CTAO
Cherenkov Telescope Array Observatory

Chasing GWs with the Cherenkov Telescope Array Observatory

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with the collaboration of the GW core team of the CTAO Consortium:
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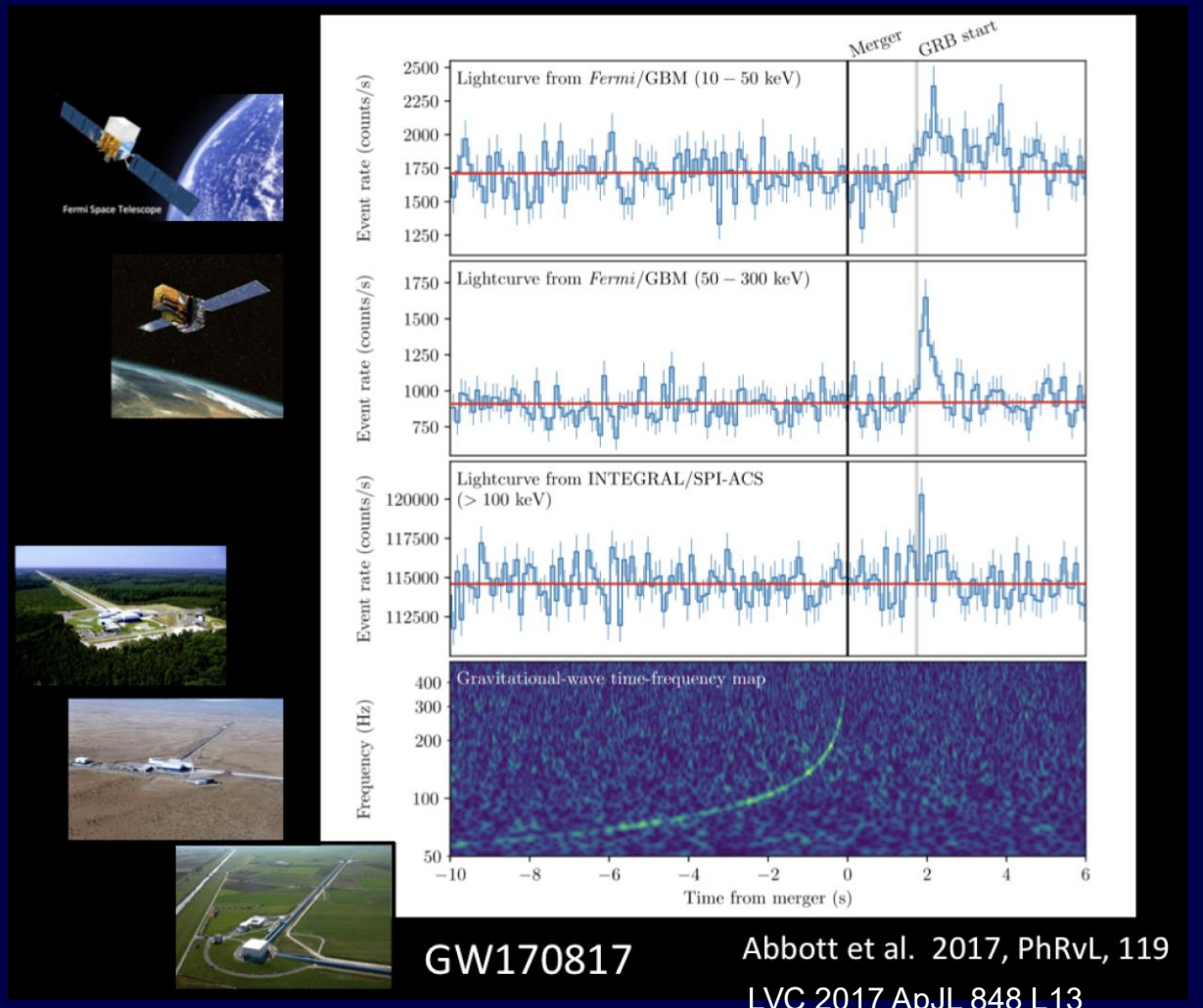
Building on a successfu story

GW170817

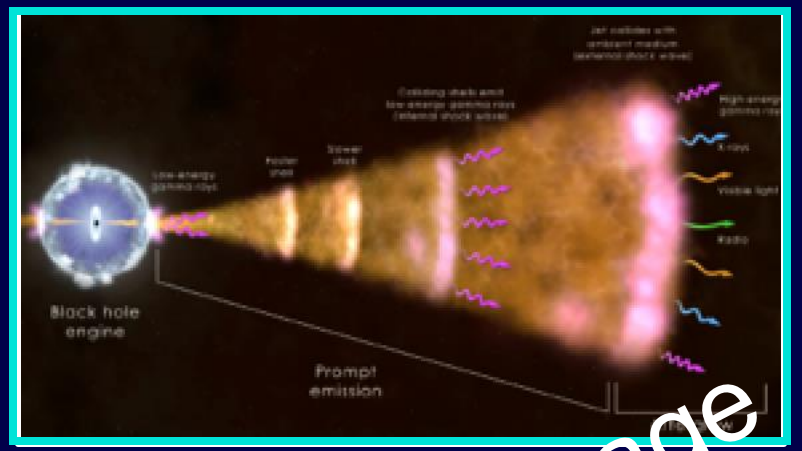
instrinsically sub-luminous or simply a classical off-axis short-GRB?



Abbott et al. 2017, PhRvL, 119

LVC 2017 ApJL 848 L13

being fast!



