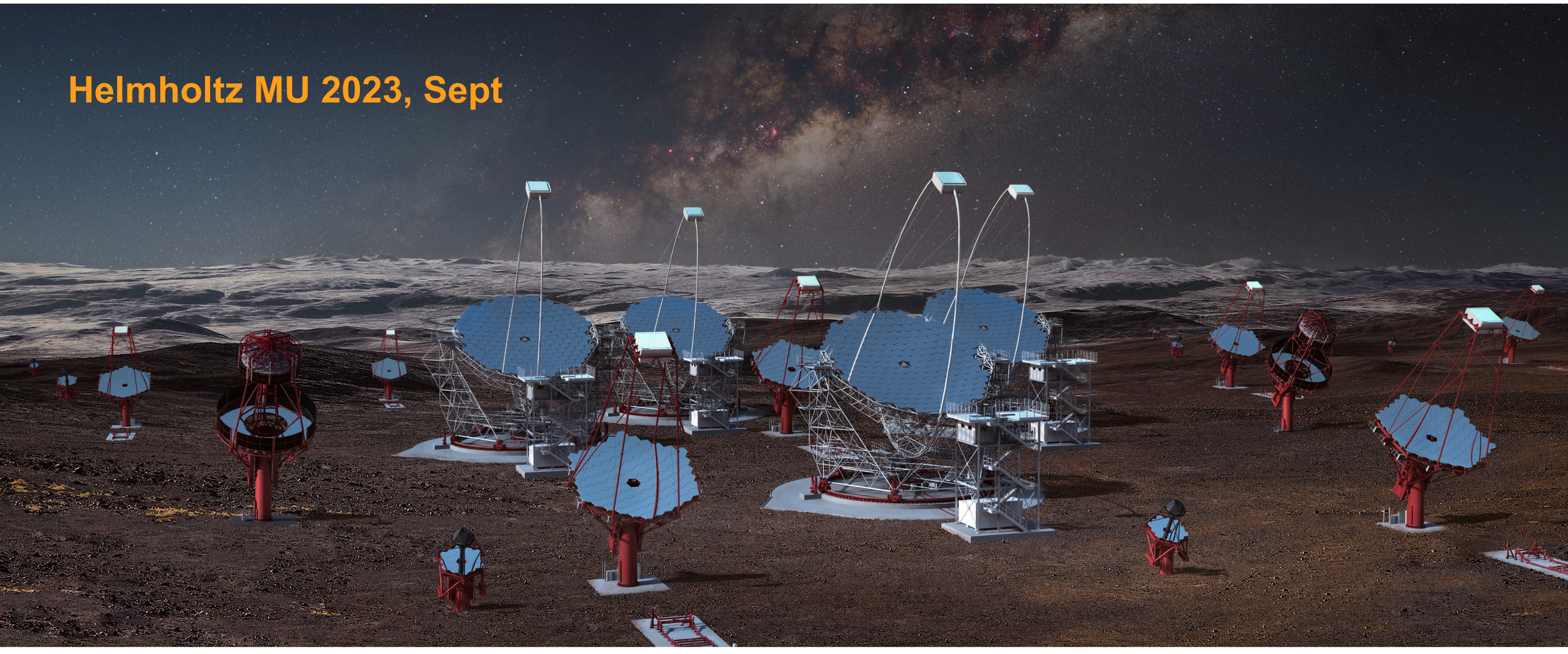
The Transient and Variable Gamma-ray Sky with CTA

Helmholtz MU 2023, Sept



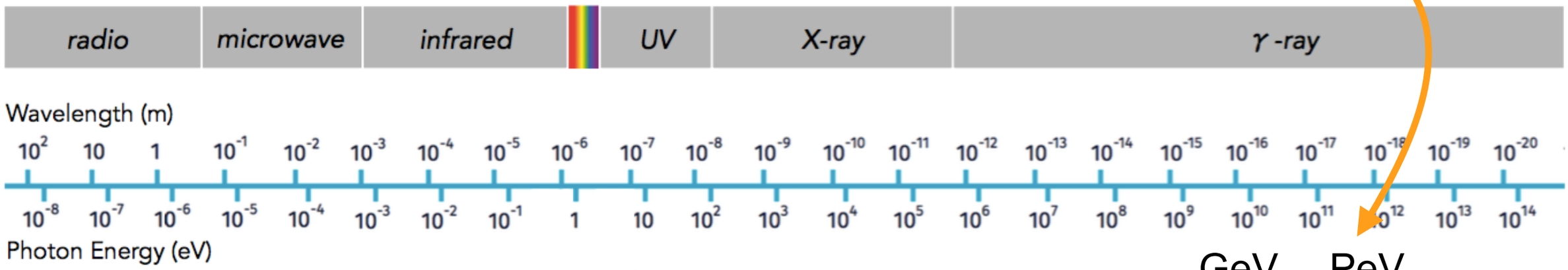
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Gernot Maier

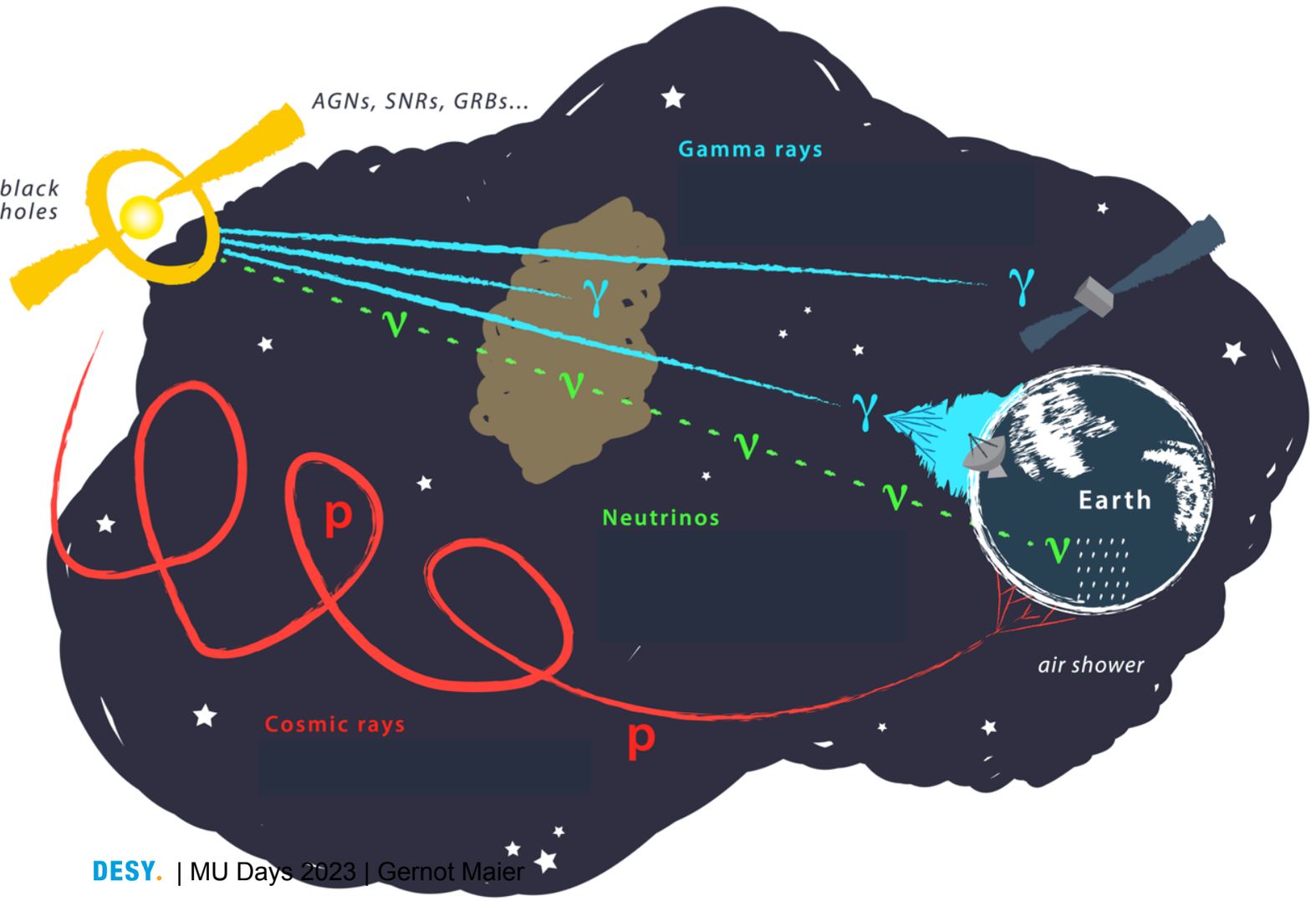
DESY.

