The Cherenkov Telescope Array Observatory (CTAO): Construction of the SSTs and LSTs

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CTAO
Cherenkov Telescope Array Observatory

History of IACTs

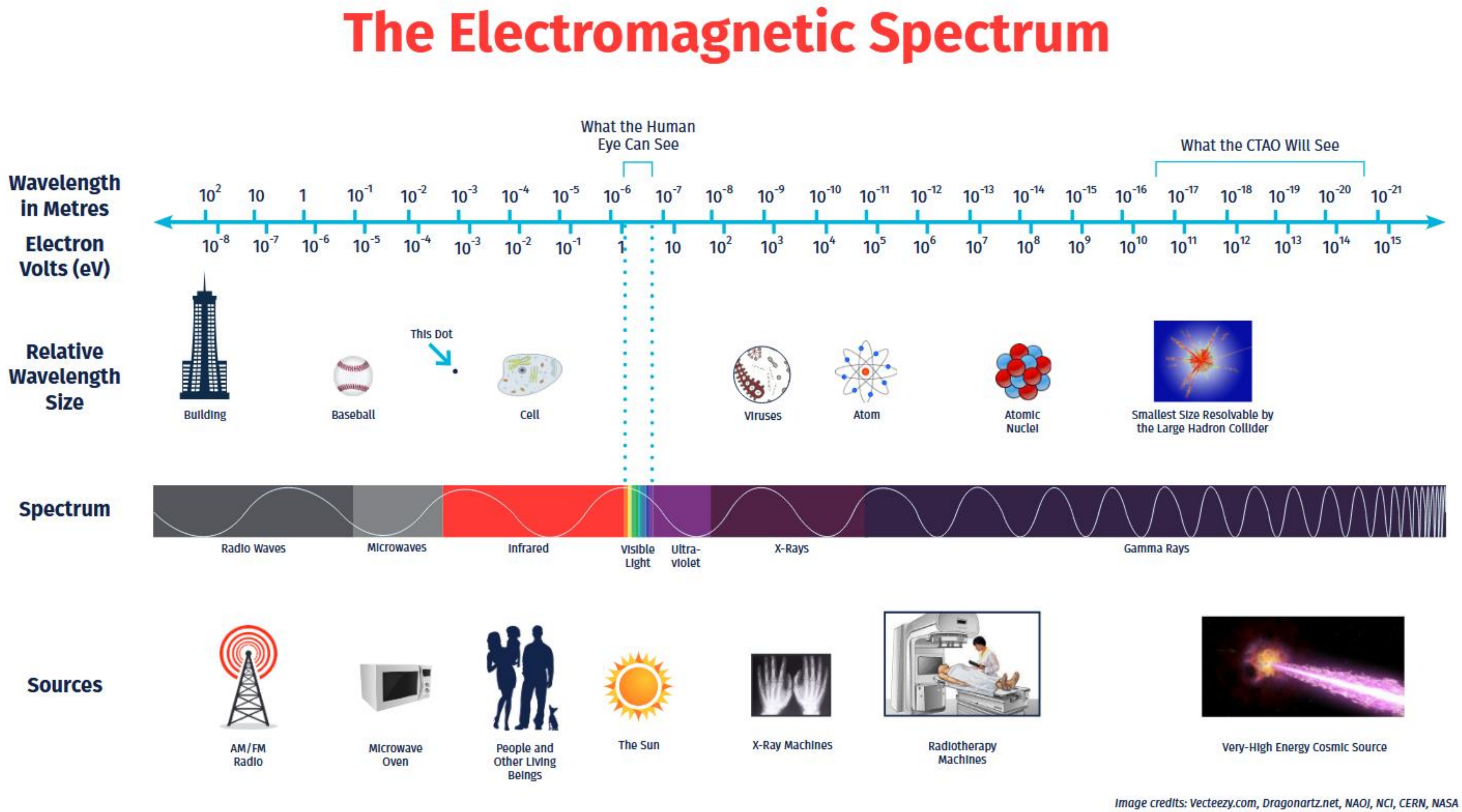
Victor Hess (1883-1964)

In 1912, and through several balloon flights, this Austrian physicist discovered that there were extremely energetic charged particles from the Universe (like tiny balls that, individually, are invisible to the human eye but form all the matter we know) that constantly bombard the Earth's atmosphere: cosmic rays. This revolutionized the understanding of our Universe and initiated a new field of knowledge and investigations at the highest energies.

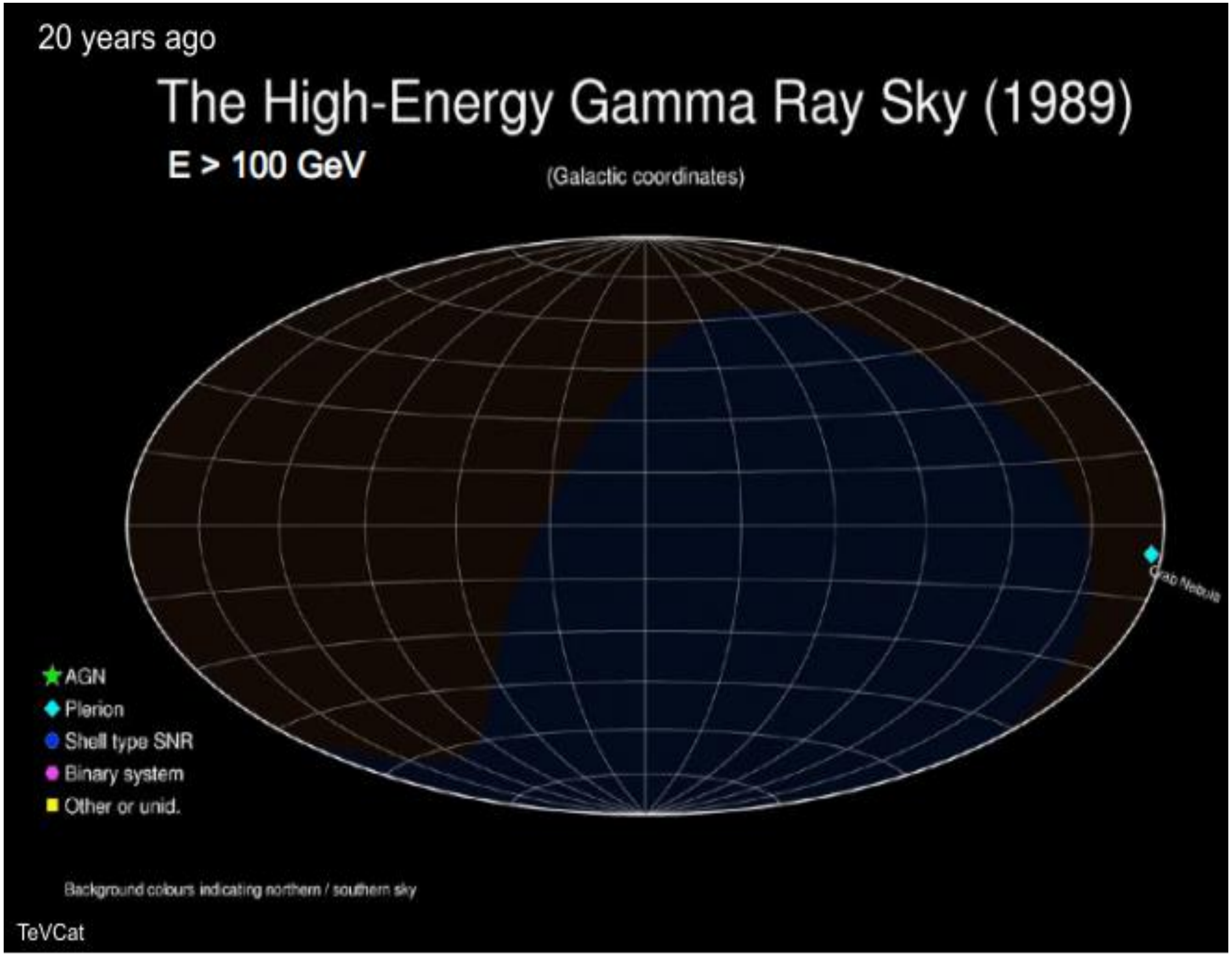
Pavel A. Cherenkov (1904-1990)

