CTA – Cherenkov Telescope Array

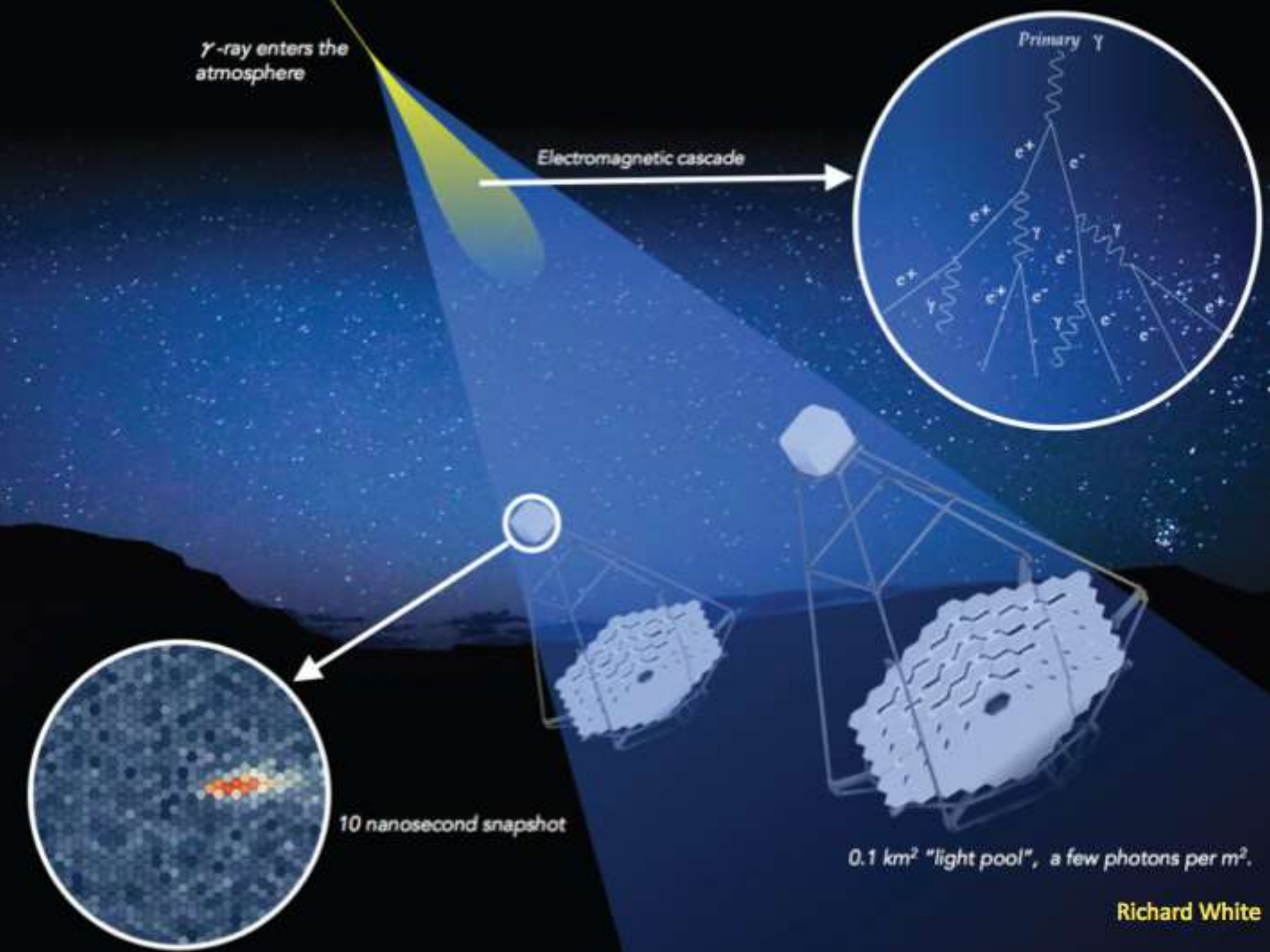
HECAP Meeting

Elisabete Maria de Gouveia Dal Pino

IAG –Universidade de São Paulo (IAG-USP)

(On behalf of CTA-Br Collaboration)

July 2020, São Paulo, Brasil


γ-ray enters the atmosphere
Electromagnetic cascade
Primary γ
10 nanosecond snapshot
0.1 km² "light pool", a few photons per m².
Richard White

A Global Observatory: 2 sites in north and south

The CTA Consortium

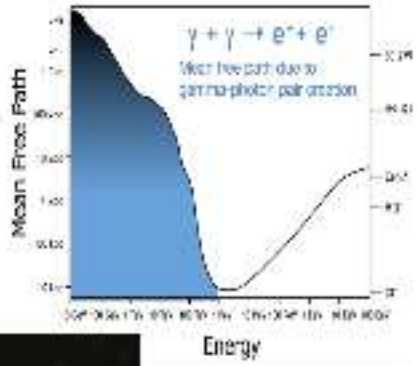
cortesy: Ulisses Barres de Almeida

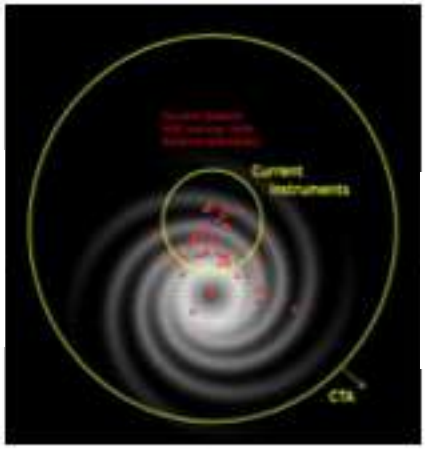
The CTA Consortium

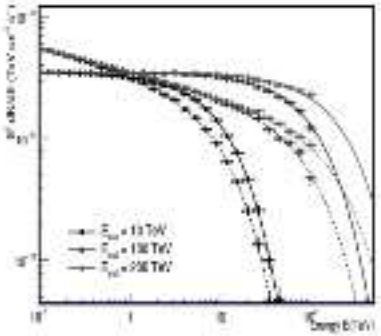
Now in a transition phase as the project moves from project & design stage to construction & operations.

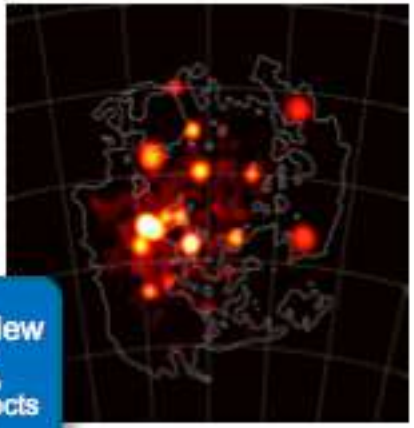
Design Drivers

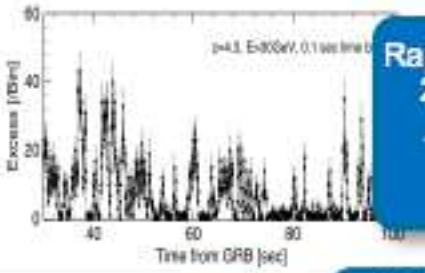
Werner Hofmann











10 x Sensitivity, Large Collection Area → all topics

Energies down to 20 GeV → Cosmology++

Energies up to 300 TeV → Pevatrons

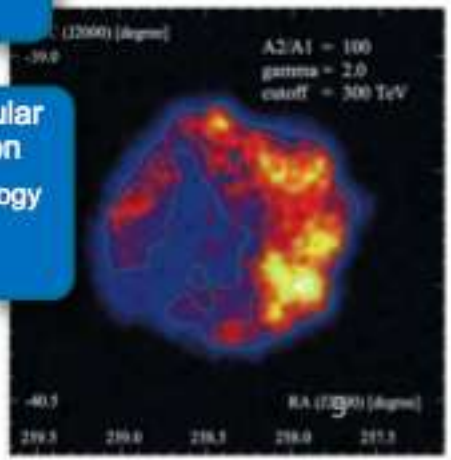
Rapid Slewing in 20 seconds → transients