Very-High Energy Gamma-ray Astronomy

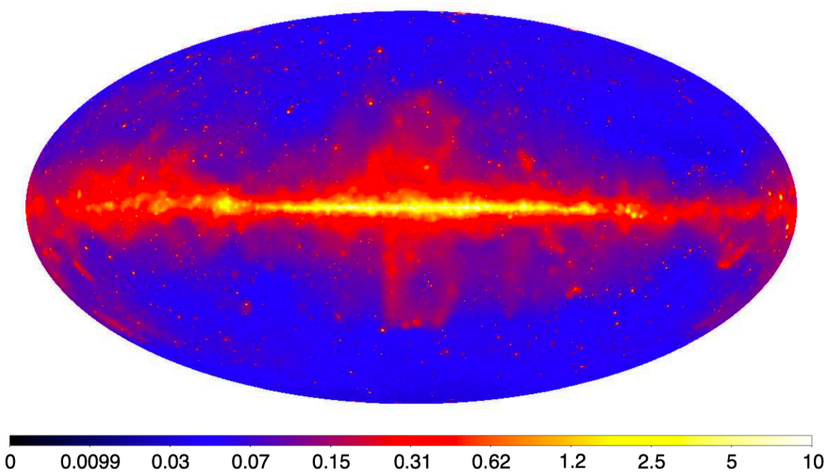
Connection photon astronomy, cosmic-ray physics, astrophysical neutrinos, gravitational waves



GeV …PeV
10^9 - 10^{15} eV



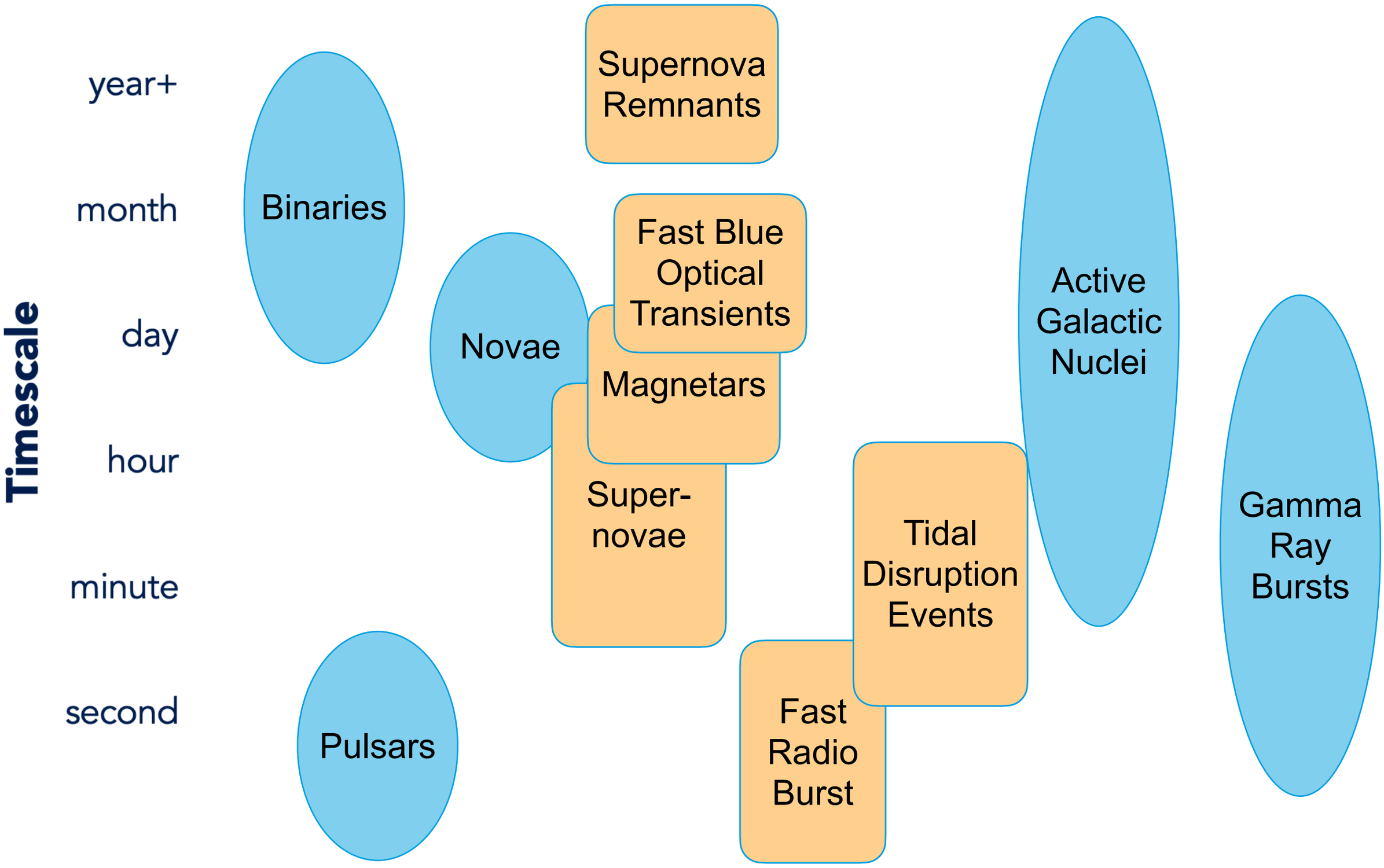
Sky > 10 GeV



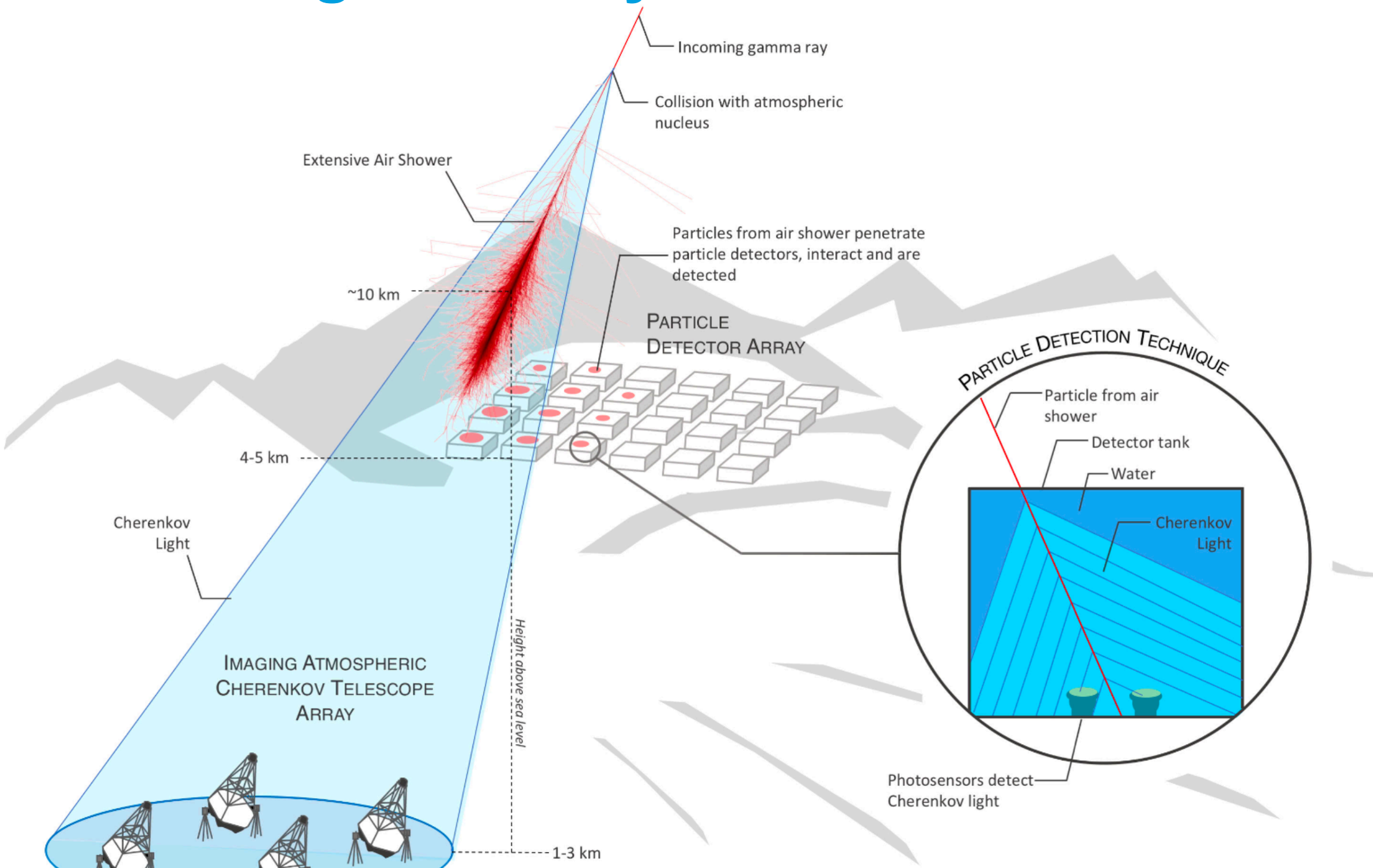
Fermi 2FHL
Ajello et al (2017); arxiv:1702.00664

