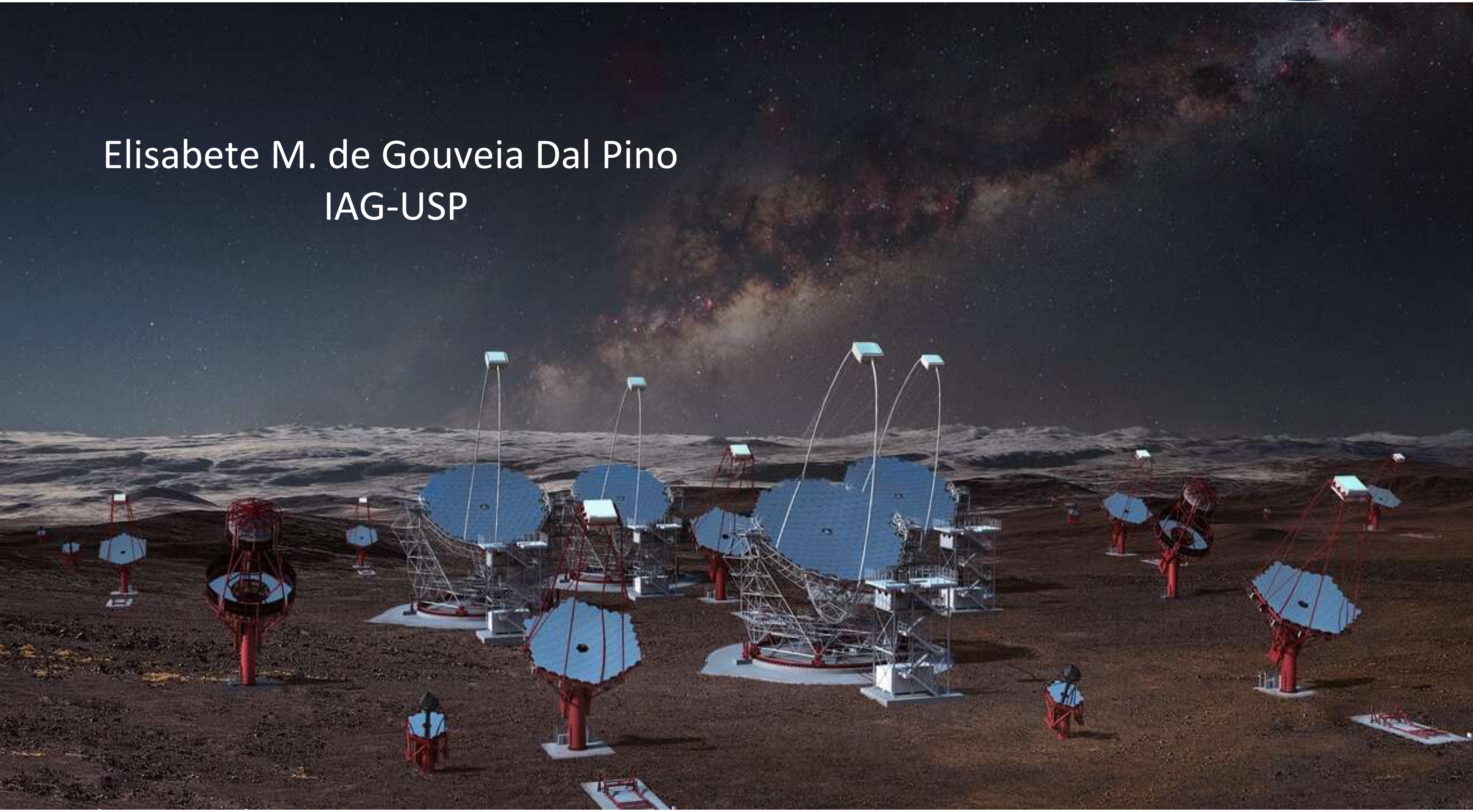
Cherenkov Telescope Array Astrophysics
& the ASTRI Mini-Array

Elisabete M. de Gouveia Dal Pino
IAG-USP

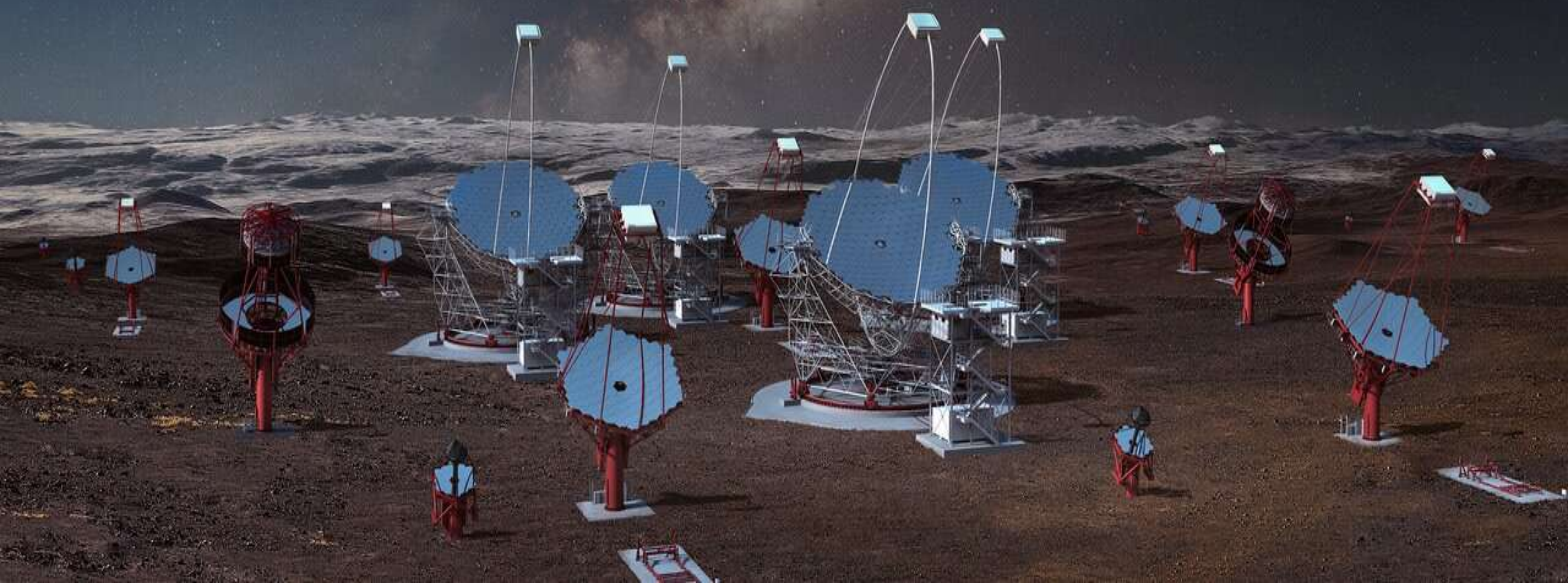


ICTP-SAIFR CTA Advanced School, March 27th, 2023

Universidade de São Paulo

Contents

- CTA concept
- CTA performance
- CTA science: astrophysics and beyond
- ASTRI Mini-Array – CTA Precursor

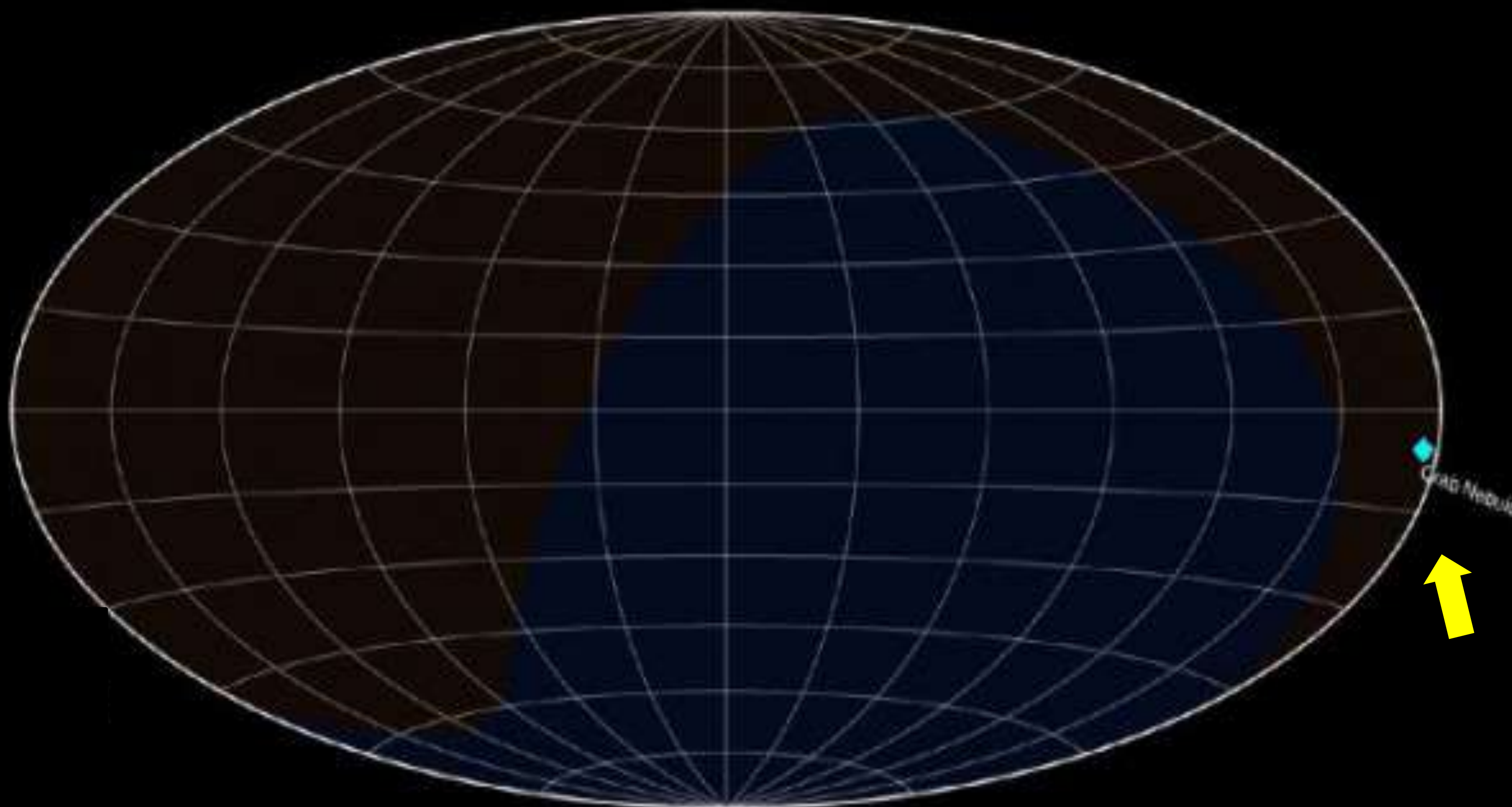


30 years ago

The High-Energy Gamma Ray Sky (1989)

E > 100 GeV

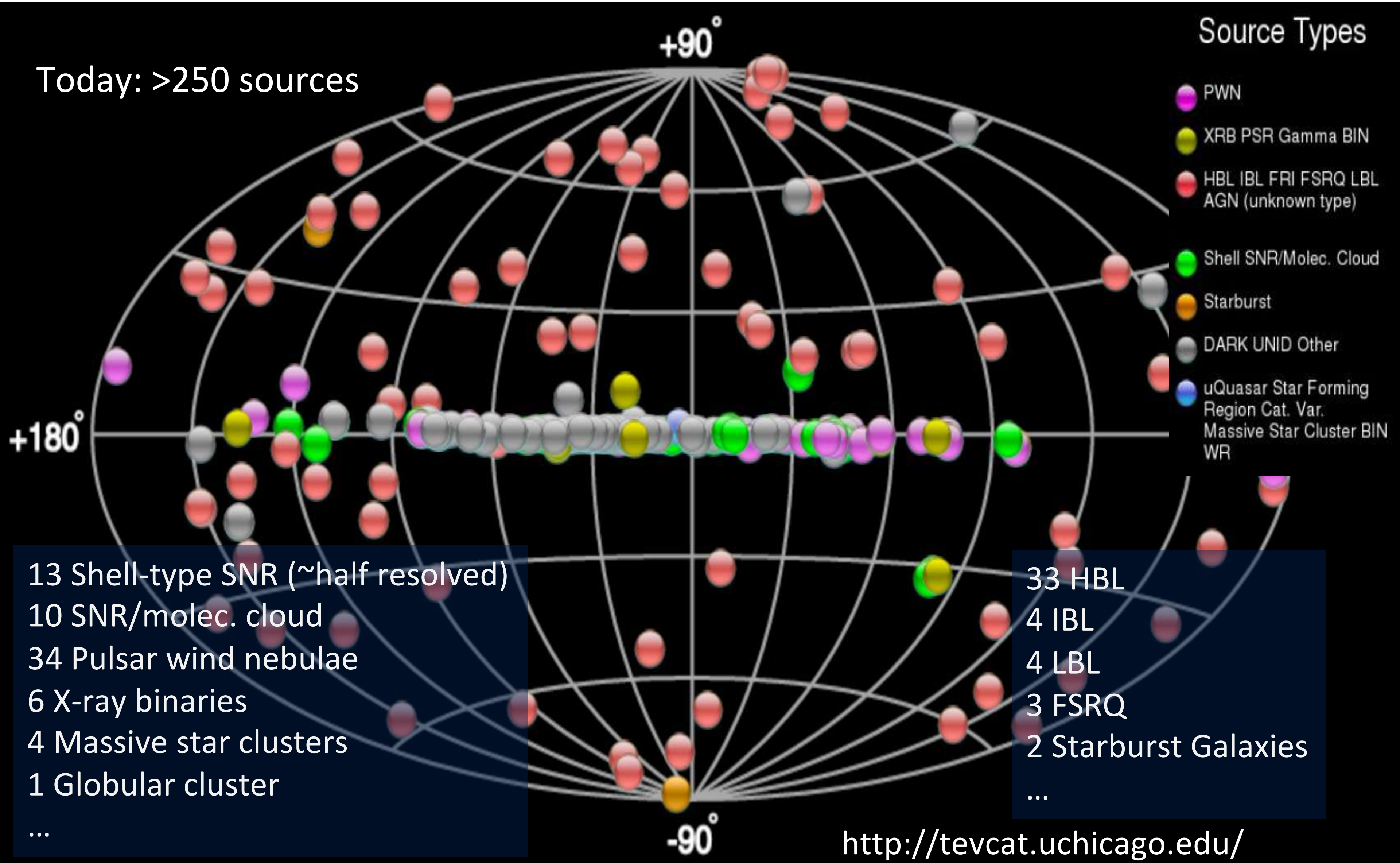
(Galactic coordinates)



Background colours indicating northern / southern sky

The TeV sky

Today: >250 sources



13 Shell-type SNR (~half resolved)
10 SNR/molec. cloud
34 Pulsar wind nebulae
6 X-ray binaries
4 Massive star clusters
1 Globular cluster
…

33 HBL
4 IBL
4 LBL
3 FSRQ
2 Starburst Galaxies
…

http://tevcat.uchicago.edu/

Major TeV observatories

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

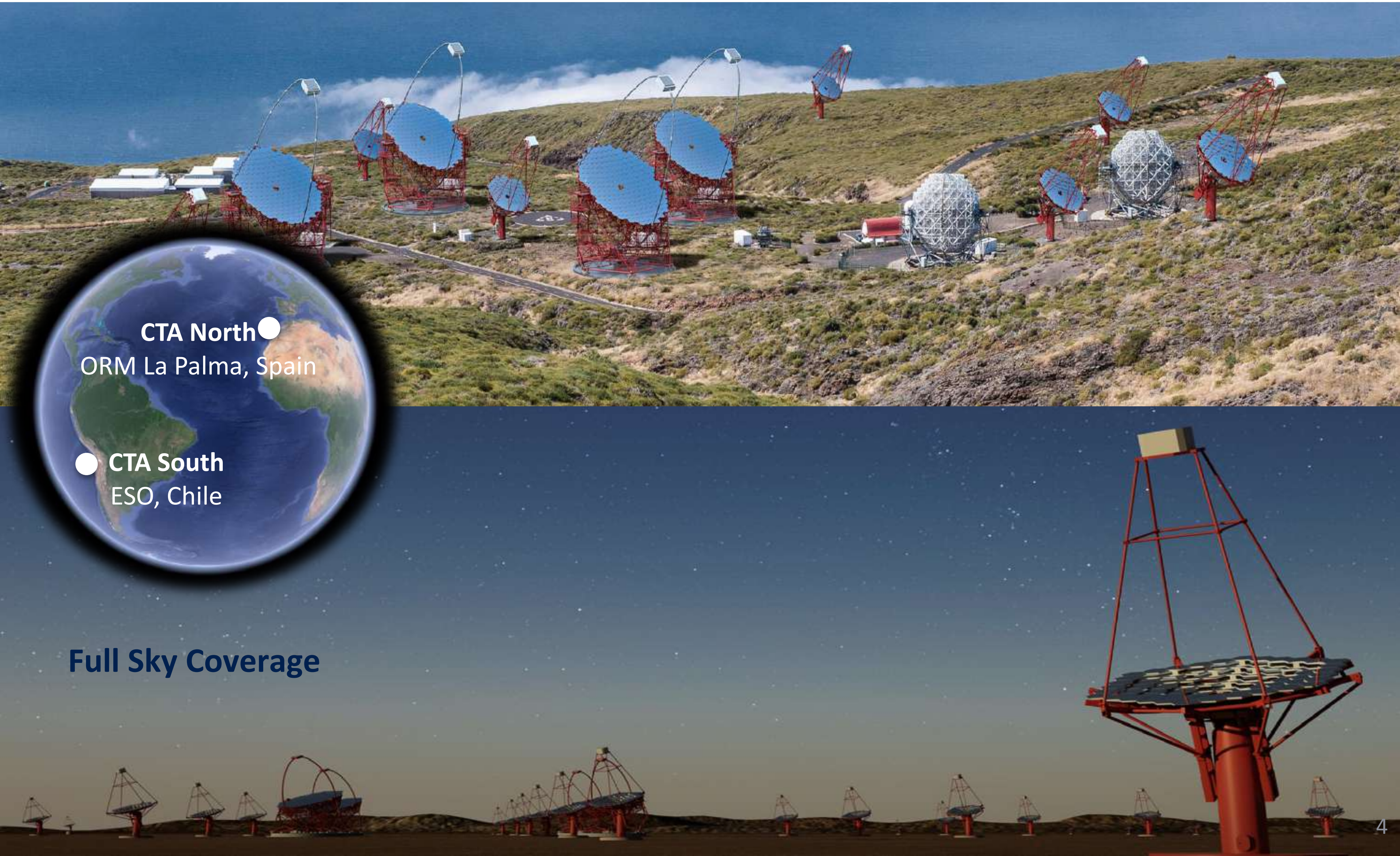
HAWC
Particle-detector water tanks (2015)

