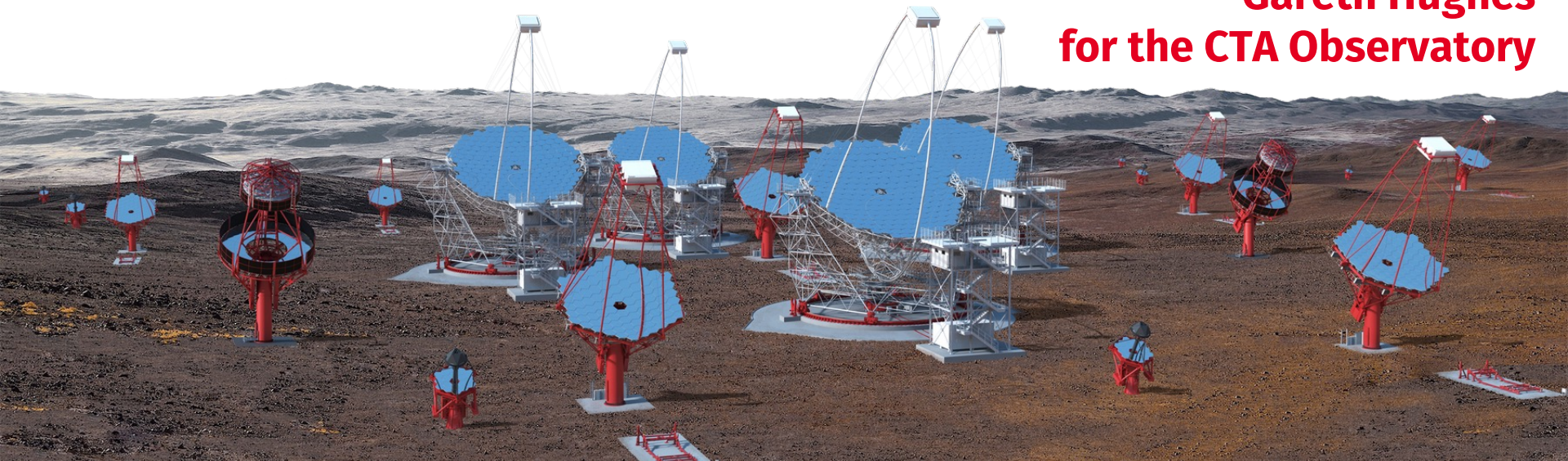
cherenkov telescope array

The Cherenkov Telescope Array Observatory

Gareth Hughes
for the CTA Observatory

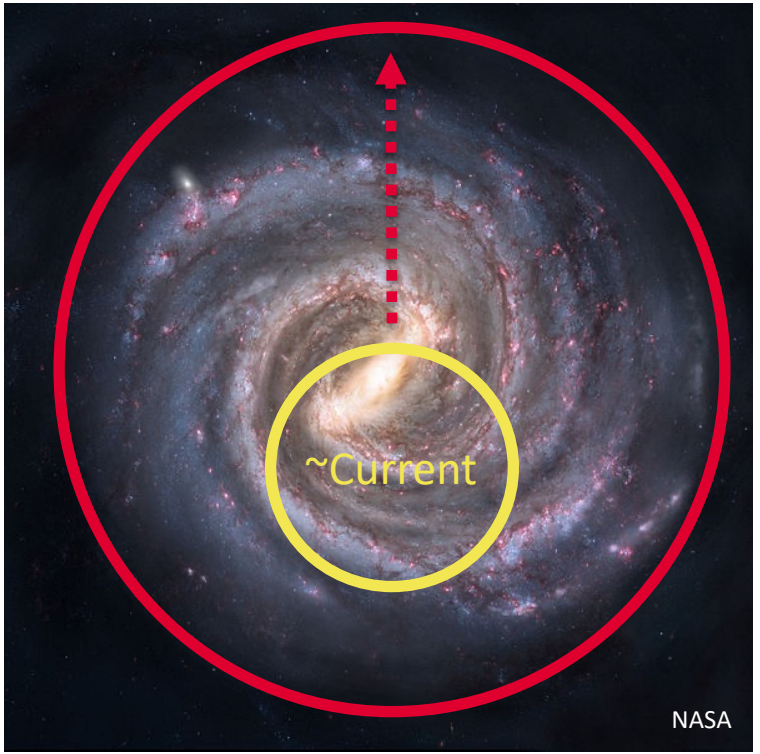


Observatory

- The first ground-based gamma-ray **observatory**
  - 5-10x increase in sensitivity
  - Broadest energy range amongst IACTs: **20 GeV to 300 TeV**
  - Will serve large user community data & science tools in fair way
  - **Proposal-driven** observatory
- 30-year lifetime
  - Significant effort in maintenance and operational cost optimization
- Two arrays, One Observatory
  - Inter-site coordination
  - Uniform approach to scientific operations

Design Drivers

- 10x sensitivity
- full sky coverage
- arcmin angular resolution
- 10° FoV
- 10% energy resolution
- 30s response to alerts
- energy range 20 GeV-300 TeV