NS merger

short-GRB

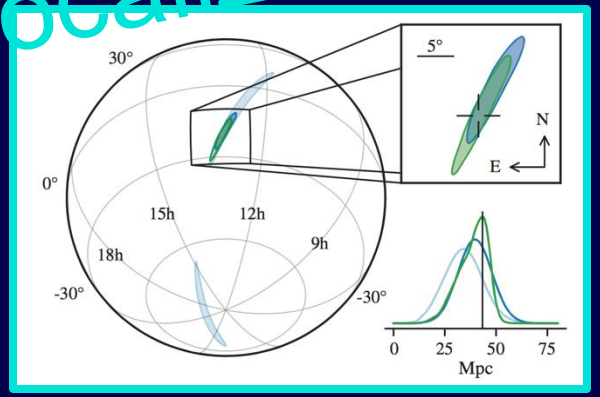
X-ray afterglow

Radio

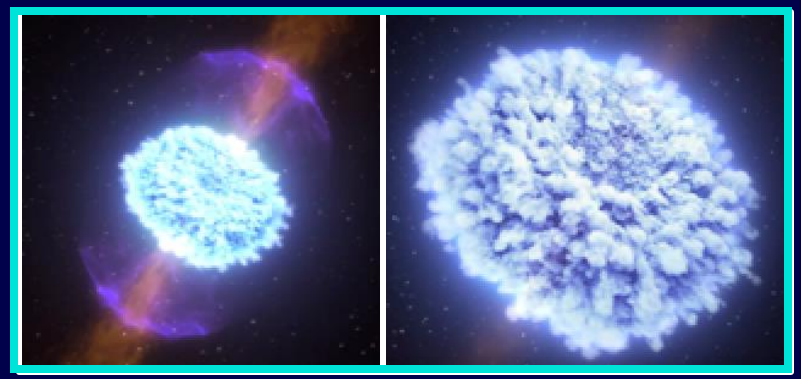
MWL coverage

t0 1.7s +5.23hrs +10.87 hrs +9 days +16 days

sky localization

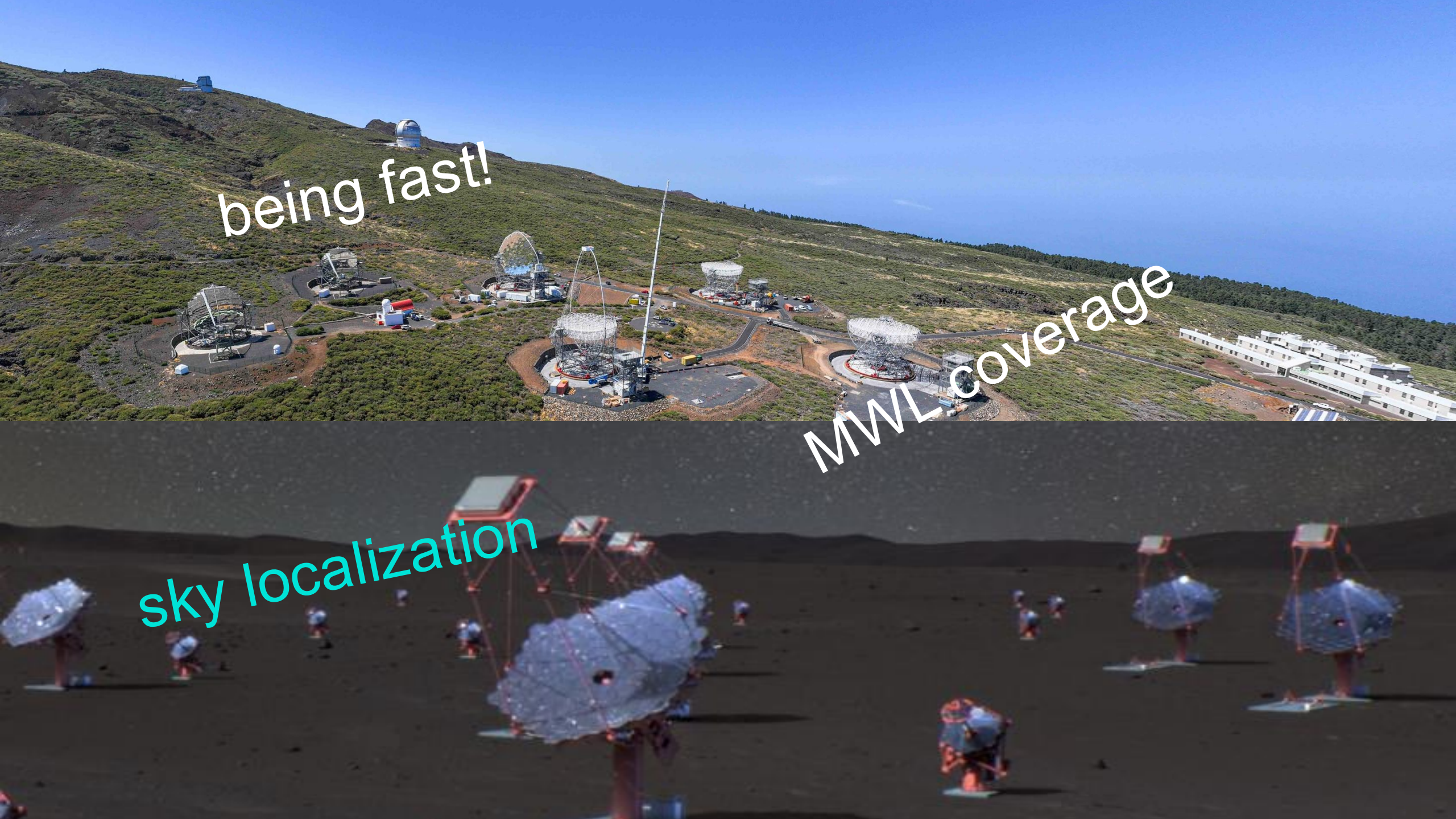


UV/Optical/NIR Kilonova



LVC + astronomers, ApJL, 848, L12

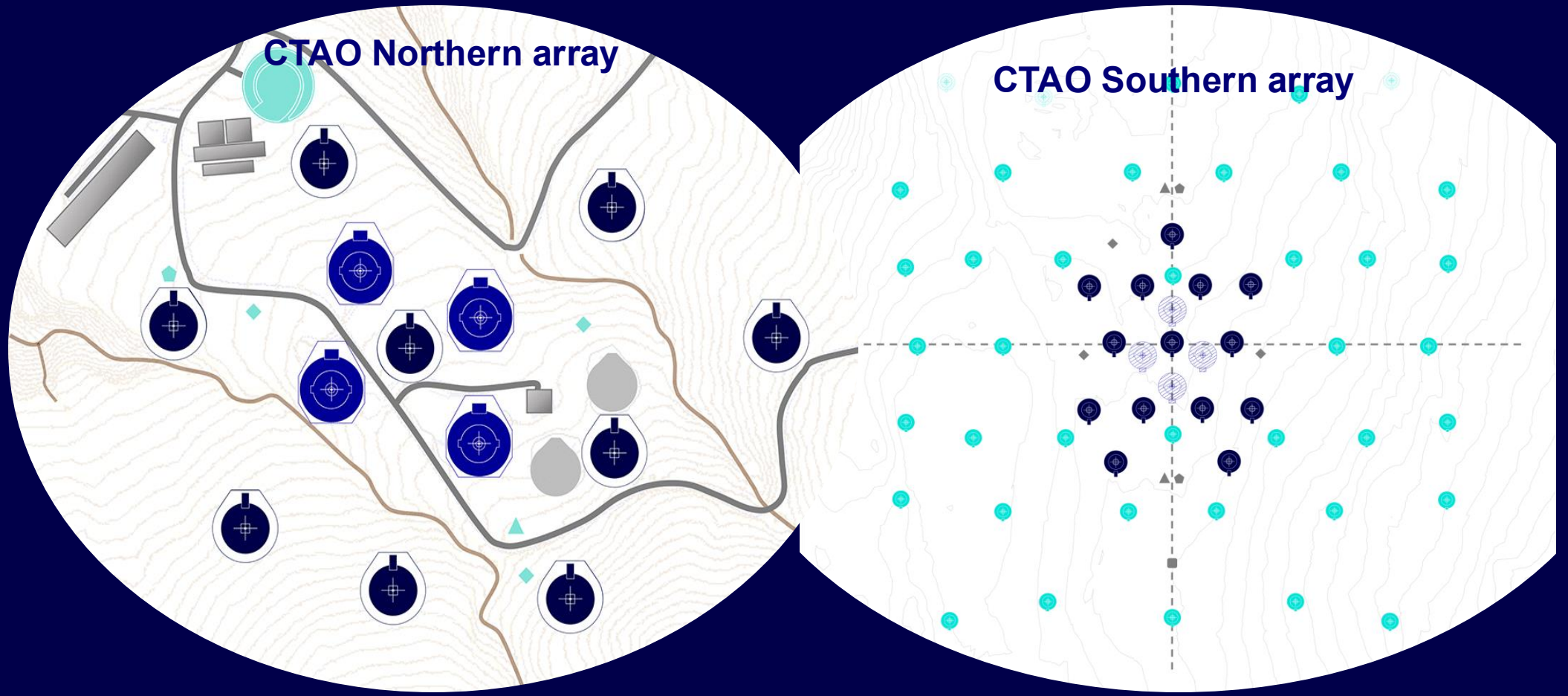
Credits to M. Branchesi


being fast!