8° Field of View → surveys, extended objects

cta

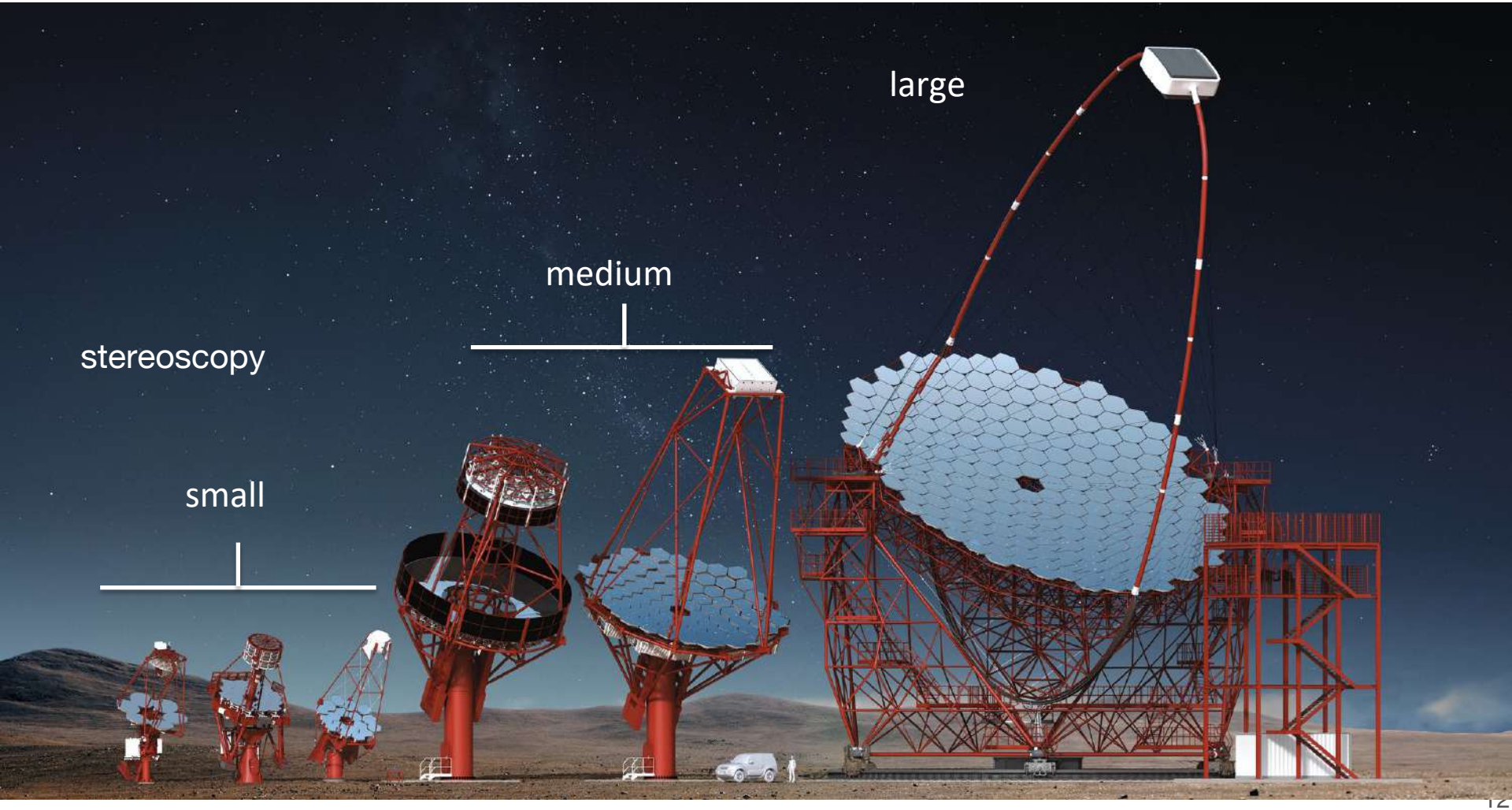
10% Energy Resolution → lines, features

Few ' Angular Resolution → morphology



See “Science with the Cherenkov Telescope Array” book by World Scientific, also @ arXiv:1709.07997

THE CTA TELESCOPE PROTOTYPES



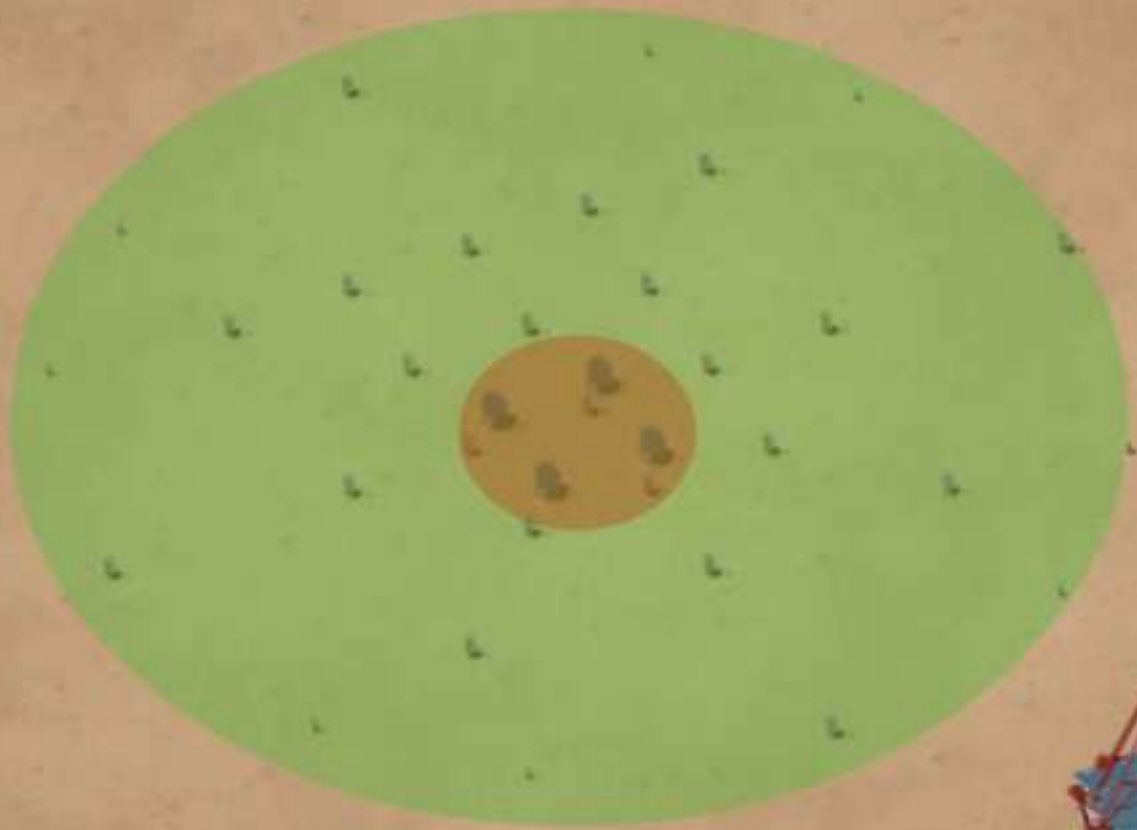

10 GeV
100 GeV
1 TeV
10 TeV
100 TeV
1000 γ / h km²
10 γ / h km²
0.1 γ / h km²
Southern array
of Cherenkov telescopes
- about 3 km across
Also stolen from Werner Hofmann!