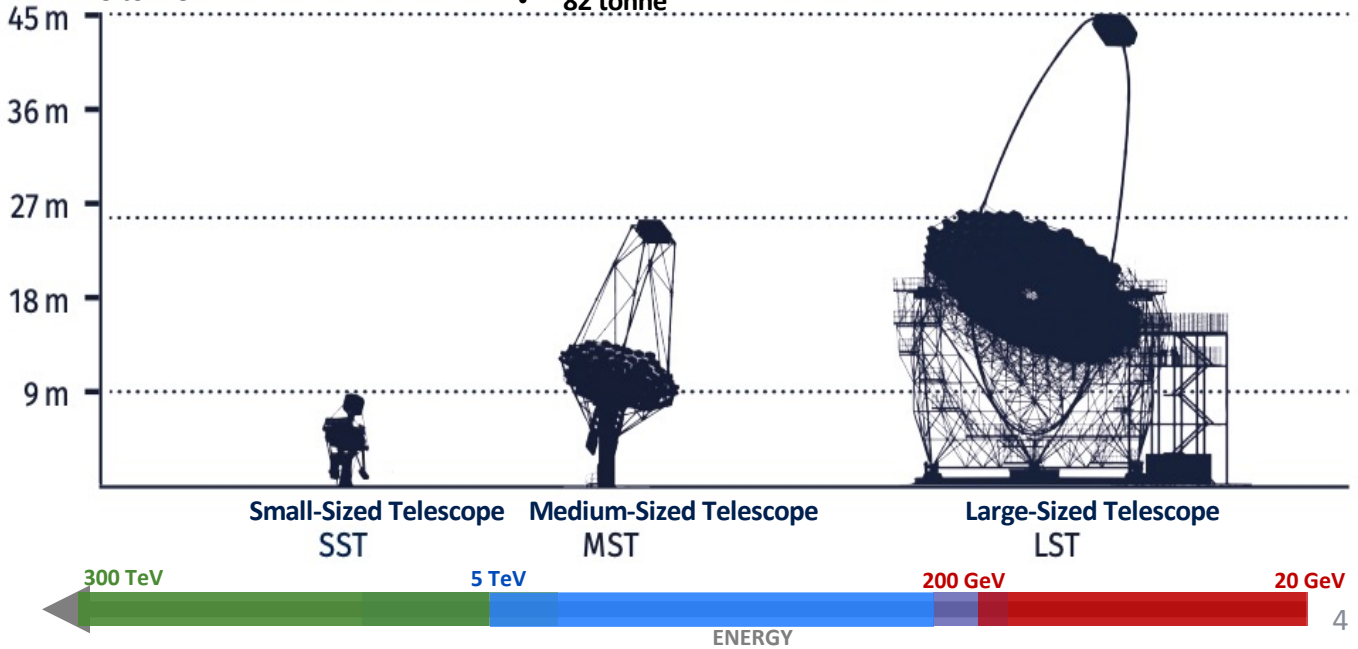


Telescope Designs

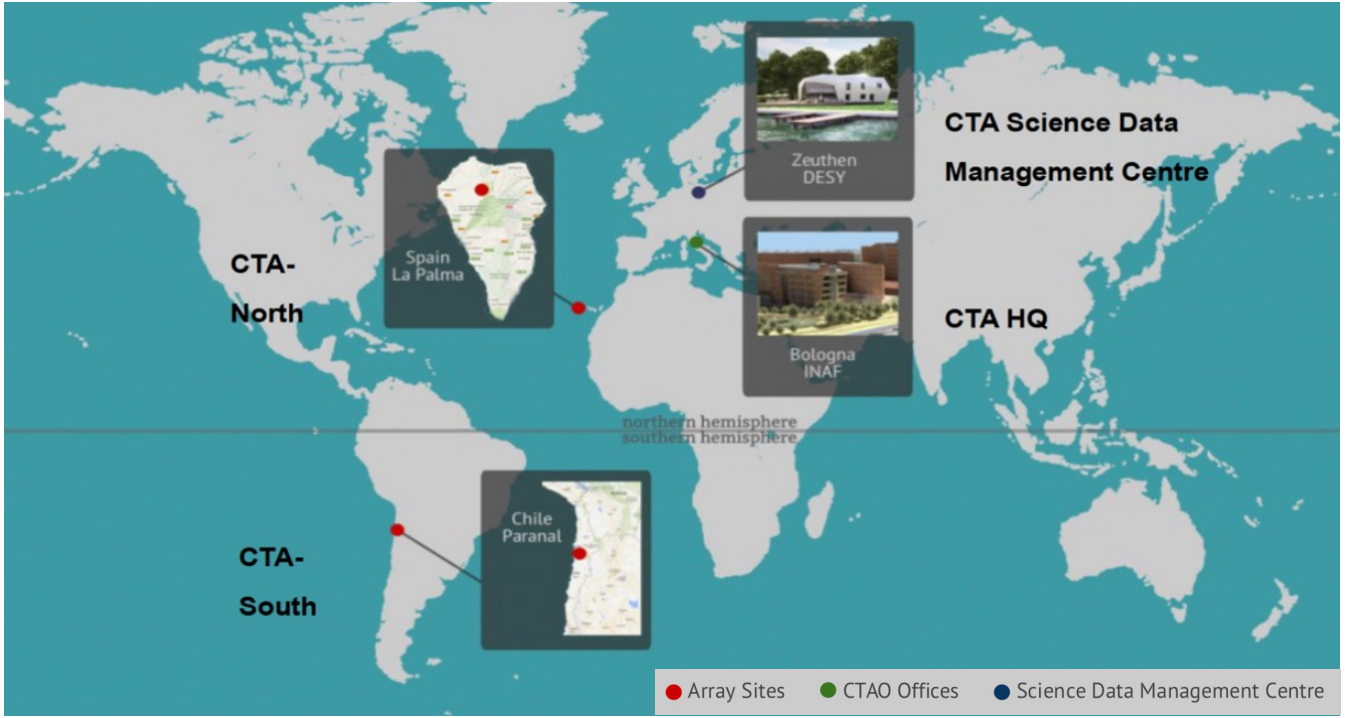
- 2-mirror Schwarzschild-Couder optical design
- 4.3 m ∅ primary reflective surface
- SiPM camera: 2048 pixels (0.16 °)
- 8.8° FoV
- 17.5 tonne