There is nothing that can move faster than light in a vacuum. However, in other mediums, like air or water, the light's velocity is slower, allowing the high-energy particles to move faster than light. In 1934, the Russian physicist Pavel Cherenkov discovered that when charged particles move faster than light in a medium, they emit a bluish light, which was named after him: Cherenkov light. When a gamma ray hits the Earth's atmosphere, it produces a cascade of high-energy particles that give rise to this phenomenon. The **Cherenkov Telescope Array (CTA)** will use its telescopes to capture the Cherenkov light that is produced in these particle cascades so that scientists can collect indirectly information about the gamma ray and its cosmic source.

History of IACTs

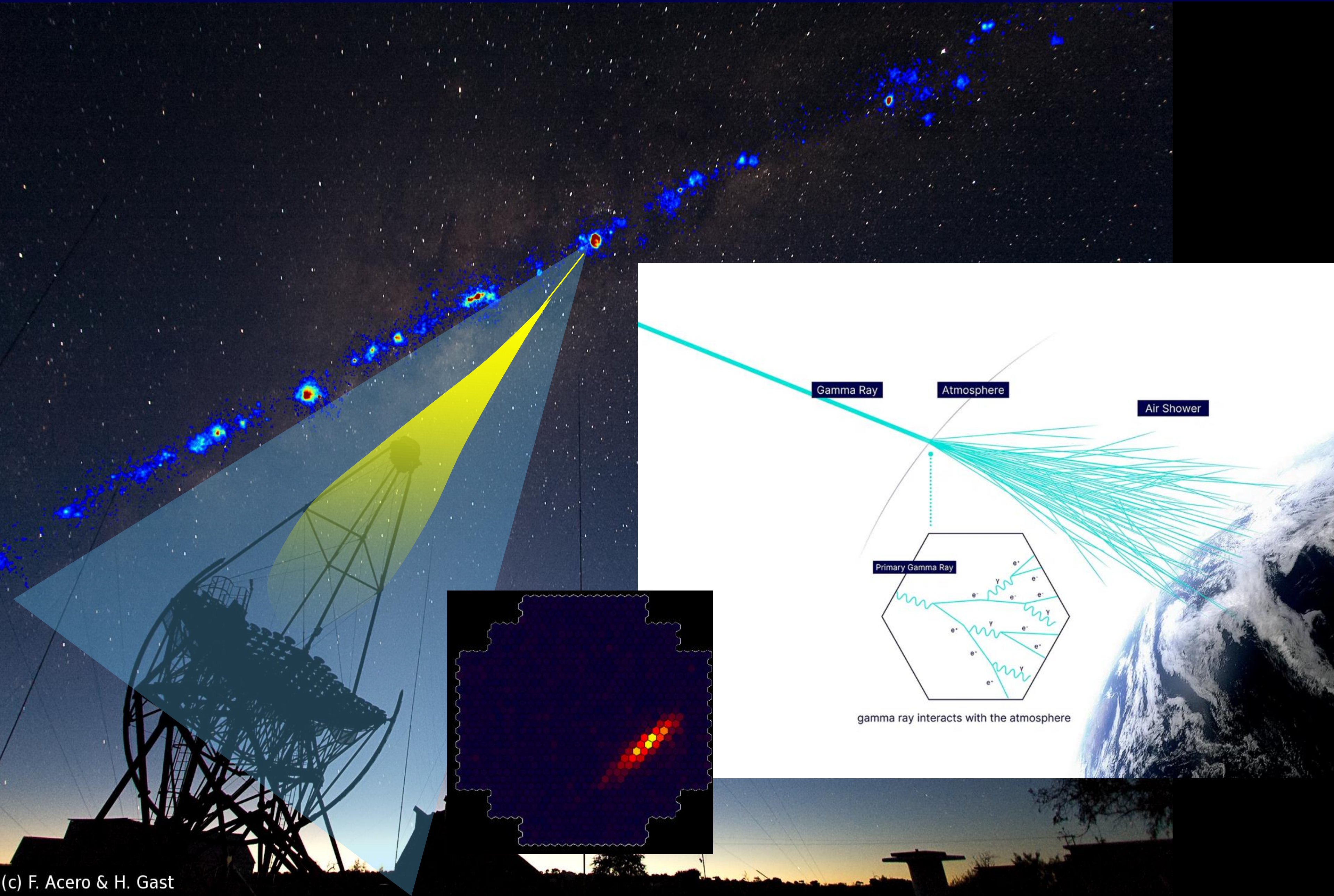


SAO/Arizona – Whipple Observatory (early 1980´s)



CTAO

History of IACTs



Major TeV observatories

VERITAS
4 Medium-Sized Tel. ('MSTs')
2007: Full operation
2009: Relocation of T1
2012: PMT upgrade