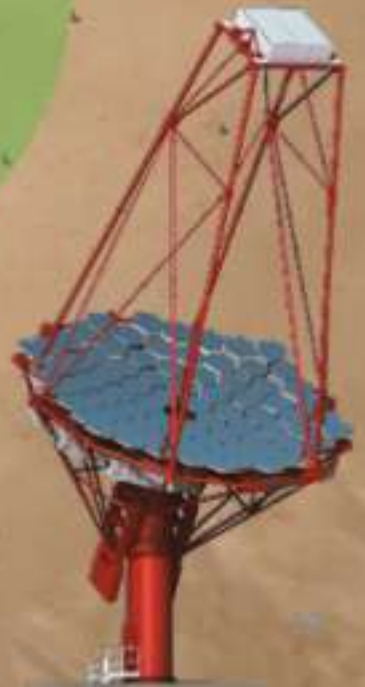
10 GeV | 100 GeV | 1 TeV | 10 TeV | 100 TeV

4 x 23 m ø Large Size Telescopes (LST)

10 GeV | 100 GeV | 1 TeV | 10 TeV | 100 TeV

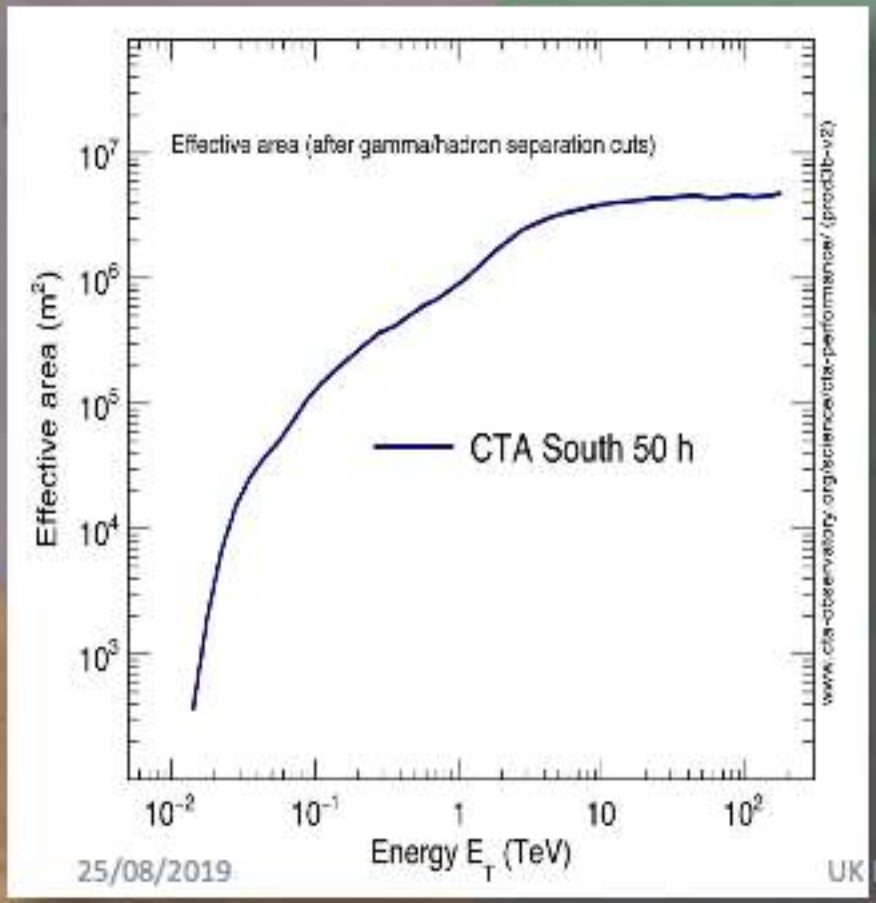
25 x 12 m ø Medium Size Telescopes (MST) (North: 15)





10 GeV | 100 GeV | 1 TeV | 10 TeV | 100 TeV

70 x 4 m ø Small Size Telescopes (SST) (South)



Brazilian Involvement

Slide by V. de Souza

CTA Brazil

12 Institutions
38 Scientists
14 Students
5 Technicians

CTA - SP - MST

- IFSC- USP
  - Prof. Vitor de Souza
  - Profa. Manuela Vecchi
  - Profa. Cibelle Celestino
  - Dr. Humberto Huerta
  - Dr. Aion Viana
  - Edyvania Martins
  - Rodrigo Lang
  - Luan Arbeletche
  - Andres Delgado
  - Rodrigo Guedes Lang
  - Danielle Kaori
- IF-USP
  - Prof. Edivaldo Moura
  - Douglas Pimentel
- UFABC
  - Prof. Marcelo Leigui
  - Raquel de Almeida
- UFSCar
  - Dr. Gustavo Rojas
- UFPR
  - Prof. Rita de Cássia
- EEL / USP
  - Prof. Fernando Catalani
  - Prof. Carlos Todero
- SAIFR / IFT - UNESP ....
  - Dr. Fabio Iocco
  - Dr Ekaterina Karukes
  - Maria Benito

CTA – Rio (LST)

- CBPF
  - Prof. Ulisses de Almeida
  - Prof. Ronald Shellard
  - Bruno Arsioli
  - Bernardo Fraga...
  - Rodrigo Cardoso
  - Amanda Carvalho

CTA - SP – SST (ASTRI Mini-Array)

- IAG – USP
  - Profa. Elisabete de Gouveia Dal Pino
  - Prof. Reinaldo Santos-Lima
  - Prof. Antonio Mario Magallaes
  - Prof. Rodrigo Nemmen
  - Dr. Paramita Barai
  - Dr. Rafael Alves-Batista
  - Dr. Chandra Singh
  - Dr. Luis Kadowki
  - Dr. Claudio Melioli
  - Dr. Juan Ramirez-Rodriguez
  - Tania Torrejon
  - Renato Gimenes (Eng.)
  - Pankaj Kushwaha
  - Saqib Hussein
  - Carlos Fermino (Eng.)
  - Raniere Menezes
  - William Bohórquez
  - Lucas Santos
- UNICSul
  - Prof. Anderson Caproni
- EACH / USP ....
  - Prof. Diego Falceta-Gonçalves
  - Prof. Grzegorz Kowal
  - Dr. Mohammad Ali