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

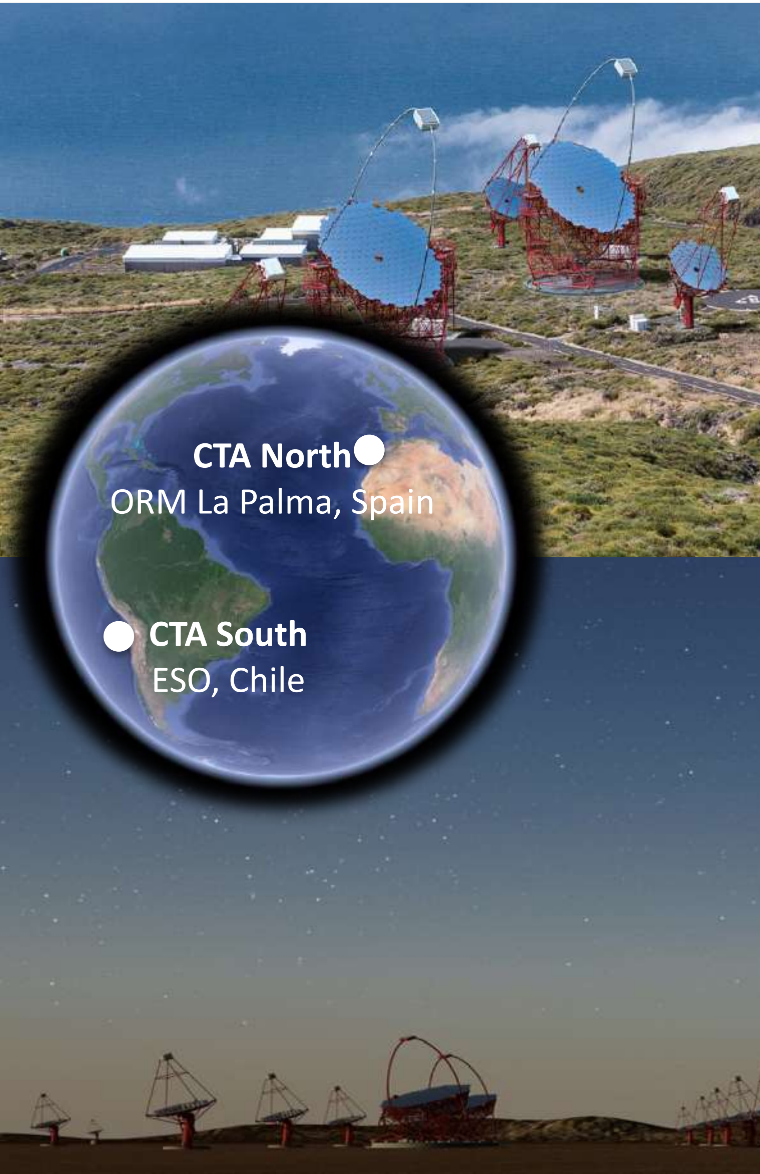
LHAASO
Particle-detector water tanks
+ 18 Small-Sized Tels ('SSTs')
since 2018

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

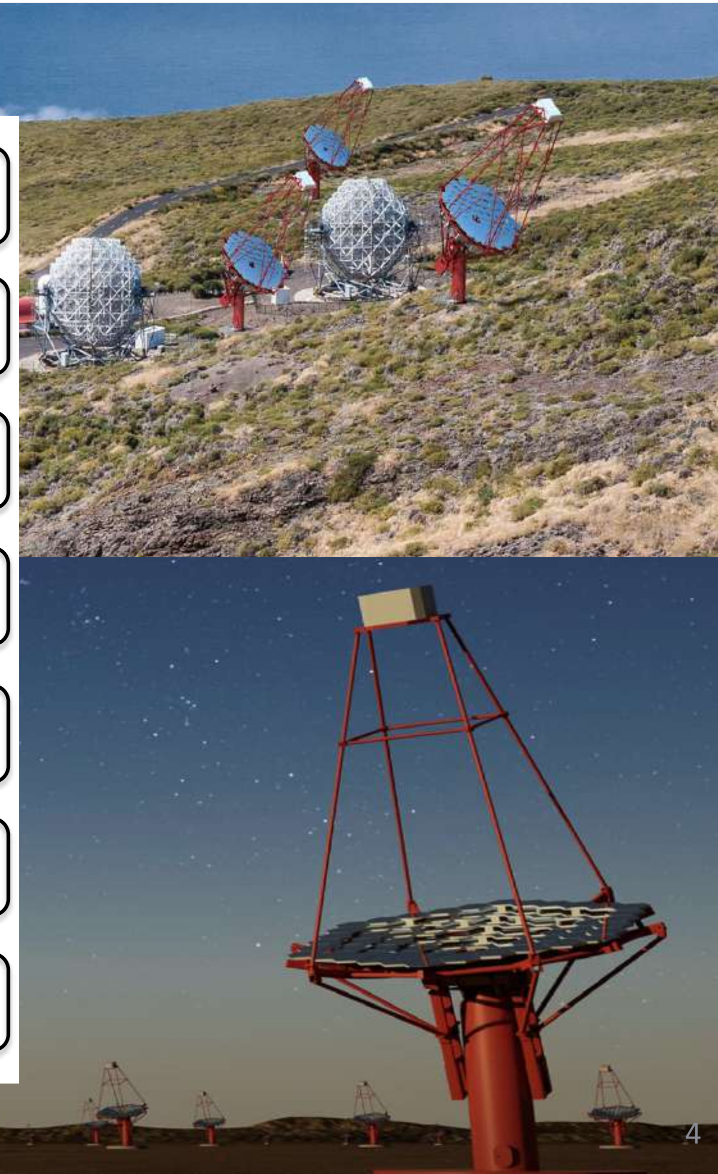
Why to build CTA?



Why to build CTA? Key Capabilities



- SENSITIVITY x 10
- ARCMINUTE ANGULAR RESOLUTION
- 10% ENERGY RESOLUTION
- WIDE ENERGY RANGE 20 GeV – 300 TeV
- FoV x 2
- FULL SKY COVERAGE
- 30 s RESPONSE TO EXTERNAL ALERTS



CTA Science Questions *in Astrophysics and beyond*

Theme 1: Cosmic Particle Acceleration

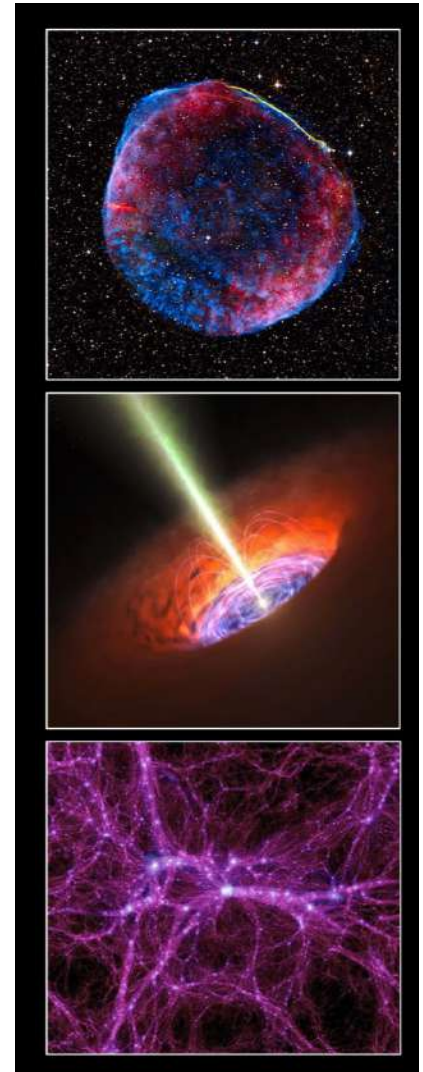
- How and where are particles accelerated?
- How do they propagate?
- What is their impact on the environment?

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?

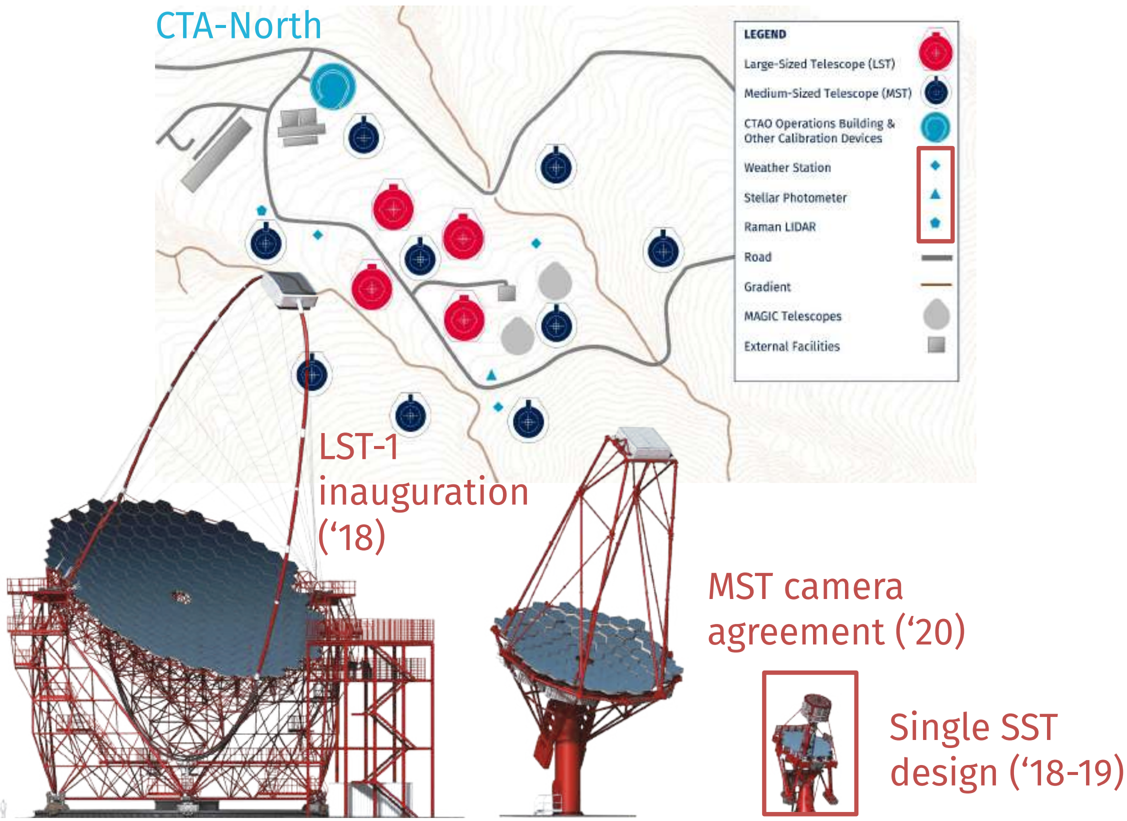


Initial CTA Array: α-configuration

Science-based optimization

North: extragalactic oriented (high-*E*/*z* absorption)

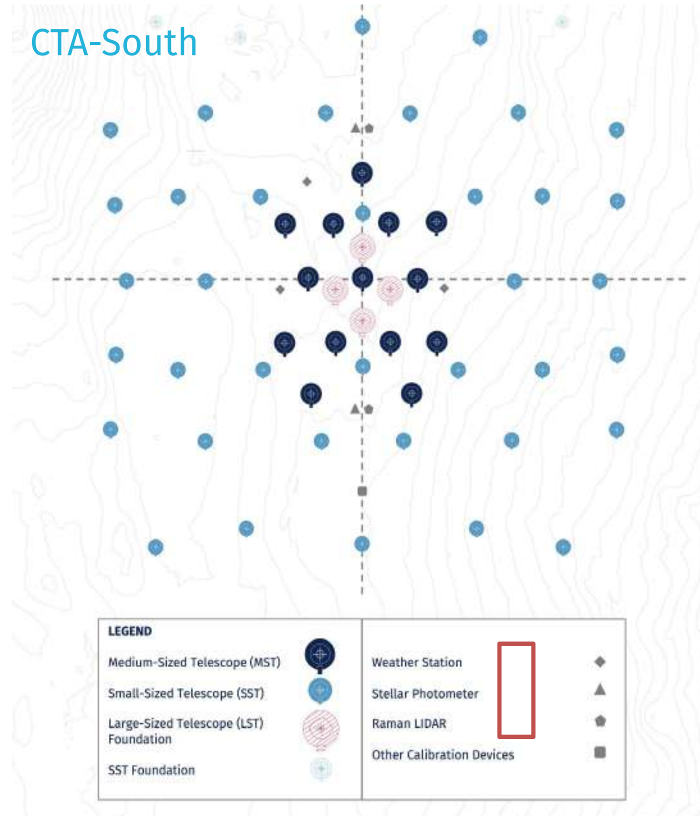
CTA-North



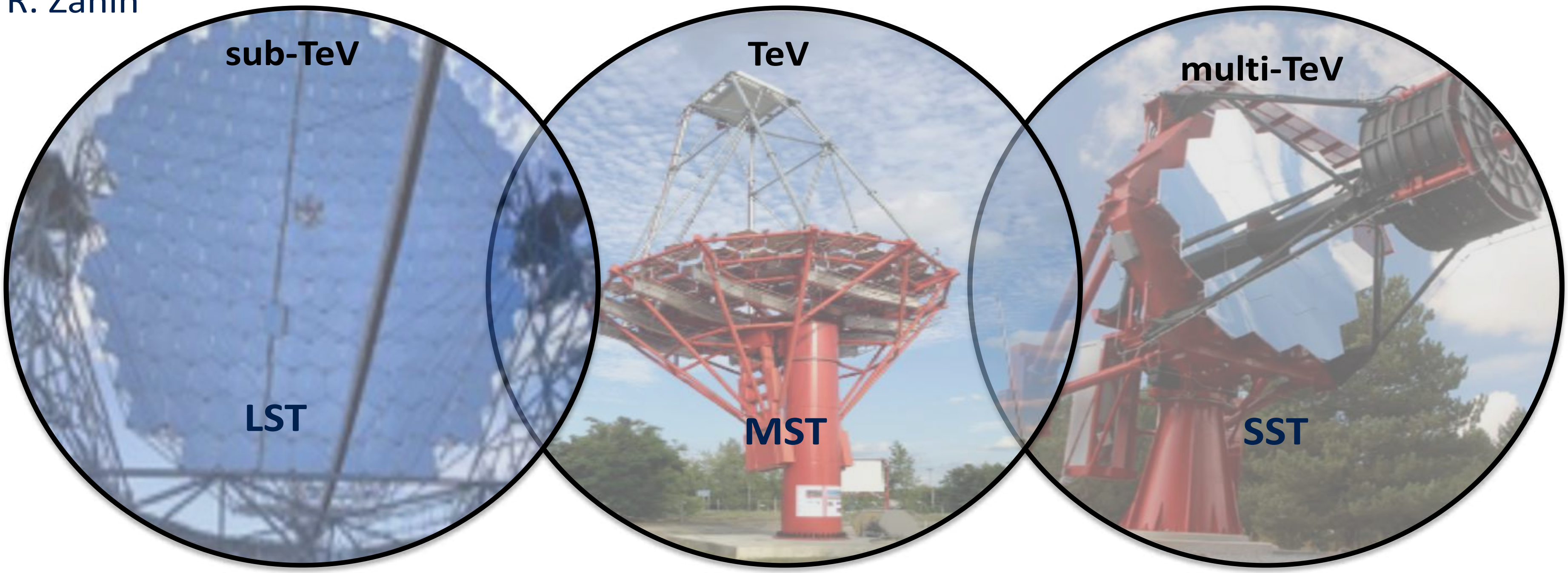
Shower-based optimization

LSTs ~20-200 GeV, MSTs 0.2-2 TeV, SSTs >2 TeV

CTA-South



CTA Science and Design



- Parabolic optical design
- 23 m mirror diameter
- PMT camera
- ~4 deg FoV
- 4 LSTs at the array center

- Davies-Cotton optical design
- 12 m mirror diameter
- PMT camera
- ~7 deg FoV
- MSTs are workhorse
- ~1km² area covered

- Schwarzschild-Couder optical design
- 4 m dual mirror
- SiPM camera
- ~8 deg FoV
- >50 SSTs

~4km² area coverage

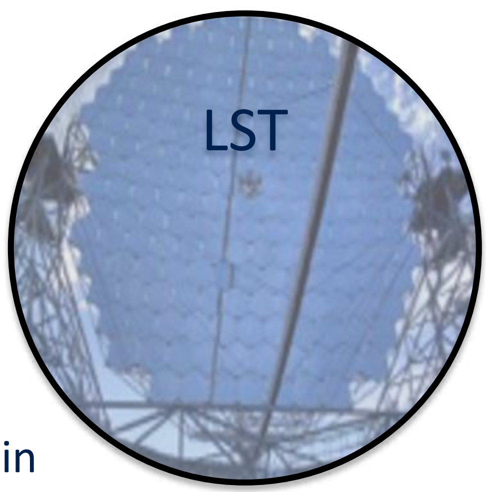
CTA Science and Design

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

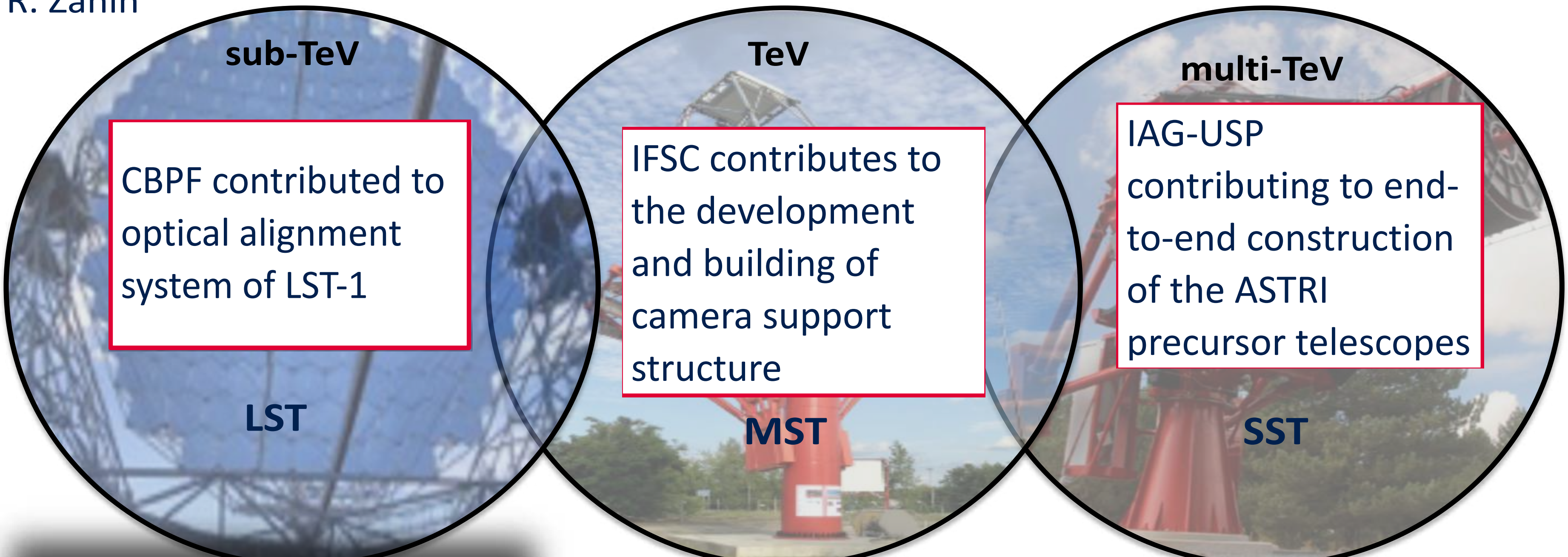
TeV
- EBL
- Surveys
- Morphological studies
- Dark matter
- UHE neutrinos
- Extreme blazars

multi-TeV
- PeVatrons
- Star-forming regions
- Galactic plane survey
- Neraby galaxies