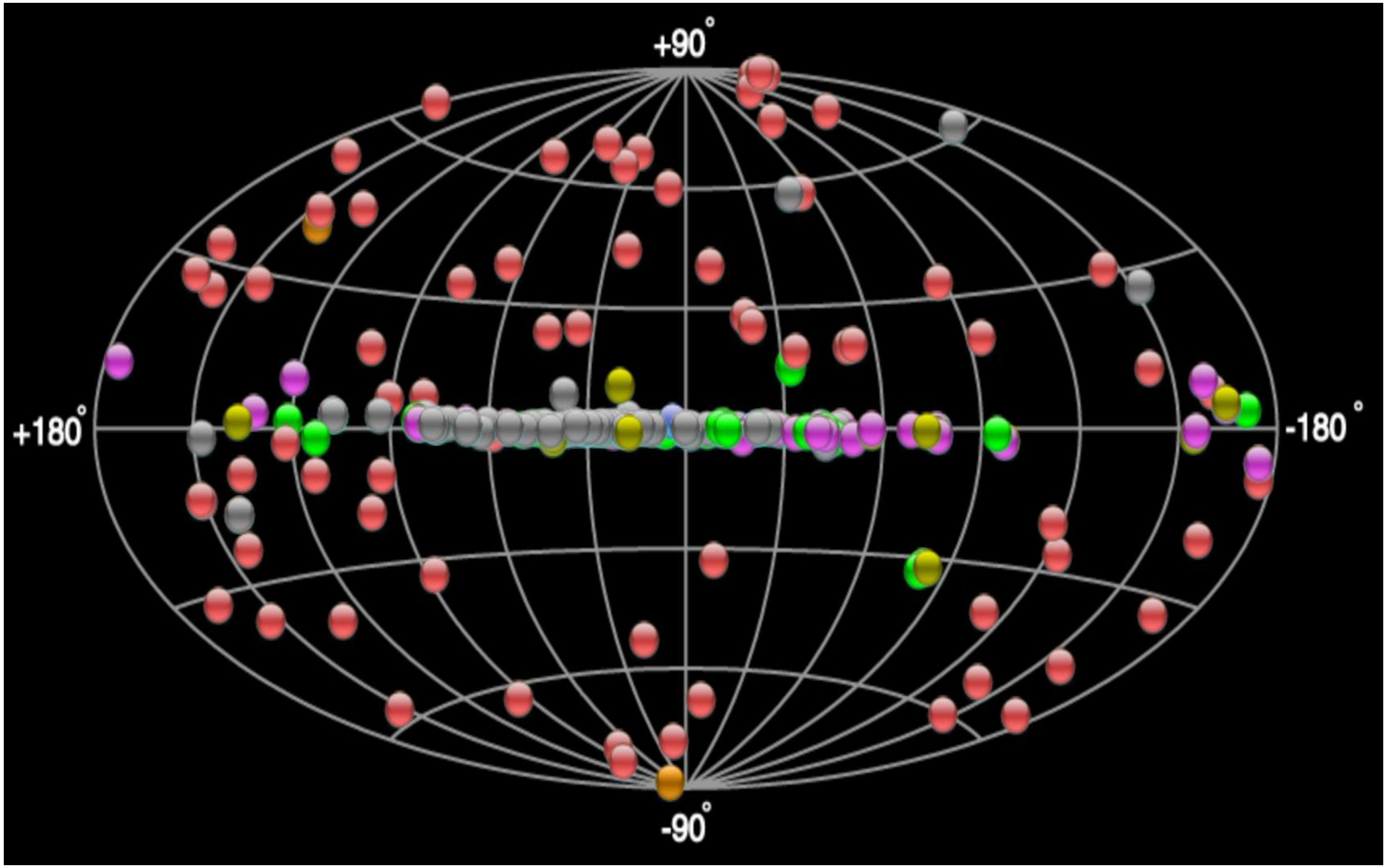
MAGIC
2 Large-Sized Tel. ('LSTs')
2003: MAGIC-I
2009: MAGIC-II
2012: PMT upgrade

LHAASO
Particle-detector water tanks
+ 18 Small-Sized Tels ('SSTs')
since 2018

HAWC
Particle-detector water tanks (2015)

H.E.S.S.
4 MSTs (2003)
+ 1 LST (2012)

Current view of the gamma-ray sources in the sky



Its time for CTAO !

Aiming....

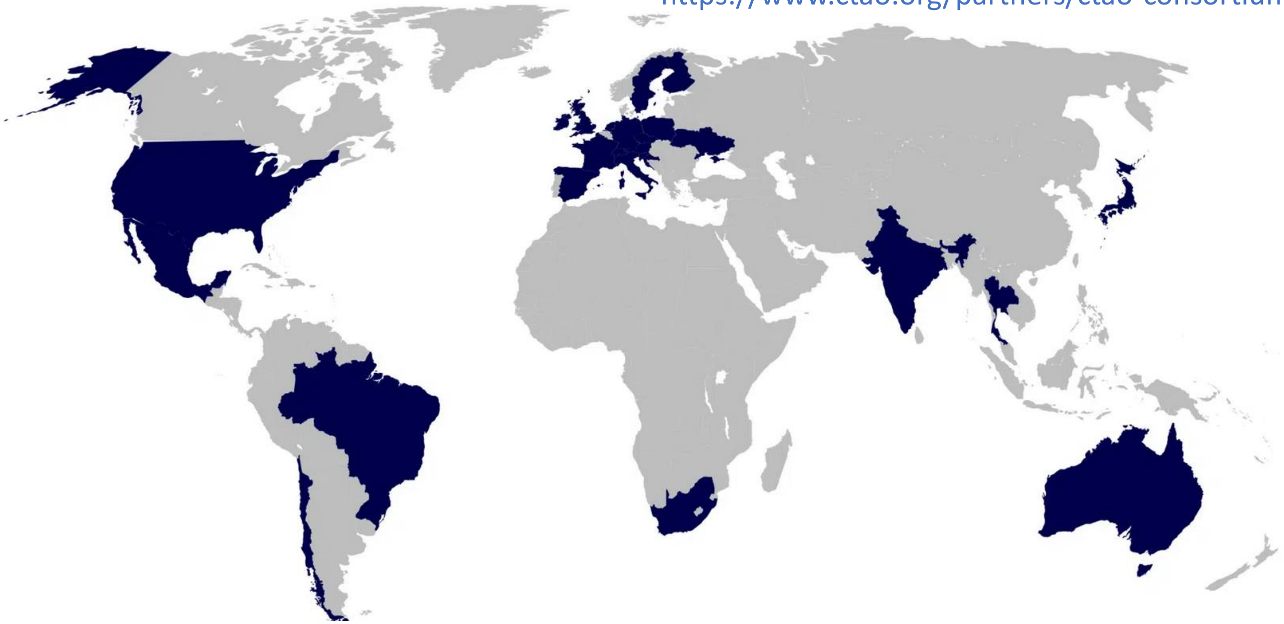
- beat the sensitivity level of current instruments by **one order of magnitude at 1 TeV**,
- boost detection area providing access to the **shortest timescale phenomena**,
- improve **angular resolution** and field of view to image extended sources,
- energy coverage from **20 GeV to 300 TeV** (reach to high-redshifts and extreme accelerators),
- provide access to the entire sky, with sites in **two hemispheres**.