ASTRI SMALL SIZE TELESCOPE

ASTRI SST
4 m telescope
70 SSTs for CTA

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

IAG INSTITUTO DE ASTRONOMIA, GEOFÍSICA E CIÊNCIAS ATMOSFÉRICAS
USP Universidade de São Paulo

FAPESP

CTA Mini-Array Precursor @ Canarias

9 SST telescopes in construction:
3 structures from Brasil
(IAG-USP, FAPESP funding)

(Talk by Reinaldo Santos-Lima)

MEDIUM SIZE TELESCOPE (MST)

12 m telescope

25 MSTs in South
15 MSTs in North

Brazil developed support of the camera (UFSC-USP, FAPESP funding)

(talk by Vitor de Souza)

Universidade de São Paulo

FAPESP

Berlin
MST prototype

LARGE SIZE TELESCOPE (LST)

23 m telescope

4 LSTs in South
4 LSTs in North

Brazil developed support components for strcuture (CBPF, FAPERJ funding)

CBPF

FAPERJ
Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
MCTIC

LA PARTICIPATION IN CTA *so far*

CTA: 400 MEuro, 31 countries average contribution ~13 MEuro

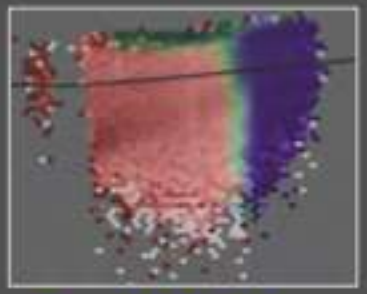
BRAZIL so far: 3.5 MEuro

- **University of São Paulo (FAPESP funding)**: **3.5 MEuro**
  - **For ASTRI SST** development (IAG-USP): **3.1 MEuro**
  - **For MST** structure development (IFSC-USP): **360 KEuro**
- **CBPF (FAPERJ): For LST** structure development : **~50 KEuro**

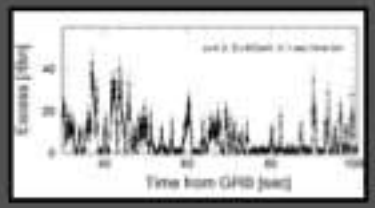
CHILE: 1 MEuro (secured)

CTA Key Science Projects

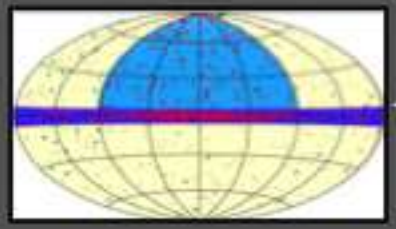
See “Science with the Cherenkov Telescope Array” book by World Scientific, also @ arXiv:1709.07997