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



CTA Science and Design: Brazil @ cta



sub-TeV

CBPF contributed to optical alignment system of LST-1

LST

TeV

IFSC contributes to the development and building of camera support structure

MST

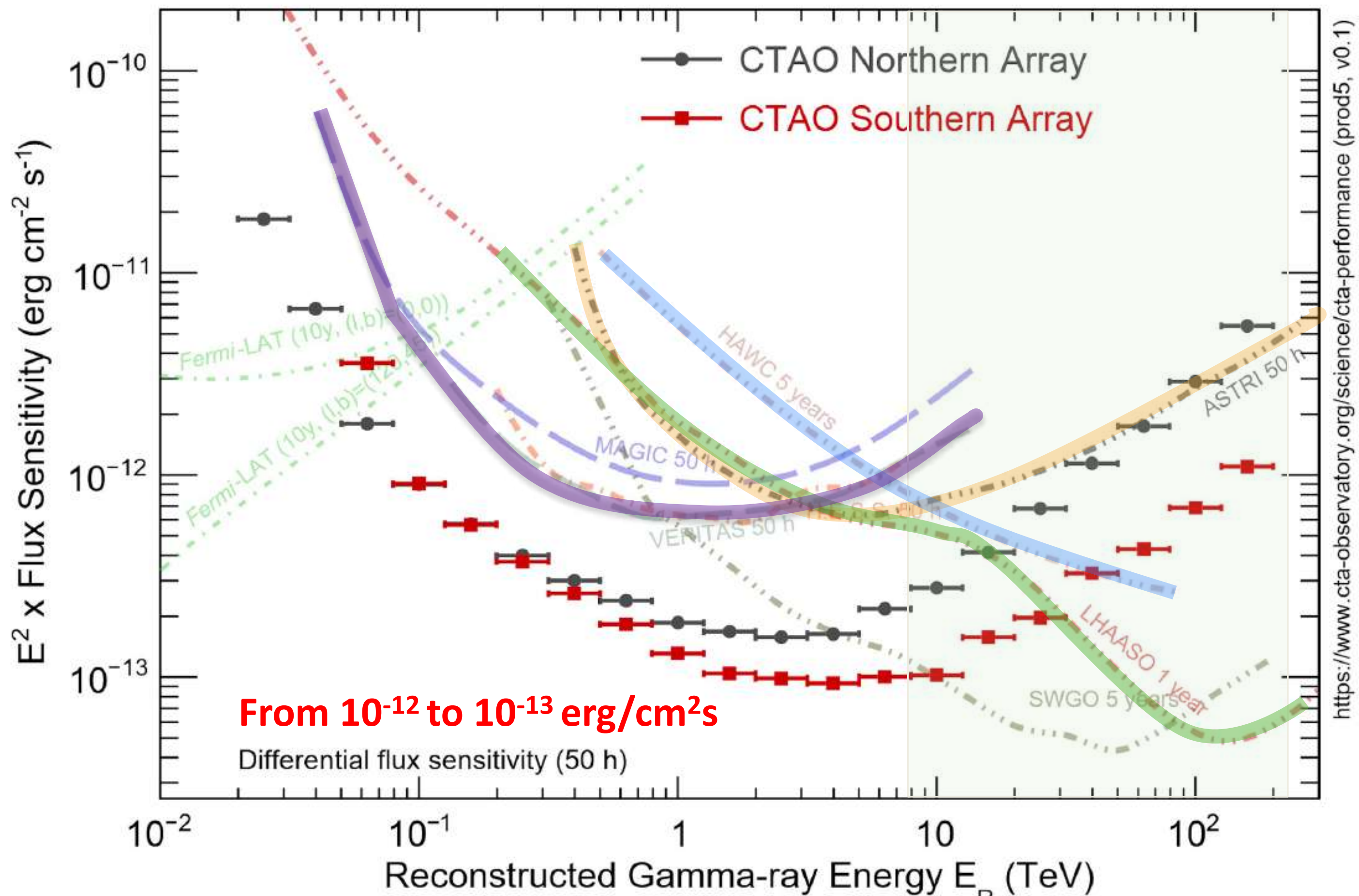
multi-TeV

IAG-USP contributing to end-to-end construction of the ASTRI precursor telescopes

SST

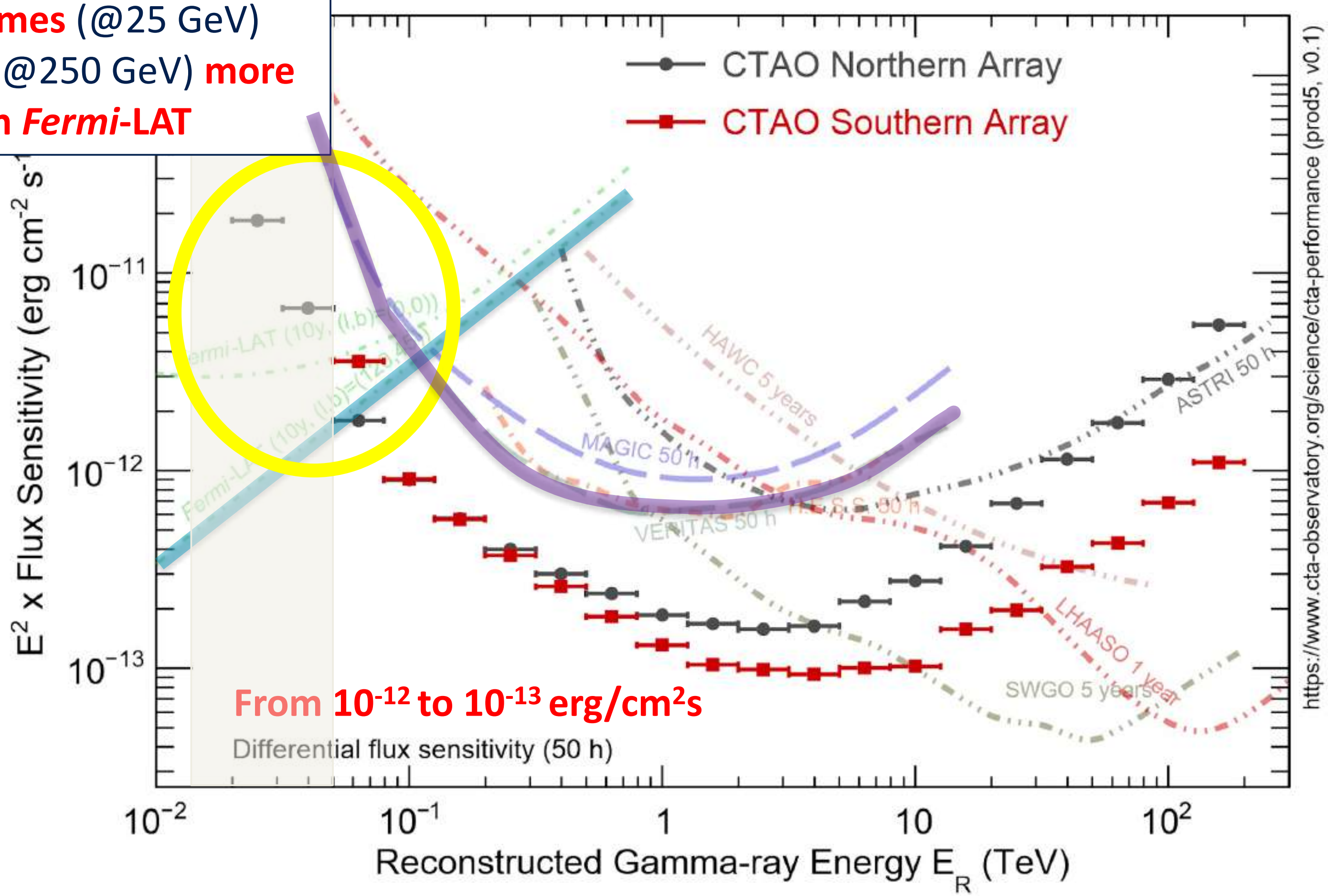
CTA comparative performance

α-configuration



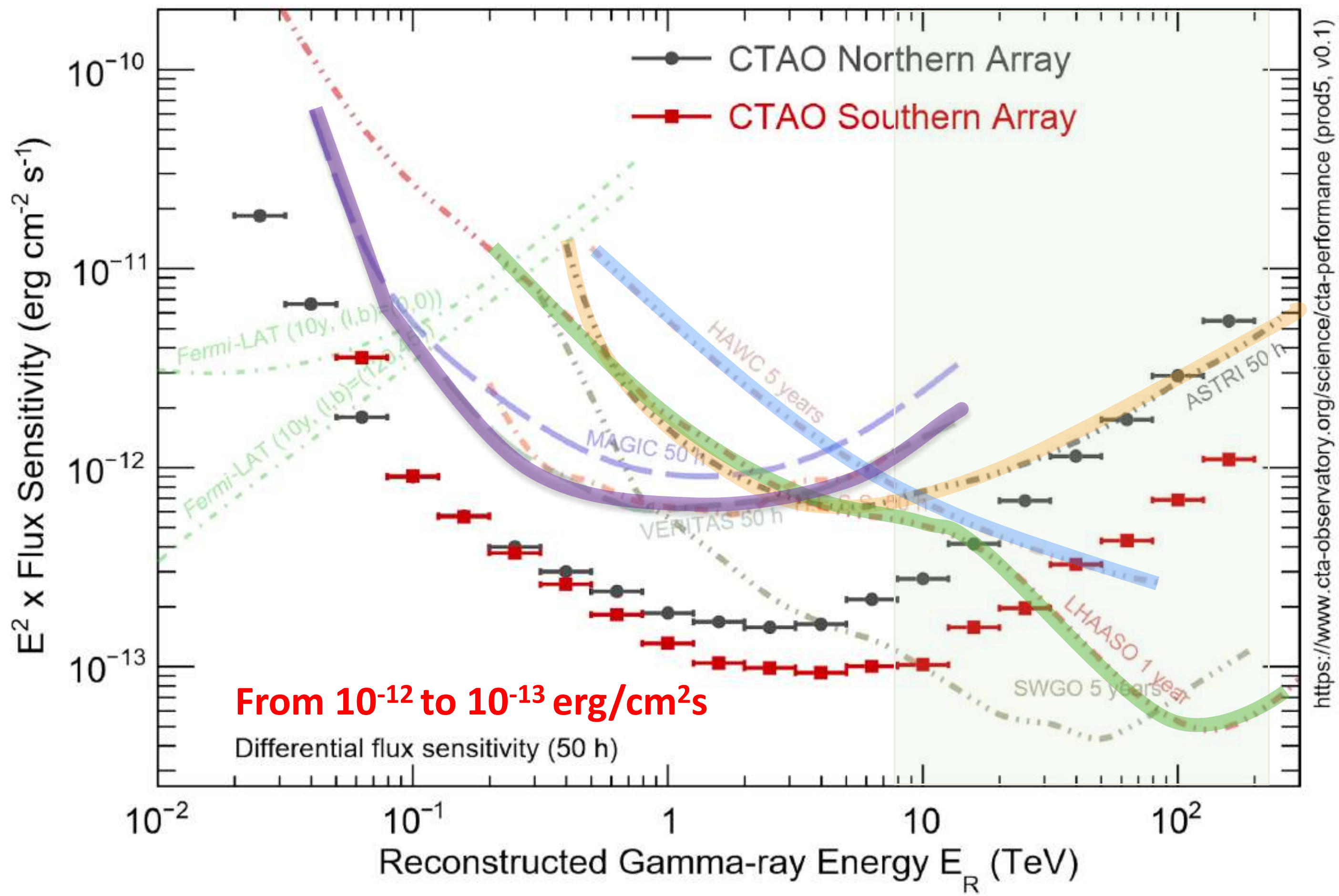
CTA comparative performance

On time scales <1 h
CTAO is **10³ times** (@25 GeV) to **10⁶ times** (@250 GeV) **more sensitive than *Fermi*-LAT**

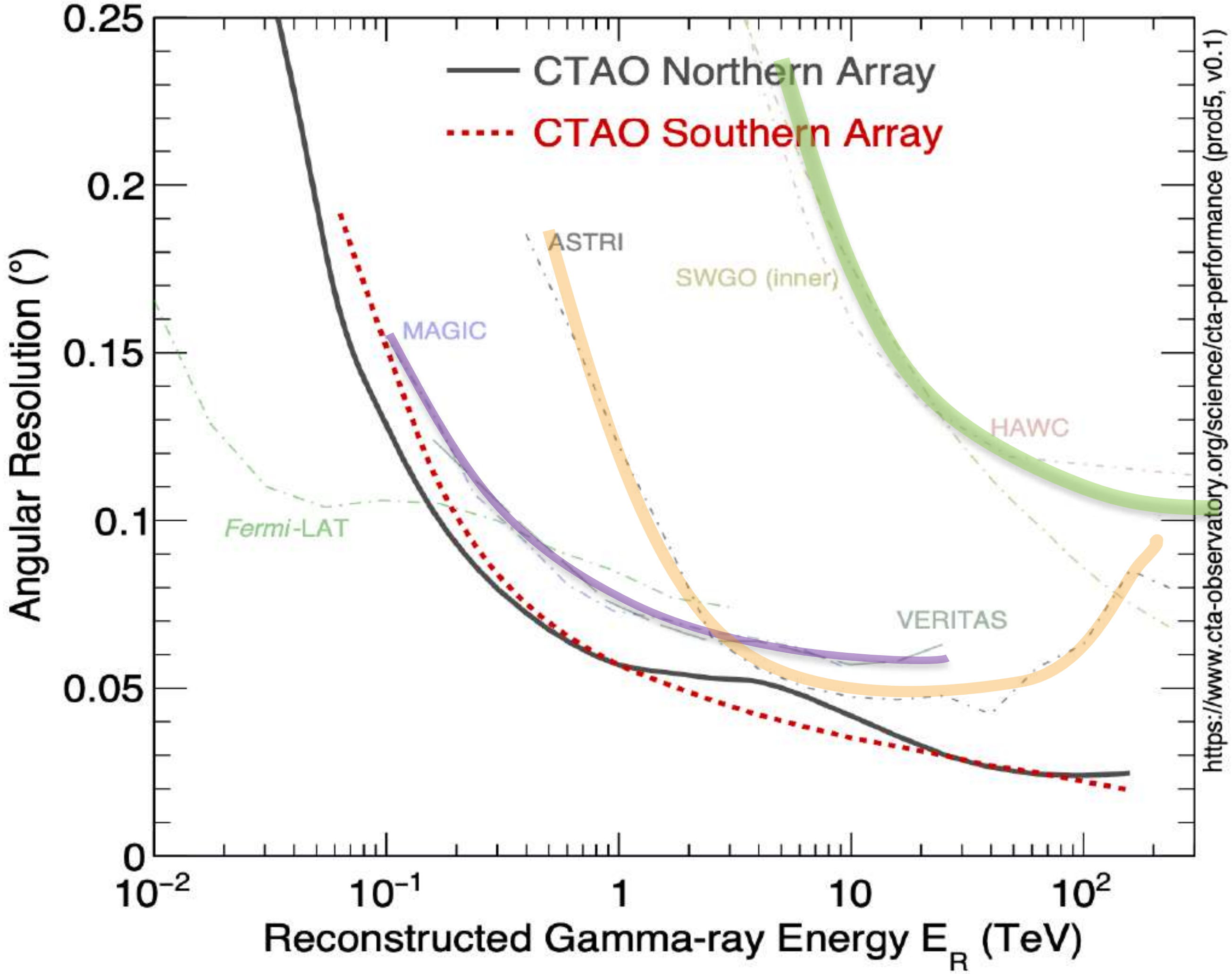


CTA comparative performance

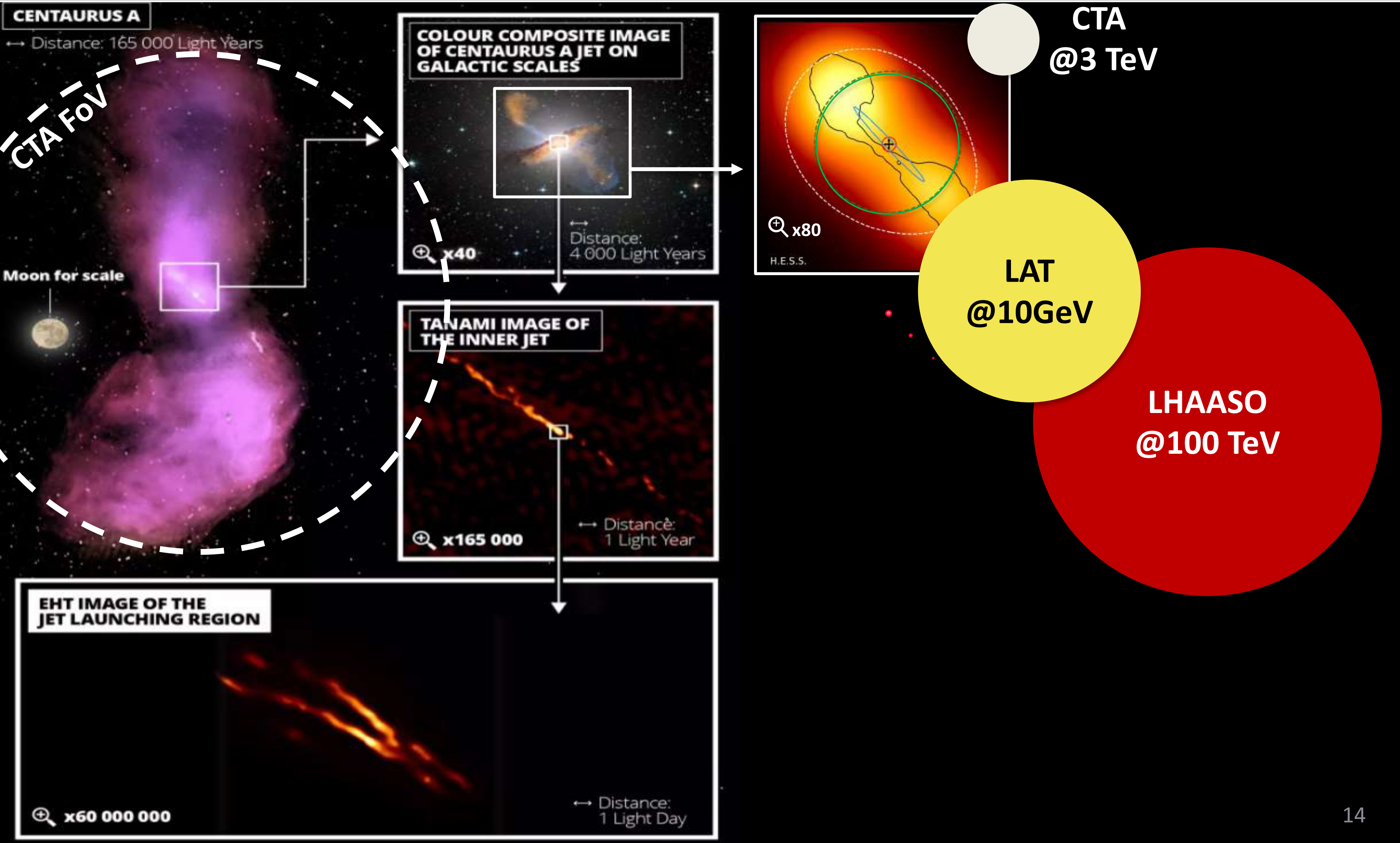
α-configuration



CTA Angular Resolution



CTA Performance: FOV & Resolution



CTA Science Questions *in and beyond Astrophysics*

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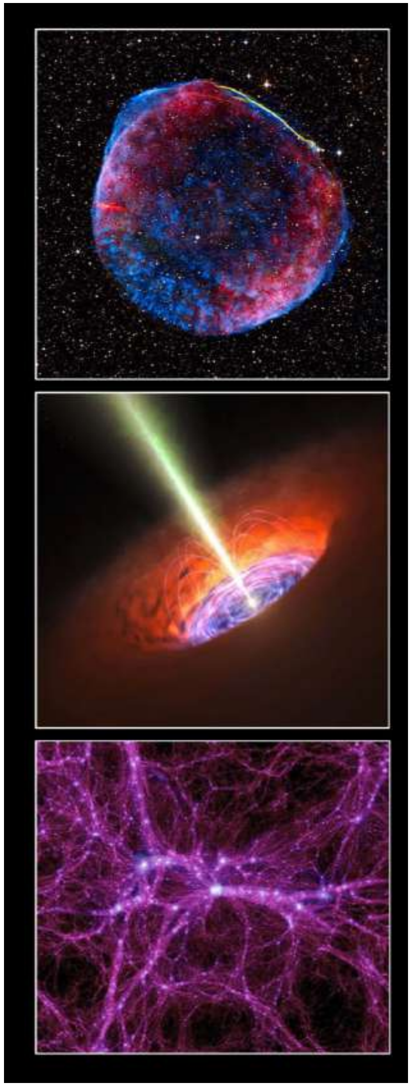
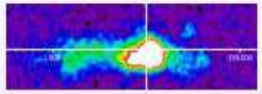