CTAO will be the major facility in high-energy and very high-energy photon astronomy over the next decade and beyond.

The CTAO

- The CTAO Consortium includes 1,500 members from more than 200 institutes in 31 countries.
- the CTAO concept was developed more than a decade ago and have been the driving force behind its design.
- Estimated cost of 400 MEuro.

https://www.ctao.org/partners/ctao-consortium/



Brazil in the CTAO

Centro Brasileiro de Pesquisas Físicas

Centro de Ciências Naturais e Humanas – Universidade Federal do ABC
Departamento de Engenharias e Exatas, Universidade Federal do Parana

Escola de Artes, Ciências e Humanidades, Universidade de São Paulo

Escola de Engenharia de Lorena, Universidade de São Paulo

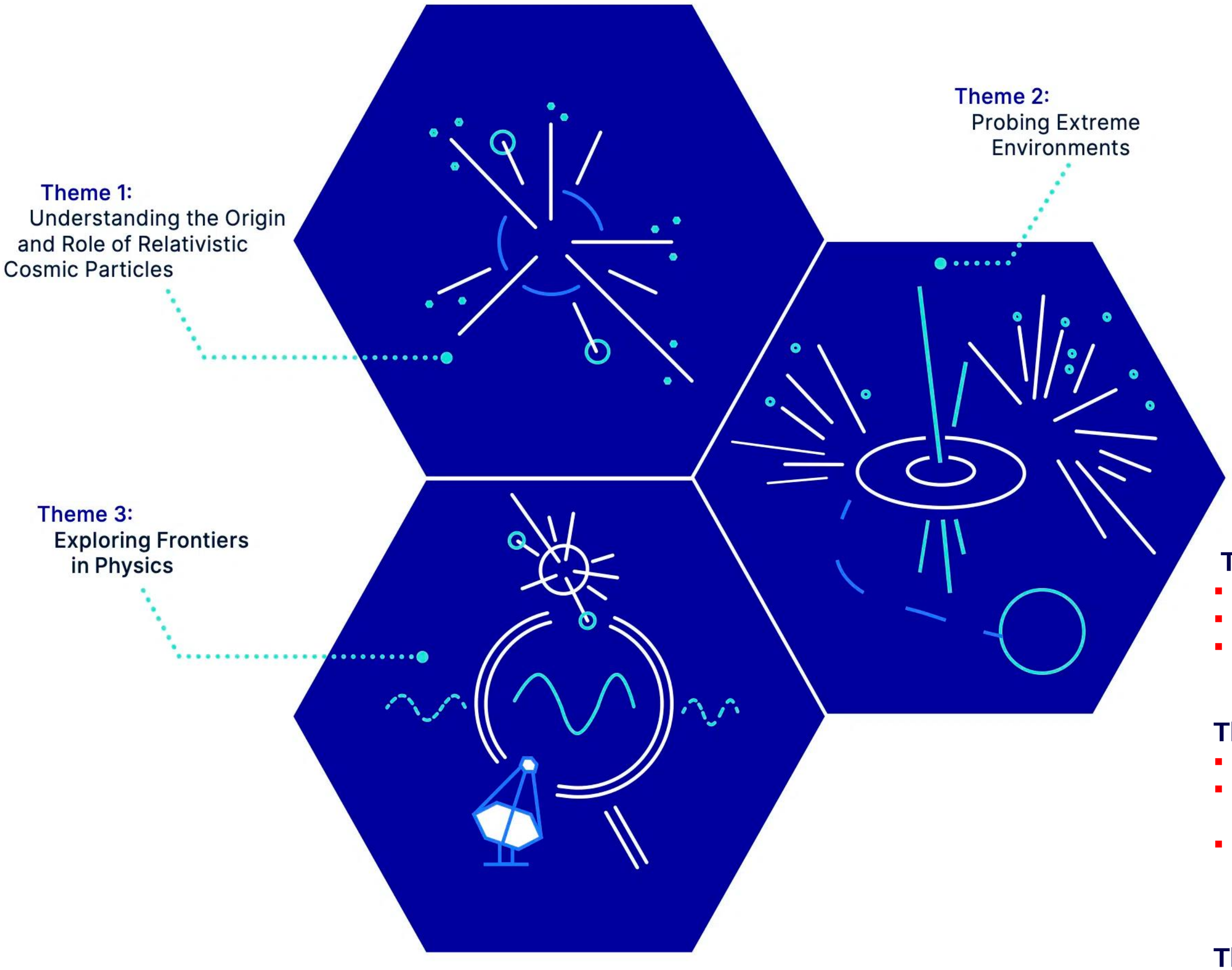
Instituto de Astronomia, Geofísico, e Ciências Atmosféricas

Instituto de Física de São Carlos, Universidade de São Paulo

Instituto de Física – Universidade de São Paulo
International Centre for Theoretical Physics, Universidade Estadual Paulista
Nucleo de Astrofisica Teorica, Universidade Cruzeiro do Sul

Núcleo de Formação de Professores – Universidade Federal de São Carlos

The Science of CTAO



Theme 1: Cosmic Particle Acceleration

- How and where are particles accelerated?
- How do they propagate?
- What is their impact on the environment?

Theme 2: Probing Extreme Environments

- Processes close to neutron stars and black holes?
- Characteristics of relativistic jets, winds and explosions?
- Cosmic voids: their radiation fields and magnetic fields

Theme 3: Physics Frontiers

- What is the nature of Dark Matter?
- Is the speed of light a constant?
- Do axion-like particles (ALPs) exist?