- Davies-Cotton optical design
- 12 m ∅ reflective surface
- PMT camera – 2 designs:
  - NectarCam: 1855 pixels
  - FlashCam: 1764 pixels
- ~7° FoV
- 82 tonne

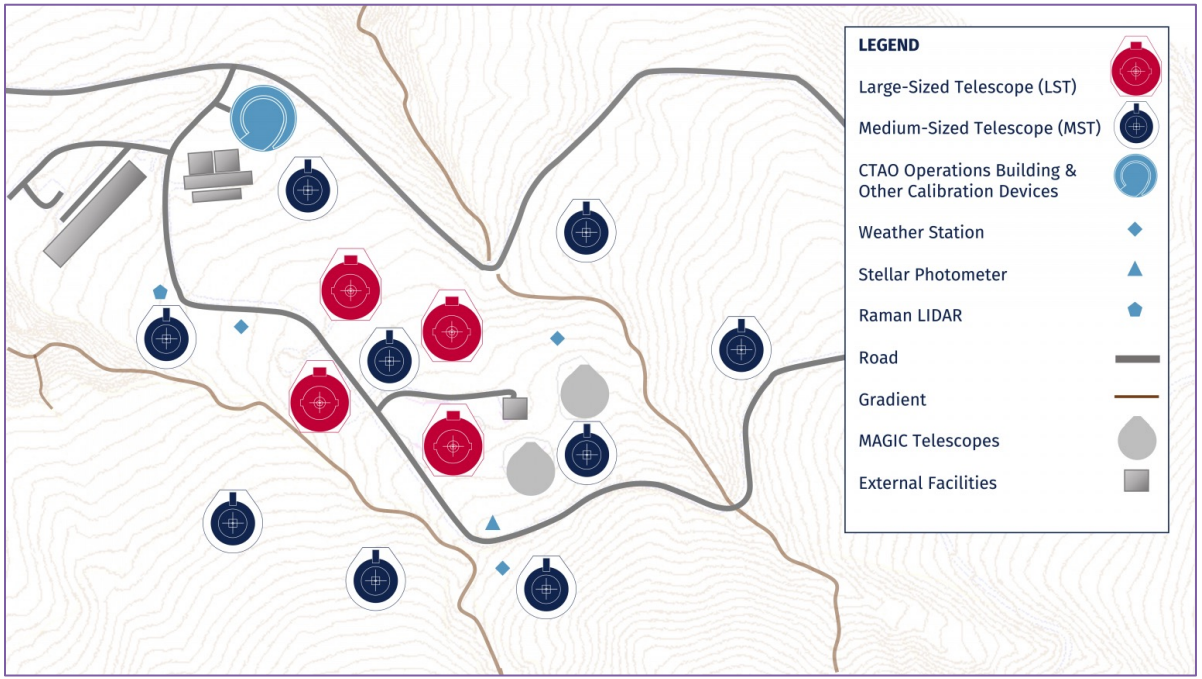
- Parabolic optical design
- 23 m ∅ reflective surface
- PMT camera: 1855 pixels (0.1°)
- 4.3° FoV
- 100 tonne



CTAO Locations



Array Layout: Alpha Configuration

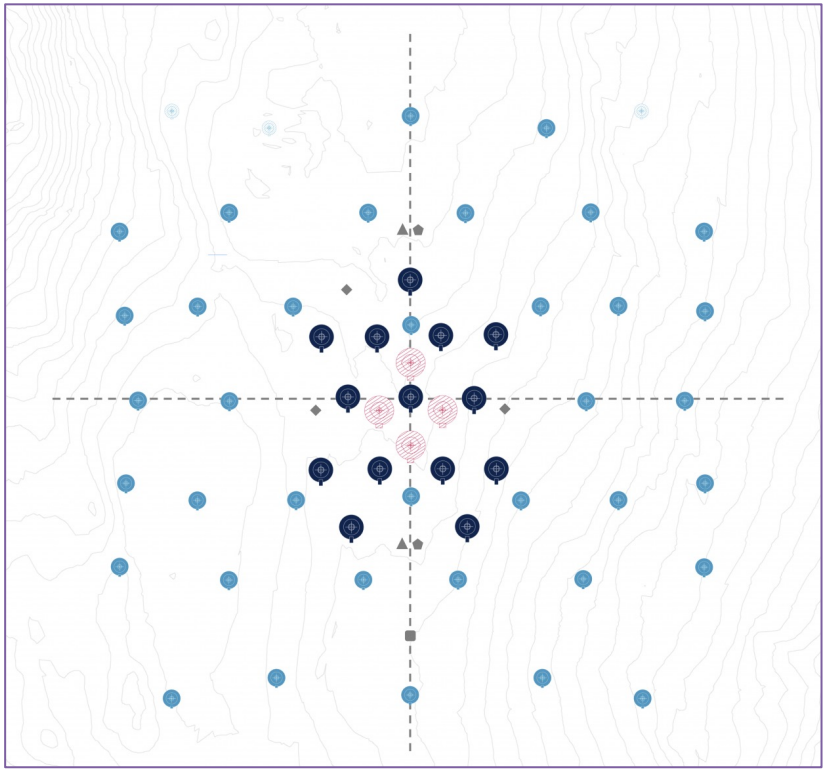


North

Observatorio del Roque de los Muchachos
Longitude: 17º 53’ 31.218” West
Latitude: 28º 45’ 43.7904” North