MWL coverage
sky localization

CTAO arrays

Alpha Configuration

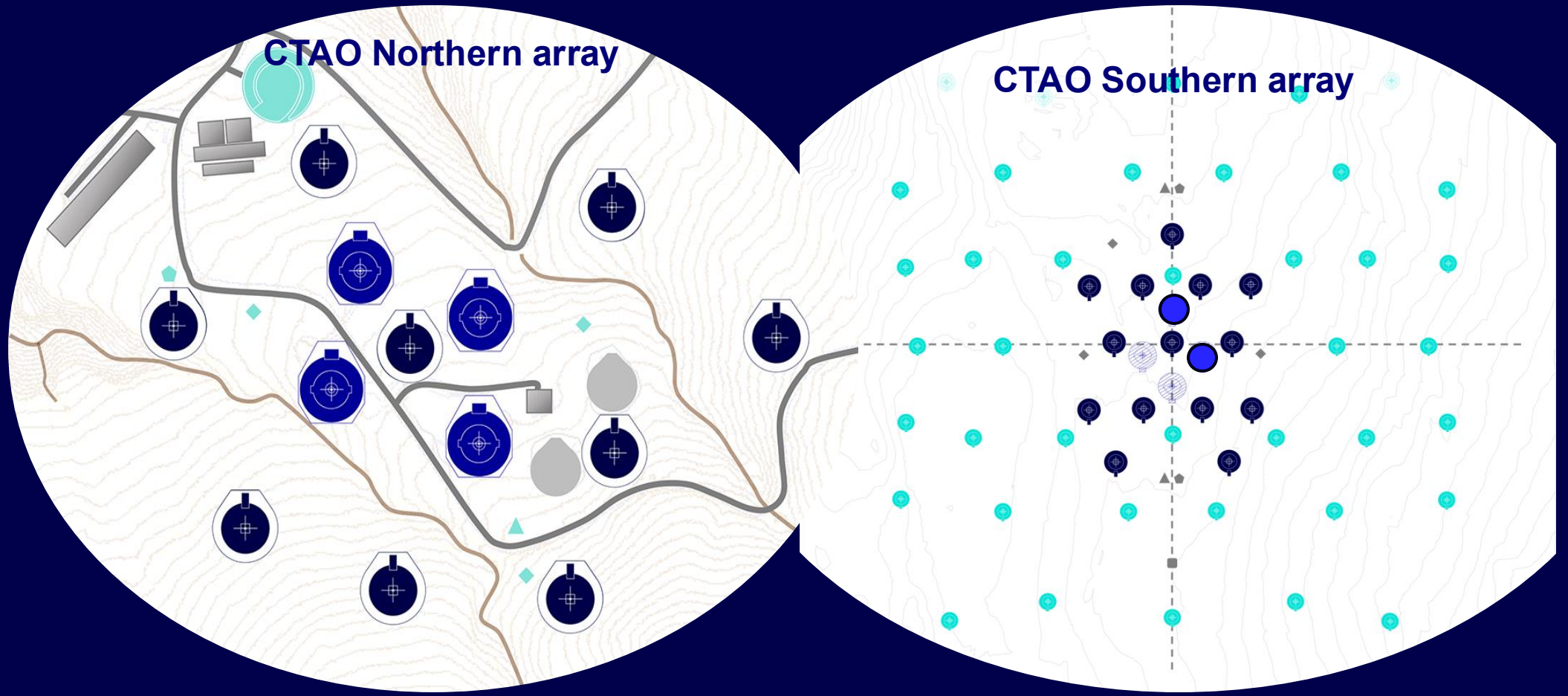
E = [20 GeV – 300 TeV]
γ-ray FoV ~6∘
energy resolution ~ 10%
angular resolution ~ 0.04 ∘



CTAO arrays

Alpha Configuration + (2 LST @ CTAO-South)

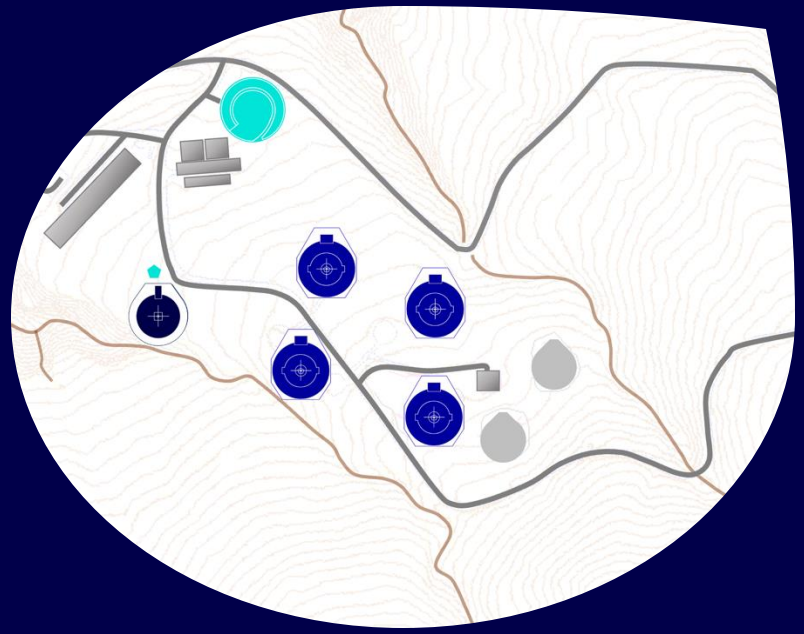
E = [20 GeV – 300 TeV]
γ-ray FoV ~6∘
energy resolution ~ 10%
angular resolution ~ 0.04 ∘