Dark Matter Programme



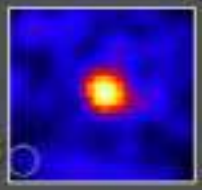
Transients



ExGal Survey

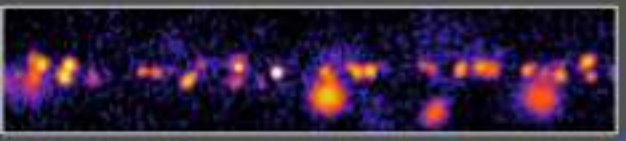
Extragalactic

Galaxy Clusters



Star Forming Systems

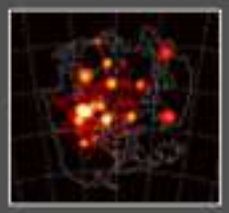
AGN



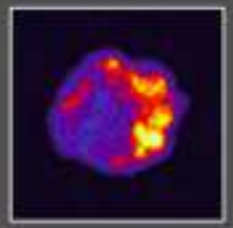
Galactic Plane Survey

Galactic

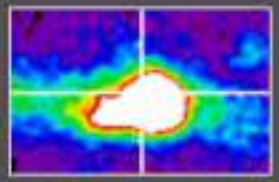
LMC Survey



PeVatrons



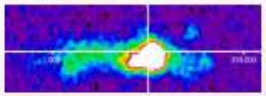
Galactic Centre Survey



cta cherenkov telescope array

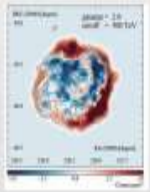
Key Science projects

Galactic Centre

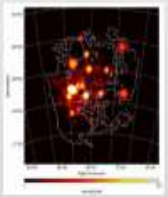


Galactic Plane Survey

Cosmic Ray PeVatrons

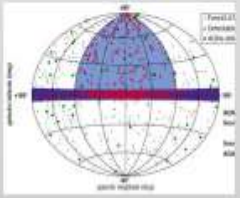


Star Forming Systems



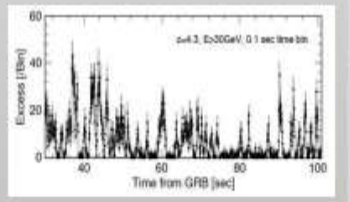
LMC Survey

Extragalactic Survey



Active Galactic Nuclei

Transients