4 LSTs + 9 MSTs

Array Layout: Alpha Configuration



South

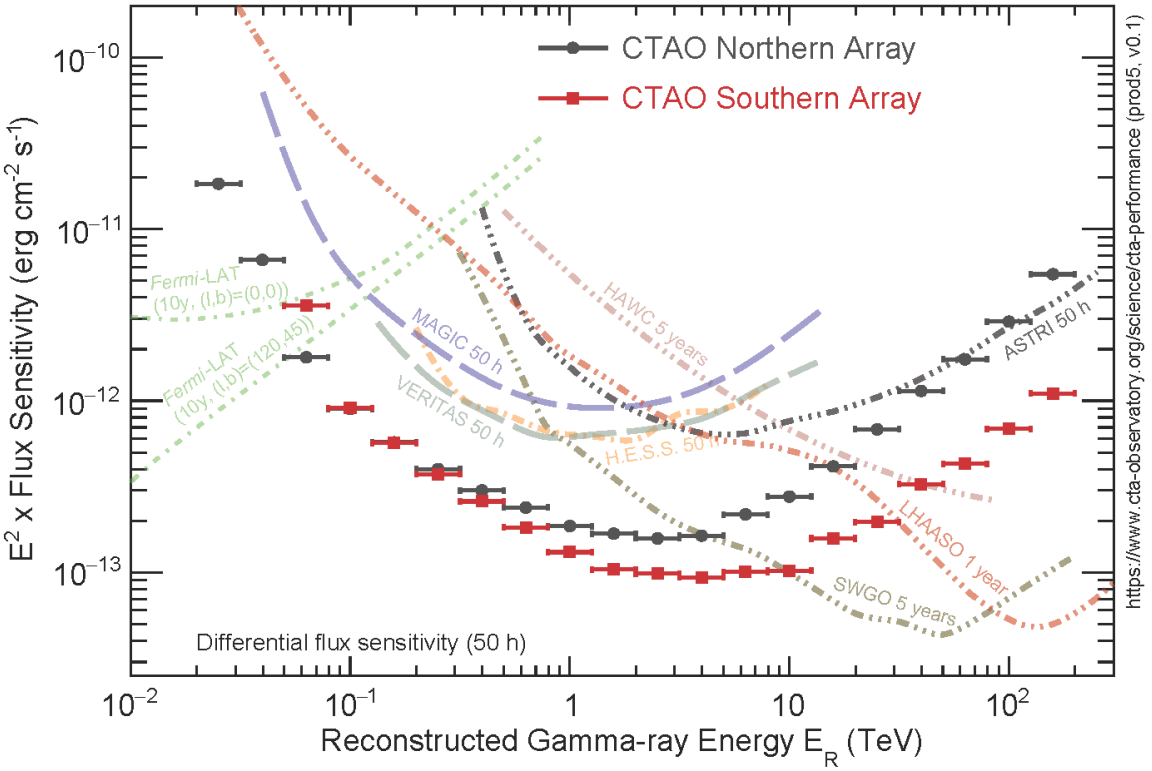
Paranal Observatory
Latitude: 24º 41’ 0.34” South
Longitude: 70º 18’ 58.84” West

LEGEND

- Medium-Sized Telescope (MST)
- Small-Sized Telescope (SST)
- Large-Sized Telescope (LST) Foundation
- SST Foundation
- Weather Station
- Stellar Photometer
- Raman LIDAR
- Other Calibration Devices