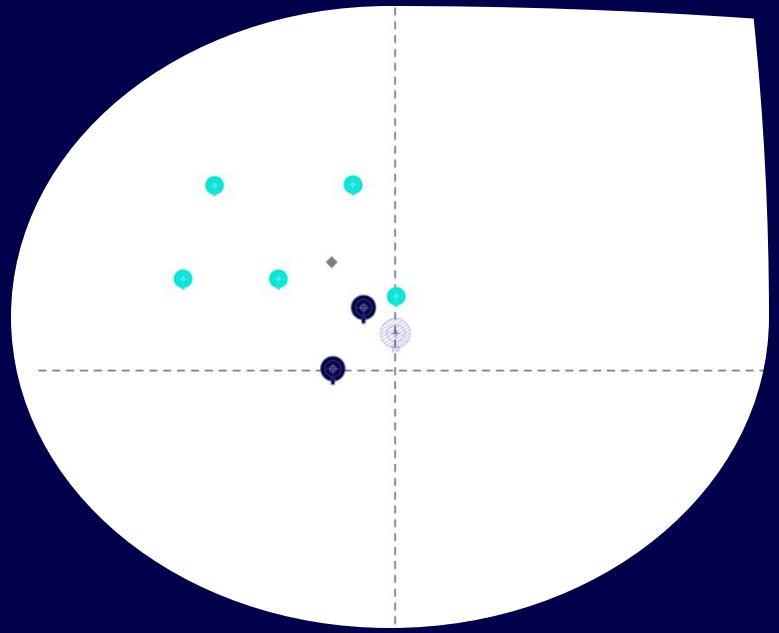
1st intermediate configuration

In two years from now

CTAO Northern array

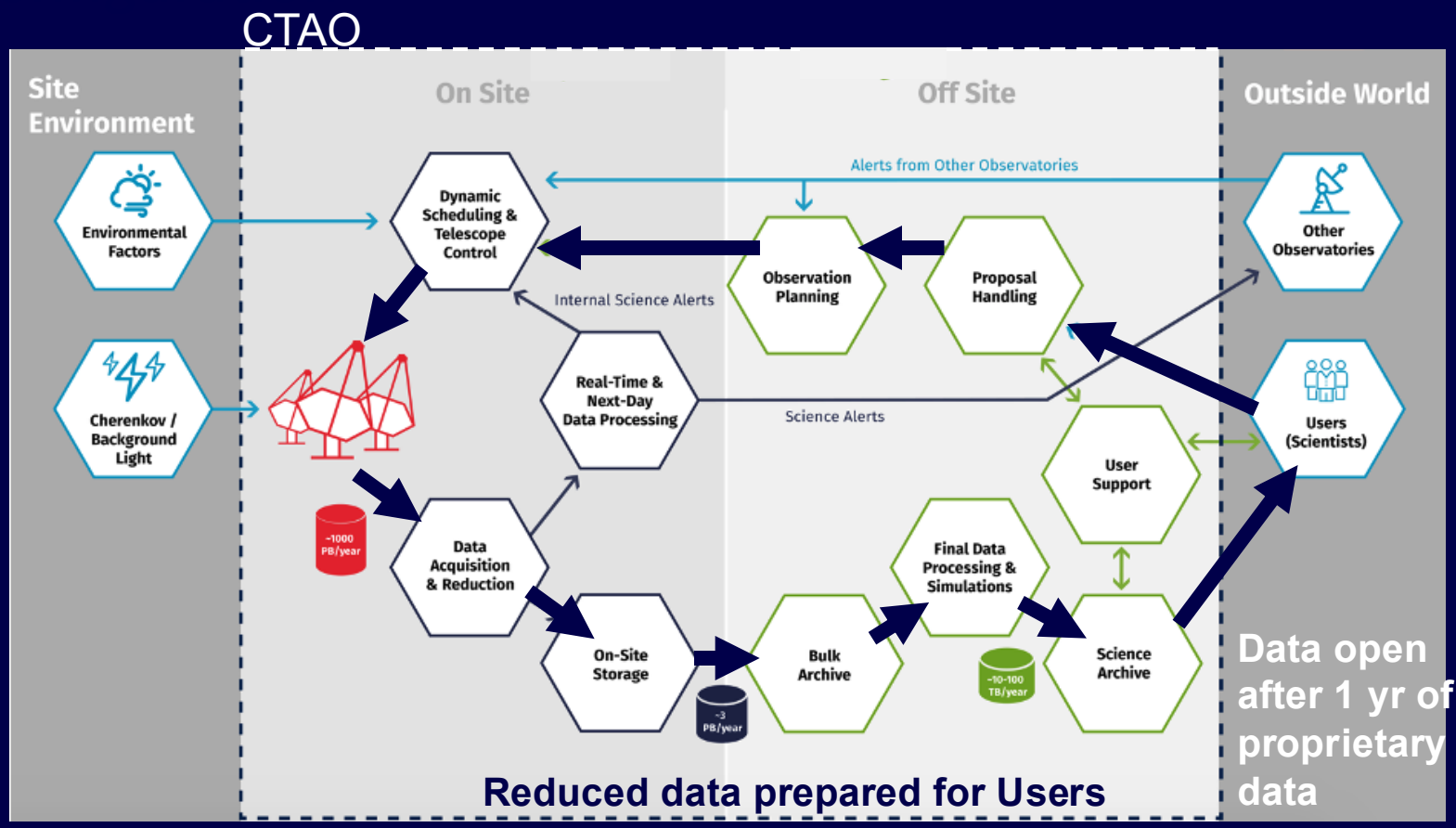


CTAO Southern array

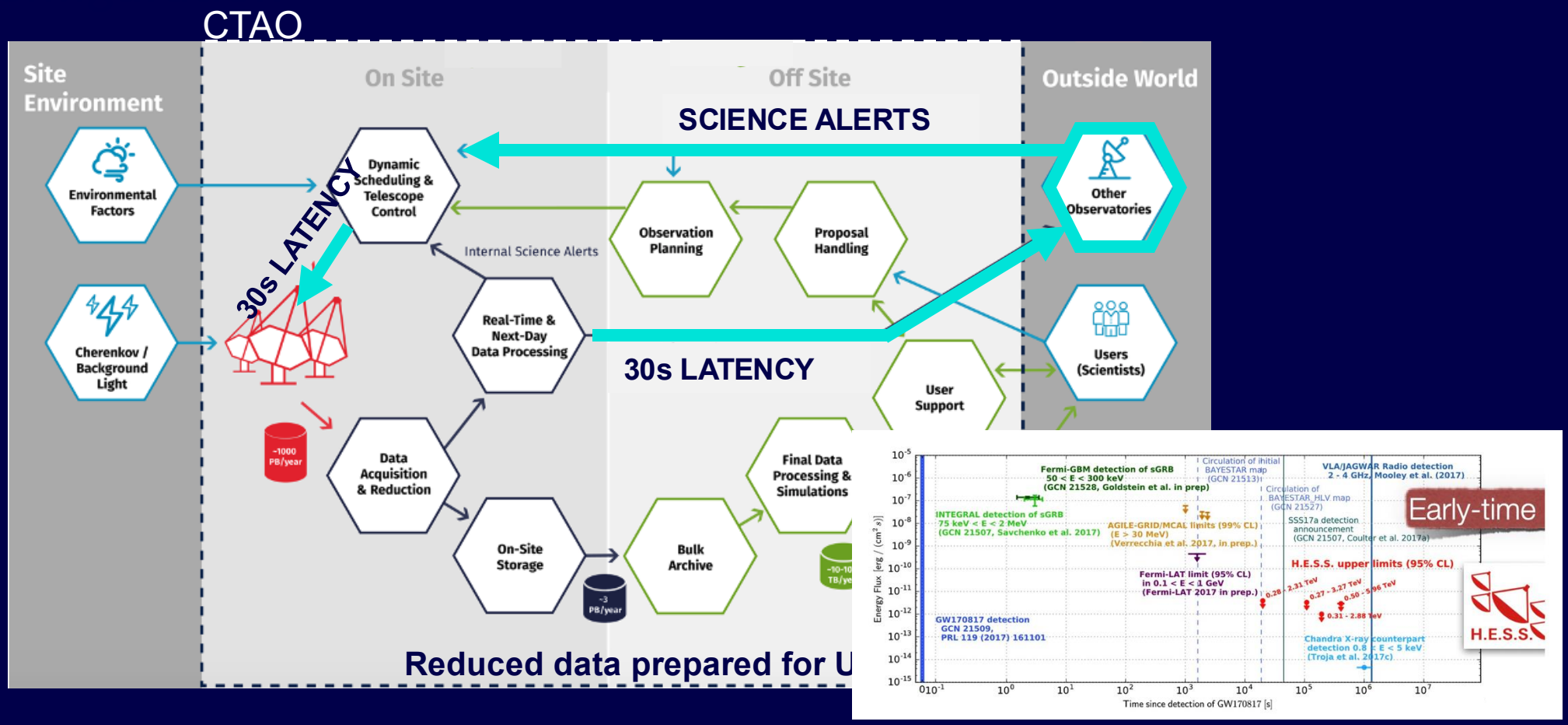


Optimal capabilities for the transient science cases already from the 1st intermediate configuration