CTAO Design

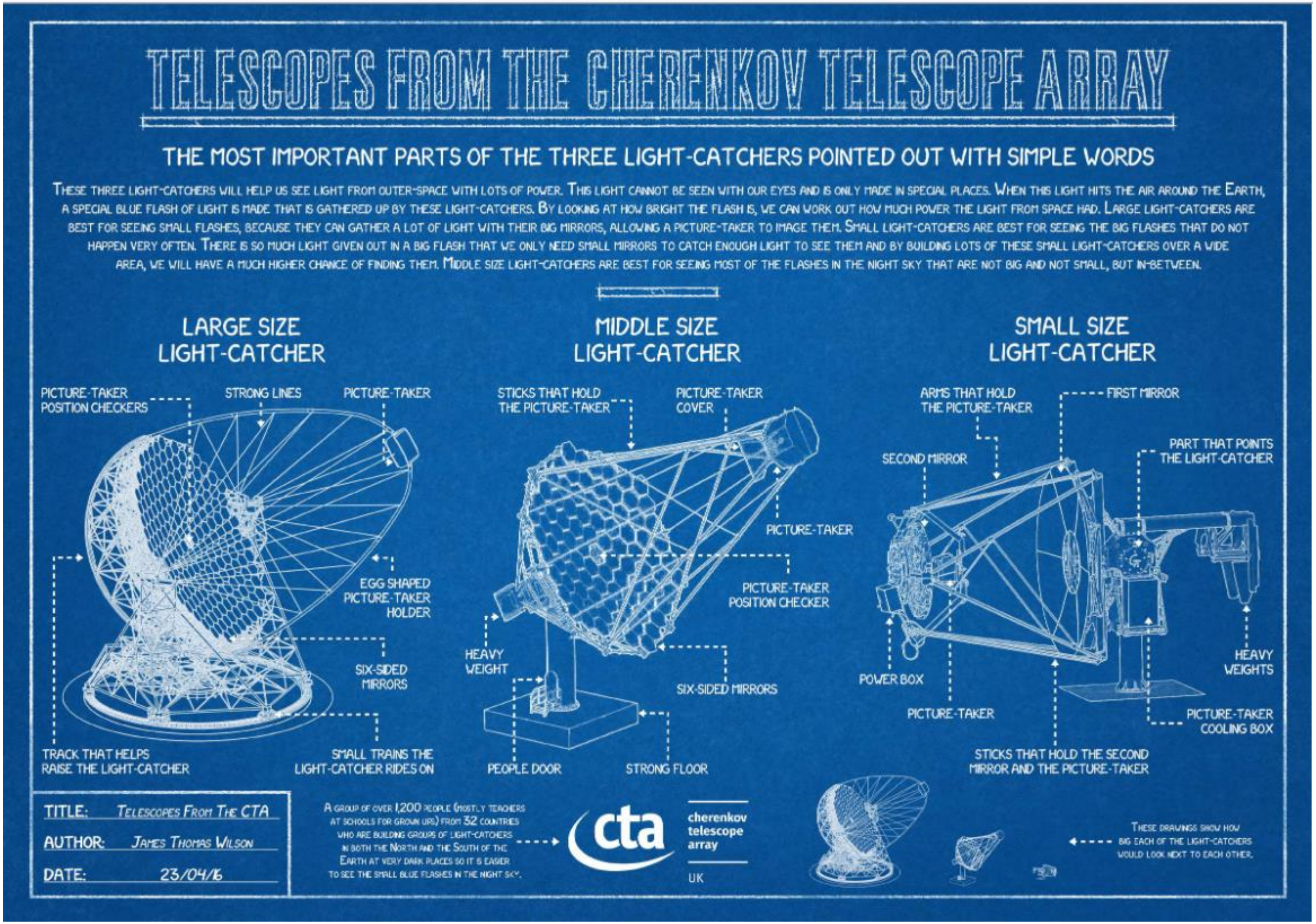
Sub-TeV
- GRBs
- Transient sources
- AGNs
- Cosmological sources
- Pulsars
- Grav. waves

TeV
- EBL
- Surveys
- Morphological studies
- Dark matter
- UHE neutrinos
- Extreme blazars