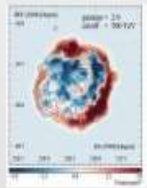
Key Science projects

1. Galactic Centre

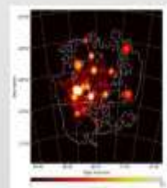


2. Galactic Plane Survey

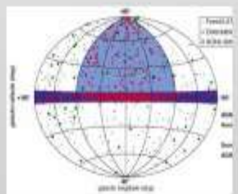
3. Cosmic Ray PeVatrons



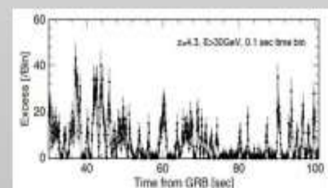
4. Star Forming Systems



5. LMC Survey
6. Extragalactic Survey



7. Active Galactic Nuclei
8. Transients

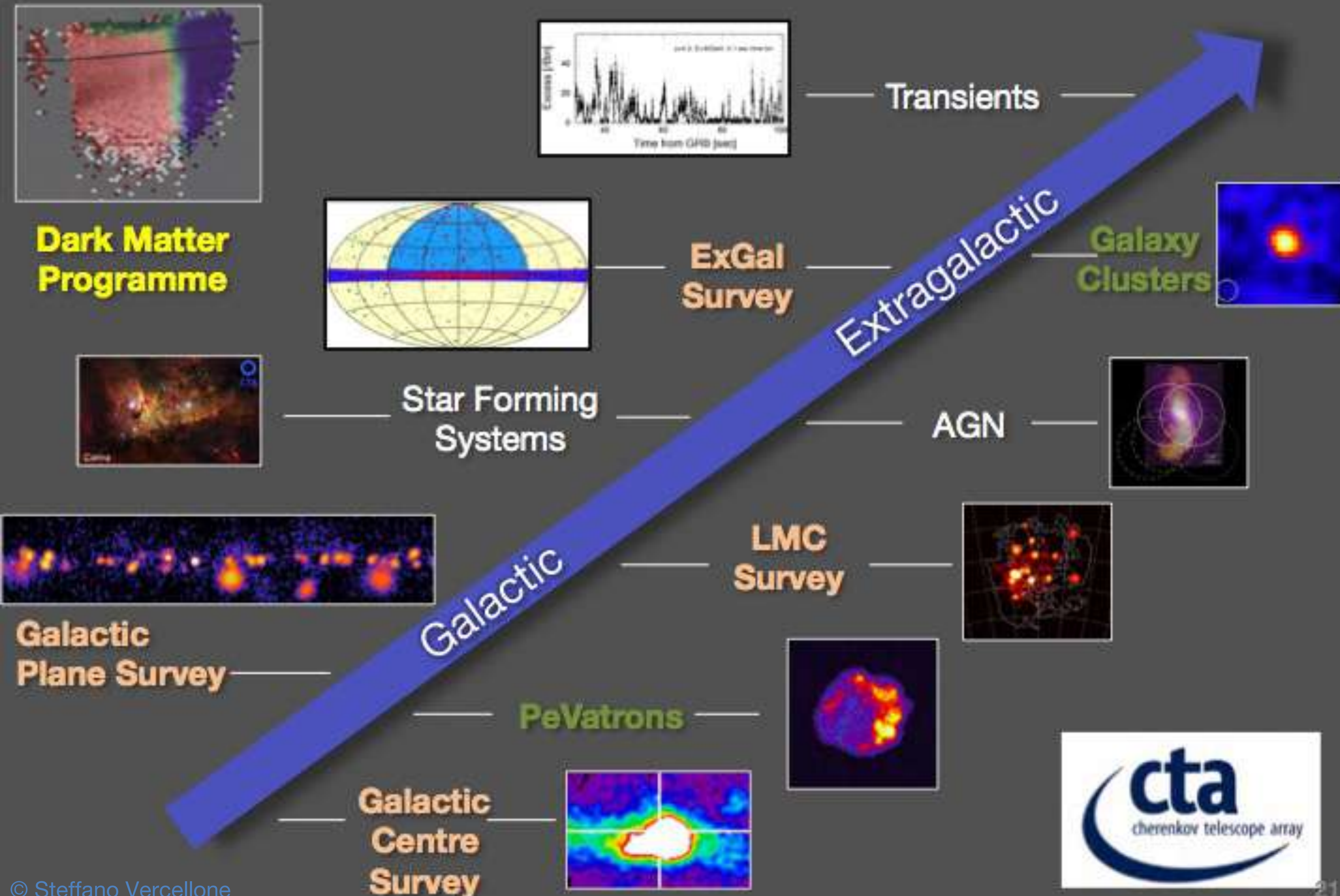


9. Clusters of Galaxies

+ Dark Matter Programme

CTA Key Science Projects

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



Cosmic Particle Accelerators

Particle acceleration to very high energies is associated with extreme environments:

- SN explosions, neutron stars, black holes, relativistic outflows

Major Questions:

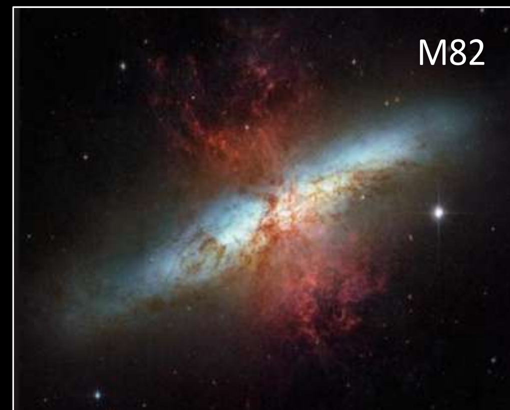
- Are SNR the main CR accelerators in our Galaxy?
- Where in our Galaxy are particles accelerated to PeV (10^{15} eV) energies?
- What are the sources of UHECRs ($E>10^{18}$ eV): AGNs?

To answer:

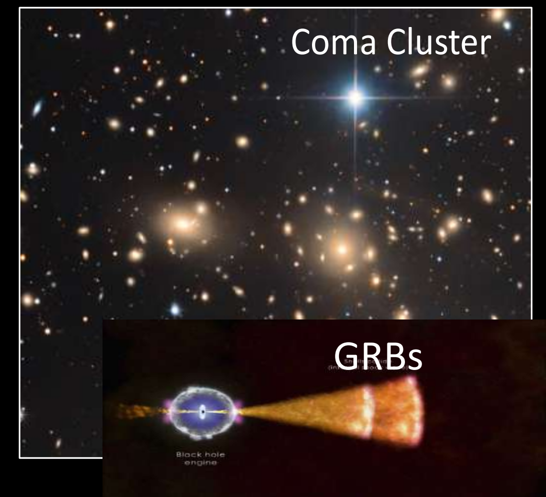
- Galactic and Extragalactic Surveys
- Deep Observations of nearby sources, galaxies and clusters
- Precision measurements of bright targets to probe physical processes

Cosmic Particle Accelerators

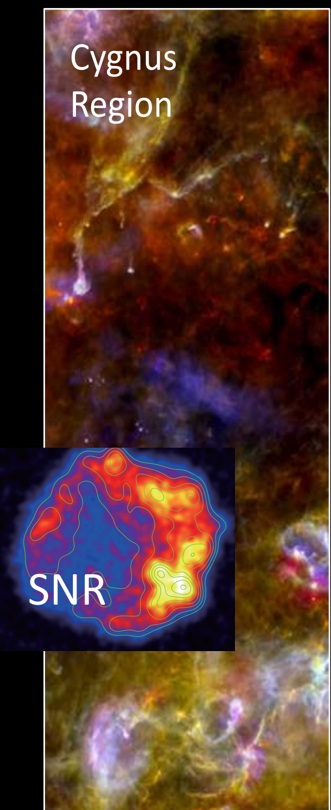
a census of cosmic particle accelerators



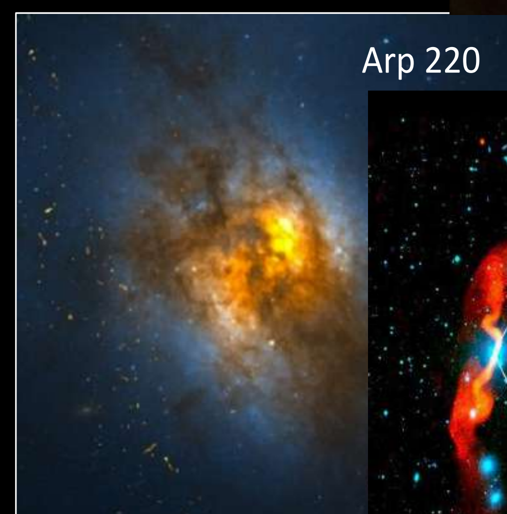
Hubble Heritage Team



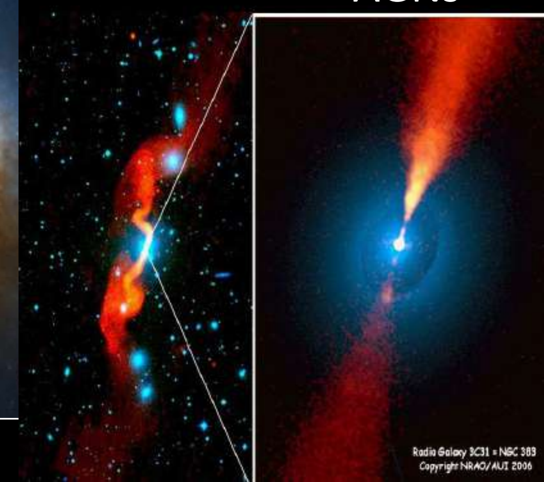
R. Carroll,
R. Gendler



J.Fritz,
W. Pietsch,
R. Gendler



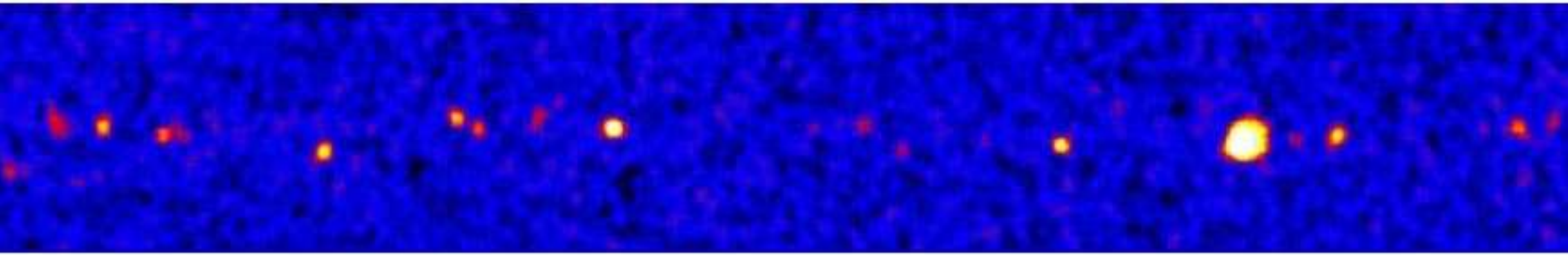
AGNs



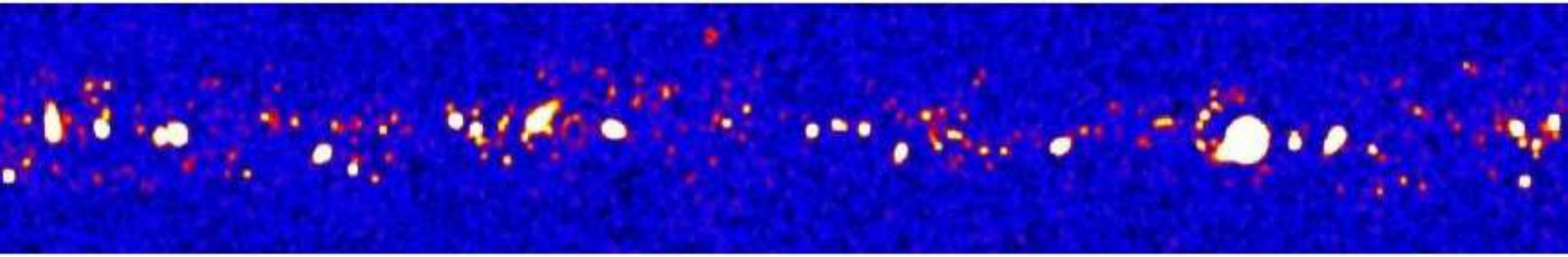
ACROSS ALL
COSMIC SCALES

Galactic Plane Survey

H.E.S.S.



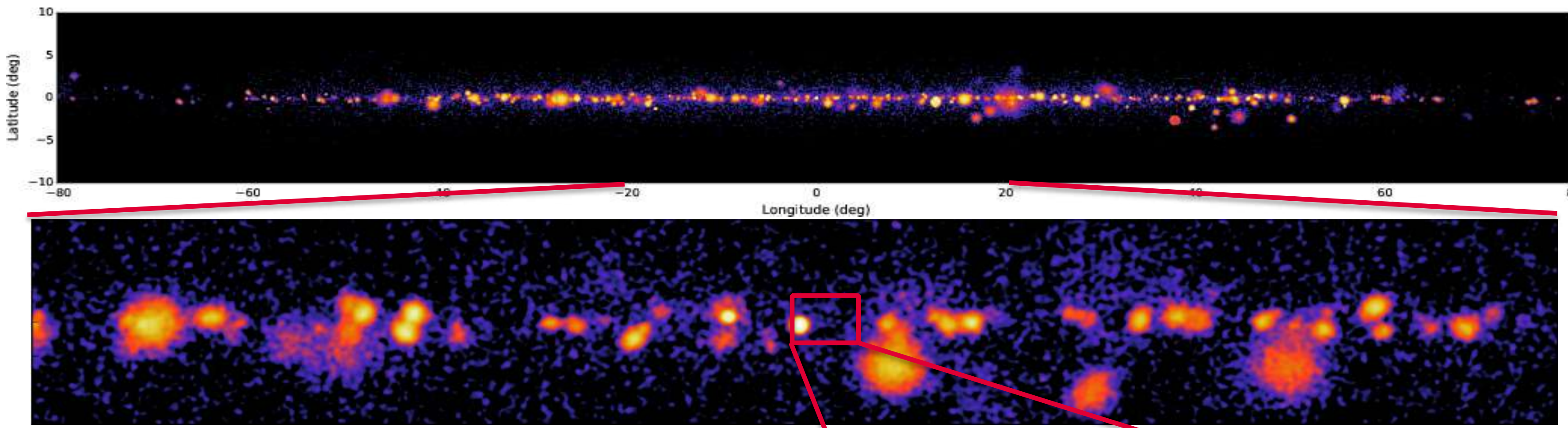
CTA, for same exposure

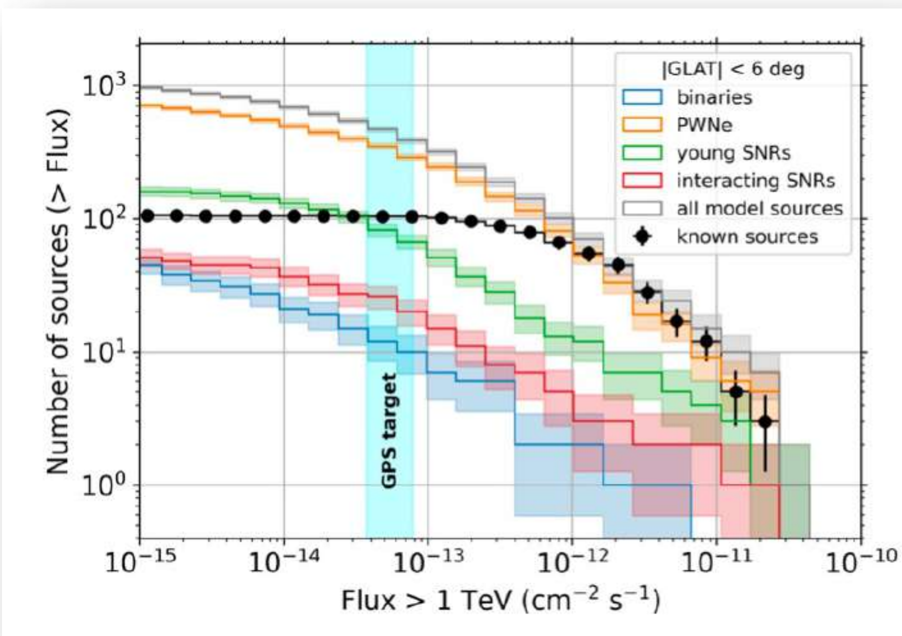


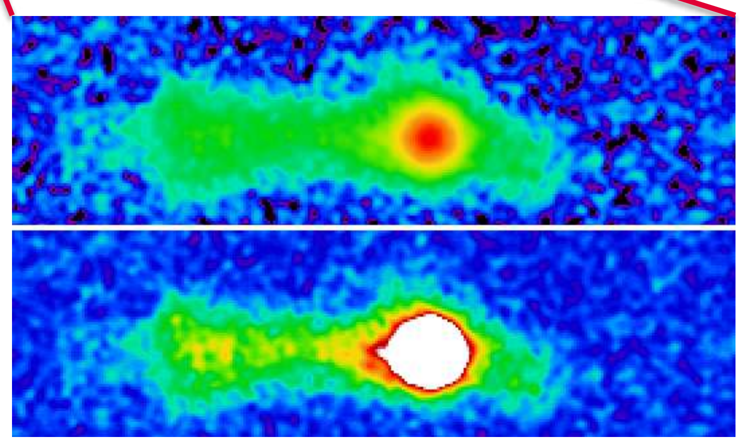
expect ~500 detected sources

Distance reach ~20 kpc

Galactic Plane Survey







GC

Search for PeVatrons in the Galaxy

- **CR able to produce 100 Te**V photons should have E_{CR} ~ PeV:

PeVatrons

- **Photons with E~100 TeV**: produced preferentially by **hadronic process** (proton-photon, proton-proton interactions)

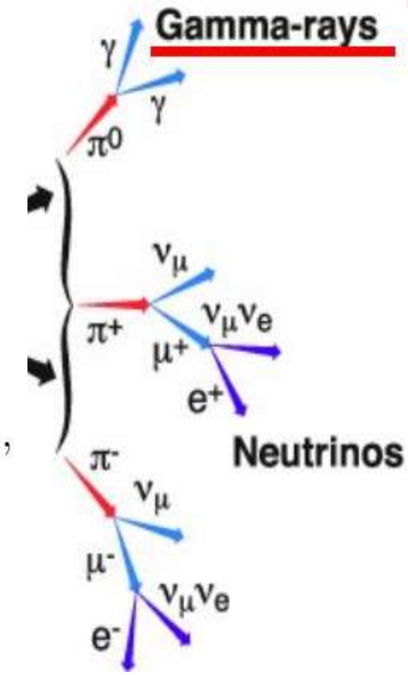
- Cross-section for **IC interactions electron-photon** decreases very quickly for E> 10 TeV (Klein-Nishina effect)

Cosmic Ray Interactions (cascading)

Hadronic

- photo-hadronic processes $p + \gamma_b \rightarrow \begin{cases} \pi^0 + p \rightarrow 2\gamma, \\ \pi^{\pm} + n \rightarrow \mathrm{e}\pm + \nu_s, \end{cases}$

- proton-proton interactions $p + p_b \rightarrow \begin{cases} p + p + \pi^0 \rightarrow 2\gamma, \\ p + n + \pi^+ \rightarrow \mathrm{e}^+ + \nu_s, \end{cases}$

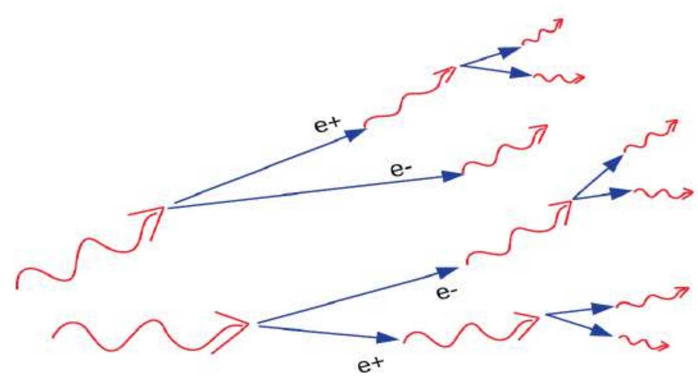


Leptonic

- pair creation $\gamma + \gamma_b \rightarrow \mathrm{e}\pm,$

- synchrotron cooling $\mathrm{e} \pm + \vec{B} \rightarrow \gamma_{synch} \rightarrow \gamma_b,$

- inverse Compton scattering $\mathrm{e} \pm + \gamma_b \rightarrow \gamma,$



LHAASO discovered PeVatrons @ Galaxy

Cao et al., 2021, Nature

Source name	RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326	276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545	279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338	280.75	−3.65	8.5	$0.26\,{-0.10}^{+0.16}$	0.73(0.17)
LHAASO J1849-0003	282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745	292.25	17.75	7.4	$0.71\,{-0.07}^{+0.16}$	0.38(0.09)
LHAASO J1956+2845	299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102	308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157	317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

Discovery of **12 sources emitting at several hundreds of TeV**, **up to 1.4 PeV**

Candidates: SNRs, galactic center, pulsar wind nebulae, young stellar clusters?