A proposal-driven observatory

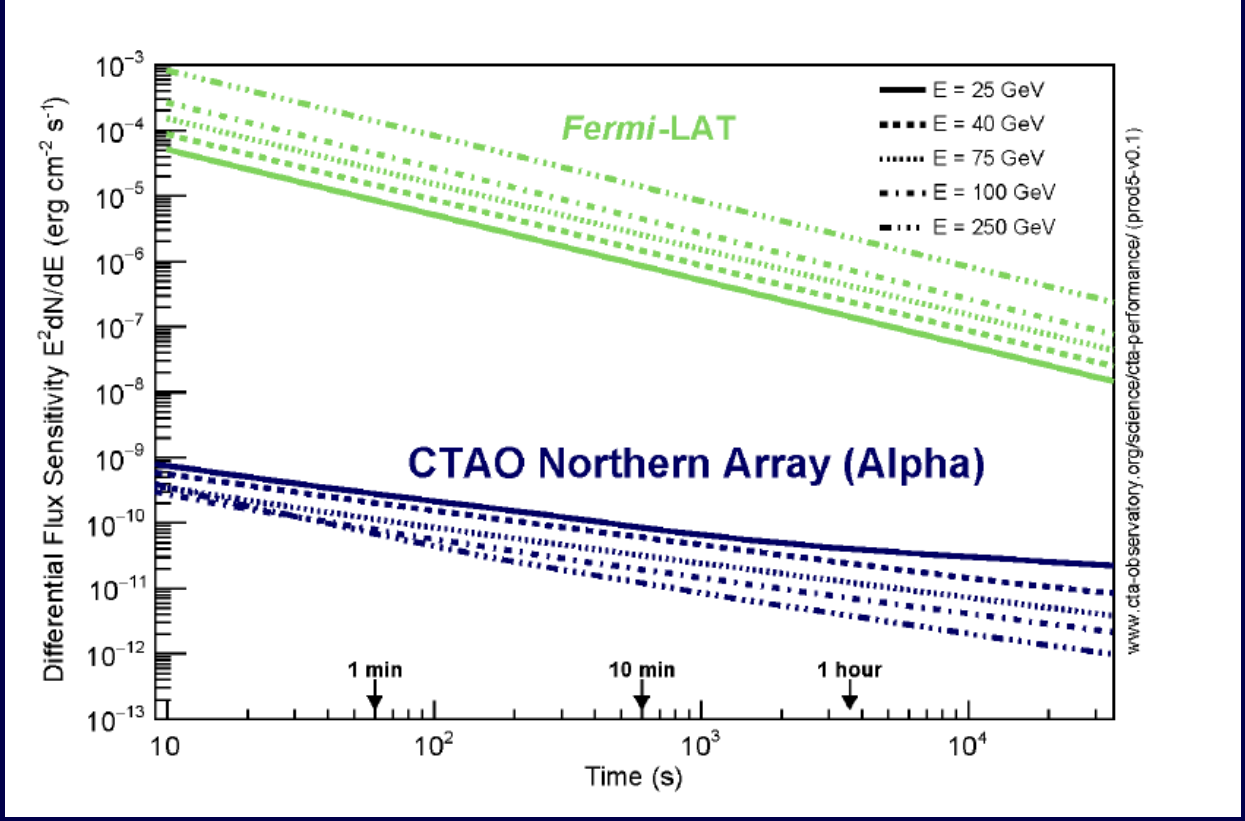


A proposal-driven observatory



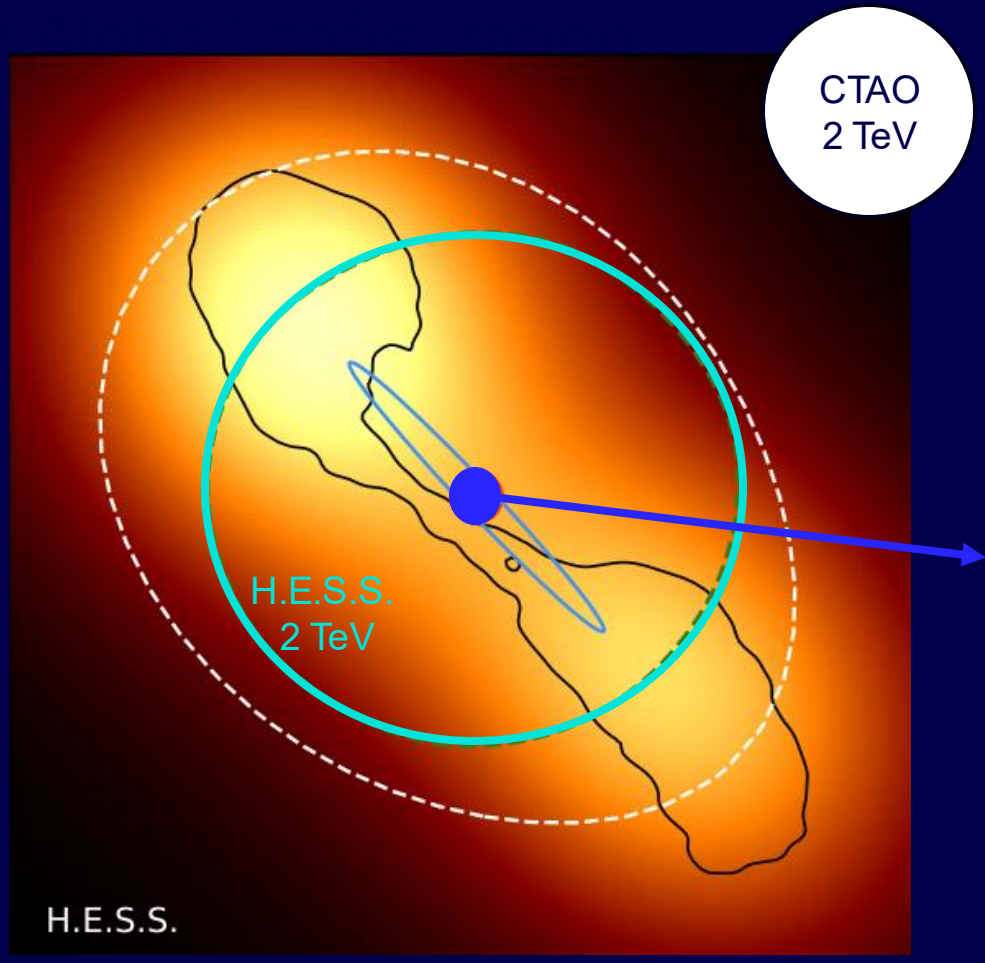
CTAO short-term obs performance

Transient science cases



- LSTs can repositinig any point in the sky in 20”
- Real-time analysis that can issue science alerts in 30”

CTAO source localization



15-30” localization

CTAO prospects on GW follow-ups

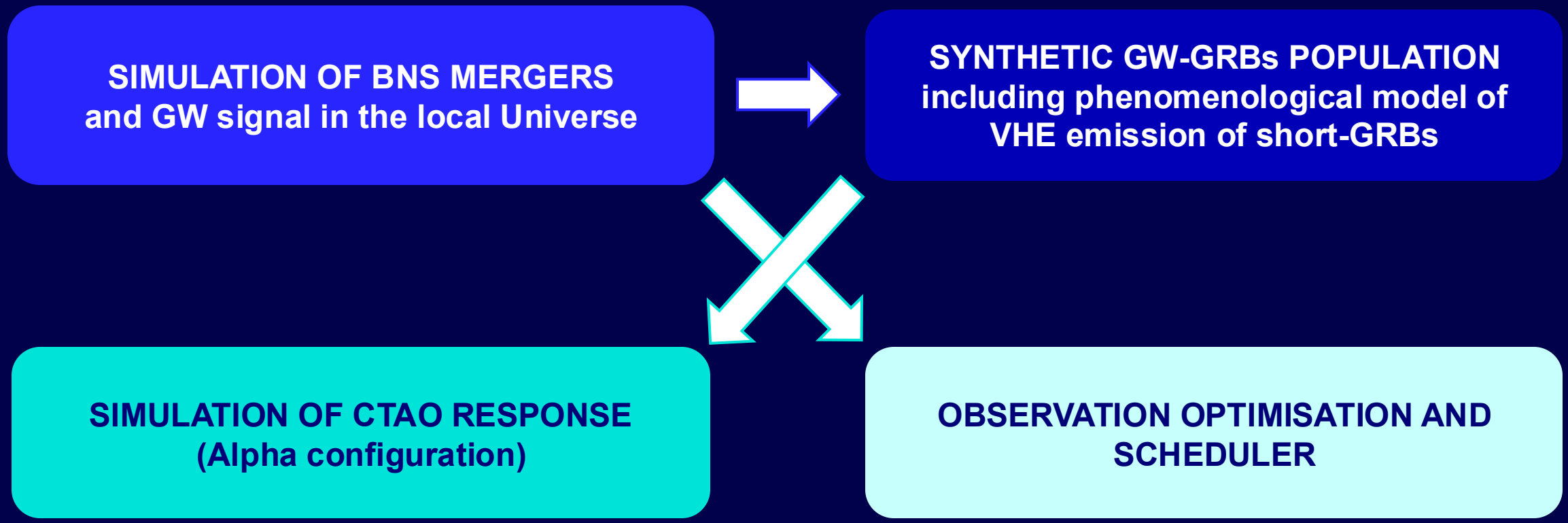
Three goals

COMPUTE THE JOINT GW-CTAO DETECTION RATE
from binary neutron stars (BNS) mergers associated with GRBs

EXPLORE THE PARAMETER SPACE of GW-GRB DETECTABLE by CTAO
both in terms of physical and observational parameters