multi-TeV
- PeVatrons
- Star-forming regions

20 GeV — 500 GeV — 1 TeV — 10 TeV — 300 TeV

CTAO Design

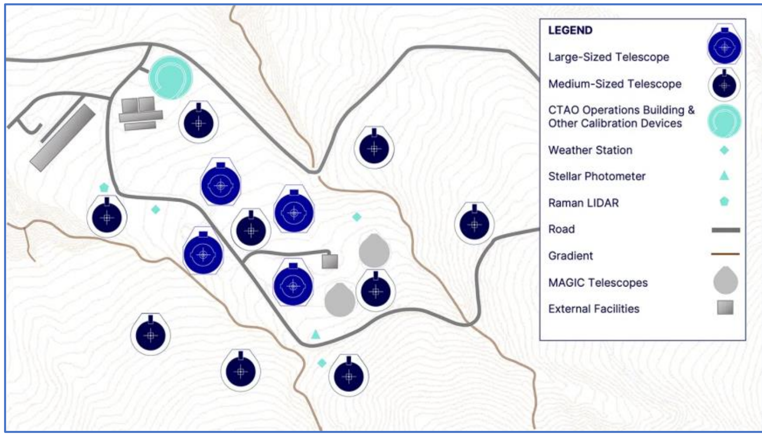


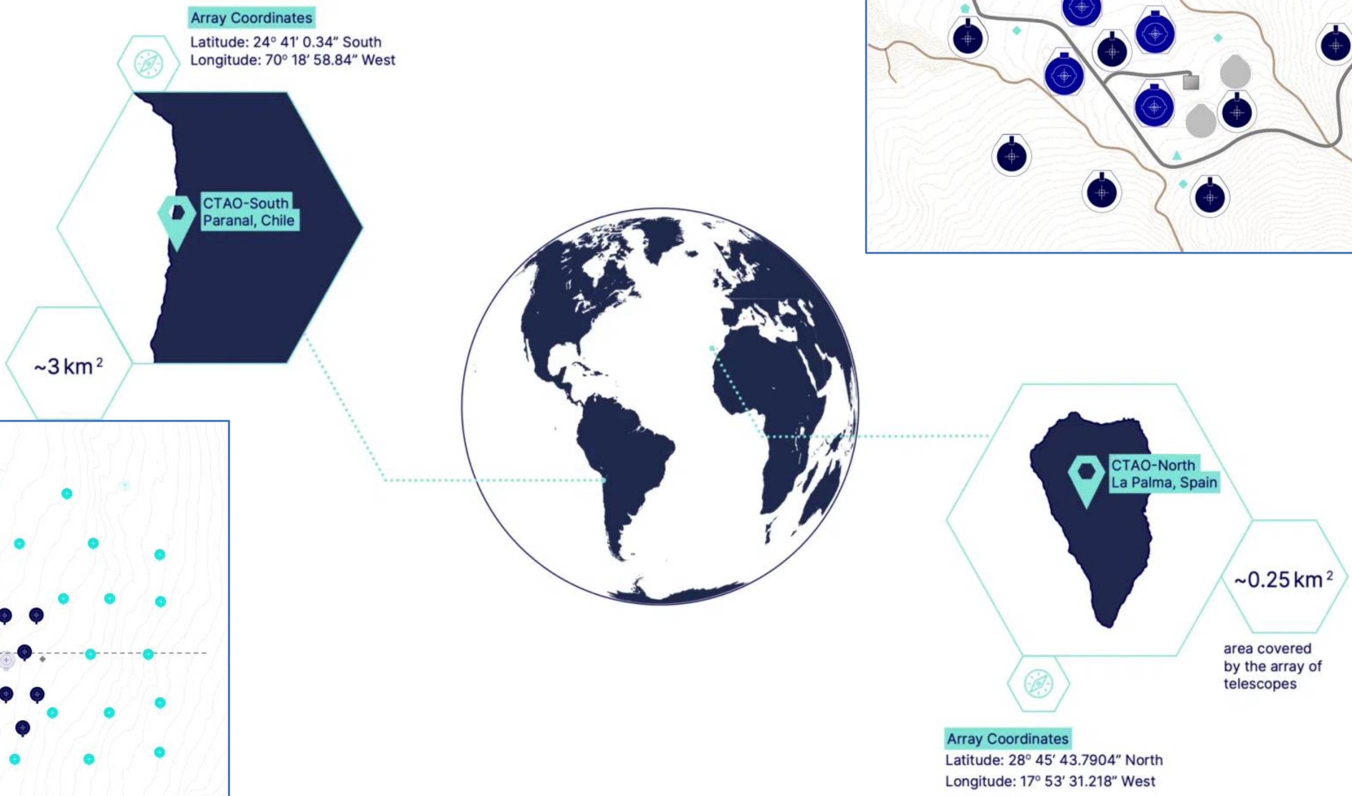
TELESCOPES FROM THE CHERENKOV TELESCOPE ARRAY
THE MOST IMPORTANT PARTS OF THE THREE LIGHT-CATCHERS POINTED OUT WITH SIMPLE WORDS
THESE THREE LIGHT-CATCHERS WILL HELP US SEE LIGHT FROM OUTER-SPACE WITH LOTS OF POWER. THIS LIGHT CANNOT BE SEEN WITH OUR EYES AND IS ONLY MADE IN SPECIAL PLACES. WHEN THIS LIGHT HITS THE AIR AROUND THE EARTH, A SPECIAL BLUE FLASH OF LIGHT IS MADE THAT IS GATHERED UP BY THESE LIGHT-CATCHERS. BY LOOKING AT HOW BRIGHT THE FLASH IS, WE CAN WORK OUT HOW MUCH POWER THE LIGHT FROM SPACE HAD. LARGE LIGHT-CATCHERS ARE BEST FOR SEEING SMALL FLASHES, BECAUSE THEY CAN GATHER A LOT OF LIGHT WITH THEIR BIG MIRRORS, ALLOWING A PICTURE-TAKER TO IMAGE THEM. SMALL LIGHT-CATCHERS ARE BEST FOR SEEING THE BIG FLASHES THAT DO NOT HAPPEN VERY OFTEN. THERE IS SO MUCH LIGHT GIVEN OUT IN A BIG FLASH THAT WE ONLY NEED SMALL MIRRORS TO CATCH ENOUGH LIGHT TO SEE THEM AND BY BUILDING LOTS OF THESE SMALL LIGHT-CATCHERS OVER A WIDE AREA, WE WILL HAVE A MUCH HIGHER CHANCE OF FINDING THEM. MIDDLE SIZE LIGHT-CATCHERS ARE BEST FOR SEEING MOST OF THE FLASHES IN THE NIGHT SKY THAT ARE NOT BIG AND NOT SMALL, BUT IN-BETWEEN.
LARGE SIZE LIGHT-CATCHER
PICTURE-TAKER POSITION CHECKERS
STRONG LINES
PICTURE-TAKER
EGG SHAPED PICTURE-TAKER HOLDER
SIX-SIDED MIRRORS
TRACK THAT HELPS RAISE THE LIGHT-CATCHER
SMALL TRAINS THE LIGHT-CATCHER RIDES ON
MIDDLE SIZE LIGHT-CATCHER
STICKS THAT HOLD THE PICTURE-TAKER
PICTURE-TAKER COVER
PICTURE-TAKER
PICTURE-TAKER POSITION CHECKER
HEAVY WEIGHT
SIX-SIDED MIRRORS
PEOPLE DOOR
STRONG FLOOR
SMALL SIZE LIGHT-CATCHER
ARMS THAT HOLD THE PICTURE-TAKER
FIRST MIRROR
PART THAT POINTS THE LIGHT-CATCHER
SECOND MIRROR
HEAVY WEIGHTS
POWER BOX
PICTURE-TAKER
PICTURE-TAKER COOLING BOX
STICKS THAT HOLD THE SECOND MIRROR AND THE PICTURE-TAKER
TITLE: TELESCOPES FROM THE CTA
AUTHOR: JAMES THOMAS WILSON
DATE: 23/04/16
A GROUP OF OVER 1,200 PEOPLE (MOSTLY TEACHERS AT SCHOOLS FOR GROWN UPS) FROM 32 COUNTRIES WHO ARE BUILDING GROUPS OF LIGHT-CATCHERS IN BOTH THE NORTH AND THE SOUTH OF THE EARTH AT VERY DARK PLACES SO IT IS EASIER TO SEE THE SMALL BLUE FLASHES IN THE NIGHT SKY.
cta cherenkov telescope array UK
THESE DRAWINGS SHOW HOW BIG EACH OF THE LIGHT-CATCHERS WOULD LOOK NEXT TO EACH OTHER.