CTA -> can identify, probe morphology and spectra

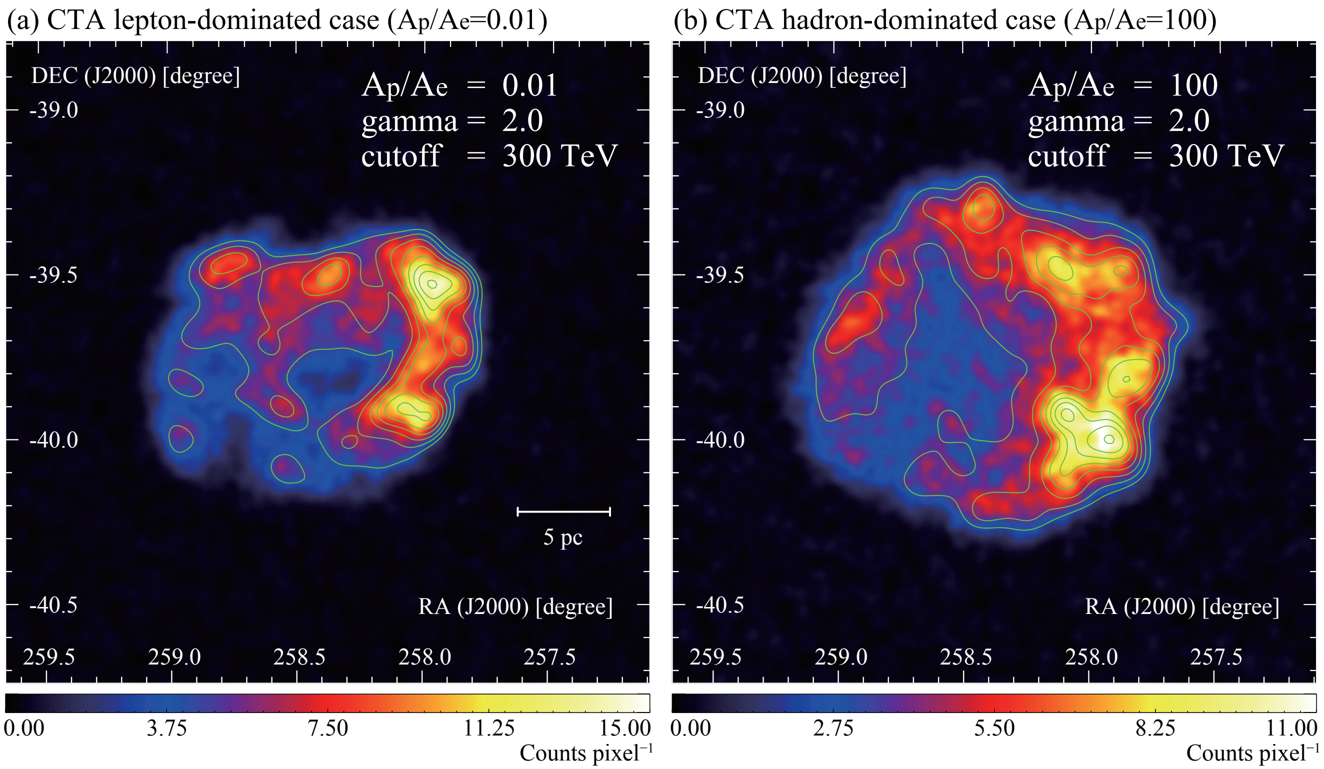
CTA Galactic Plane Survey Science

Primary goals of CTA Galactic Science

- Provide a census of the VHE Galactic source populations (identify unknown and new sources)
  - Massive stars
  - Compact objects: galactic NSs and BHs
  - Pulsars and PWNe
  - Supernova remnants
  - Microquasars, binary systems
  - Young stellar clusters
- Identify PeVatrons among them
- To be performed down to ~ 2mCrab in the inner Galaxy and around the Cygnus region, and ~ 4mCrab elsewhere in the Galactic Plane
- Detailed Study of the diffuse emission
- Multi-purpose catalogue and legacy datasets

Galactic Particle Accelerators: ex. SNR

Resolve sub-structure within SNR shell important for understanding acceleration and emission

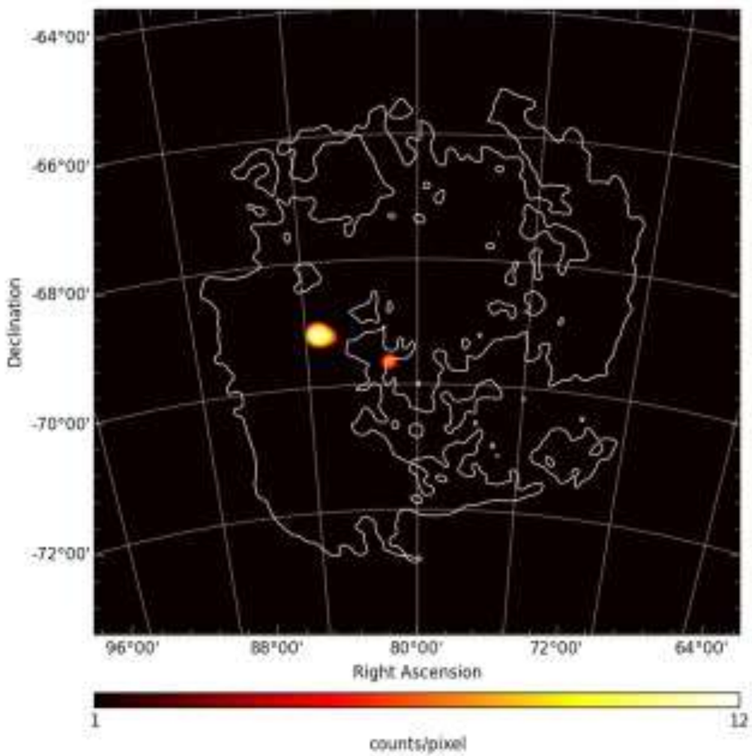


Simulated CTA TeV-bright supernova remnant **RX J1713–3946** for 2 emission scenarios:

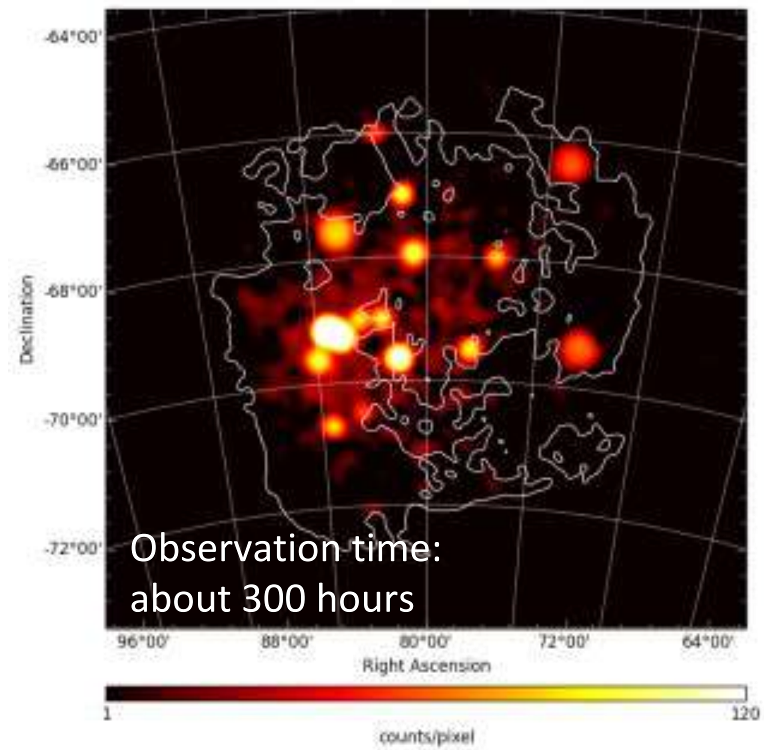
CTA will be able to differentiate between these scenarios

Large Magellanic Cloud Survey

- Global view of a near star-forming galaxy at TeV energies
- More than 60 SNRs
- Resolving regions down to 20 pc size
- Diffuse emission view of particle transport



Current (H.E.S.S)

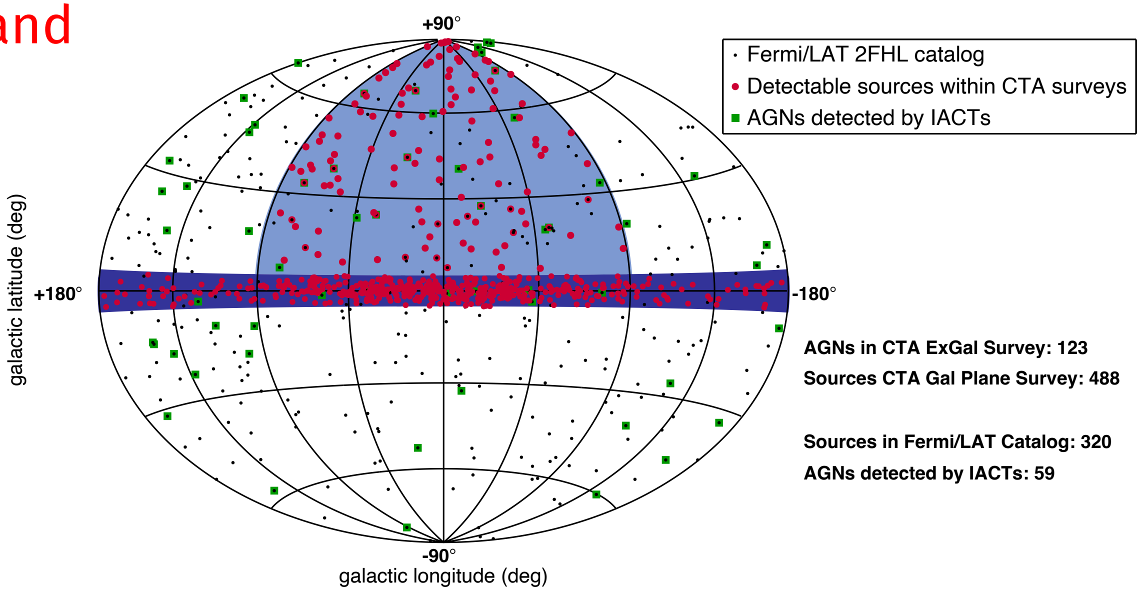


CTA

The extragalactic Survey

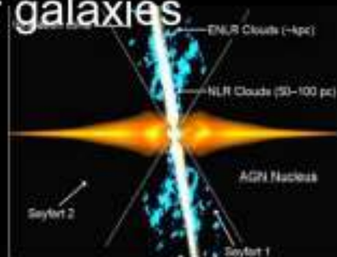
The first ever in the VHE band

- Unbiased survey of the sky
  - Coverage of 1/4 of full sky
  - Performed over 10 years
    - Complete to 5 mCrab
  - Blazar Luminosity Function
  - Probe new sources, e.g.:
    - Extreme blazars
    - Galaxy Clusters
- Serendipity transients discovery and follow-up potential, e.g. GRBs, TDEs, FRBs,…
- Monitoring (multi-band) and Follow-up of strong AGN flares
- Multi-messenger science: GW and neutrino triggers

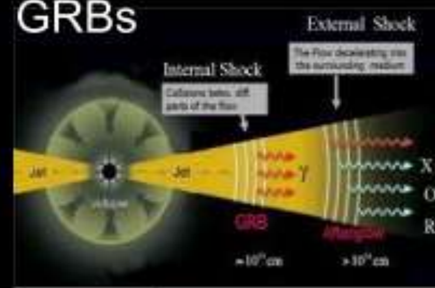


CTA EXTRAGALACTIC TARGETS

other galaxies

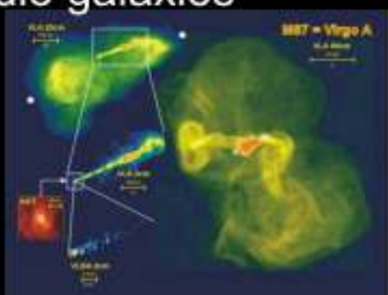


GRBs



blazars

radio galaxies



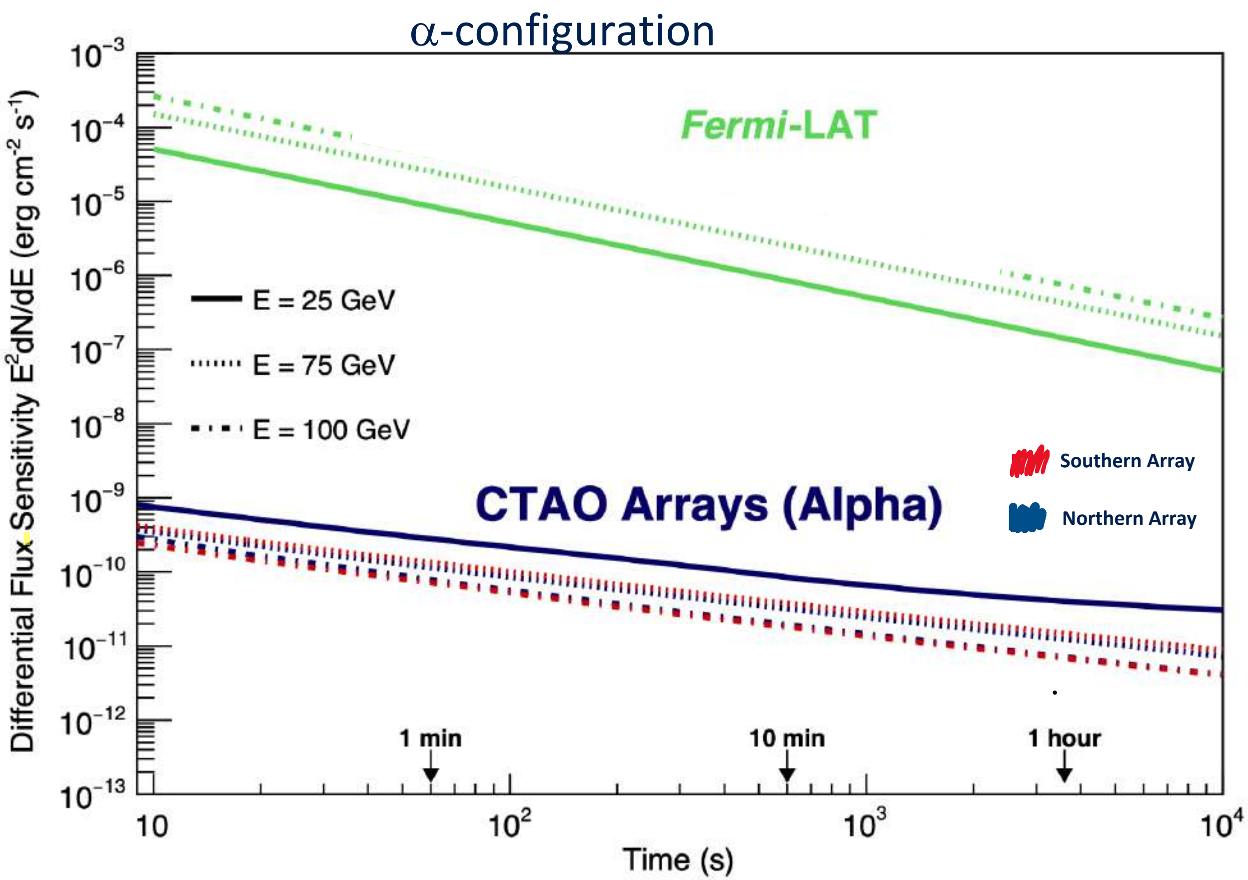
star forming regions

survey / deep field

galaxy clusters

EBL / IGMF

CTA Differential Flux Sensitivity



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

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

CTA -> ability to probe very short timescales in gamma-rays

Transients & Variability Phenomena

Credits: The LIGO Scientific Collaboration

Transients are a diverse population of astrophysical objects. Some are known to be prominent **emitters of high-energy gamma-rays**, while others are sources of non-photonic, multi-messenger signals such as cosmic rays, **neutrinos and/or gravitational waves**.