Clusters of Galaxies

Dark Matter Programme

arXiv:1709.07997

cta cherenkov telescope array

Science with the Cherenkov Telescope Array

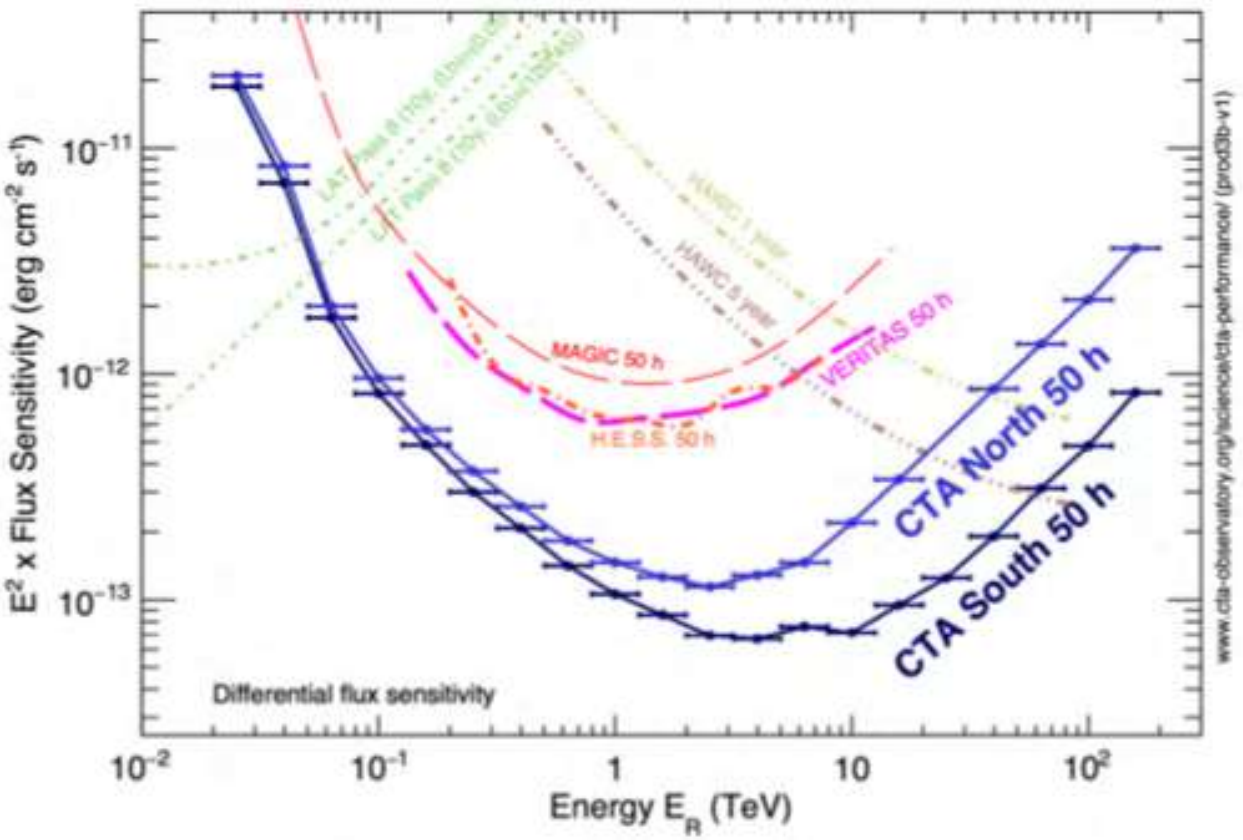
The Thick of CTA Science

- **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 on star formation and galaxy evolution?

- **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?

- **Exploring Frontier Physics**
  - What is the **nature of dark matter**? How is it distributed?
  - Are there quantum gravity effects on photon propagation?
  - Do axion-like particles exist?

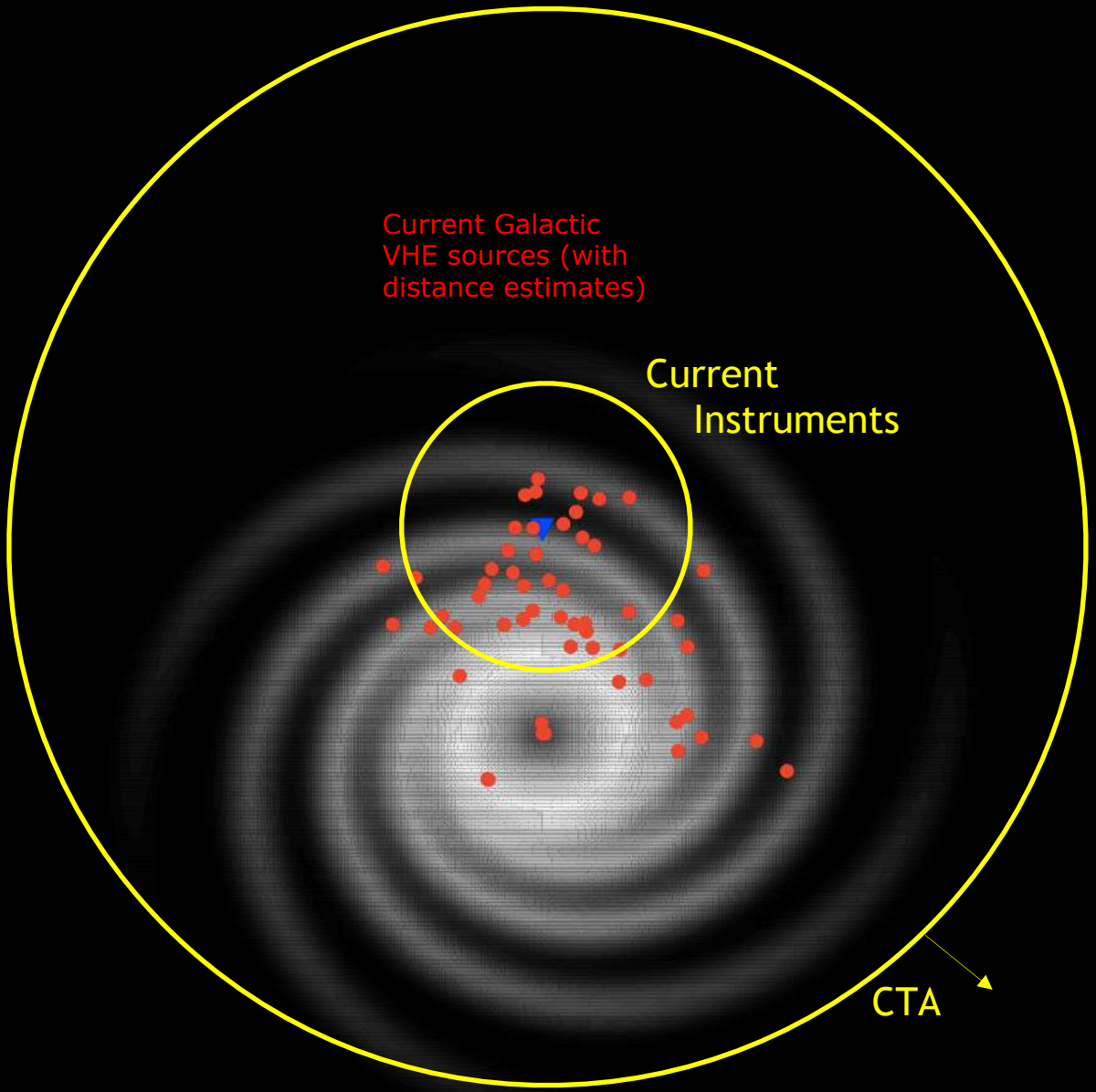
CTA Performance in Context I



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

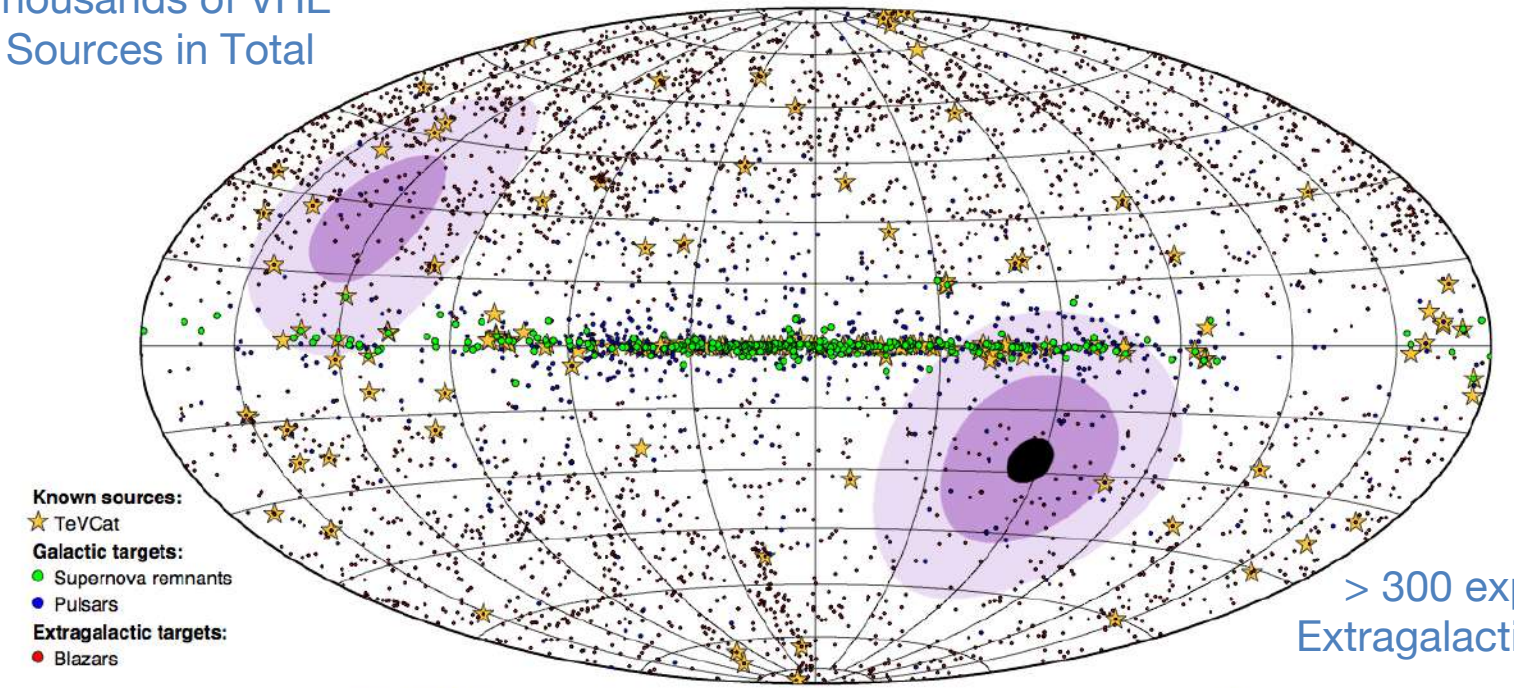
A factor of **5-20x improvement** in differential sensitivity relative to current IACTS