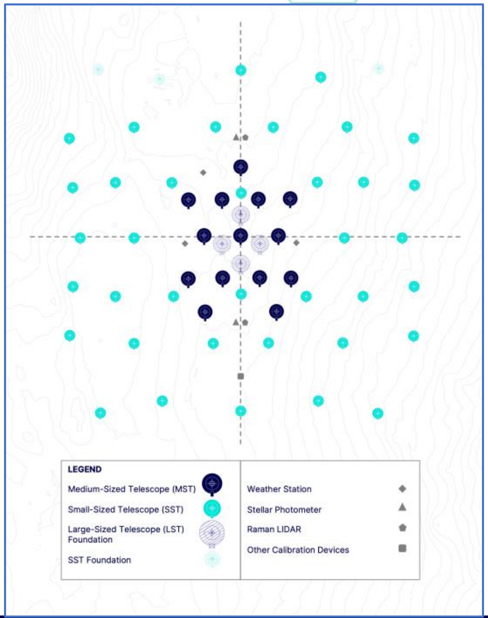
CTAO

CTAO Design

4 LSTs + 9 MSTs
(alfa configuration)



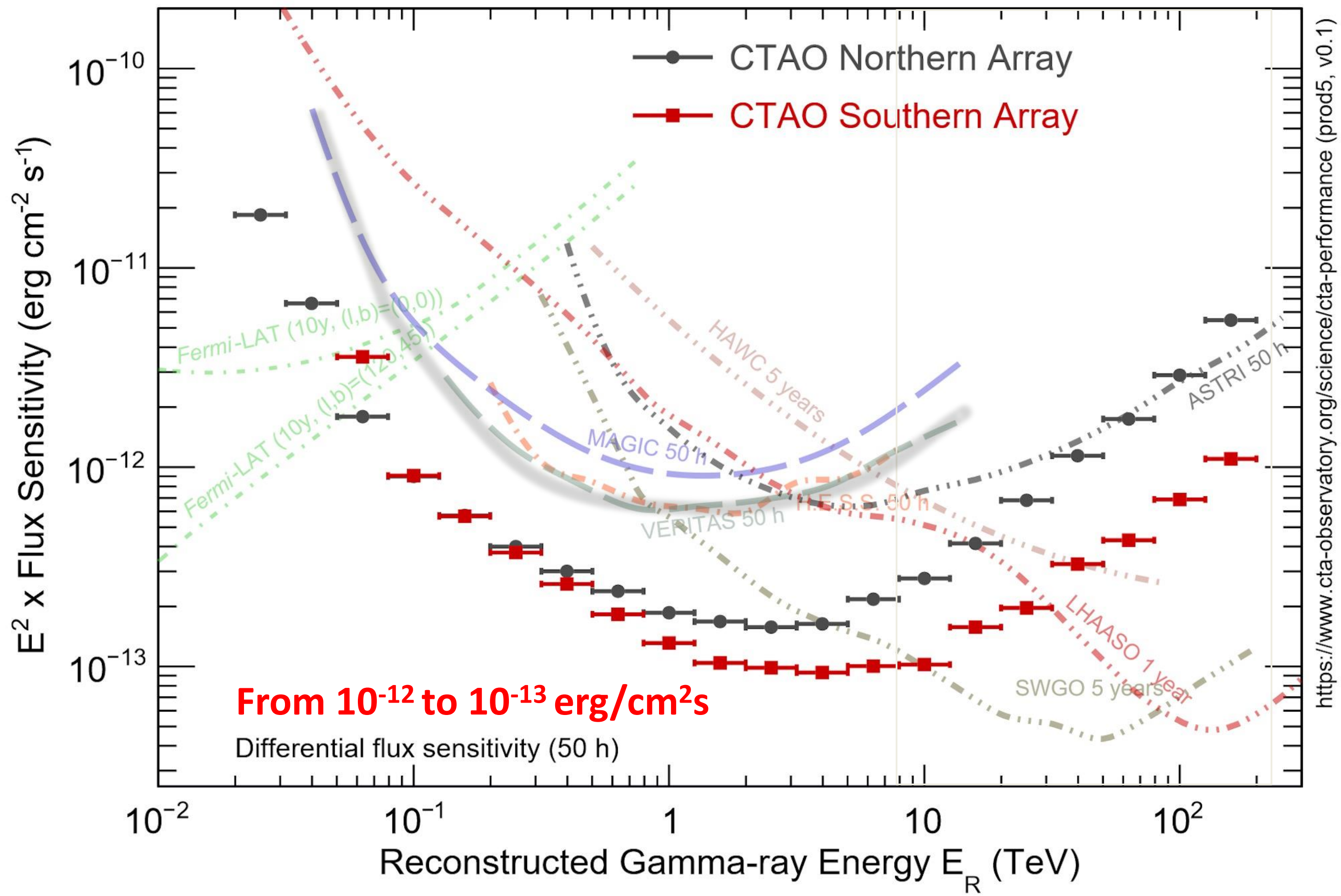




37 SSTs + 14 MSTs (alfa configuration)
+ 2 LSTs ($$ secured)

Sensitivity of the instrument

α-configuration



Large Size Telescopes (LSTs)

4 LSTs at CTAO-North

(2 in south site at CTAO+ phase)

- LST-1 has already been build and is operational.
- CBPF team (Ulisses B de Almeida) contributed to all phases.
- CBPF has contributed with 500 kBRL funding through mechanical technology for the Active Mirror Control (AMC) system.
- Specifications:
  - **23m diameter – effective 370m2**
  - **45m / 100tons**
  - **Only 20s pointing**
  - **Designed to high sensitivity at 20 – 150 GeV**

CTAO under construction

LST-1 Discovers the Most Distant AGN at Very High Energies

DATE
26 December 2023

TOPICS
LST, Science, Telescopes, Press Releases, CTAO-North

LST-1 during observation at CTAO-North, La Palma, Spain. Credit: CTAO gGmbH

La Palma, Spain – On 15 December, the Large-Sized Telescope (LST) Collaboration announced through an Astronomer's Telegram (ATel) the detection of the source OP 313 at very high energies with the LST-1. Although OP 313 was known at lower energies, it had never been detected above 100 GeV, making this the LST-1's first scientific discovery. With these results, OP 313 becomes the most distant Active Galactic Nuclei (AGN) ever detected by a Cherenkov telescope, further showcasing the LST prototype's exceptional performance while it is being commissioned on the CTAO-North site on the island of La Palma, Spain.

Small Size Telescopes (SSTs)

- 37 SSTs at CTAO-South

  - SST design has been approved (and closed) by 2023,
  - It has the ASTRI-MA telescopes as optical/mechanical prototypes, which are already under implementation and partially operational.
  - CHEC camera has been commissioned for CTAO design.
  - More info about ASTRI-MA by Elisabete de Gouveia Dal Pino´s talk.
  - Specifications:
    - **4.3m diameter – effective 5m2**
    - **9m / 7.3tons**
    - **Fast image processing: 128-frame movies, with each frame lasting one billionth of a second**
    - **Designed to high sensitivity at 5 – 300 TeV**

CTAO under construction

Brasil in the SST-CTAO Program:

- Currently: approx. 60 members in CTA-BR, being 30 related to the SST (IAG-USP, EACH-USP, Mackenzie, UFABC, IFUSP, CBPF)
- **Budget** : approx. **1 Million US$** (secured from 2023/Thematic Project FAPESP)
- Main contribution: AIV phase

Brazilian team, as codeveloper of the SST mechanical and optical design, will take part on the **assembly, integration and verification** phase of the SSTs at the CTAO-South array

CTAO-North Status

- LST-1 being commissioned by LST collaboration
- Infrastructure construction initiated
  - Three more LST foundations, one MST foundation
  - Roads, data and power network
  - Tendered by *Instituto de Astrofisica de Canarias* (IAC) in collaboration with CTAO
  - Operation building
- CTAO building up its organization on La Palma
  - North Site Manager in place since 1 Jan 2019
  - Setting up CTAO Low Elevation Office (LEO)
- CTAO Systems Engineering very busy with detailed system design
  - Addressing all system level details

CTAO-South Status

- Hosting agreements between Republic of Chile, ESO, CTAO and CONICYT were signed in Dec 2018
- CTAO-South Site Manager appointed (starting 1 July 2019)
- Seismic investigation for the specific site finalised
- CTAO South infrastructure is underway
  - Access Road procurement is on track
    - Procurement carried out by ESO on behalf of CTAO
    - Scope: 4 km of access road incl. junction to the public road
  - Foundations, roads, power and data networks

Schedule

SSTs

- Budget is fully secured for the construction, installation and testing of the 37 telescopes (alfa configuration)
- FAPESP Thematic Project as part of this.
- 5 SSTs to be built in 2025 (contract signed)
- Final set to be delivered by 2029