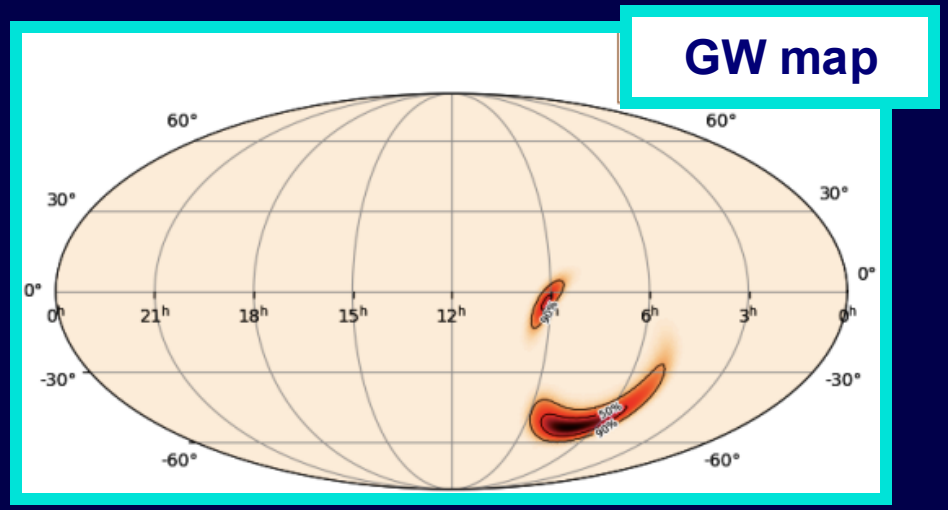
OPTIMIZE THE OBSERVING STRATEGY

GW-TeV simulation chain



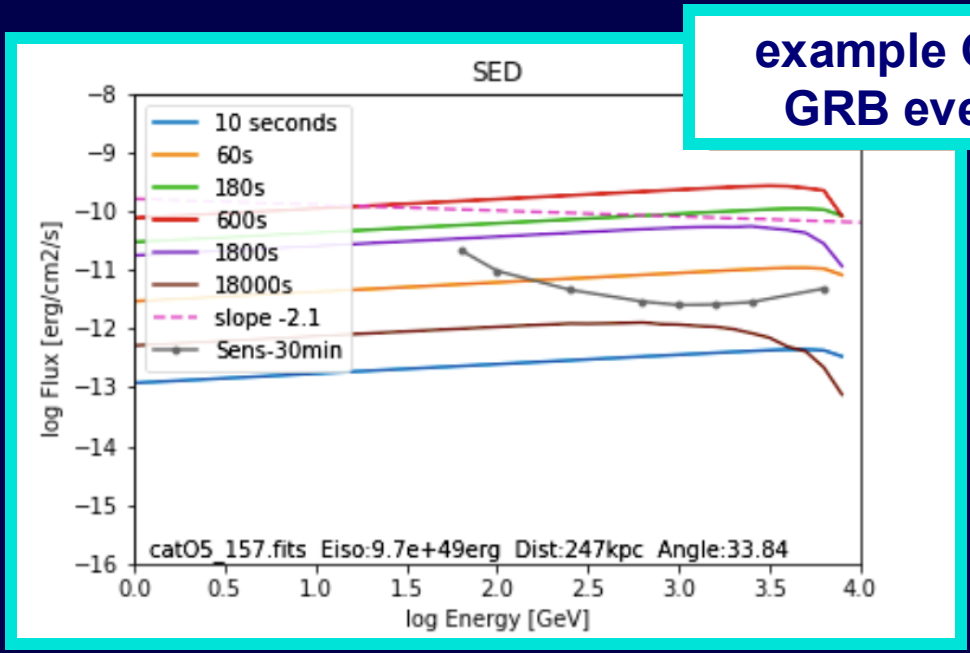
GW-TeV simulation chain

SIMULATION OF BNS MERGERS
and GW signal in the local Universe



- **GW catalogue of simulated BNS mergers from Petrov et al. 2022 for O5**
- **GW detector sensitivities from Abbott et al 2020b**
  - **4 interferometers in O5: 2 aLIGO 330 Mpc, AdV 150-260 Mpc, KAGRA 130+Mpc**
  - **5 interferometers in O6:** 3 aLIGO 330 Mpc, AdV 150-260 Mpc, KAGRA 130+Mpc
- **~2300 compact binaries in O5 detected**

GW-TeV simulation chain



example GW-GRB event

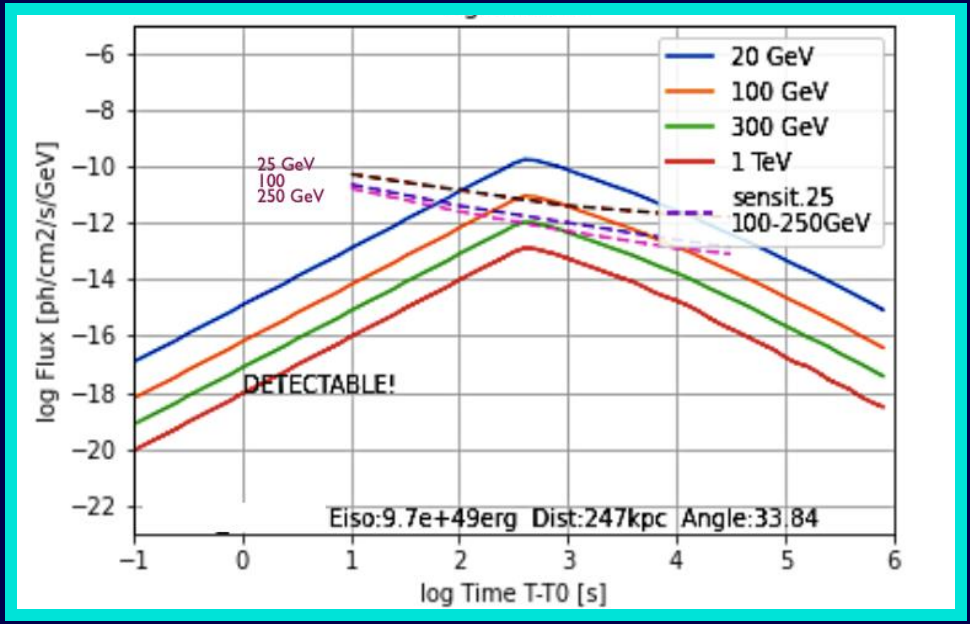
SYNTHETIC GW-GRBs POPULATION

phenomenological simulations of afterglow emission from short GRBs, built on

- short-GRB detections
- GRB detections/obs at TeV energies
- X-ray observations

- **Viewing angle** inferred from the BNS inclination
- **Jet opening angle:** inferred from sGRB seen on-axis ~14 deg (ARA&A 2014)
- **Lightcurve:** temporal decay and luminosity at TeV similar to the softX-ray band
- **Spectrum:** photon index ~ 2
- **Jet structure:** Gaussiam distribution for both energy and Lorentz factor

GW-TeV simulation chain



detection probability depends on the evolution of the source flux (time delay and exposure)

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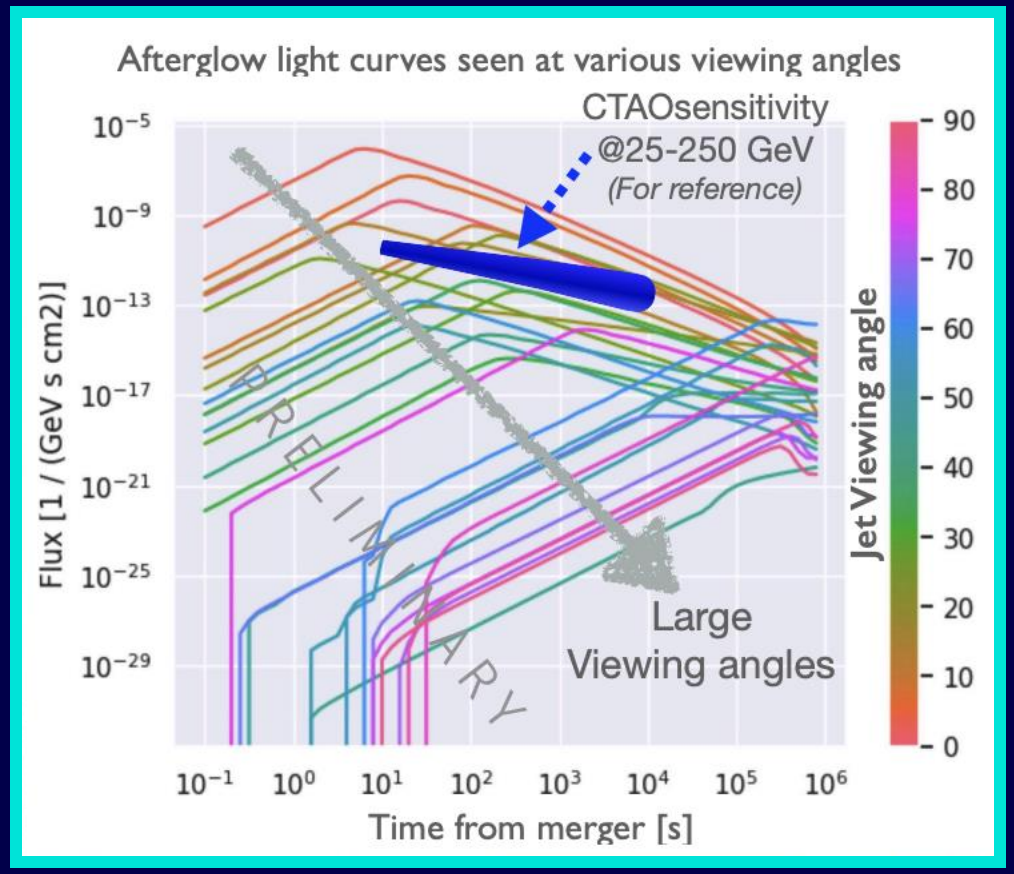
GW-TeV simulation chain