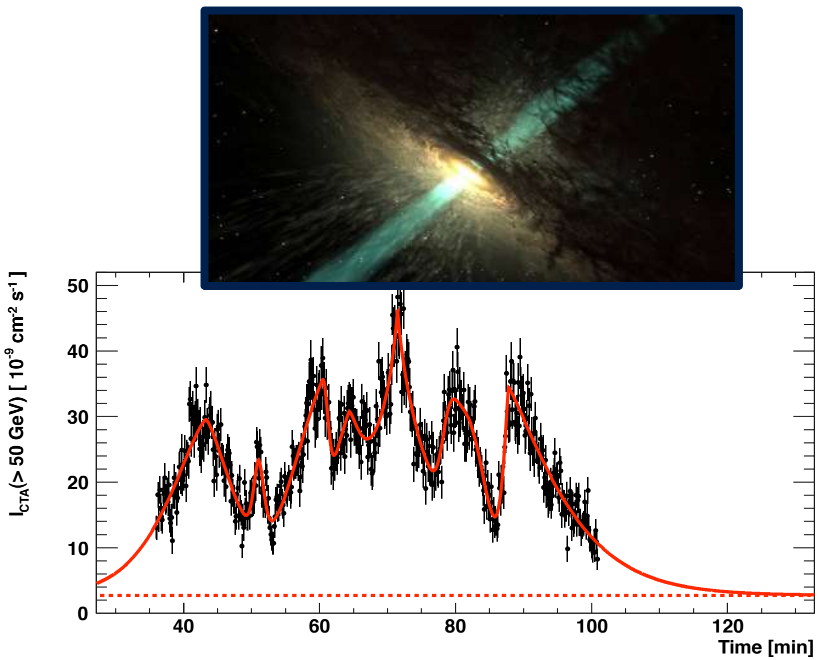
Possible classes of targets

- Gamma-ray bursts
- Galactic transients
- High-energy neutrino transients
- Gravitational wave transients
- Radio, optical, and X-ray transients
- Serendipitous VHE transients
- AGNs, PWN, binaries, accretion & relativistic outflows

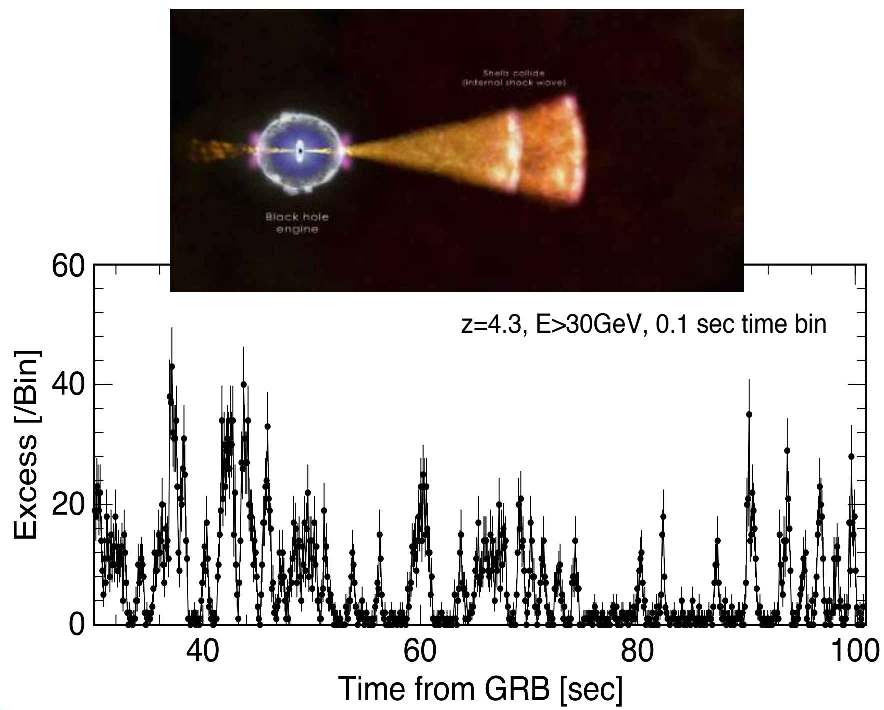
Variability with CTA

CTA ability to probe very short timescales in gamma-rays:

- explore connection between accretion and ejection phenomena in compact objects
- study phenomena in relativistic outflows: GRBs, AGN, PWN, binary systems
- In GRBs: high-statistics measurements for the first time >10 GeV; detect ~2 GRB/yr



CTA simulated light curve flare of PKS 2155−304 provides access to timescales << light-crossing time of the supermassive black hole

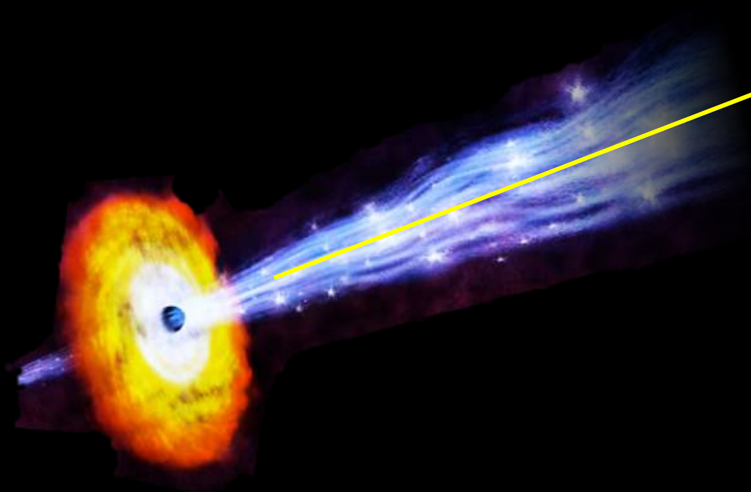


CTA Simulated light curve GRB 080916C, z =4.3

AGN monitoring

What is the jet made of?
How is it launched?
What causes the variability?
What is the acceleration mechanism?

- Long-term monitoring of selected AGN over 10 years
- Follow-up of flaring AGN
- High-quality measurement of selected AGN spectra

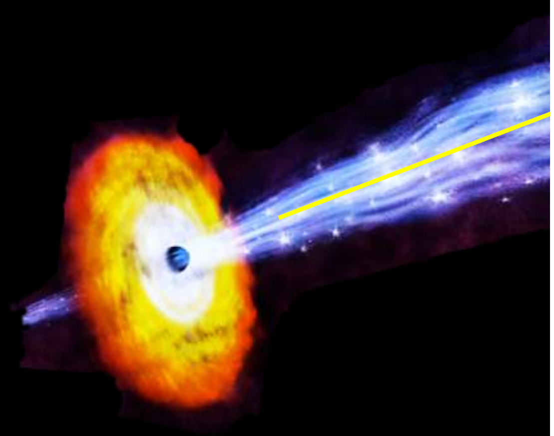


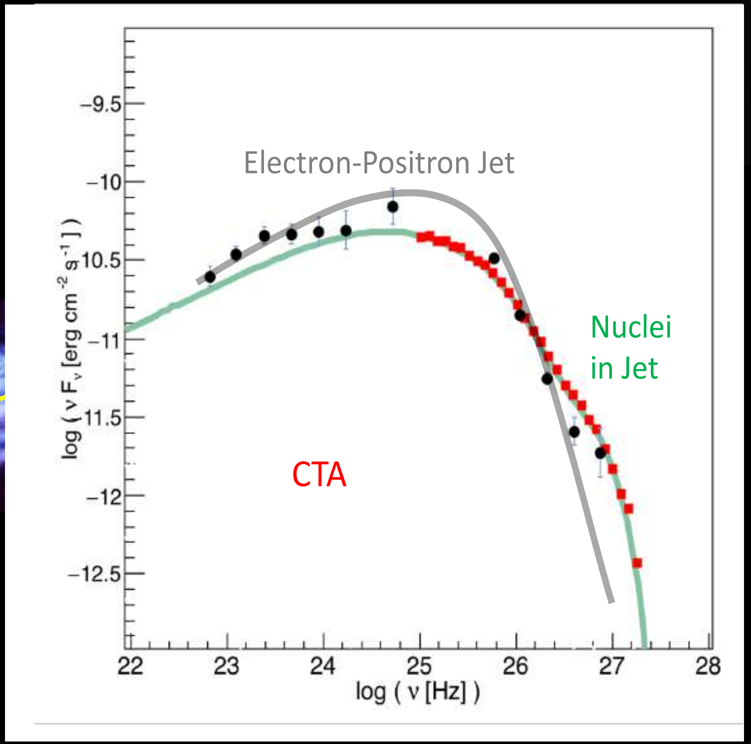
Total observation time:
about 3000 hours

AGN monitoring

What is the jet made of? ✓
How is it launched?
What causes the variability?
What is the acceleration mechanism?

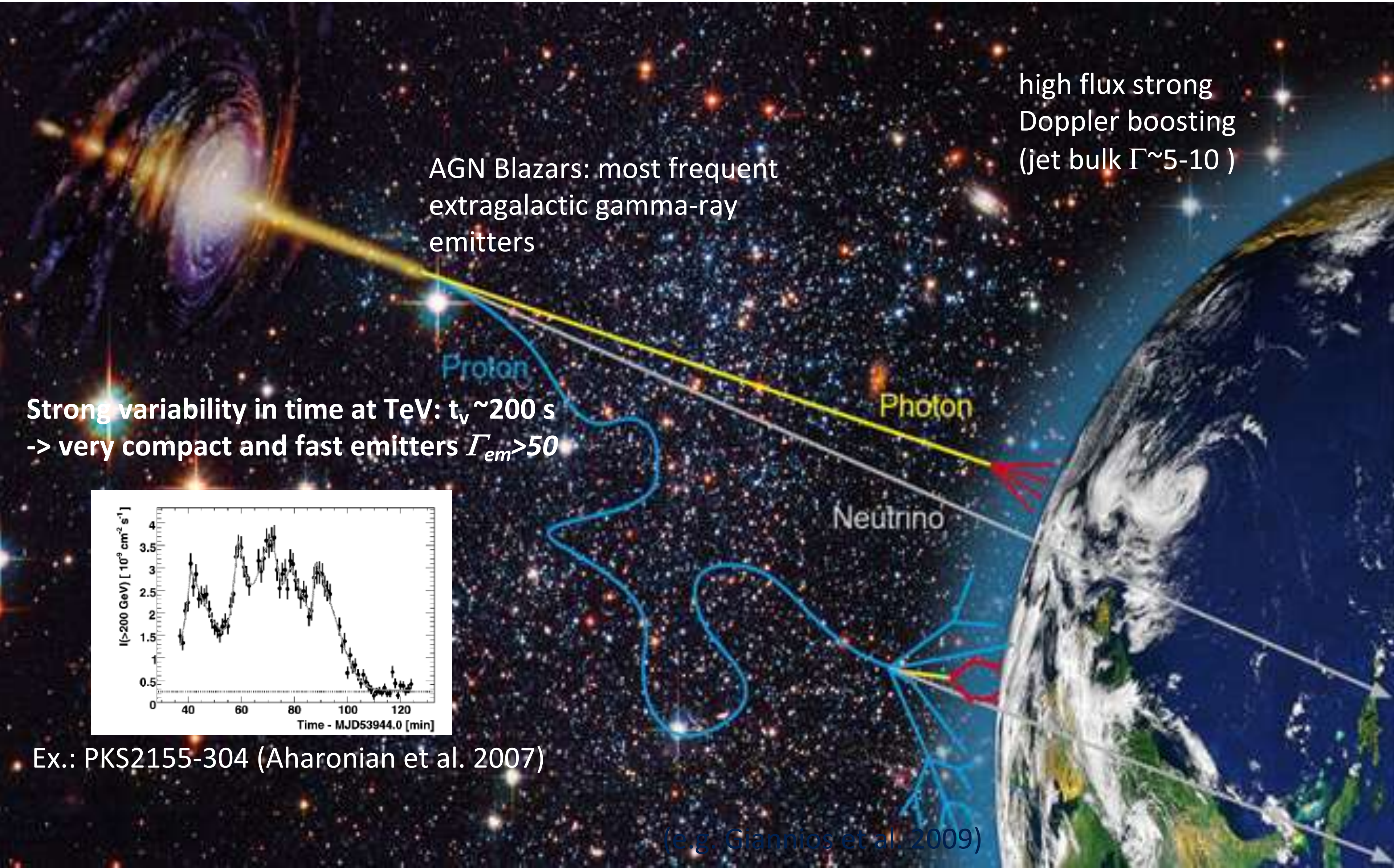
from: Science with CTA
www.worldscientific.com/worldscibooks/10.1142/10986





AGN Variability

Where is emission region? Jet launching? Acceleration Mechanism?



AGN Blazars: most frequent extragalactic gamma-ray emitters

high flux strong Doppler boosting (jet bulk Γ~5-10)

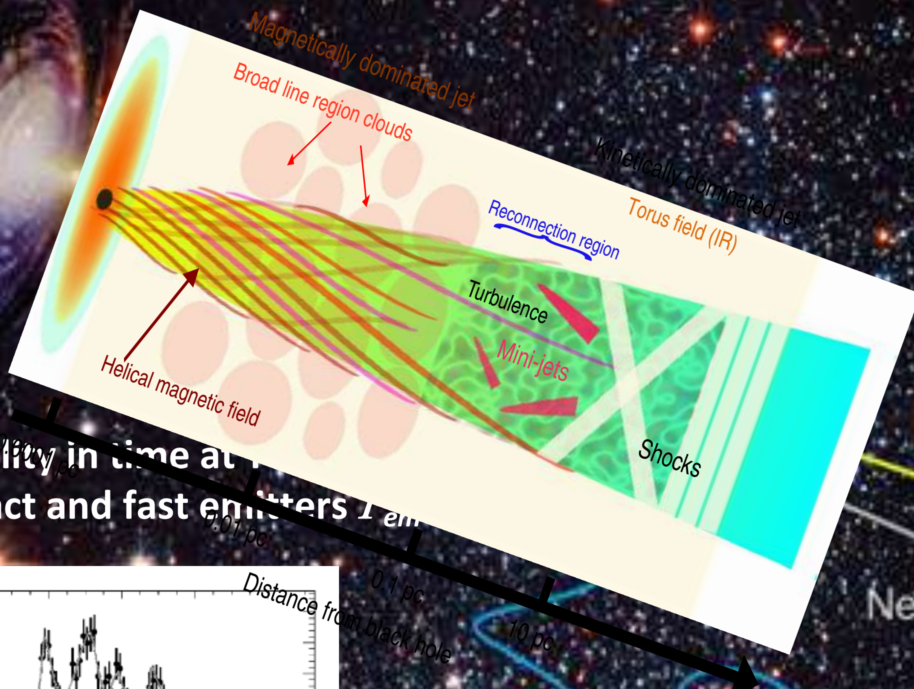
Strong variability in time at TeV: t_v~200 s
-> very compact and fast emitters Γ_{em}>50

Ex.: PKS2155-304 (Aharonian et al. 2007)

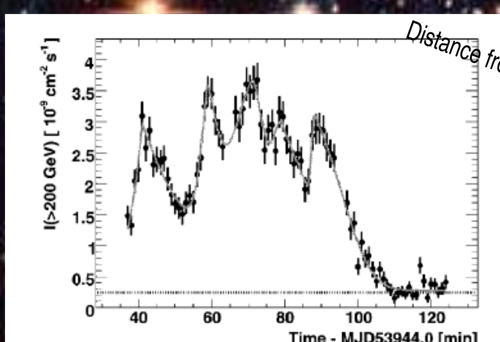
(e.g. Giannios et al. 2009)

AGN Variability
Shock or Magnetic Reconnection Acceleration?

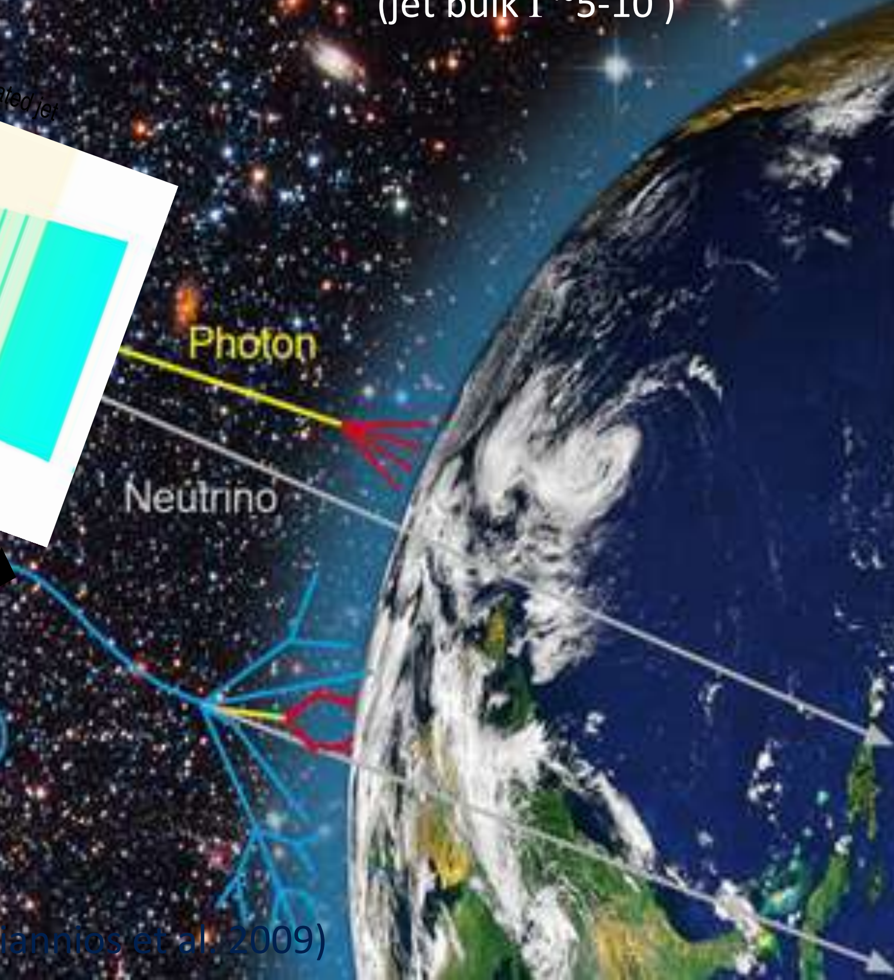
high flux strong Doppler boosting (jet bulk Γ~5-10)



Strong variability in time at
-> very compact and fast emitters Γ_{em}



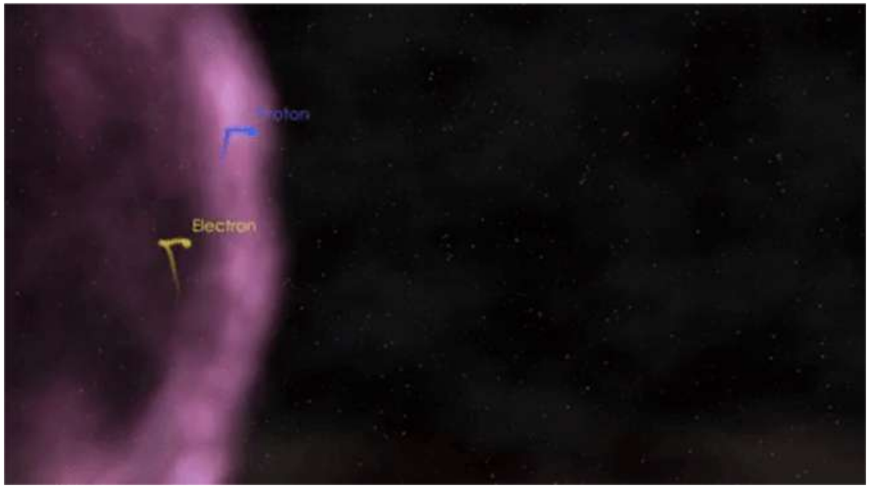
Ex.: PKS2155-304 (Aharonian et al. 2007)



(e.g. Giannios et al. 2009)