Transients & Variables

Detected at energies > 10 GeV



Detection of gamma-rays 20 GeV to > PeV

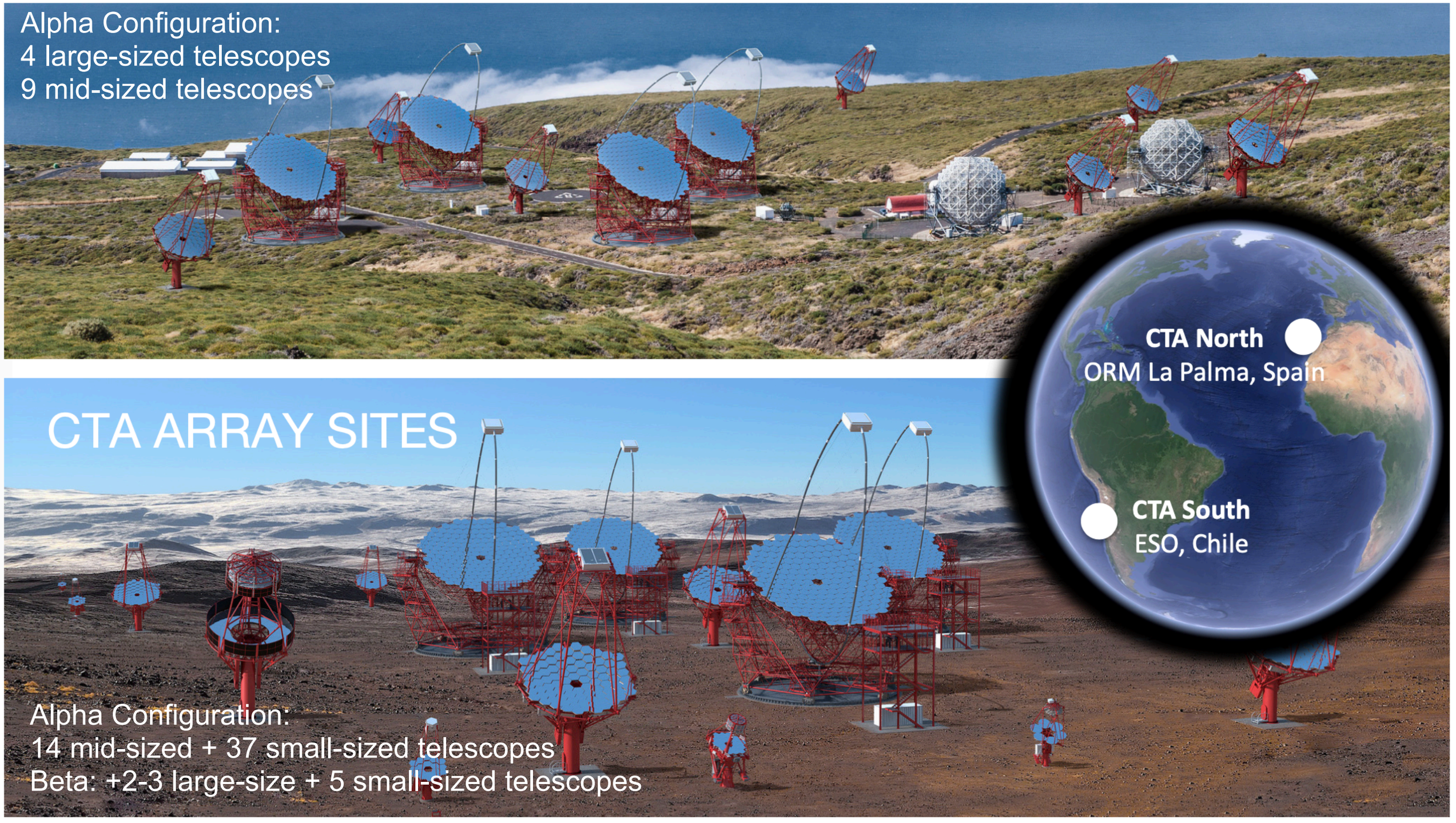


Shower image, 100 GeV γ-ray adapted from: F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

Mitchell 2021 (arxiv:2109.13753)

Cherenkov Telescope Array (CTA)

- next generation ground-based observatory for gamma-ray astronomy at very high energies
- 55 telescope (alpha configuration) on two sites in the Northern and Southern hemispheres (La Palma, Spain; Paranal, Chile)
- designed and built by a large international collaboration with CTAO as central organisation
- DESY Zeuthen Science Data Management Centre of CTAO
- entering construction phase now

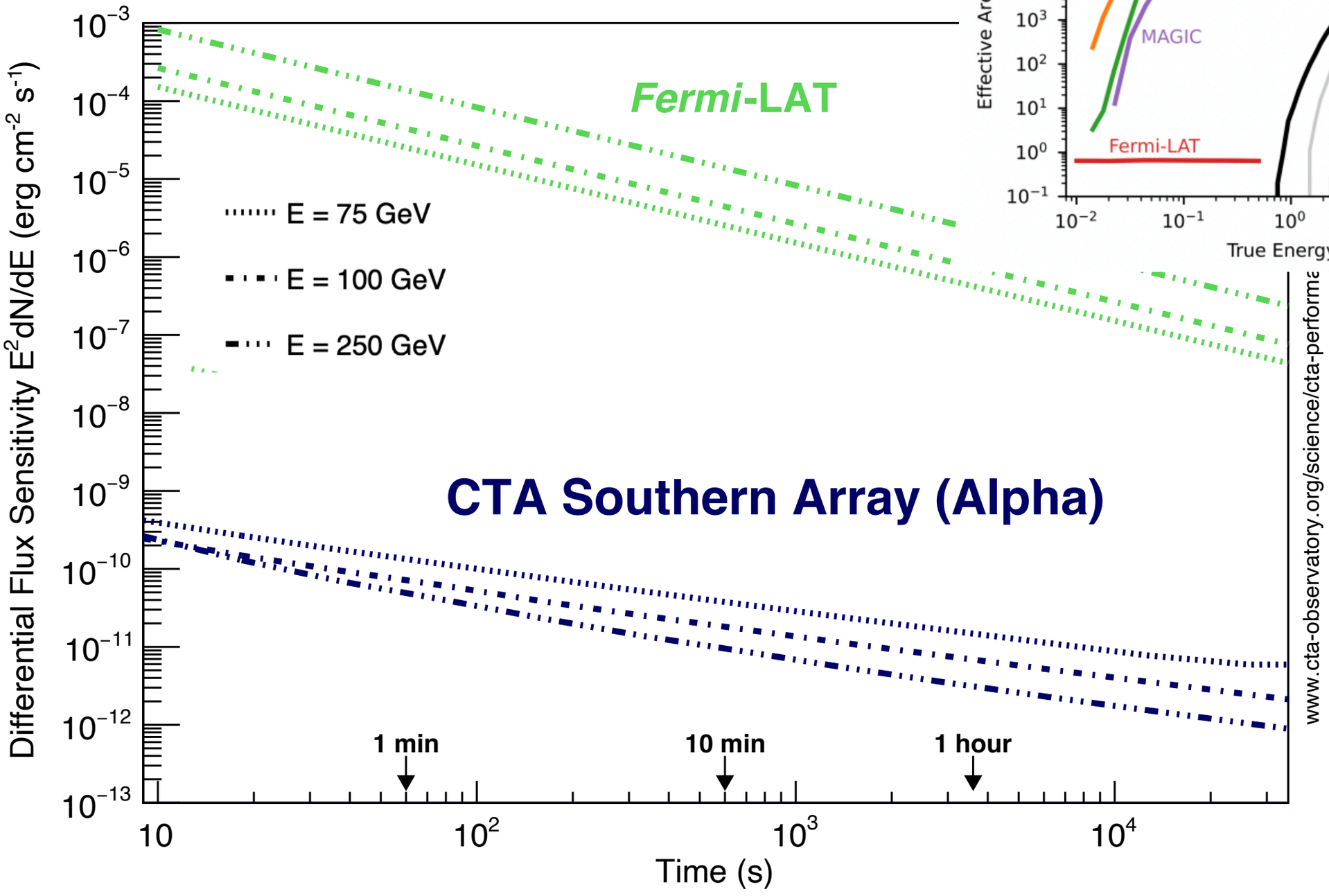


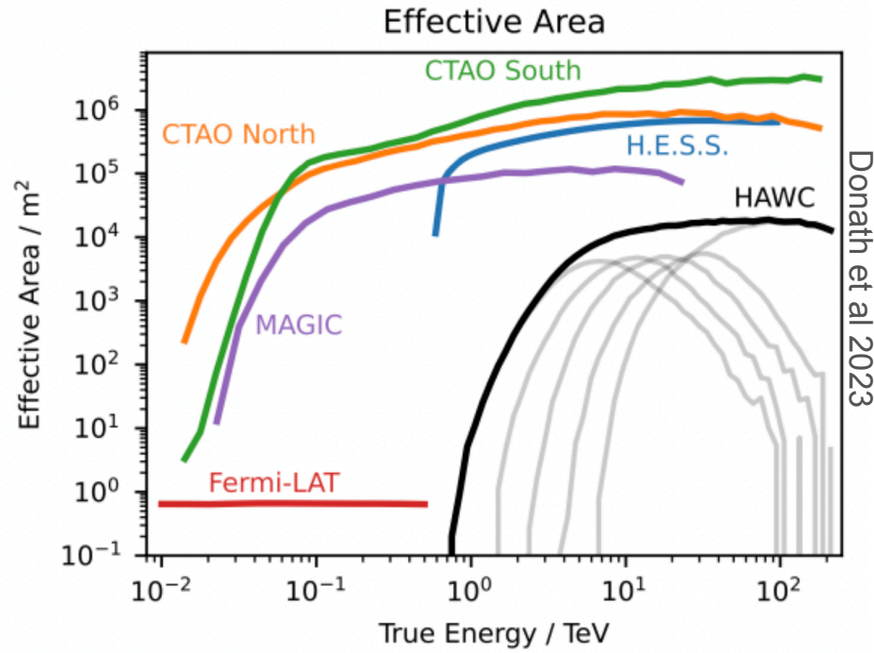
- large energy range (20 GeV to > 300 TeV)
- large field of view (>8 deg) for surveys
- all sky coverage (two sites)
- precision in direction (‘) and energy
- rapid slewing (30 s) for transients
- x10 sensitivity


La Palma

Paranal, Chile
Vulcano Llullaillaco
6739 m, 190 km east
Cherenkov Telescope Array Site
Cerro Paranal
Very Large Telescope