SIMULATION OF CTAO RESPONSE
(Alpha configuration)



GW-TeV simulation chain

SIMULATION OF CTAO RESPONSE
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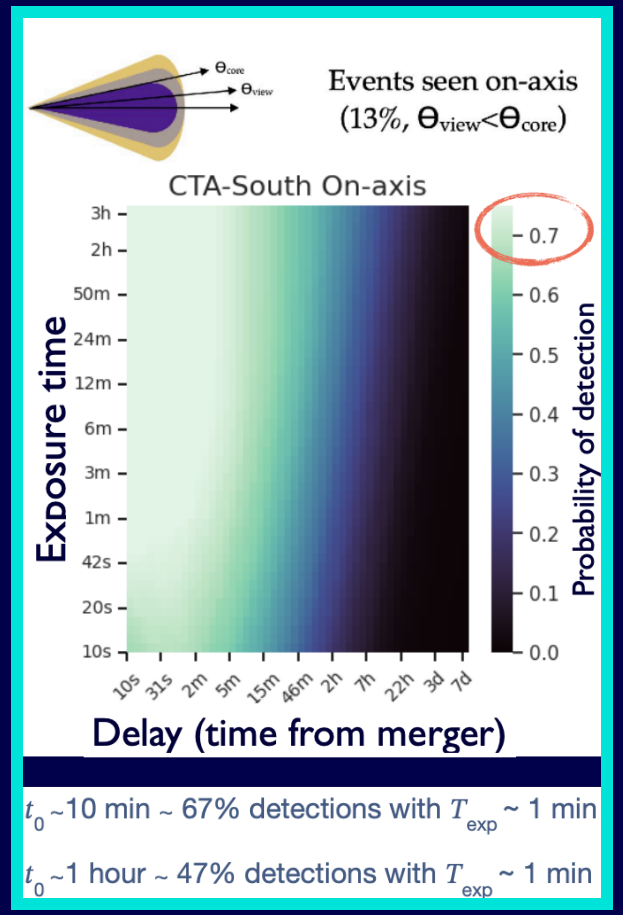
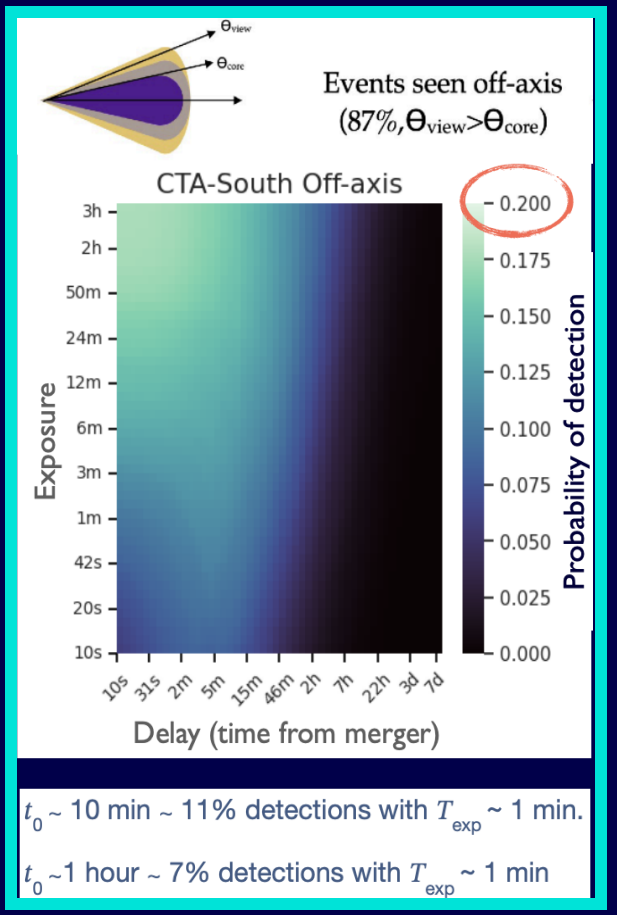
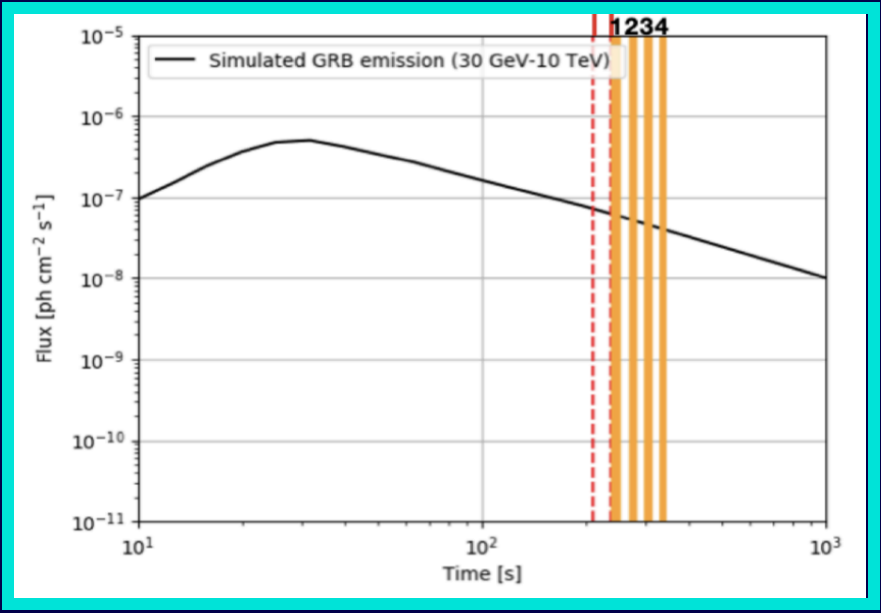
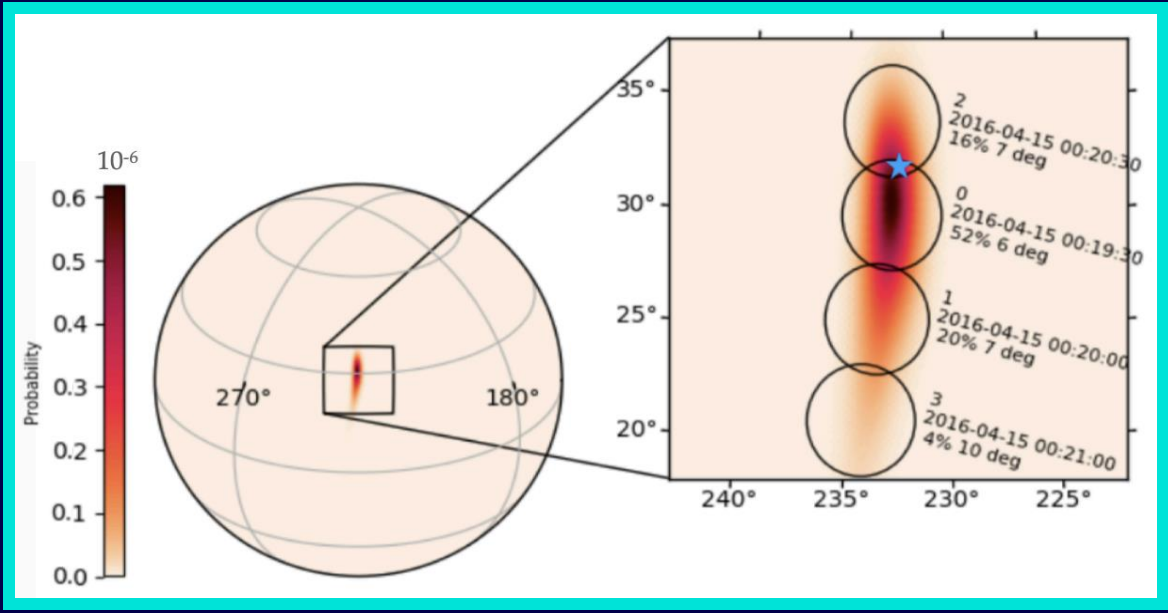