Extension of the accessible energy range **from below 100 GeV to above 100 TeV**

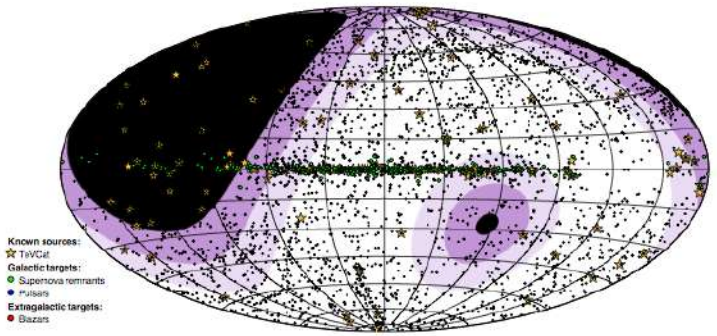

Current Galactic
VHE sources (with
distance estimates)
Current
Instruments
CTA

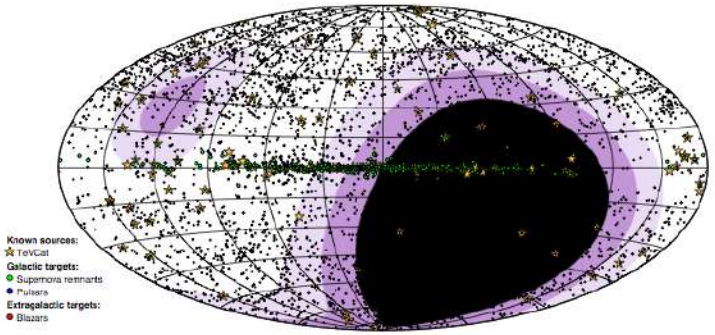
THE EXPECTED CTA ALL SKY VIEW

Thousands of VHE Sources in Total



> 300 expected Extragalactic Objects



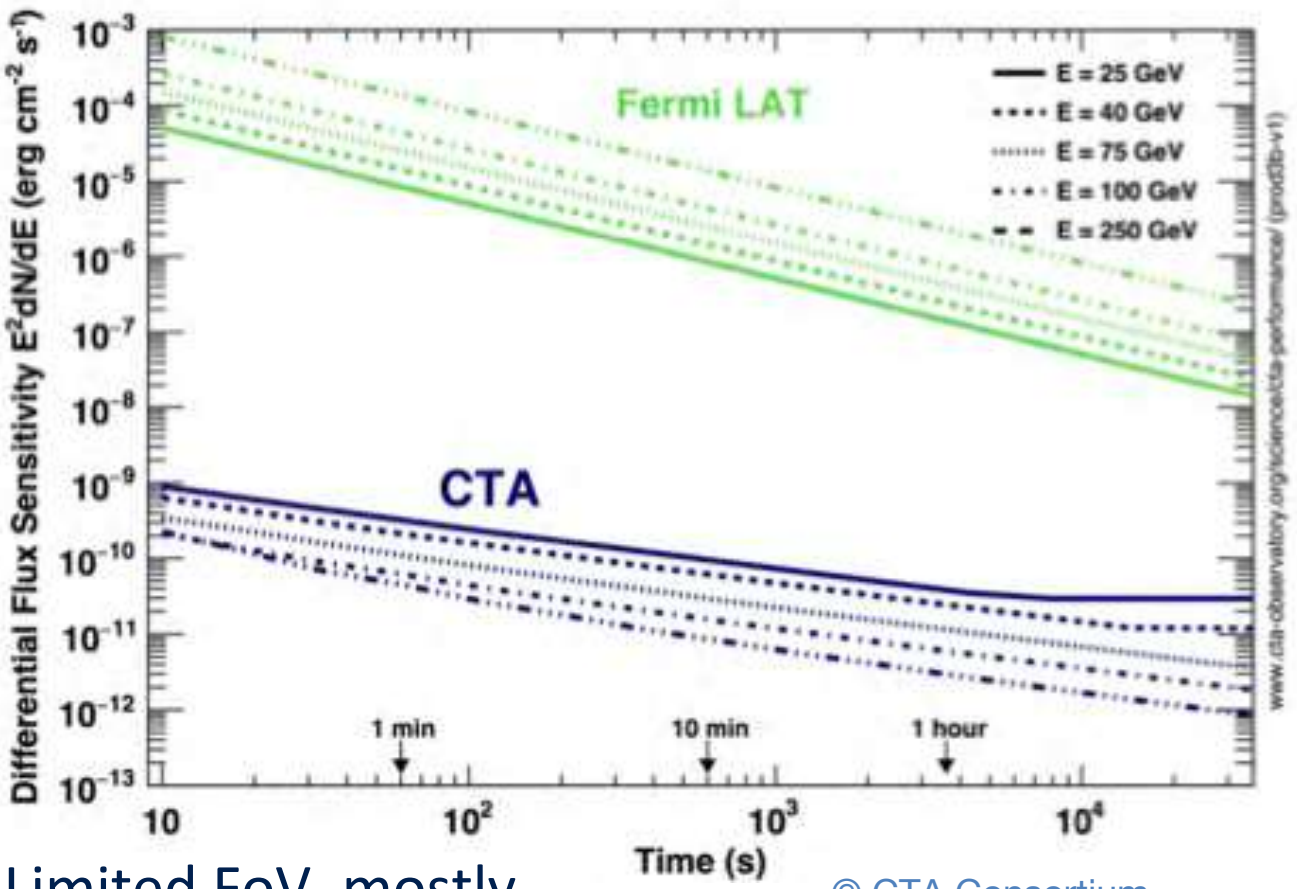


Credits: CTA Consortium

CTA Performance in Context II

CTA will be a high-energy **transient monitor**

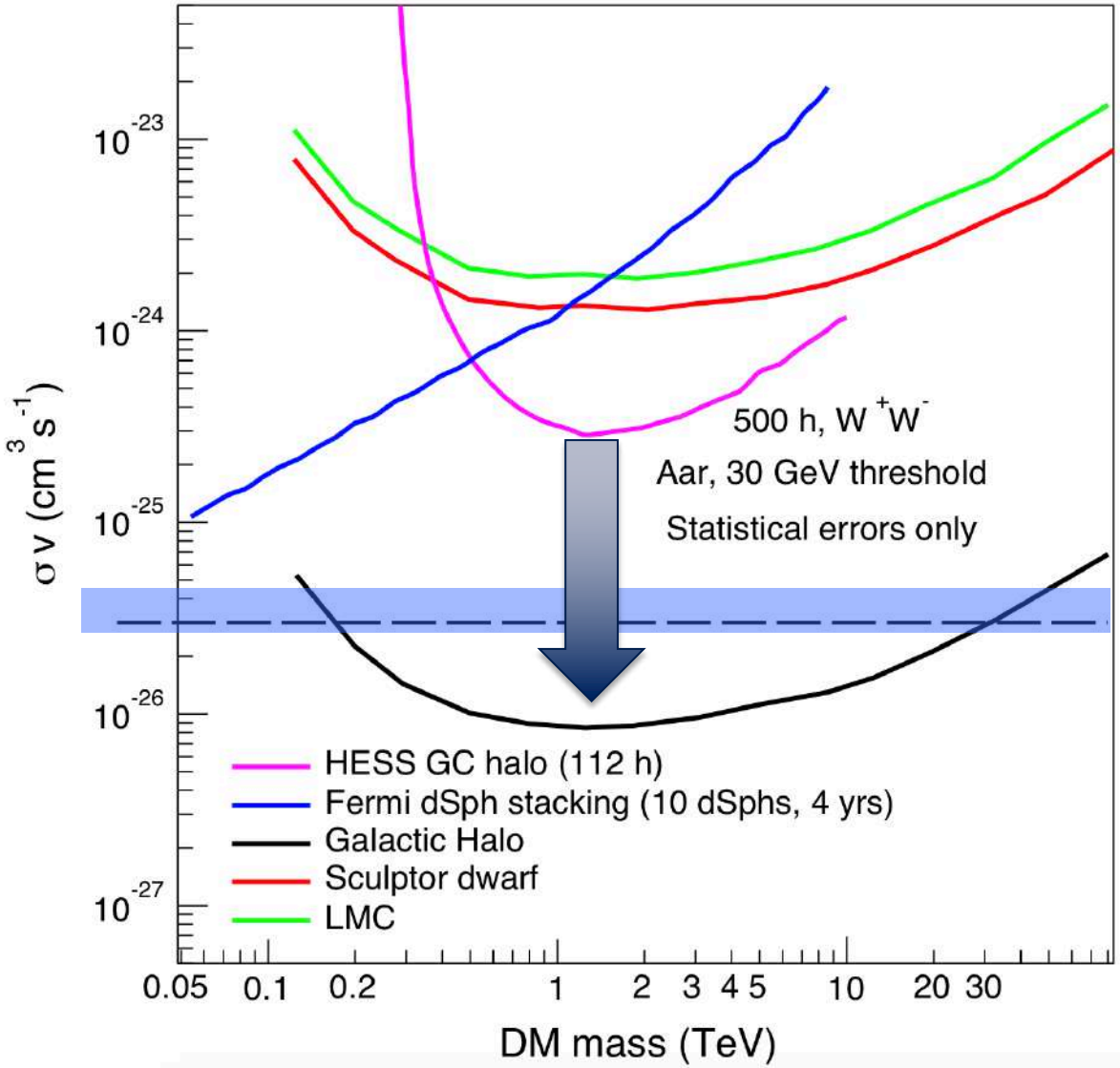
Orders of magnitude **advantage over Fermi-LAT** in intra-day timescales: GRBs, AGN flares, binaries.



Caveat & Synergies: Limited FoV, mostly depending on external triggers.

© CTA Consortium, "Science with CTA Book"

Dark matter annihilation

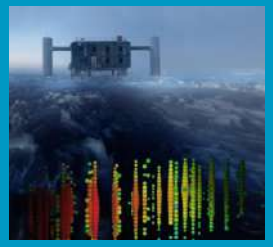


Canonical cross section

Multi-messenger science

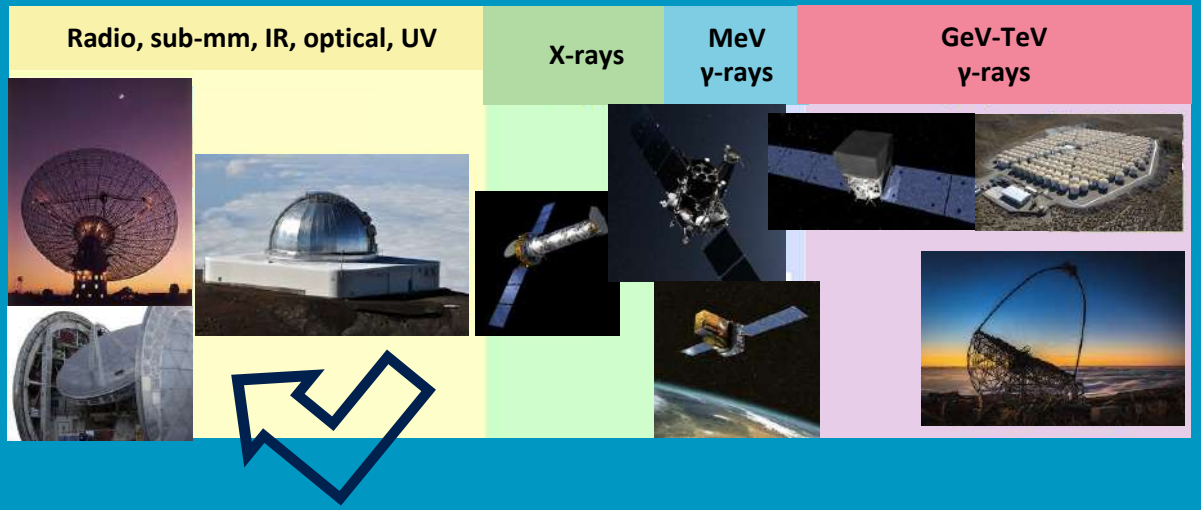
Large MWL follow-up campaigns

Recent IceCube neutrino & GW events, and the sub-TeV GRB detection by MAGIC sparked large MWL / MM follow-up campaigns



ALERTS

ALERTS



low latency searches for EM counterpart IDs

- Over 150 instruments participate in follow-up campaigns of such events and related MoUs; dozens of alerts in past years.
- Follow-up & RTA searches covering entire EM.