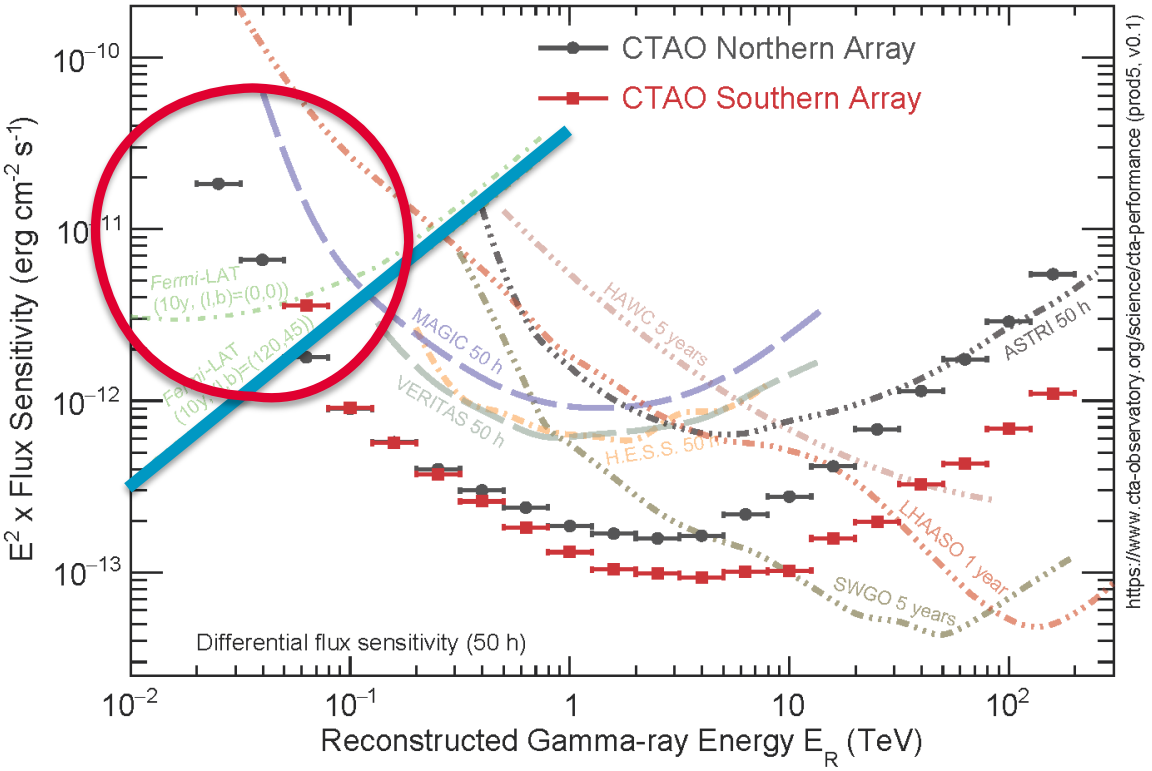
14 MSTs + 37 SSTs

Performance (Alpha Configuration)



Performance (Alpha Configuration)

On time scales <1 h
CTA is **10^3 times** (@25 GeV)
to **10^6 times** (@250 GeV) **more sensitive than *Fermi*-LAT**

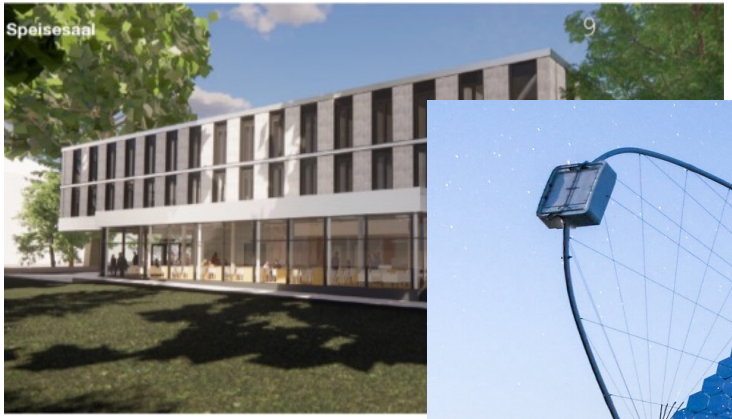


Open Observatory

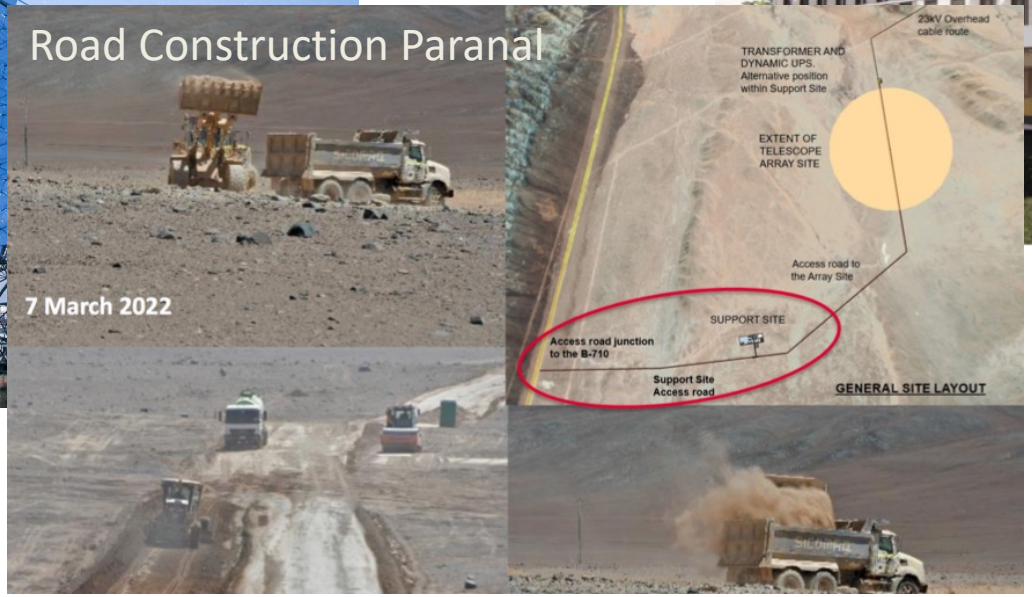
Timeline

- The construction phase will start with the establishment of the final legal entity: CTAO European Research Infrastructure Consortium (ERIC)
  - **May 2022: BGR submitted the formal request to the European Commission to establish the ERIC**
  - mid 2023 ERIC is expected to be in place
- Early science operations foreseen during the construction phase (prototypes already taking science data)