Transient Sensitivity



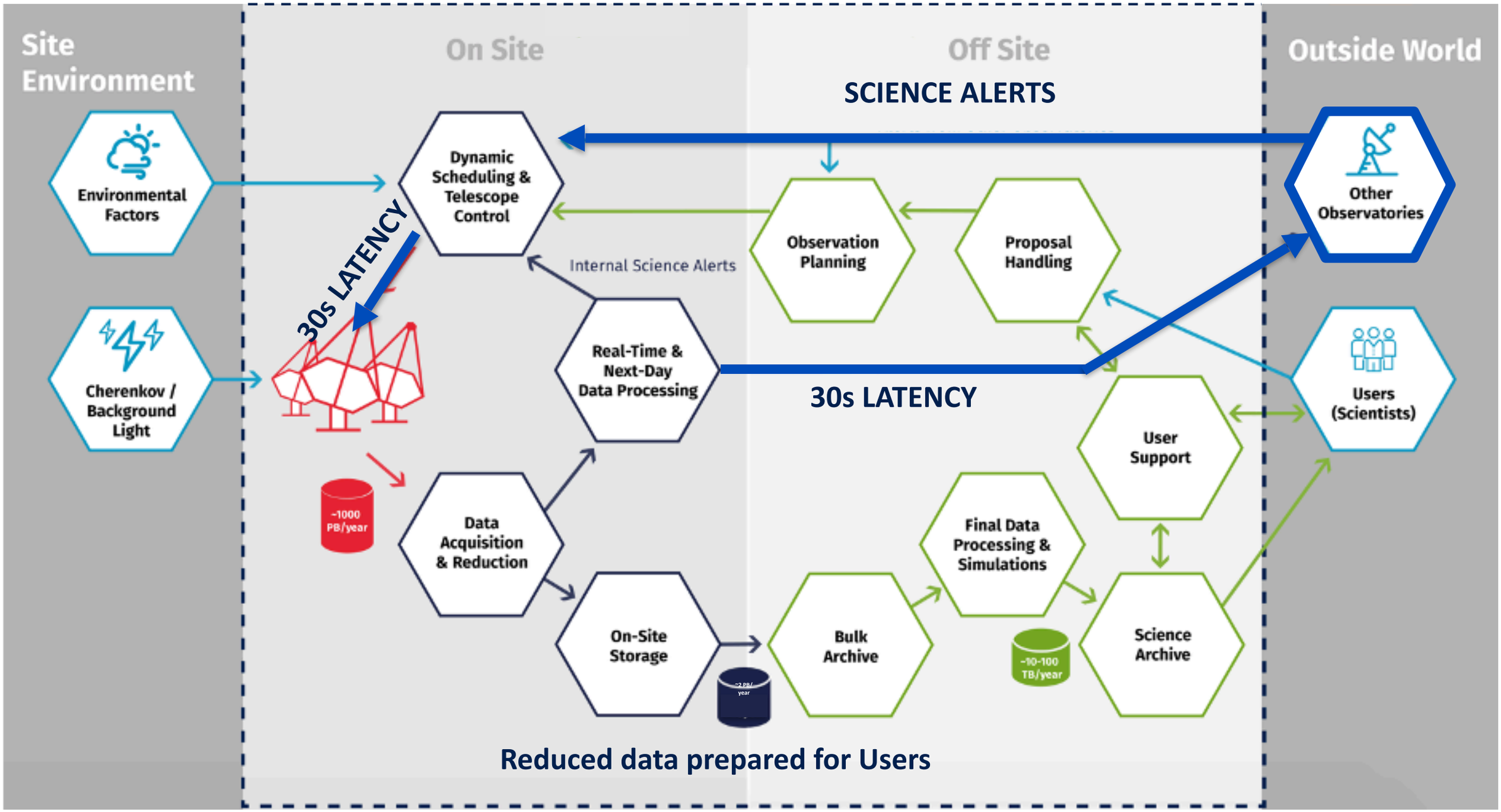


New observatories across all wavelengths and messengers:
gravitational waves, neutrinos, optical transients (Vera Rubin, UltraSat),
Radio (SKAO), …

CTA Observatory

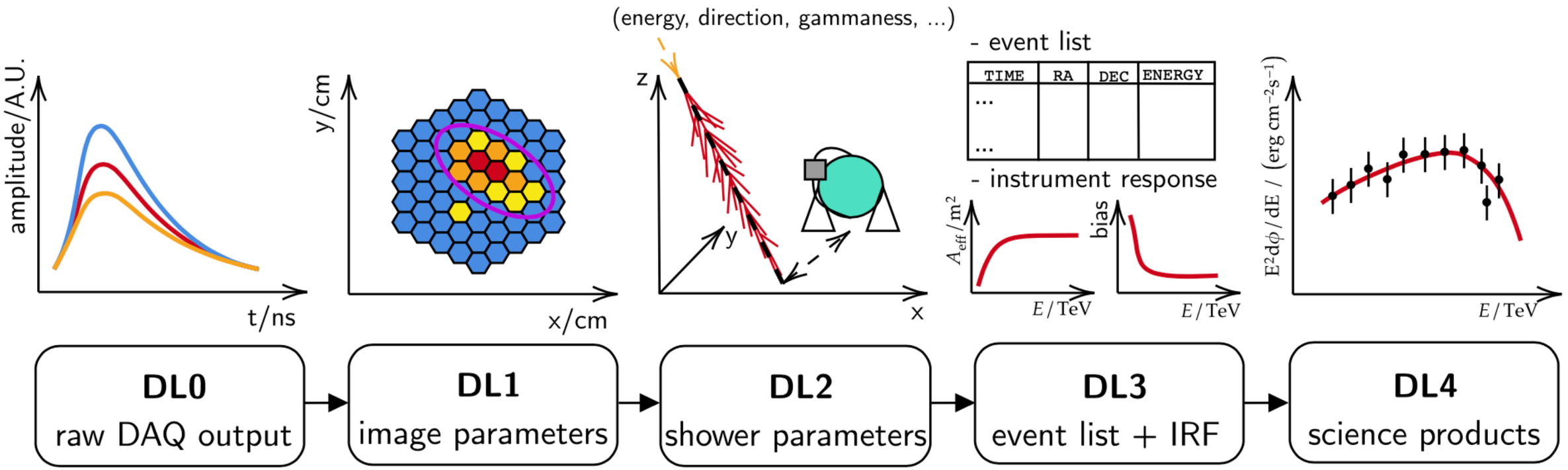
first open access observatory for very-high energy astronomy