Credit: Ulisses Barres de Almeida

Follow-up campaigns of validated events

THE LAST MILESTONE

Towards Construction:
CTA North (La Palma): started construction
CTA South (Paranal, Chiel): site preparation

Threshold Implementation first :
North: 4 LSTs, 5 MSTs
South: 15 MSTs, 50 SSTs

Baseline -> final goal:
North: 4 LSTs, 15 MSTs
South: 4 LSTs, 25 MST, 70 SSTs

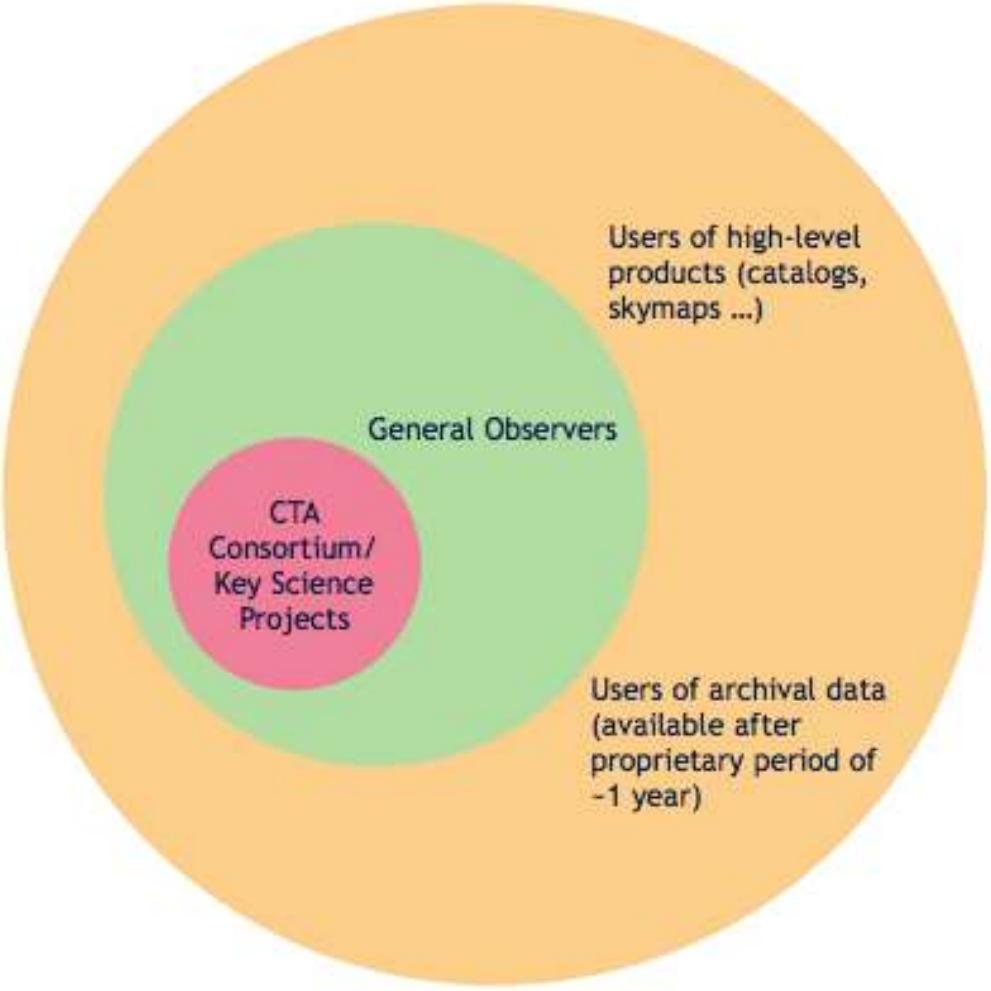
cherenkov telescope array

Universidade de São Paulo

Thank you very much!

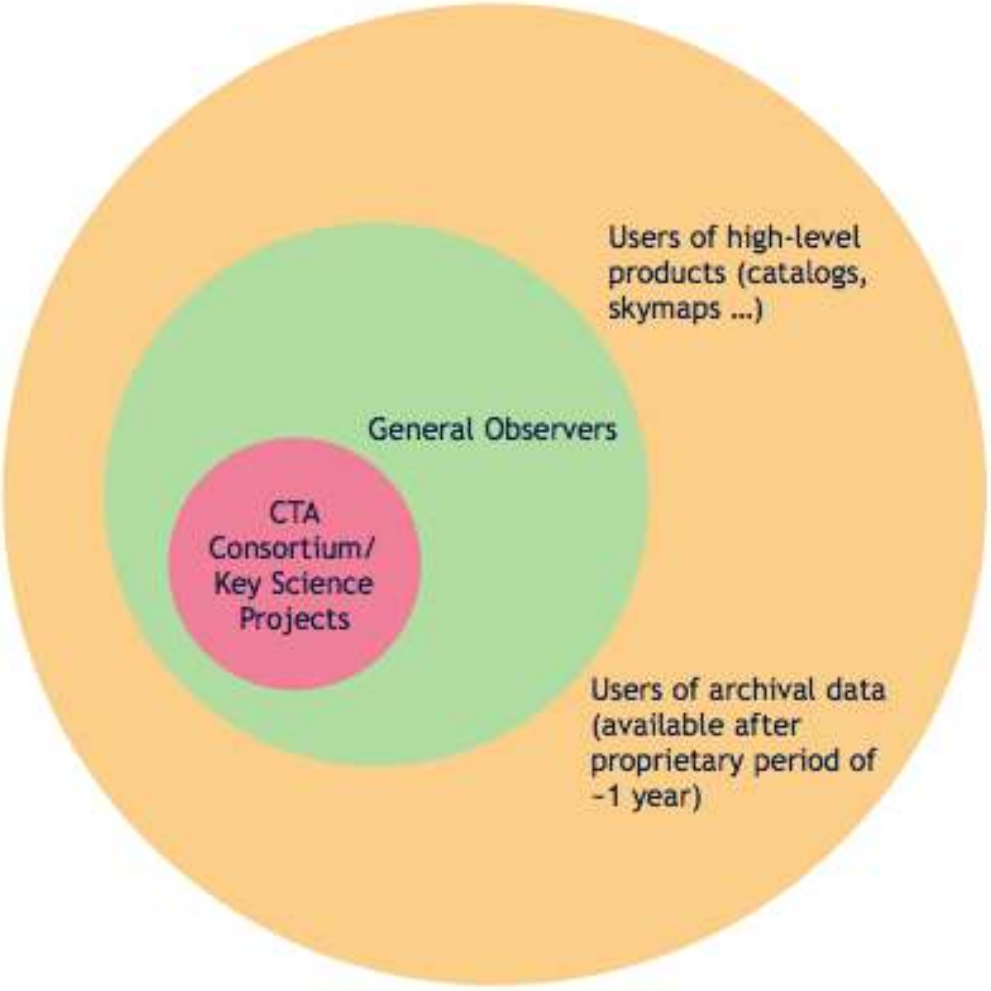
Open Observatory and Key Science Programme

CTA will function in two modes in the first decade



Open Observatory and Key Science Programme

CTA will function in two modes in the first decade



- Consortium Key Science Projects
  - 40% of the time for 10 years
  - legacy datasets for general observers
  - **all data** ultimately public
- Galactic KSPs
  - Galactic Plane Survey
    - Deep view of key topics: Galactic Center, PeVatrons, Star Forming Systems.
- Extragalactic KSPs
  - First Extragalactic Survey
- Dark Matter Programme

SMALL SIZE TELESCOPE

Great News:

ASTRI SST structure (+CHEC camera) chosen to be THE 70 SSTs of CTA

(Talk by Reinaldo Santos-Lima)