detection rate as a function of delay
and exposure for different viewing angles

Observation optimization





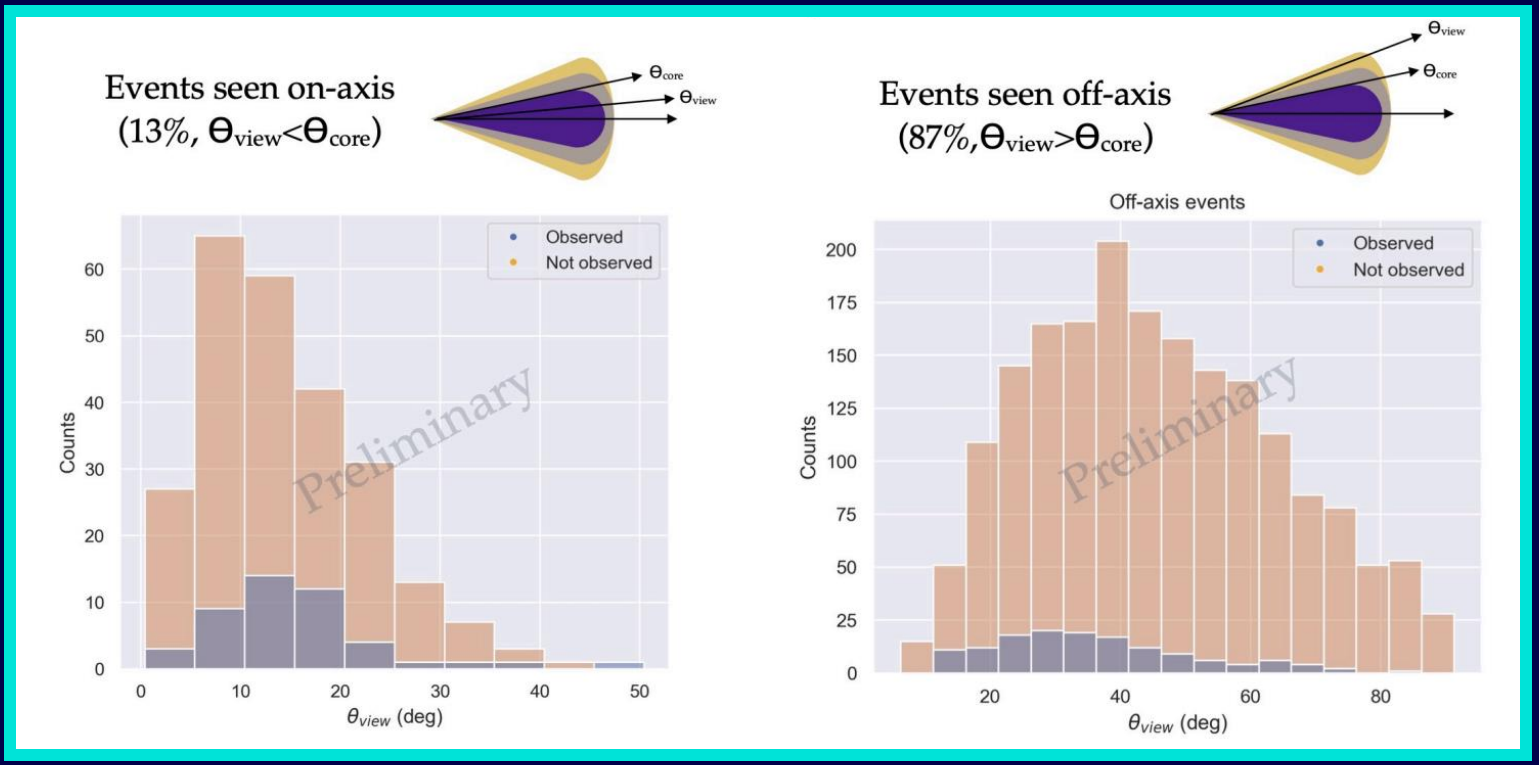
The scheduler iterates on the best pointing positions. If the true position is covered, by construction, it is detected.

OBSERVATION OPTIMISATION AND SCHEDULER

Observation optimization

- Several strategy under study
  - fixed exposure versus flexible time-windows
  - sub-array strategy: maximise coverage in low-latency response by worsening of sensitivity
  - early warning alerts oriented strategies

First prospects

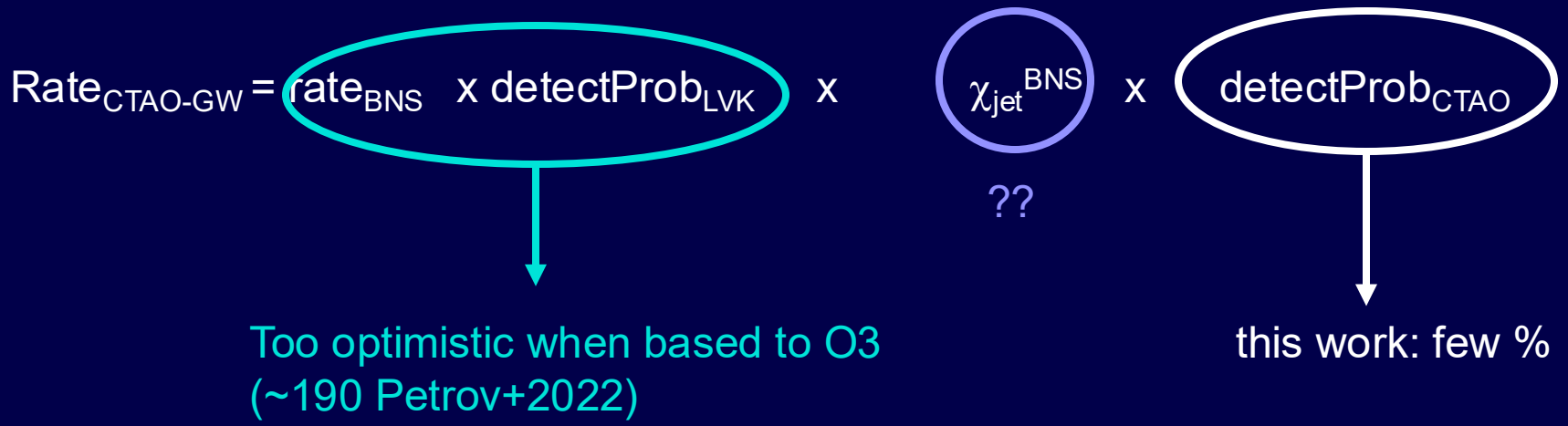


- follow-up GW-GRB events: 8% of total population
- 4-5% of follow-ups covered the true location (~8 per year in O5)
- on-axis events: 18% followed up; 10% covered the true location
- off-axis events: 7% followed up; 4% covered the true location

Joint rates CTAO-LVK(O5) depend on the large uncertainty on the BNS rate

First prospects – a word of caution

Joint rates CTAO-LVK(O5) depend on the large uncertainty on the BNS rate



Conclusions

- A new GW-GRB science cases for TeV astronomy emerged
- Plethora of GW triggers expected → optimized observation strategies required
- Groundwork laid with GW-GRB simulation chain for BNS during LVK scientific run O5 and O6
- CTAO-N and CTAO-S are key player in the transients and GW follow-ups

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Thank you

Credits to the CTAO Consortium, in particular the GW core team:
J.Green, L. Nava, B.Patricelli, F. Schussler, M. Seglar-Arroyo, A. Stamerra