CTAO



1300 observation hours / year
3 PB / year + 20 PB simulation data

CTA and Open Science

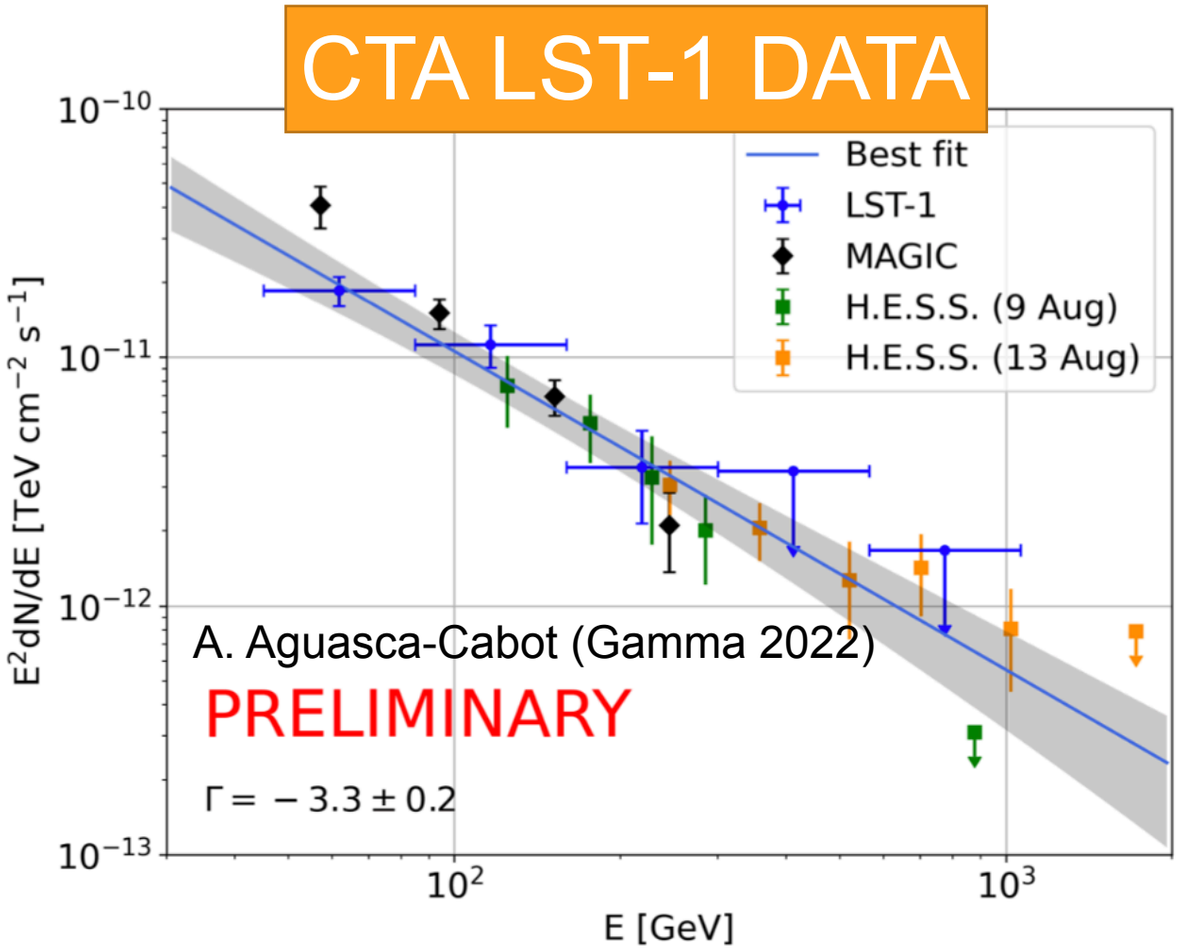


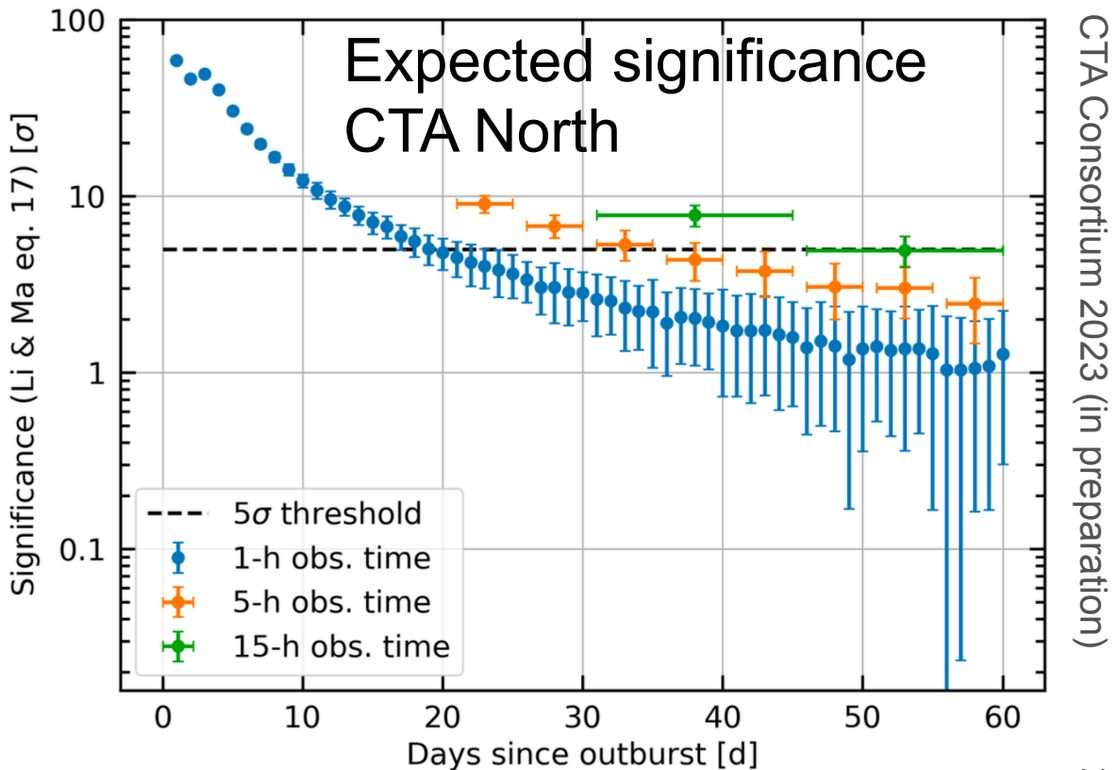
Nigro et al 2021

- community standards for data formats (DL3) developed for CTA
  - towards long-term data accessibility of data from current instruments (HESS, MAGIC, VERITAS, HAWC, FACT, …)
  - e.g., VERITAS data archive 2006-2021:
    500 TB raw data -> 4 GB event lists + instrument response functions
    (MU - ADC-MAPP)
- open software for high-level science: gammapy

RS Ophiuchi

- first nova detection with ground-based observatories
- recurrent symbiotic nova
  - ~15 years period
  - white dwarf embedded in red giant wind
  - outburst on 2021, Aug 21
- MAGIC, HESS, **CTA**-LST1 detections
- modelling seems to favour hadronic acceleration scenarios

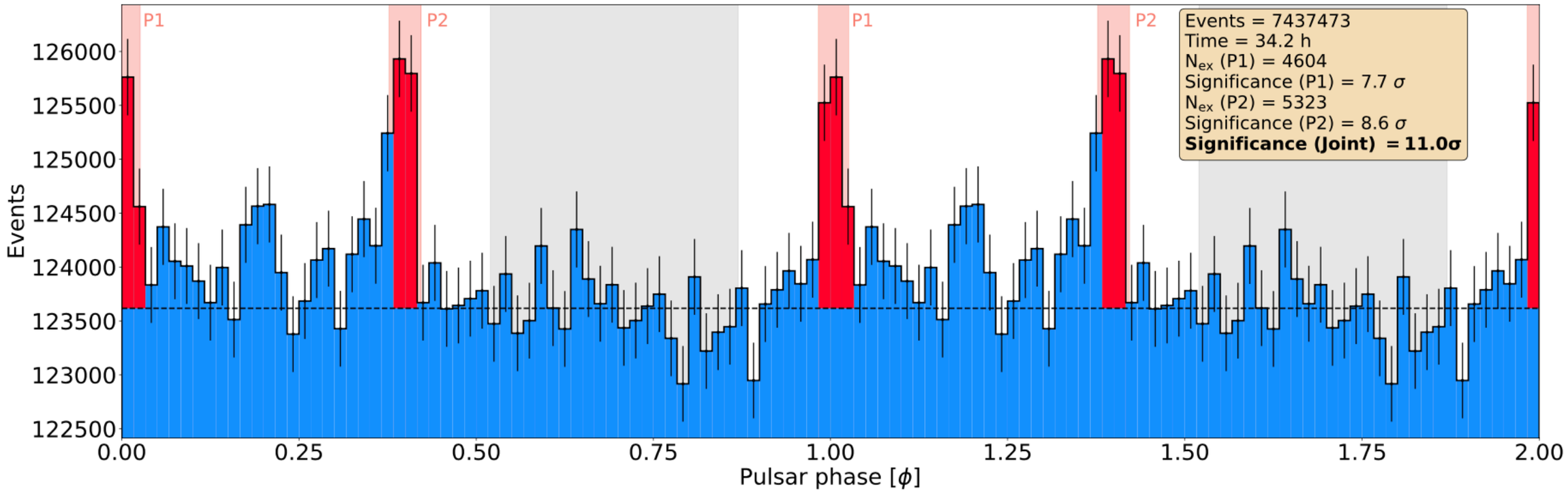




Crab Pulsar

CTA LST1 Data!!!

CTA LST Consortium
Abe et al 2023

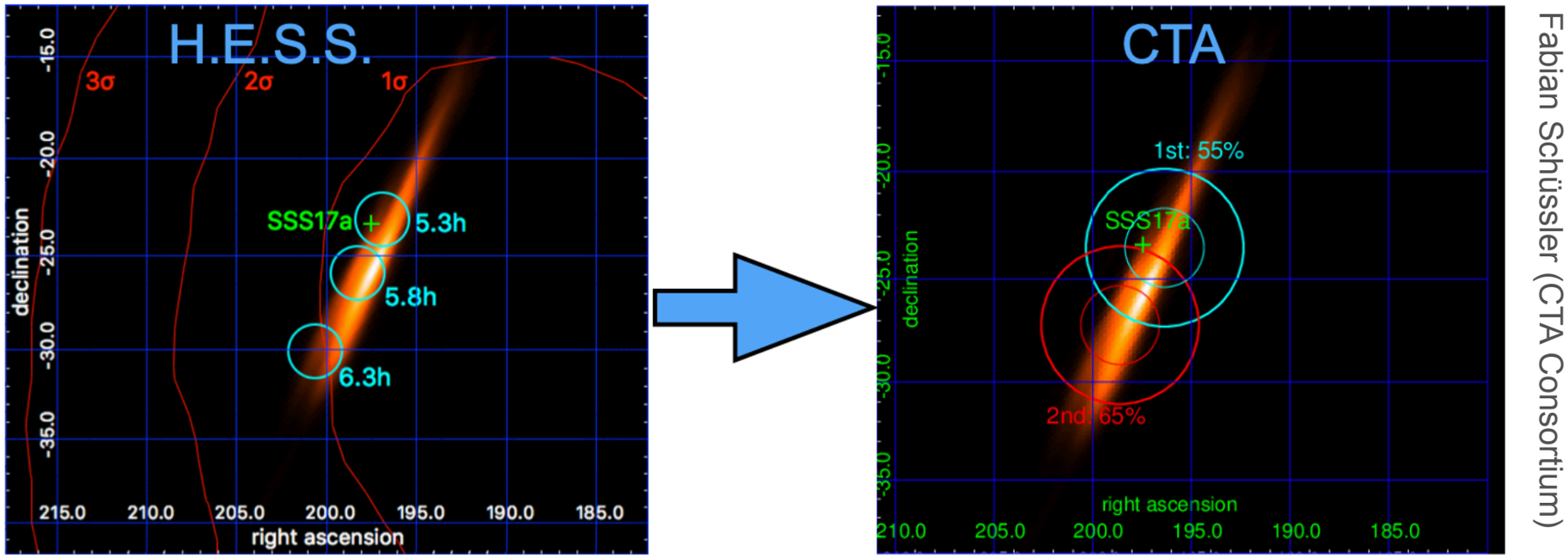


- Took many years to detect first pulsar with MAGIC and VERITAS at very-high energies
- CTA LST did this during commissioning!
- (only 4 pulsars known at very-high energies)

Gamma-ray bursts

First gamma-ray bursts detected at 10s of GeV by MAGIC, HESS, LHAASO, …

LALInference map of GW170817 (LIGO-Virgo)