Particles are accelerated stochastically - Fermi process

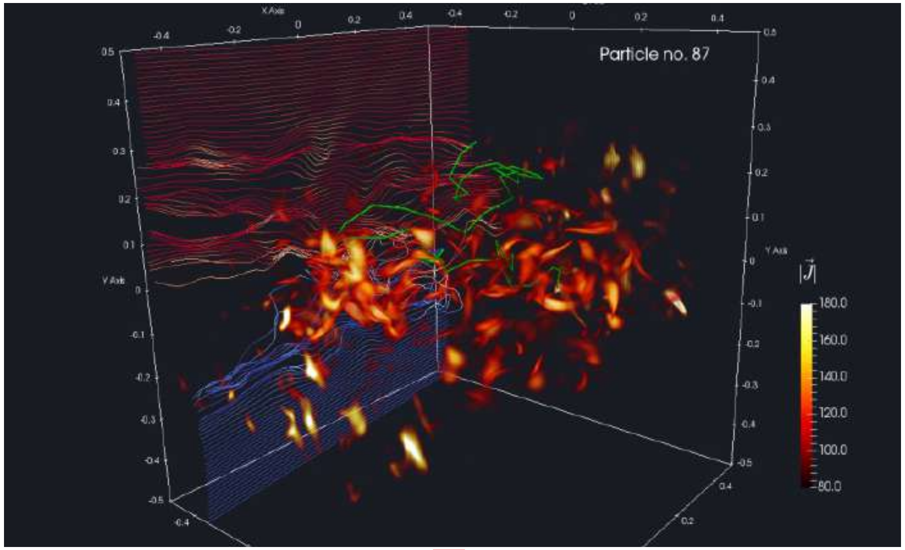
Shock Acceleration



1^{st}-order Fermi
(Bell 1978; Begelman & Eichler 1997):

$$<\Delta E/E> \sim v_{sh}/c$$

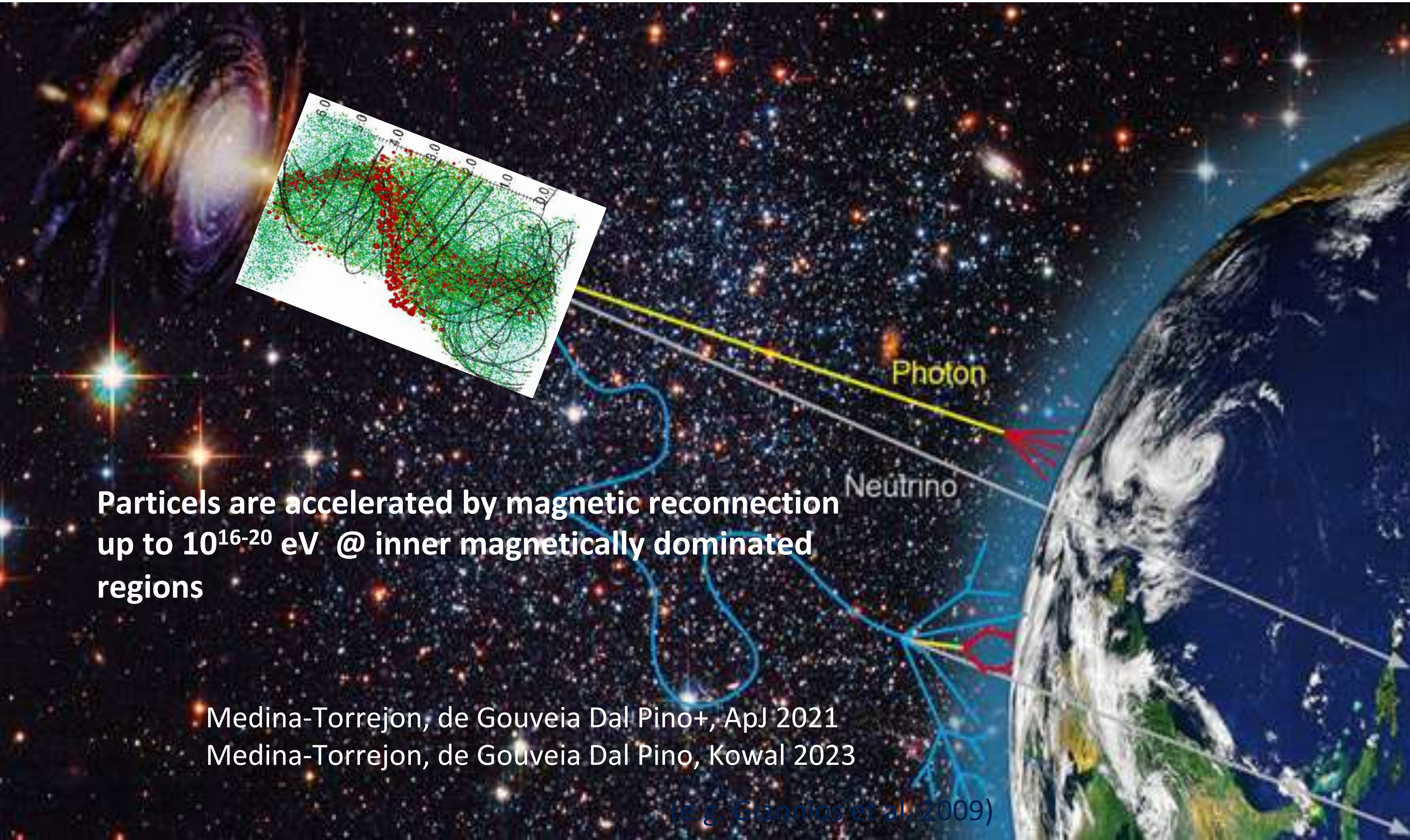
Reconnection Acceleration



As in shocks: 1^{st}-order Fermi
(de Gouveia Dal Pino & Lazarian 2005;
del Valle, de Gouveia Dal Pino, Kowal 2016):

$$<\Delta E/E> \sim v_{rec}/c$$

Magnetic Reconnection acceleration may prevail



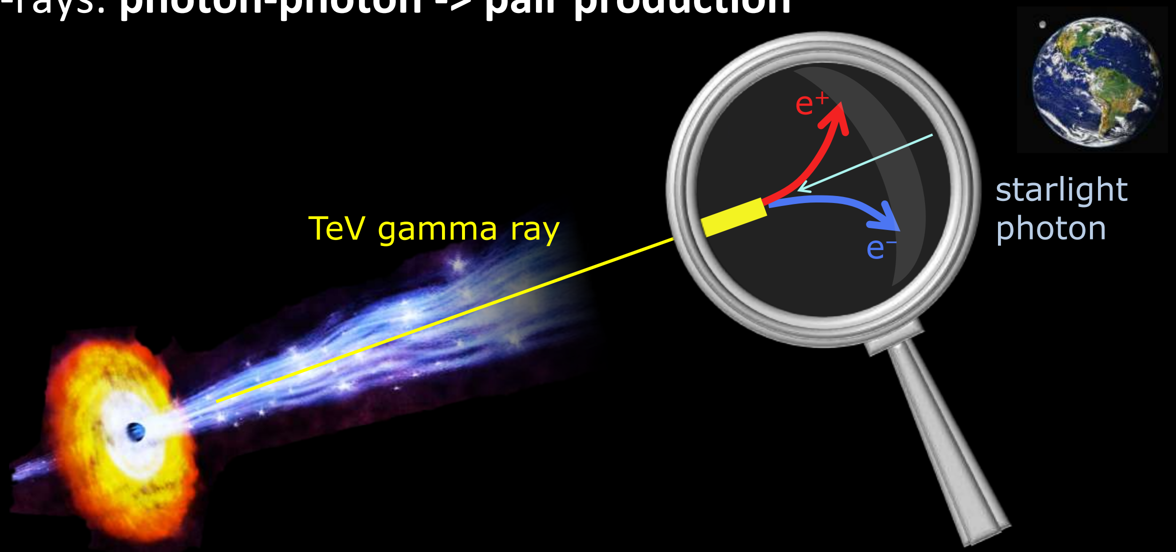
Particels are accelerated by magnetic reconnection up to 10^{16-20} eV @ inner magnetically dominated regions

Medina-Torrejon, de Gouveia Dal Pino+, ApJ 2021
Medina-Torrejon, de Gouveia Dal Pino, Kowal 2023

(e.g. Giannios et al. 2009)

Gamma-ray absorption by extragalactic background light (EBL)

- **Extragalactic Background Light (EBL)**: integrated IR and optical emission from stars and galaxies through evolution of the universe (very hard to measure)
- EBL interacts with gamma-rays: **photon-photon -> pair production**



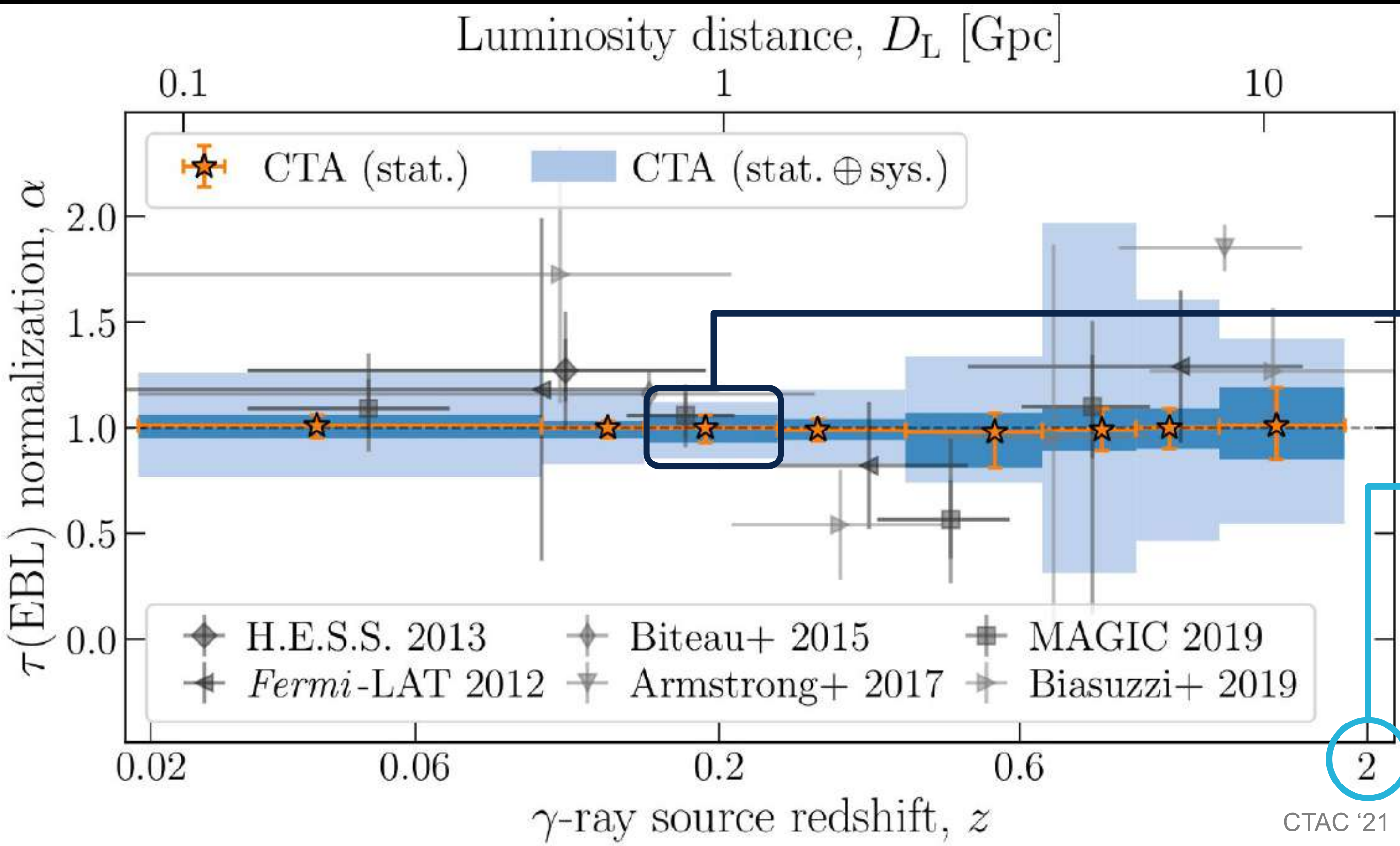
Absorption depends on the intensity of background light

CTA:

- measure EBL precisely @ z=0 for large number of objects
- large sample of blazars z=0-2: evolution of EBL

Gamma-ray absorption by extragalactic background light (EBL)

arXiv:2010.01349



Best at z ~ 0.2:
± 5%$_{\text{(stat)}}$ ± 12%$_{\text{(syst)}}$

Up to z ~ 2
(z ~ 1 for current TeV observatories)

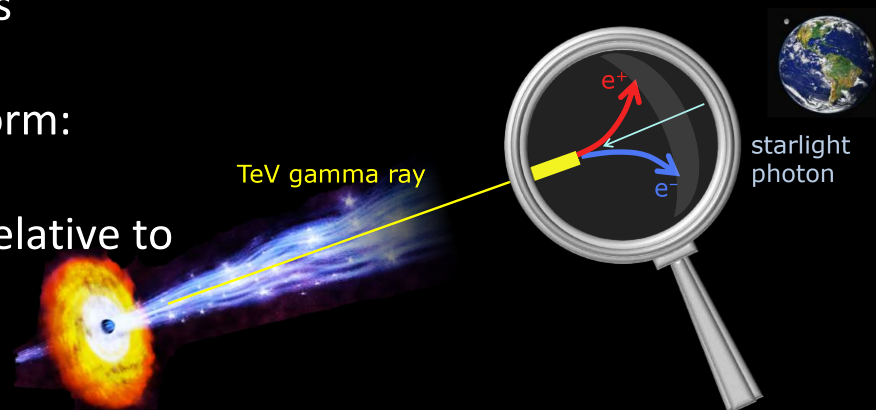
Constraints limited by instrument systematics

Gamma-ray propagation & absorption: pair echo and halo & cosmic magnetic field

Pair production by TeV photons interacting in voids: allows to measure weak magnetic fields (IGMF)

- **Secondary gamma-rays produced by primary pairs via inverse-Compton** scattering on the EBL -> cascade from further pair and inverse-Compton interactions

- **Deflections of secondary pairs in the IGMF f**orm:
  - **pair halo** (around the primary source)
  - **pair echoes**: that arrive with time delay relative to primary emission

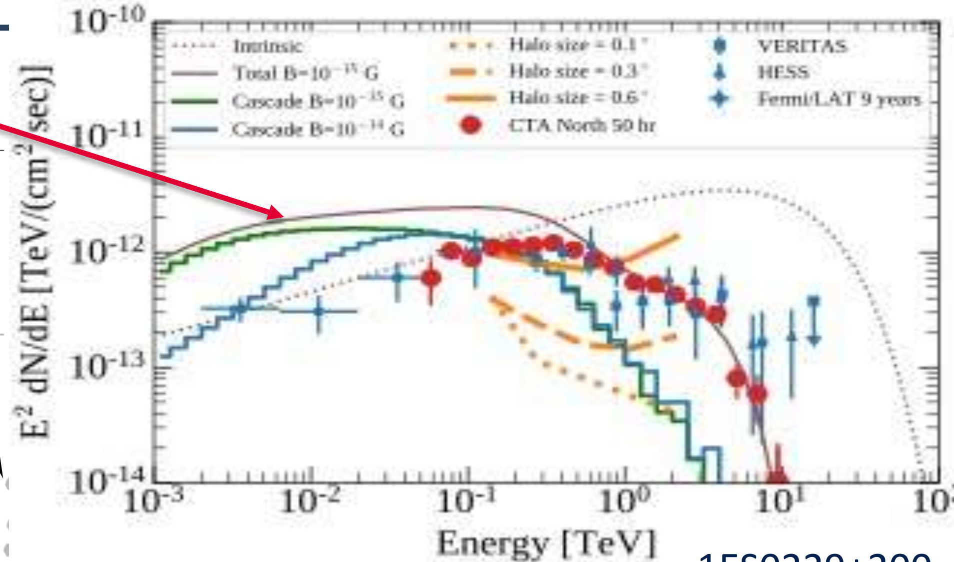


- **IGMF > 10^{-12} G**: full isotropisation of the emission: pair halo
- **IGMF < 10^{-12} G**: extended emission

CTA will detect secondary pair emission for IGMF ~ 10^{-16} - 10^{-12} G (for sources @ ~ 100Mpc)

Gamma-ray propagation & absorption: pair echo and halo & cosmic magnetic fields

B=10^{-15} G



1ES0229+200

Observables

1) Time delays

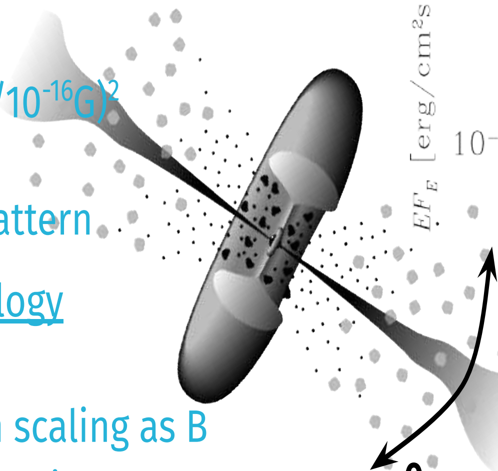
$\Delta t \sim 3$ yrs $(E/0.1\text{TeV})^{-1}(B/10^{-16}\text{G})^2$

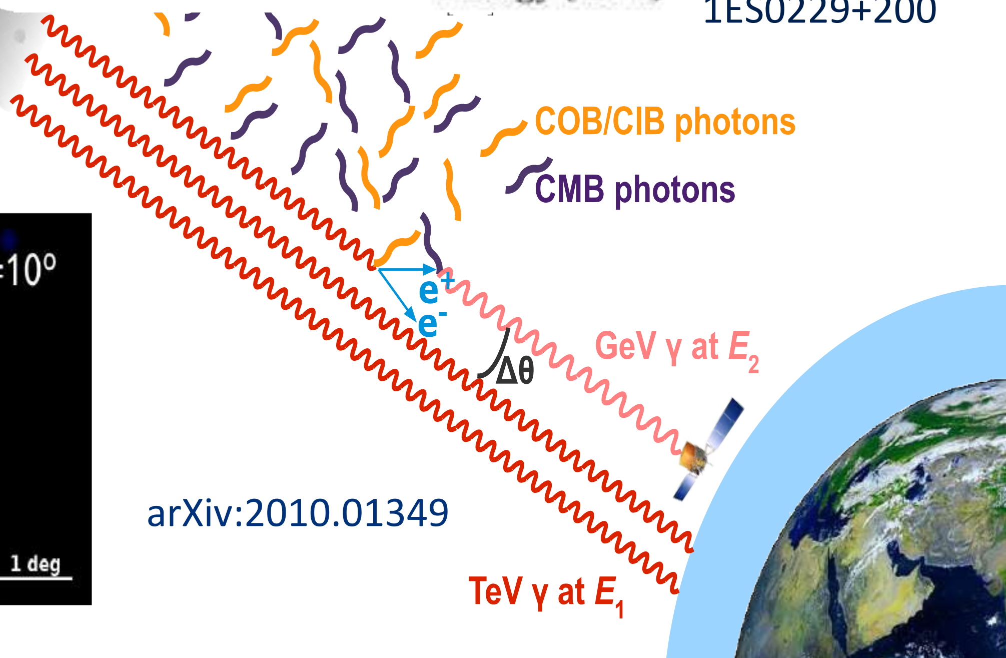
Useful for low B-field, limited by variability pattern

2) Spectrum & morphology

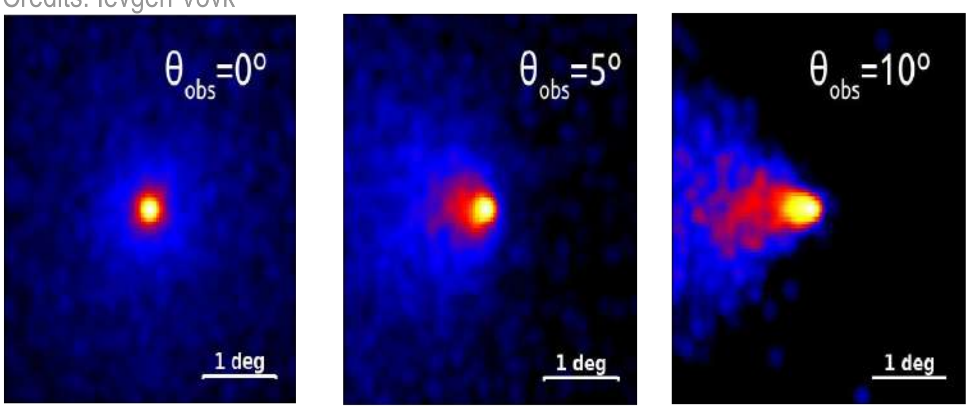
$E_2 \sim 80$ GeV $(E_1/10\ \text{TeV})^2$

Degree-scale extension scaling as B whose shape depends on jet parameters:





Credits: Ievgen Vovk



arXiv:2010.01349

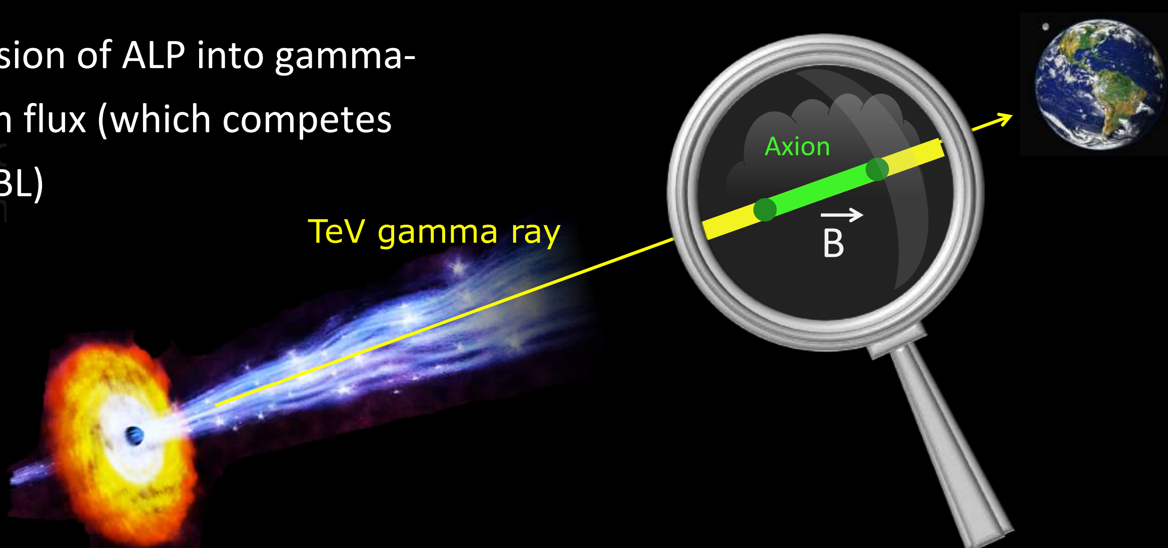
Gamma-ray propagation: photon-axion oscillations

