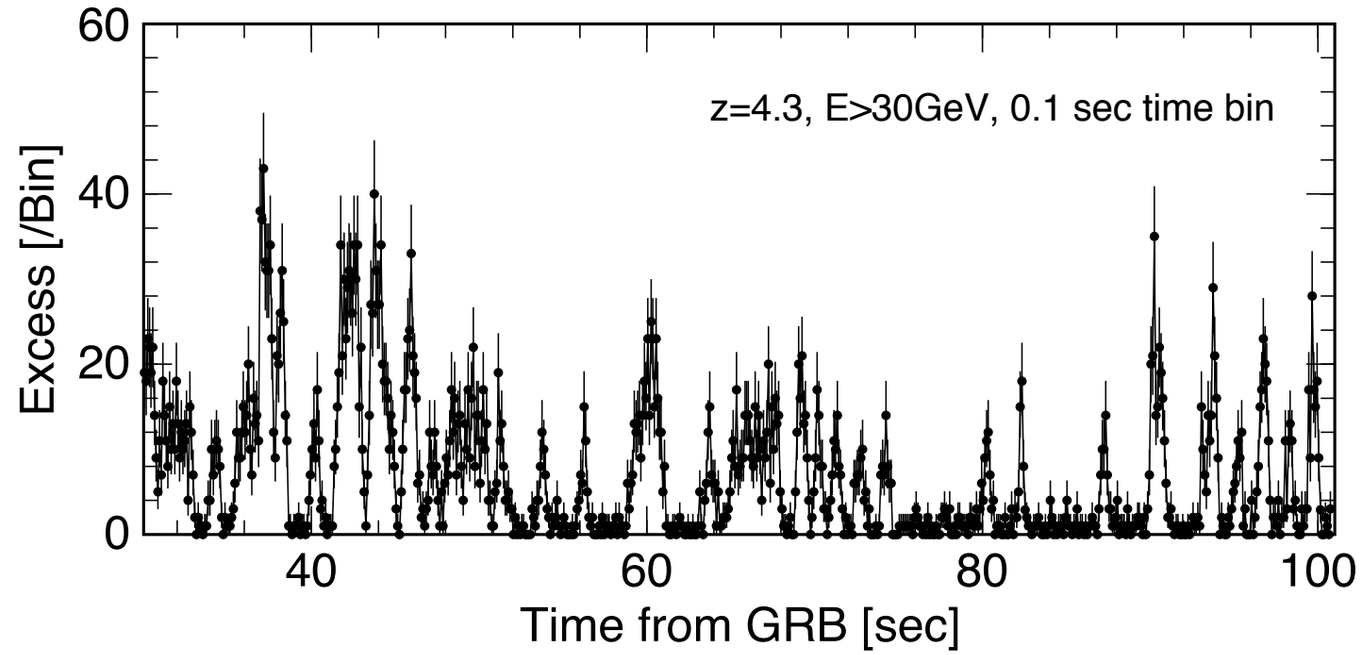
- external triggers and accurate location for follow-up of high-energy transients as:
  - long/short GRBs
  - TDEs, SN shock breakouts
  - X-ray binaries
  - MM transients
- multi-wavelength characterisation of CTA targets:
  - AGNs/blazars
  - MM emitters