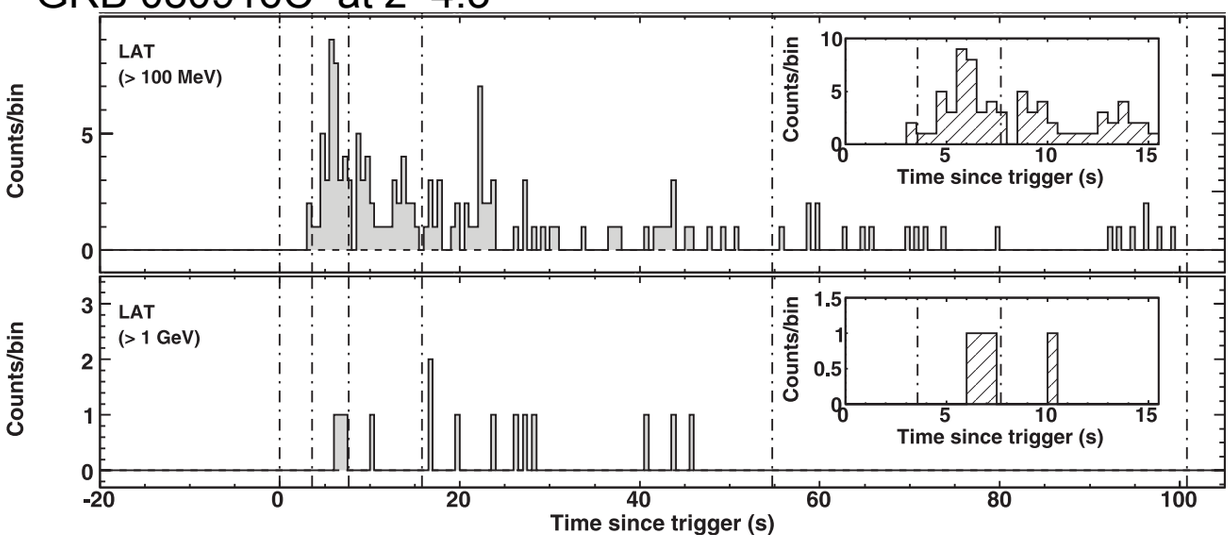


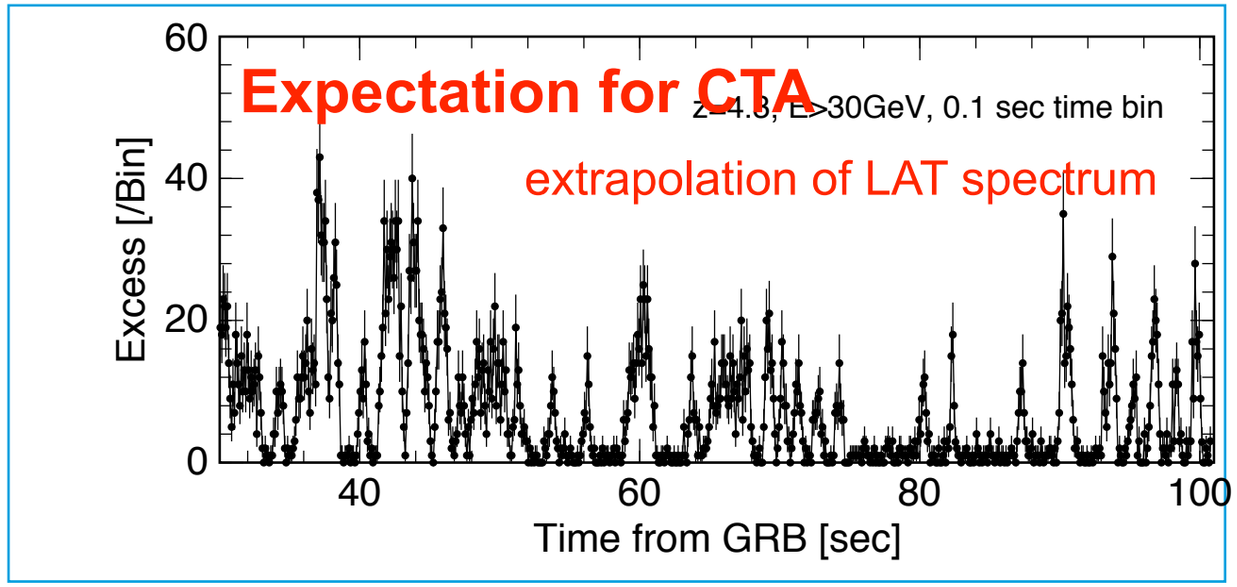
Fabian Schüssler (CTA Consortium)

H. Abdalla et al. (H.E.S.S.), ApJL 855:L22 (2017)

FS (CTA consortium), preliminary

GRB 080916C at z=4.3





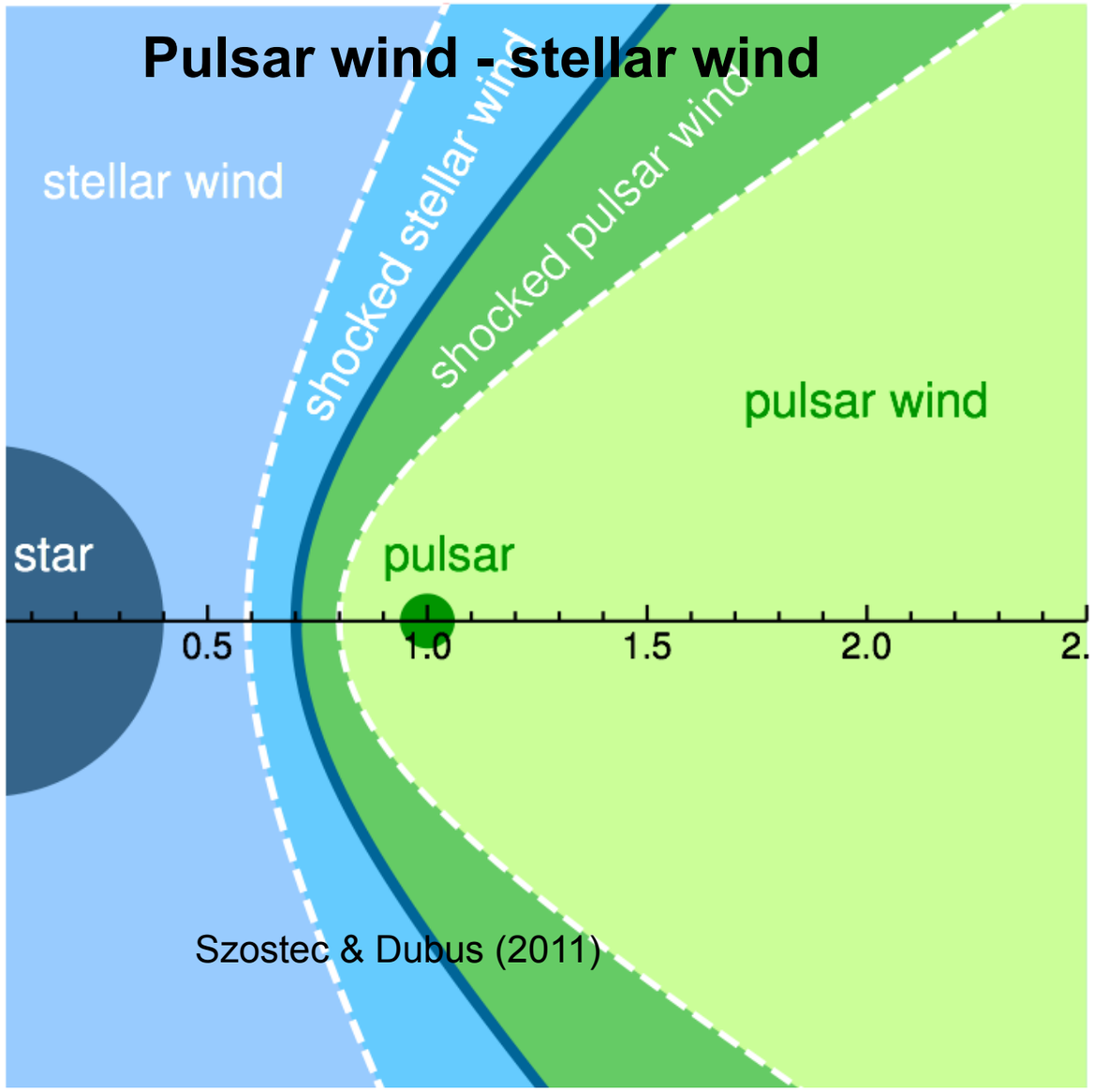
CTAO and Variable / transient sources

- ***CTA opens new phase space for transient and variable source program - expect several new source classes!***
  (especially in coordination with other instruments)