Event		Type	Responsible	Participants	Scope	Frequency	When
Design-Consolidation							
CDR	Critical Design Review	Review	CTAO	CTAO, SST-PRO	Authorise Design and Plans, Authorise Production	Once	Dec 2024
Production Phase							
TRR	Test Readiness Review	Internal Review with Key persons	SST-PRO	SST-PRO, CTAO	Authorise Tests o the item under test (Telescope or subsystem)	Once (*delta* if procedures change)	June 2025
TRB / PSR	Test Review board / Pre Shipment Review	Internal Review with Key persons	SST-PRO	SST-PRO, CTAO	Accept test results and documentation of the item under test, authorisation for shipment	Per item tested	Sept 2025
On-Site AIT/V Phase							
O-TRR	On-Site Test Readiness Review	Internal Review with Key persons	SST-PRO	SST-PRO, CTAO	Authorise Integration and Tests on-site	Once (*delta* if procedures change)	Nov 2025 (if southern site ready)
ACRV	Provisional Acceptance Review	Review	CTAO	CTAO, SST-PRO	Provisional Acceptance of the Telescope(s) from SST-PRO	Per item or batch verified	Feb/March 2026 (First Telescope) (if southern site ready)
FAR	Final Acceptance Review	Review	CTAO	CTAO, SST-PRO	Final Acceptance of the Telescope(s) from SST-PRO	Per item or batch	2030 (Last Telescope)

CTAO

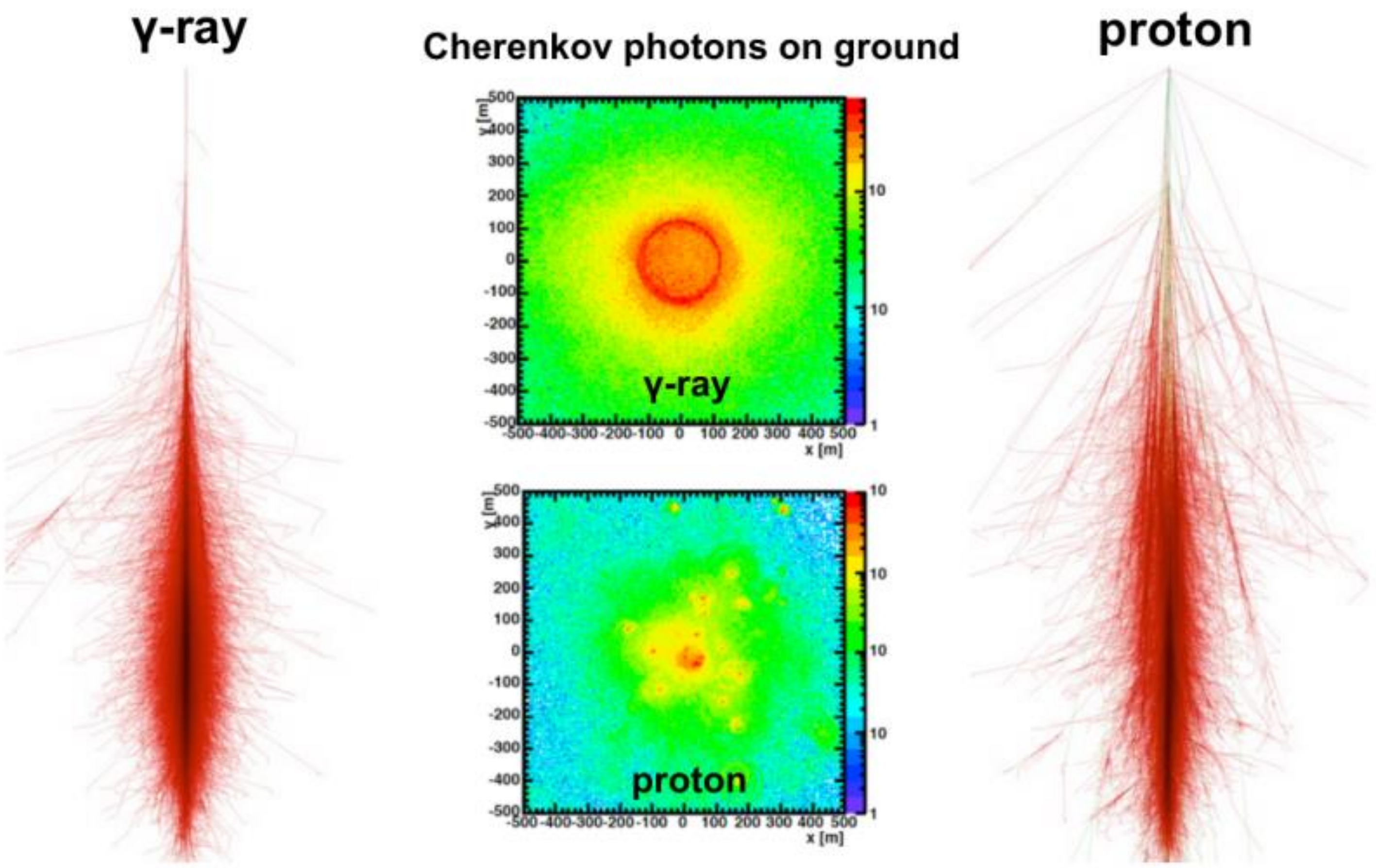
Conclusions

- CTAO will be the largest gamma ray observatory on Earth
- It will be a Leading facility for the over a decade (or more)
- 2 sites: North (Canary Islands) and South (Chile/Atacama desert)
- Construction in undergoing (1 LST already operational) -> alfa config. next 5yrs
- Brazil takes part on all three telescope designs, and our community will have access to the data (including the KSPs)
- Key Science covers
  - ✓ cosmic ray acceleration and propagation
  - ✓ high energy processes in astrophysical objects
  - ✓ testing current theories of particle physics

Thank you

CTAO

Photon versus CR shower



Slide by Gernot Mayer

Schedule

No.	Level-1 Milestone	CTA-North	CTA-South
1	Hosting Agreement Signed	Q3 2016	Q4 2018
2	Begin Initial Infrastructure Works	Q1 2021	Q1 2022 (advanced funds only)
3	Start of ERIC Legal Entity	T0	
4	Formal Start of CTAO Construction Project (incl. construction funding available)	T1 = T0 + 6 months	
5	Complete Initial Infrastructure Works	T1 + 30 Months	T1 + 36 months
5a	First telescope construction starts on-site	LST underway MST Q2-2023	MST: 2025 ??
6	Acceptance of First Telescope on Site	T1 + ?? months	T1 + 30 months
7	Begin System Commissioning & Science Verification (needs two telescopes)	T1 + 12 months	T1 + 31 months
8	Completion of Construction Project	T1 + 60 months	T1 + 60 months

alfa configuration: 2029/2030