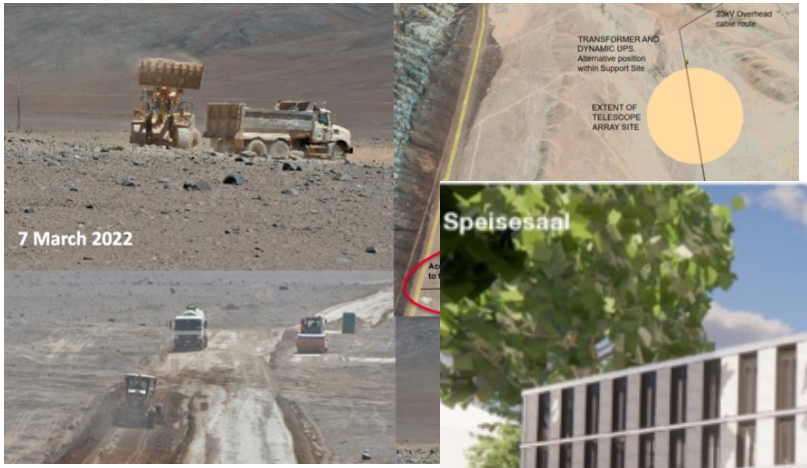
Construction



Construction



Construction



Construction

Science Themes

- **Theme 1: Understanding the Origin and Role of Relativistic Cosmic Particles**
  - What are the sites of high-energy particle acceleration in the Universe?
  - What are the mechanisms for cosmic particle acceleration?
  - What role do accelerated particles play in feedback on star formation and galaxy evolution?

- **Theme 2: Probing Extreme Environments**
  - What physical processes are at work close to neutron stars and black holes?
  - What are the characteristics of relativistic jets, winds and explosions?
  - How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?

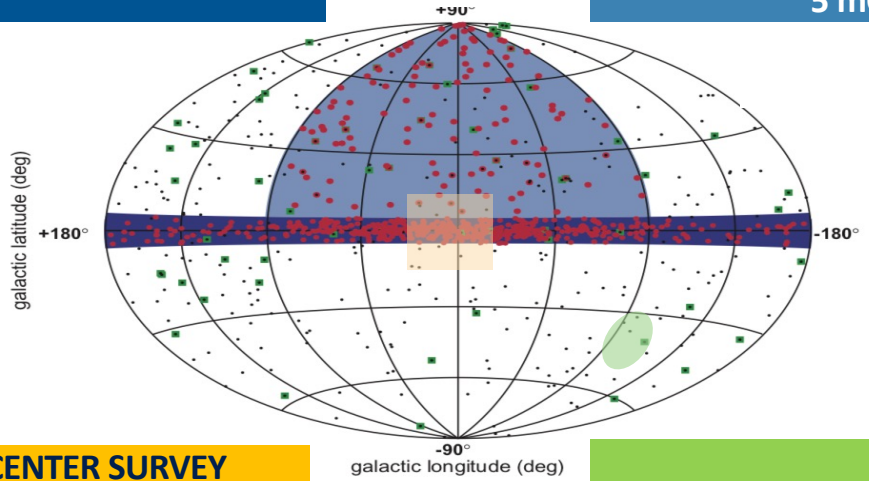
- **Theme 3: Exploring Frontiers in Physics**
  - What is the nature of dark matter? How is it distributed?
  - Are there quantum gravitational effects on photon propagation?
  - Do axion-like particles exist?

https://arxiv.org/abs/1709.07997

CTA Surveys

GALACTIC PLANE SURVEY
not uniform sensitivity across the plane 2-4 mCrab
pilot survey: first results after 1-2 yr

EXTRAGALACTIC SURVEY
first unbiased survey of VHE sky → huge discovery space
25% of the sky
5 mCrab

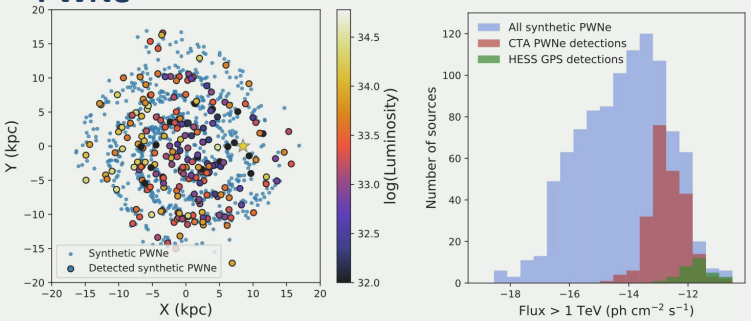


GALACTIC CENTER SURVEY
deeper observations around the GC
10∘ x 10∘
2 mCrab

LARGE MAGELLANIC CLOUD SURVEY
in only 10 pointings

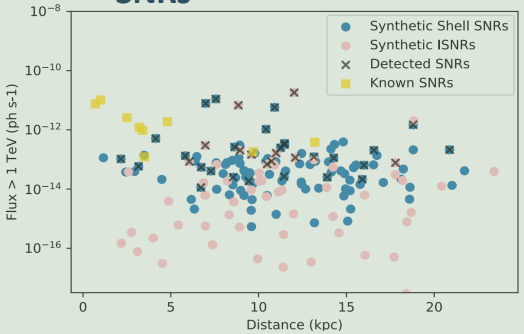
Source population studies

PWNe



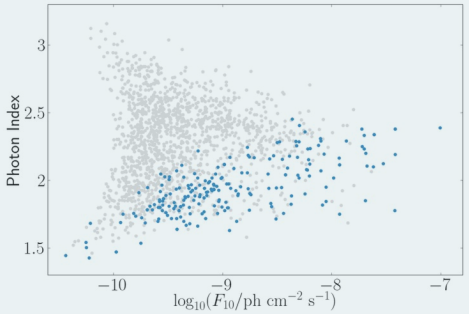
- transformational jump in population size to the PWNe field