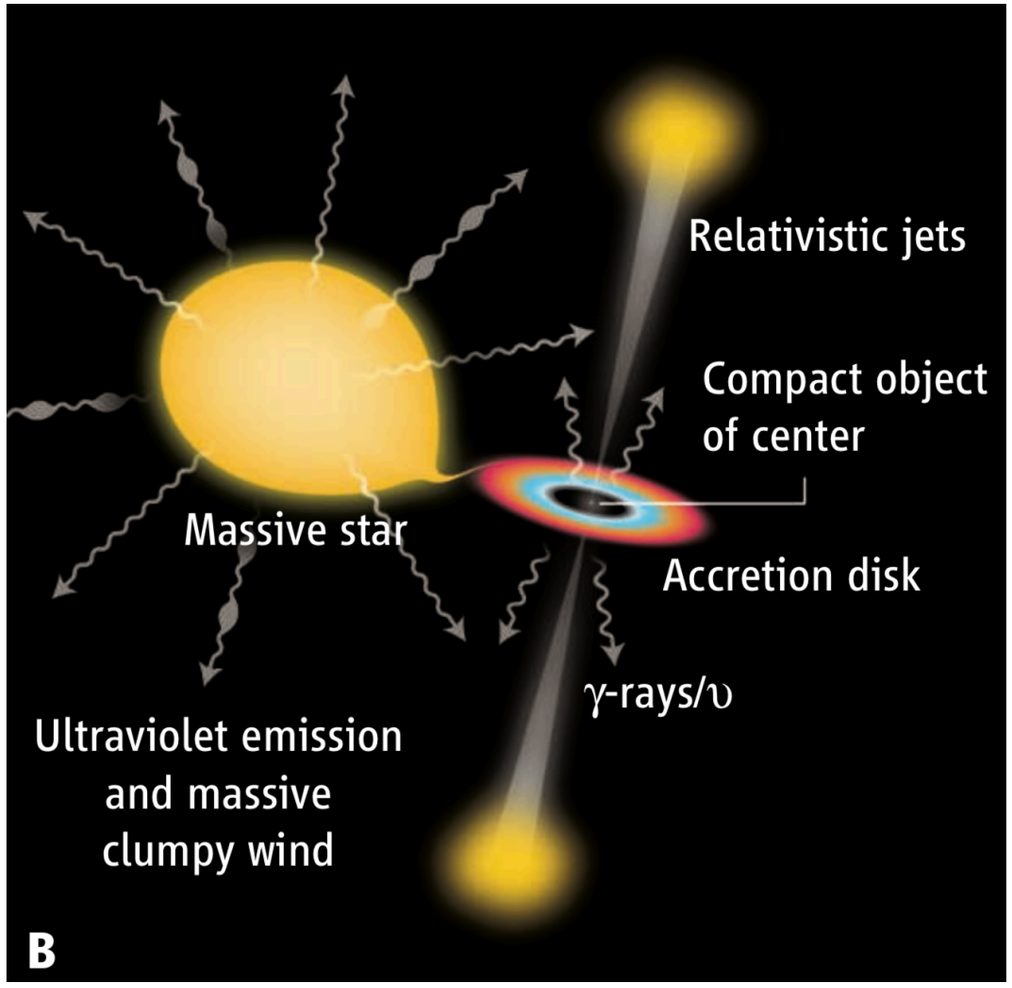
- The construction phase will start with final legal entity:
  CTAO European Research Infrastructure Consortium (ERIC)
  - ERIC operative in the coming 6 months
  - construction last about 5 years

- Early transient / variable source science operations during construction phase.
  - LST-1 Prototype on La Palma with first science results.
  - MST Pathfinder project in Paranal