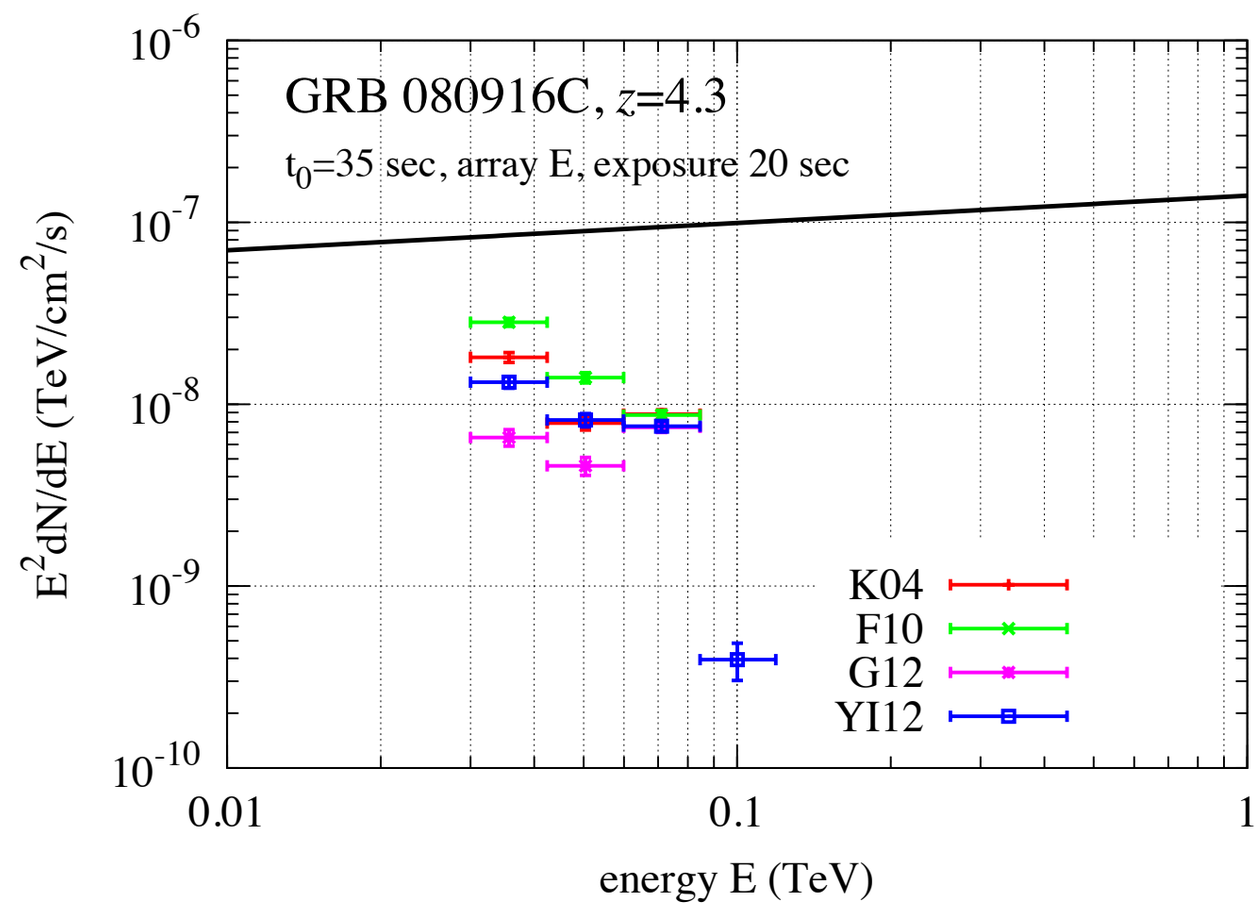
Synergies bw X- and gamma-ray observations:

- X-rays associated to shock waves, accretion or outflows, and hence with particle acceleration
- non-thermal X-rays: synchrotron+IC studies

GRBs with CTA

- expected detection: ~1 GRB/yr/site
- improved photon statistics w.r.t. Fermi/LAT:
  - ➡constrain the high-energy spectral component
    - high-energy cutoff
    - measure of the outflow Lorentz factor
  - ➡resolving GRB light curves in more details
    - variability studies
    - Lorentz invariance Violation





The CTA consortium, ArXiV:1709.07997
Inoue et al., Aph 43, 252, 2013

GRBs with CTA

GRB follow-up strategy:

- **prompt follow-up** by the full array **of all accessible GRB alerts**
- possibility to make **tilings** for large areas
- **extended observations for detected GRBs** with the full array
- possible late-time follow-up of high-energy GRBs not accessible promptly

GRB follow-up strategy and obs. time per site

Strategy	Expected event rate (yr^{-1})	Exposure per follow-up (h)	Exposure per year (h yr^{-1})
Prompt follow-up of accessible alerts	$\sim$12	2	25
Extended follow-up for detections	0.5–1.5	10–15	10–15
Late-time follow-up of HE GRBs not accessible promptly	$\sim$1	10	10

The CTA consortium, ArXiV:1709.07997

Conclusions

- CTA will be a versatile telescope for wide range of science topics
- transition from experiment to observatory: open to community access
- improved sensitivity on short timescales w.r.t. Fermi/LAT and other IACTs: probe the transient sky at very high energies
- CTA full potential reached only by strong synergies with multi-wavelength instruments