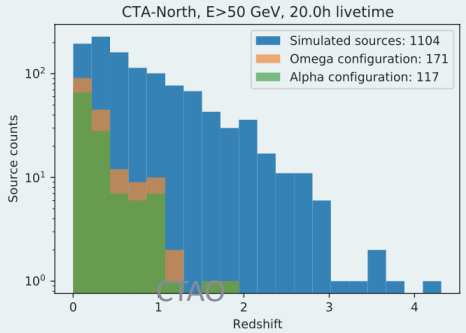
SNRs



- SNRs up to other side of the Galaxy
- 5-10 times better flux sensitivity

AGNs

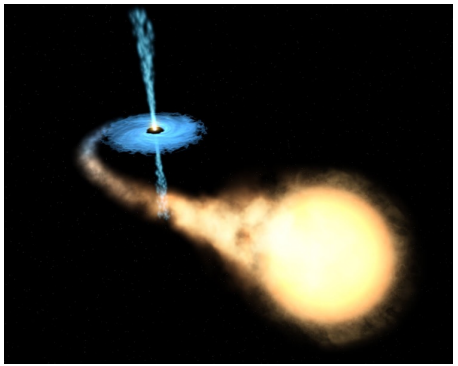




- factor >2 detected non-flaring AGNs
- enlarge the γ-ray horizon up to z≃2

Transients

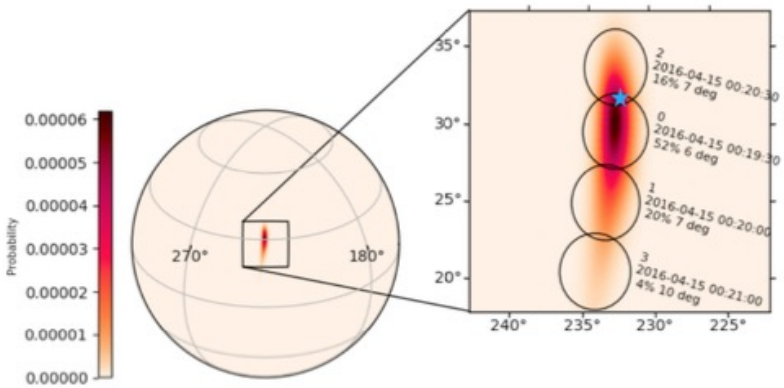
- AGNs
  - Monitoring program along with deep observations and search for new sources
  - Population of extreme blazars?
  - Further classes of AGNs?
- Galactic
  - Novae, microquasars, tidal disruption events, …
- Serendipitous
  - Real-time analysis which will issue alerts



Transients: follow-ups

Strategy
- Fast response to external alerts
- Joint MWL/MM campaigns
- Divergent pointing

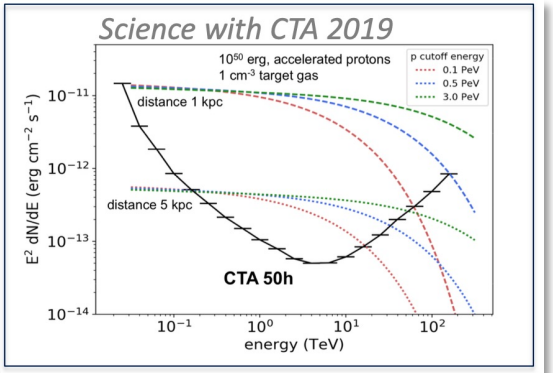
- High-energy neutrino
  - CTAO can play an important role in localizing events (arcmin)
  - Alerts within 2min
  - Origin of TeV-PeV cosmic neutrinos?
- Gravitation wave
  - Violent events with electromagnetic counterparts established
  - Is there TeV emission?
  - Shedding light on the physical parameters of the mergers
- GRB
  - How does prompt & afterglow dynamics work?
  - What is the VHE production mechanism?

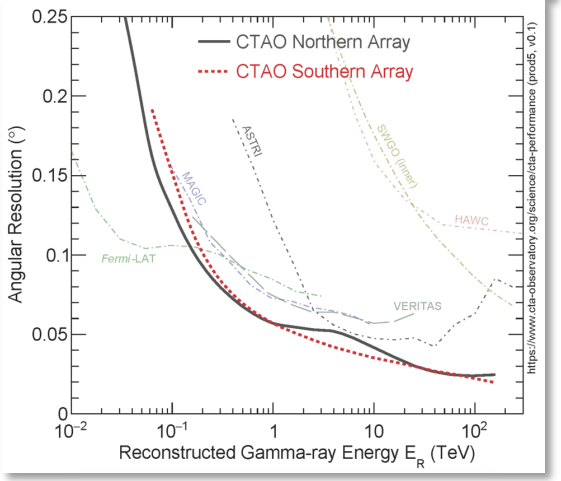


https://doi.org/10.22323/1.395.0998

Cosmic Rays

- What is the origin of Galactic Cosmic Rays
  - 100+ yr open question
  - Sources should be visible ~100 TeV energies
- The existence of sources emitting at more than 100 TeV has been shown by by HAWC, LHAASO and Tibet Array
  - e.g. G106.3+2.7
- Synergy between arrays and IACTs (CTAO) will help answer this question
- Cosmic rays and Star forming regions
  - Deep observations of SFR (Galactic, extra-Galactic & starburst galaxies)