Gamma-ray Binaries



Microquasar

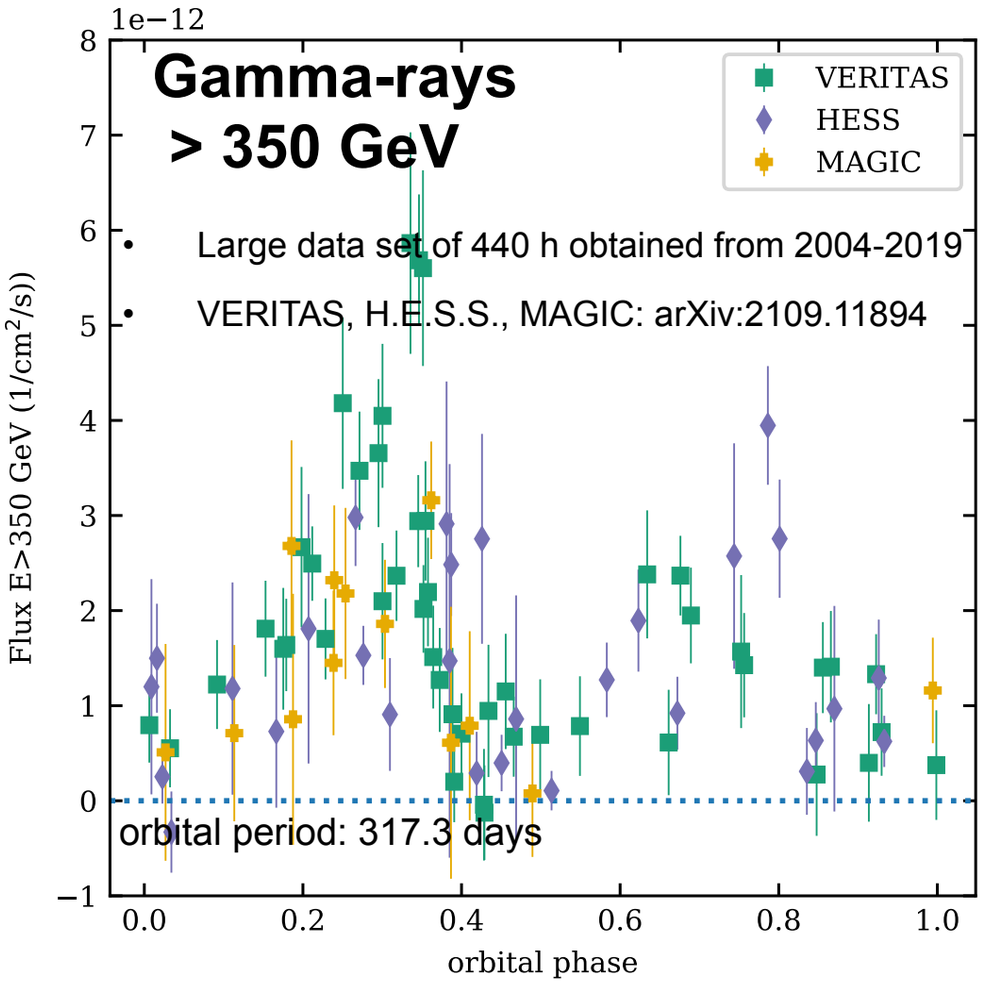


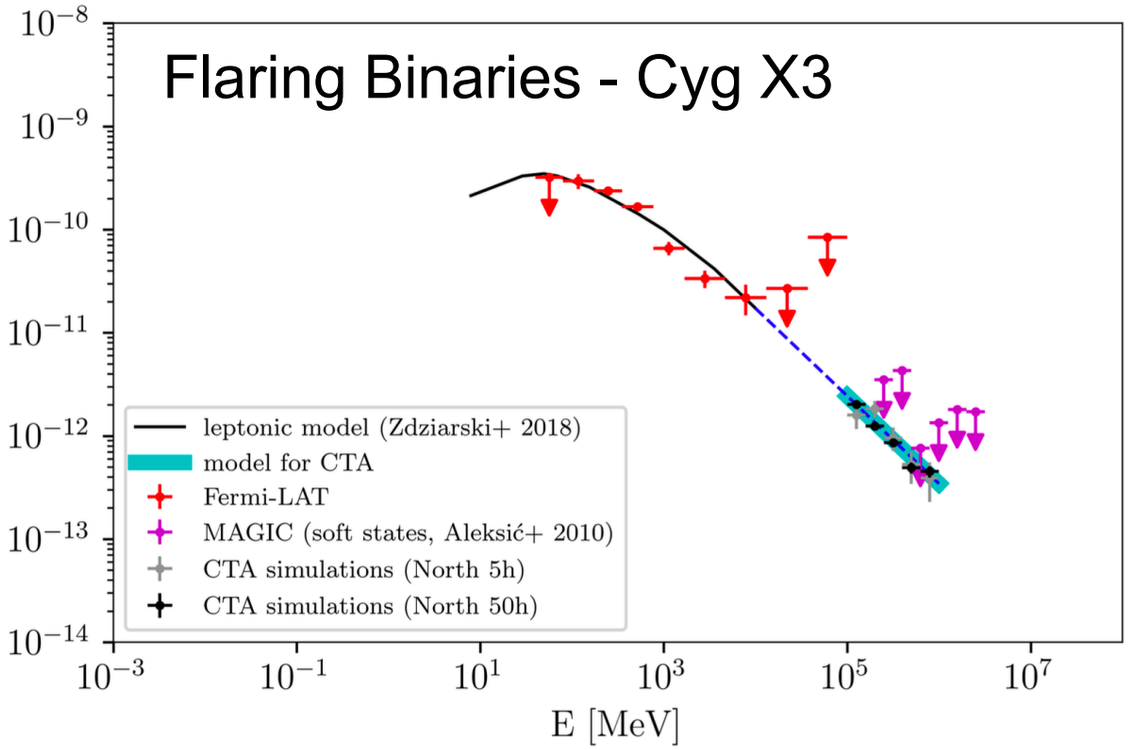
Mirabel 2012

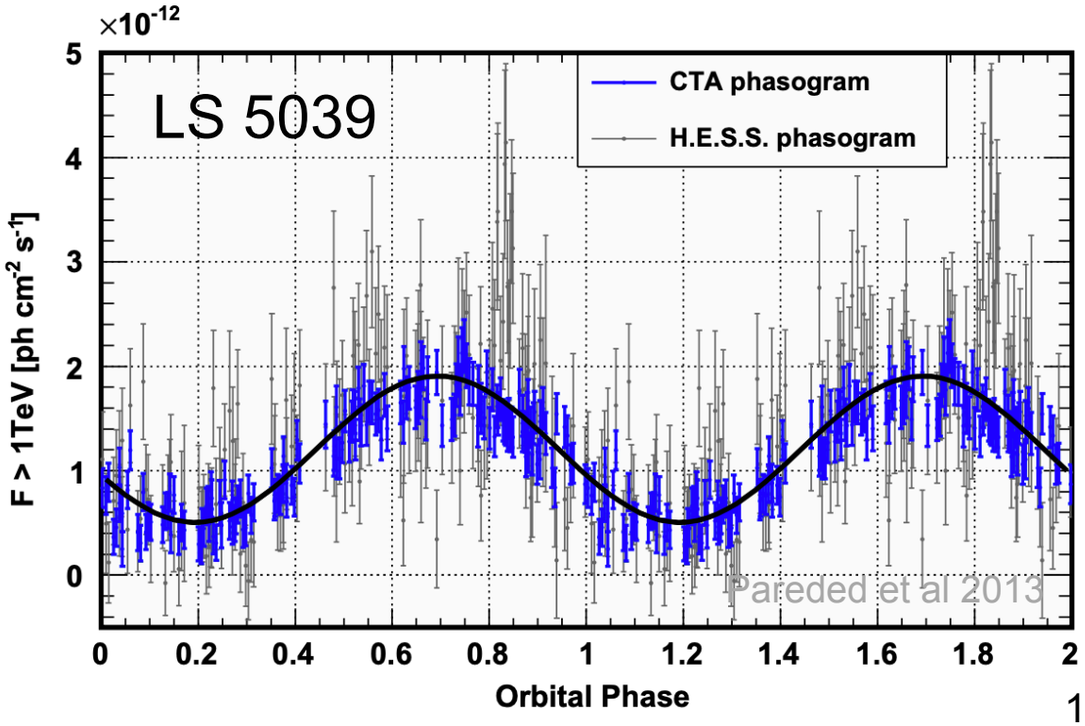
clumpy winds, transient accretion disks, disk/jet precession, quiescence/flaring periods, …

goal to understand acceleration processes, environment, pulsar wind and jet properties, dynamical changes

Gamma-ray Binaries



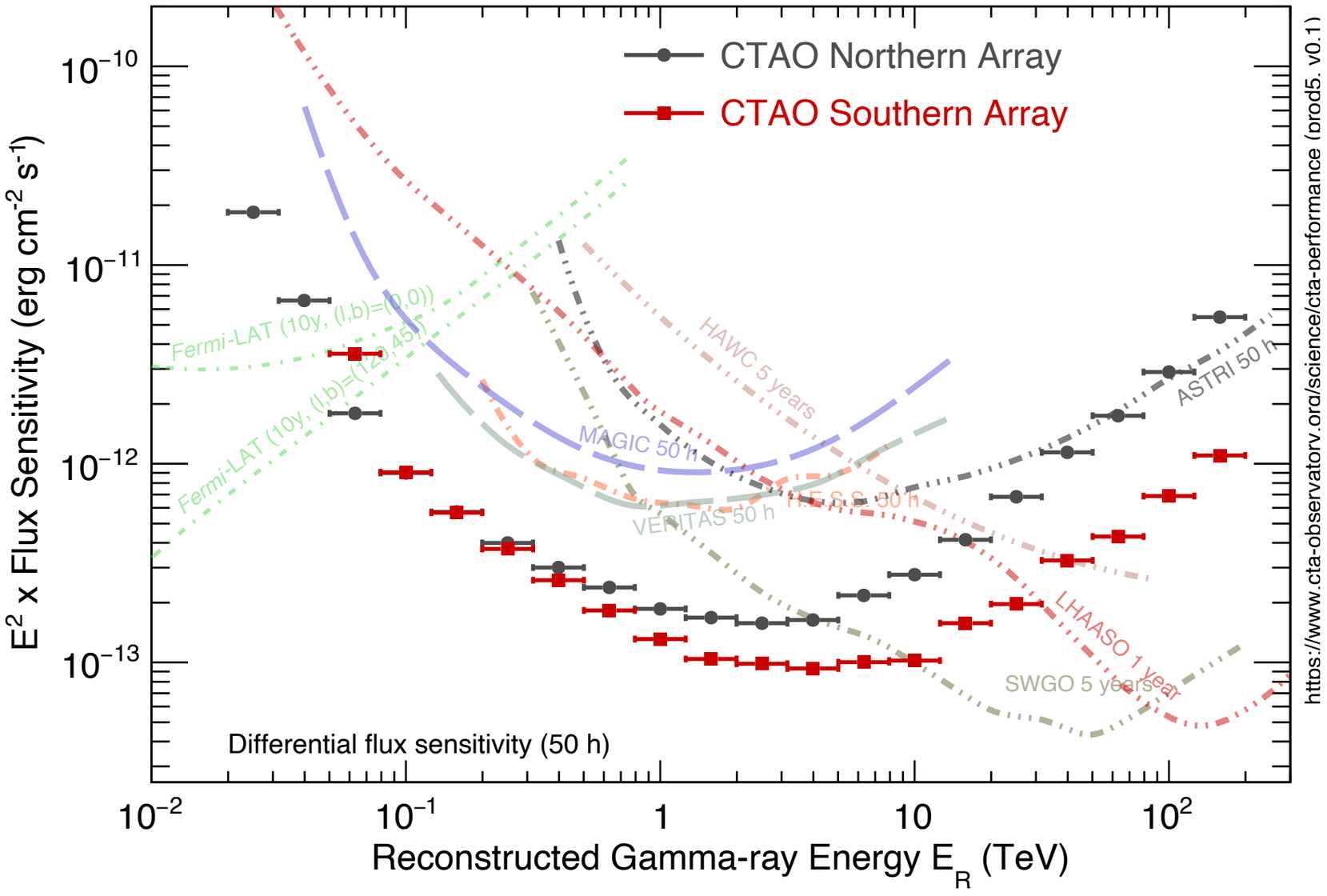


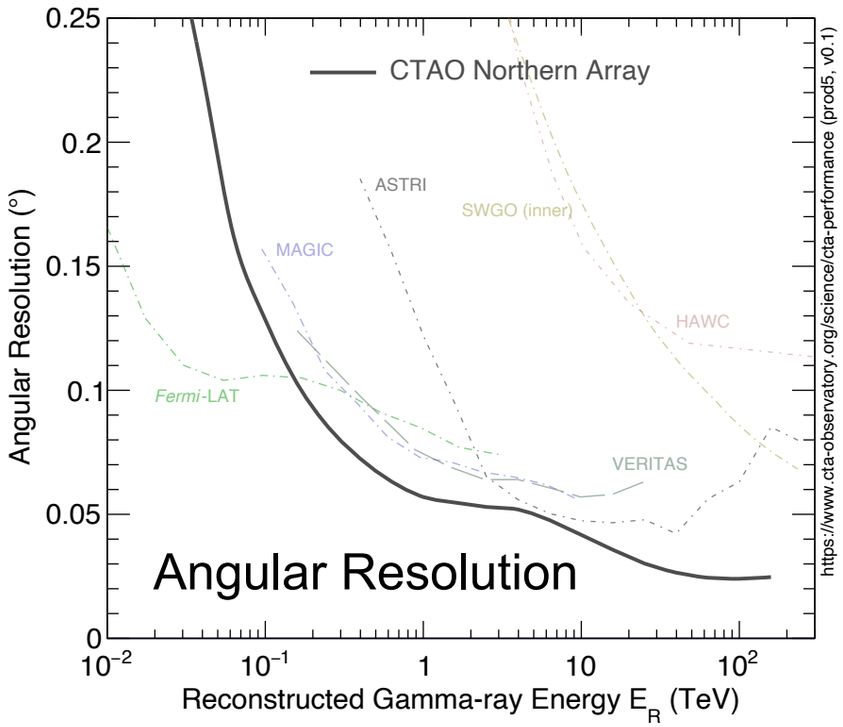


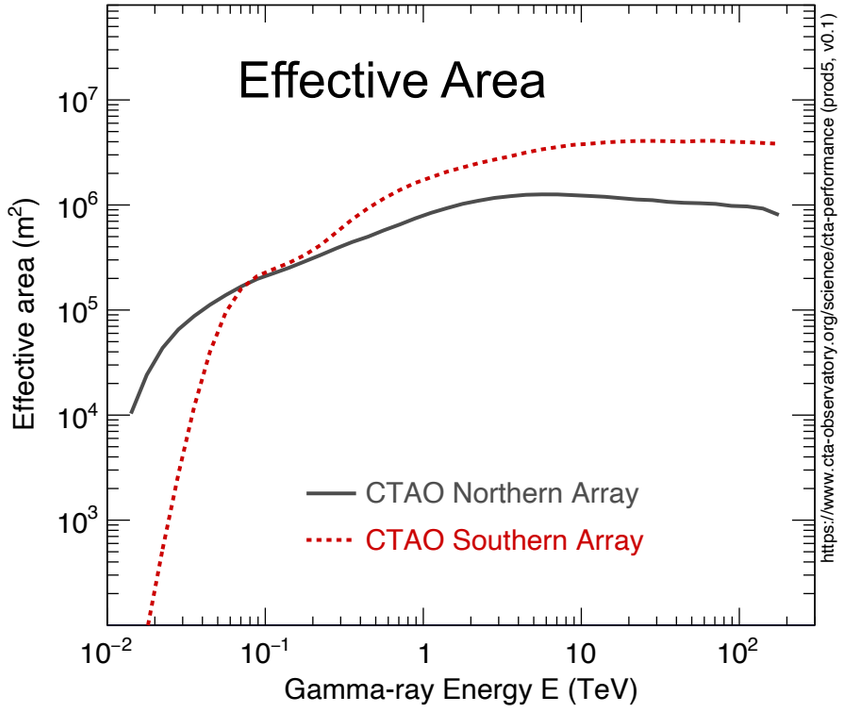
CTA Consortium 2023 (in preparation)

Performance - flux sensitivity

5 sigma detection per flux bin (five bins per logarithmic decade)







Sensitivity x10
Angular resolution x3

Note! Prepared with non-CTA reconstruction software

Cherenkov Telescope Array