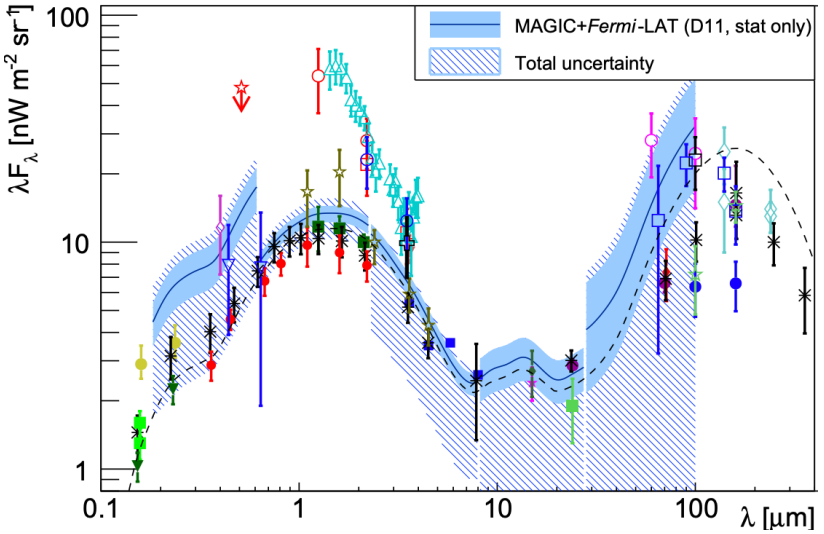




Cosmology: EBL

- Extragalactic Background Light
  - How does the EBL evolve with z?
  - What is the spectrum of the EBL at z=0
  - What is the strength of the IGMF?

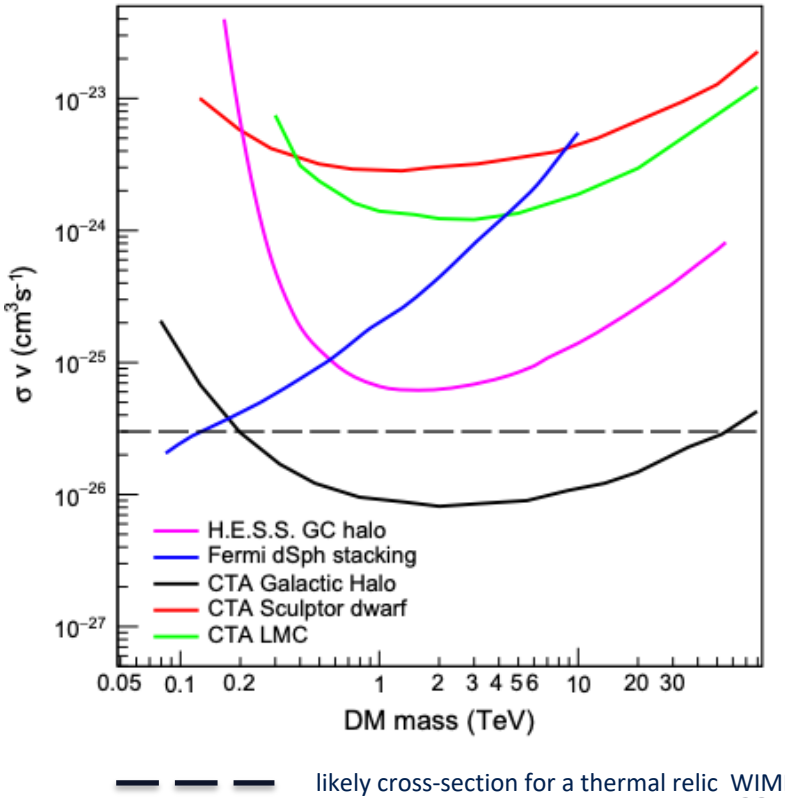
- CTAO can improve precision in the infrared band
  - GeV to TeV coverage of energy spectra
  - Large sample of sources
  - Use of GRBs



MAGIC MNRAS 000, 1–21 (2018)

Dark Matter

- What is the nature of dark matter?
  How is it distributed?
- Search for the annihilation signature of weakly interacting massive particles (WIMPs)
- CTA is complimentary to other approaches
- Observations will constrain the WIMP paradigm in case of non-detection
- CTA will reach the expected thermal relic cross-section for self-annihilating dark matter for a wide range of dark matter masses



ESCAPE

One of several science clusters contributing to the EOSC

ESCAPE & CTAO

CTAO will perform open science and follow FAIR principles

- For the past three years: CTA has been working with other ESFRIs and RIs on common topics:
  - Data lake
    - distributed, policy based big data storage
  - Science Platform
    - observatory requires a method for scientists to explore and use data
  - Software Repositories
    - including software metadata, provenance & licensing
  - Connections to the IVOA
    - support MWL/MM campaigns, common data formats
- Lessons learnt during these efforts used to assist CTA in construction efforts and testing

Summary

- CTAO will be the first gamma-ray ground-based observatory, openly delivering data to the community
- CTAO will increase our understanding of known objects and their physical mechanisms
- CTAO expects to discover new classes of objects
  Has the potential to observe things that we have not yet thought of
- CTAO is working with other ESFRIs via ESCAPE to prototype technology and learn how to integrate open science and FAIR principles
- ERIC is expected to be in place mid 2023