- **Axion Like Particles (ALPs):** massless particles predicted by quantum chromodynamics (and also DM candidates)

- ALPS: **convert into photons (and vice versa) when traverse ambient MF**

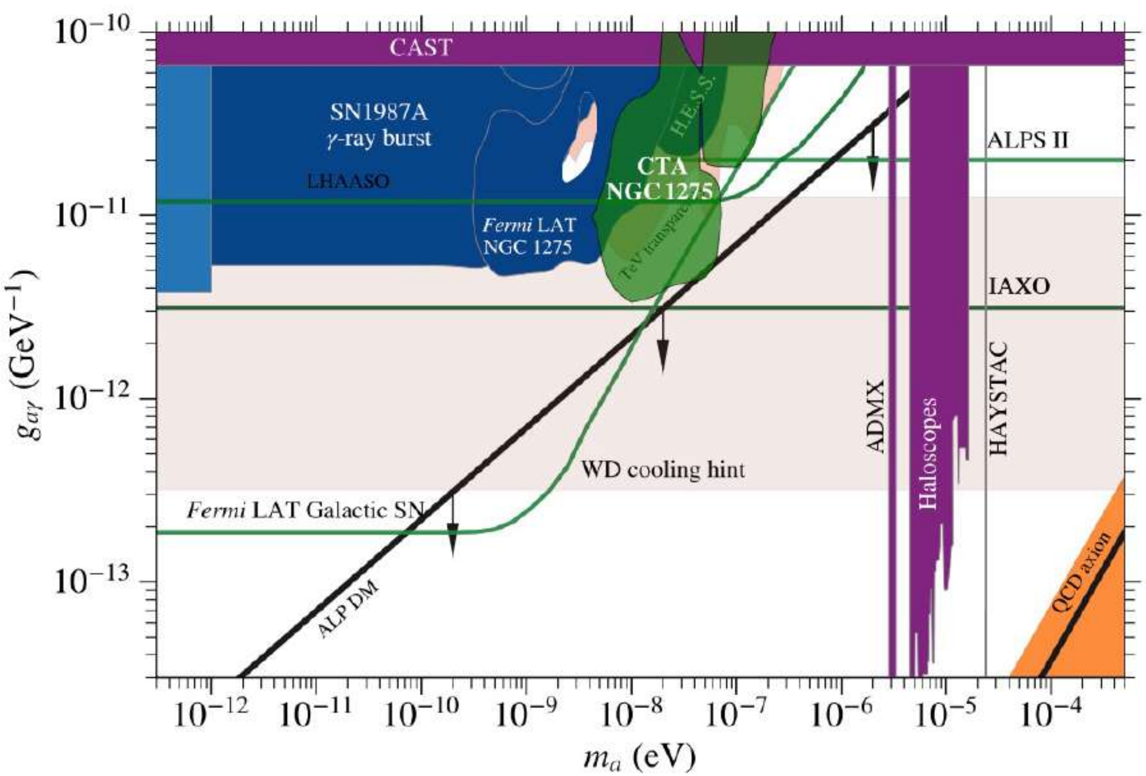
- For very distant AGN: conversion of ALP into gamma-ray enhances the TeV photon flux (which competes with the absorption on the EBL)

Axions are a proposed solution tc lso well motivated candidates to con



- Clue:
  To probe ALPs we need distant AGN embedded in measurable MFs -> a distant AGN in the center of a galaxy cluster: e.g. **NGC1275 in Perseus cluster (**75 Mpc)

Gamma-ray propagation: photon-axion oscillations



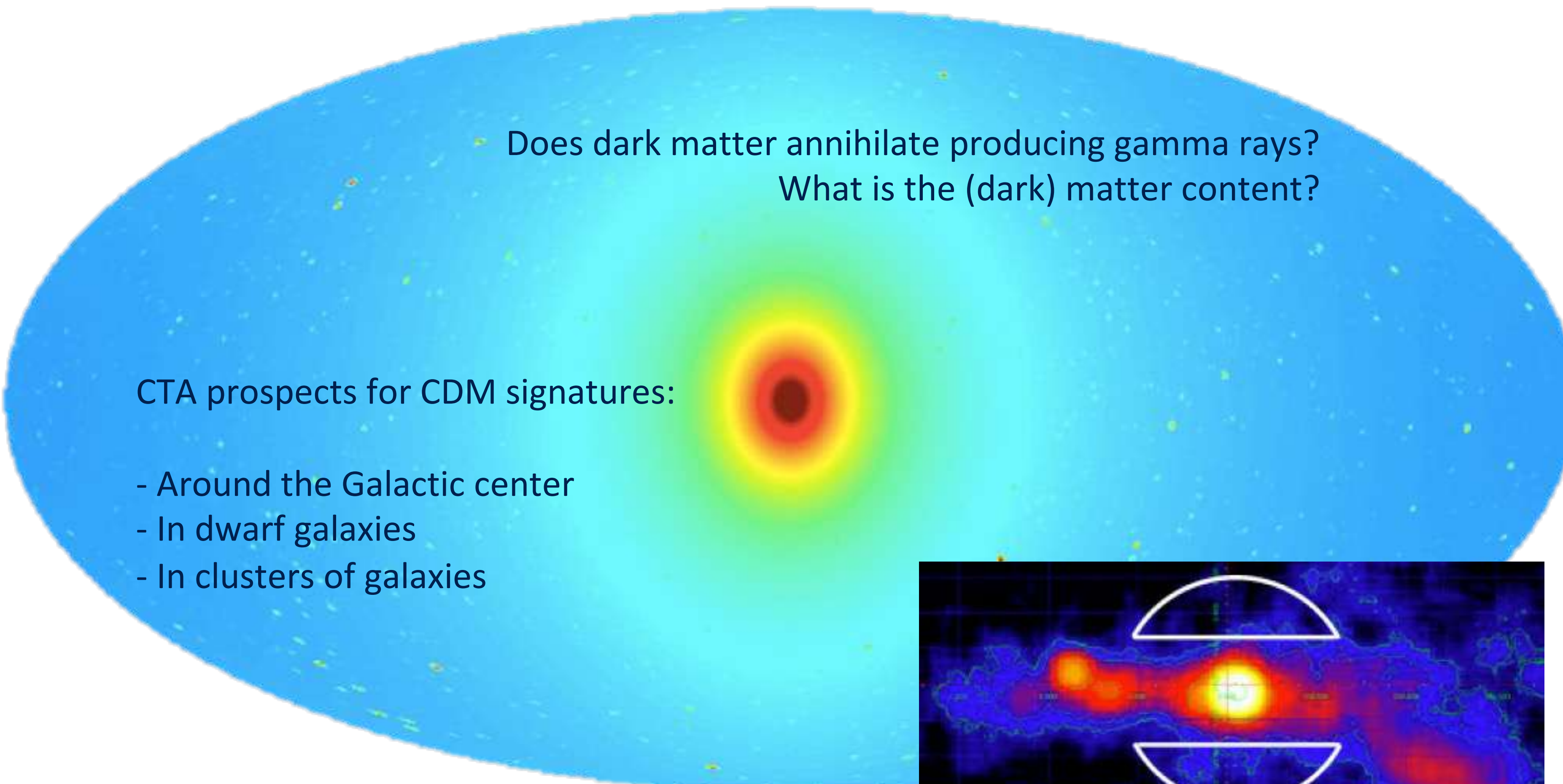
CTA constraints on ALPs:

m_a versus ALP-coupling to photons $g_{a\gamma}$

- Green regions: exclusion in the ALP parameter space by CTA from flaring state of the radio galaxy NGC 1275
- Purple and blue: exclusion regions from current-generation instruments
- Salmon: hints for ALPs from additional cooling of white dwarfs (WD) and increased transparency of the Universe to TeV γ-rays
- Green lines: other projected sensitivities
- Dark orange: parameter space for QCD axion

arXiv:2010.01349

Searching for Dark Matter annihilation



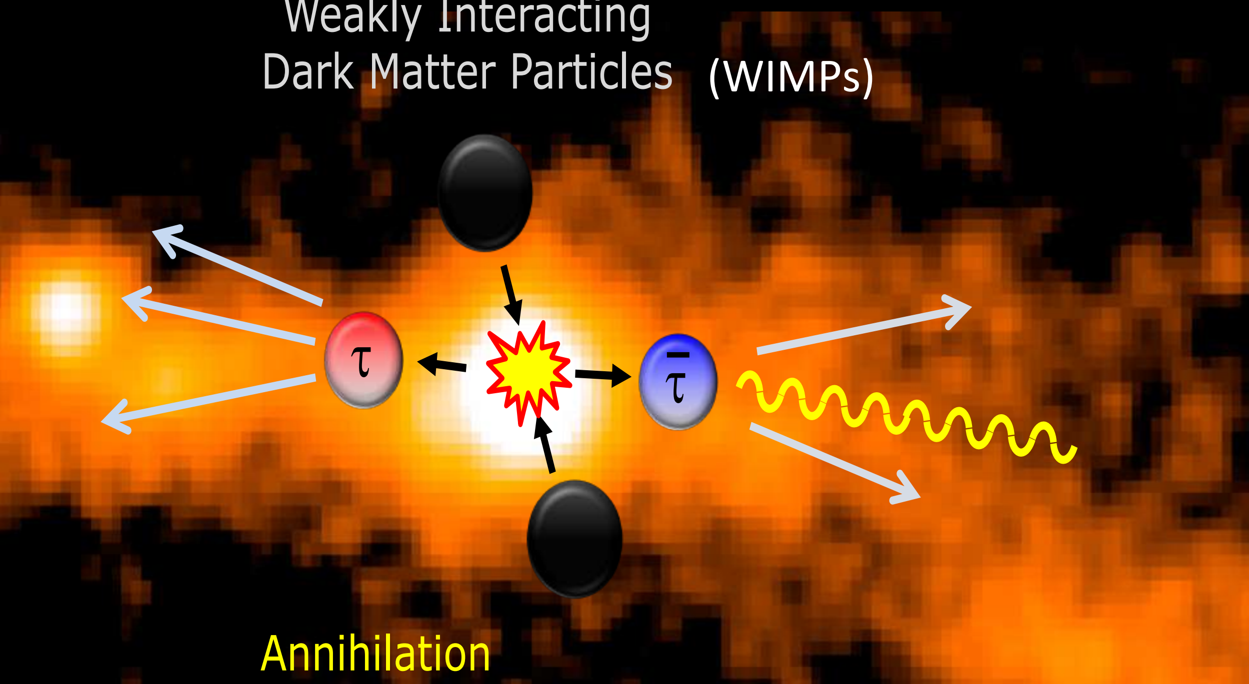
Does dark matter annihilate producing gamma rays?
What is the (dark) matter content?

CTA prospects for CDM signatures:

- Around the Galactic center
- In dwarf galaxies
- In clusters of galaxies

Dark matter search in galactic center

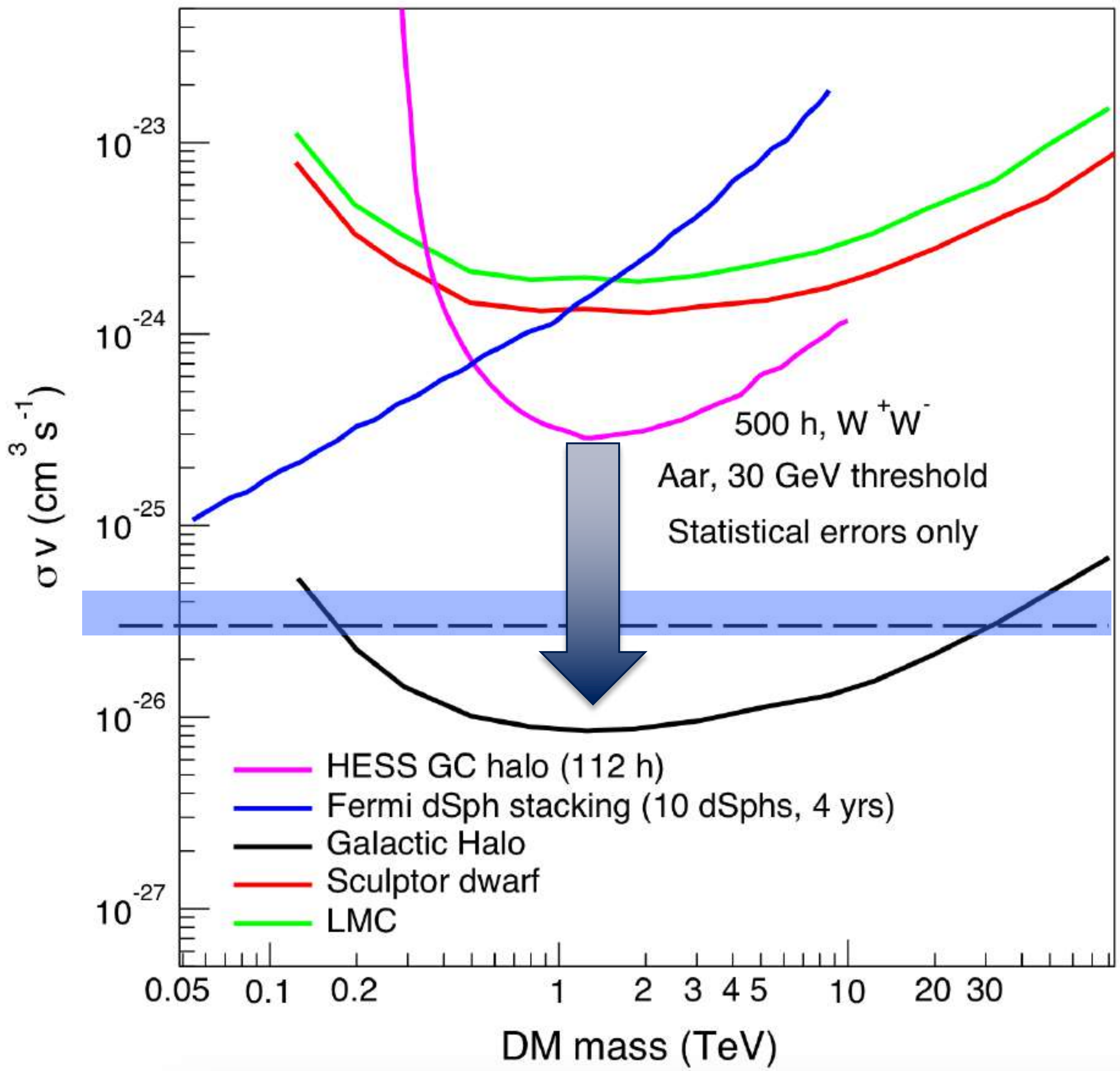
Weakly Interacting
Dark Matter Particles (WIMPs)



Annihilation
cross section
"known" from
Dark Matter
abundance

Characteristic spectral signature
known from particle physics

Dark matter annihilation

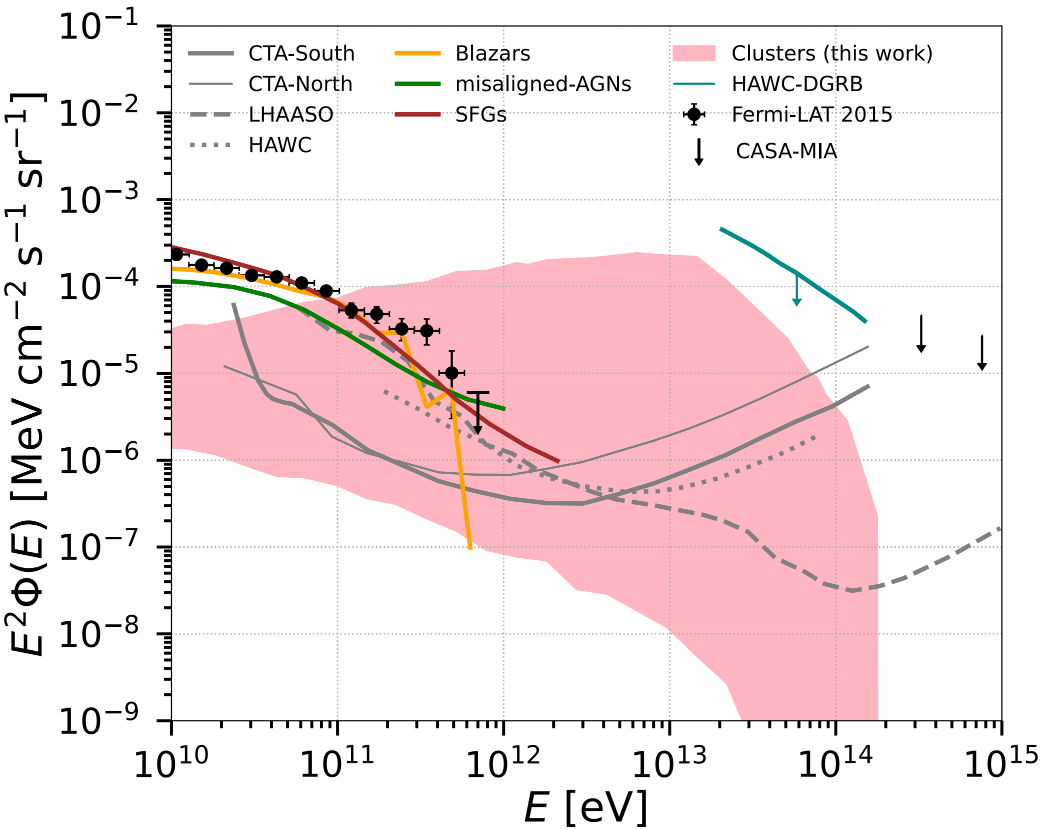


Canonical cross section

arXiv:2010.01349
arXiv:2007.16129

Gamma-Rays & DM in galaxy clusters

- Galaxy clusters able retain VHECR for Hubble time-> produce gamma-rays



CTA will probe gamma-ray and DM: Perseus cluster (in prep.)

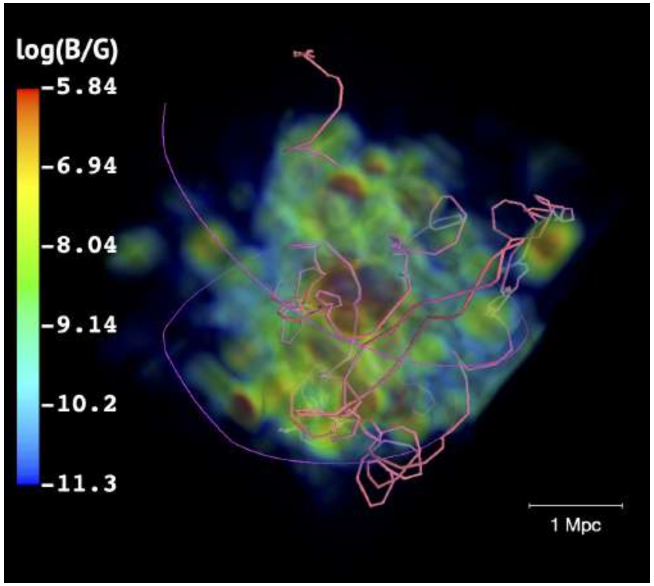
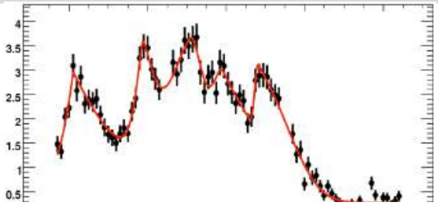


Figure 1. **Trajectories of CRs through a cluster** of mass $\sim 10^{15}\,M_\odot$ selected from our background simulation. The thick line corresponds to a CR with energy of 10 PeV, and the thin line to a CR with energy 500 PeV.

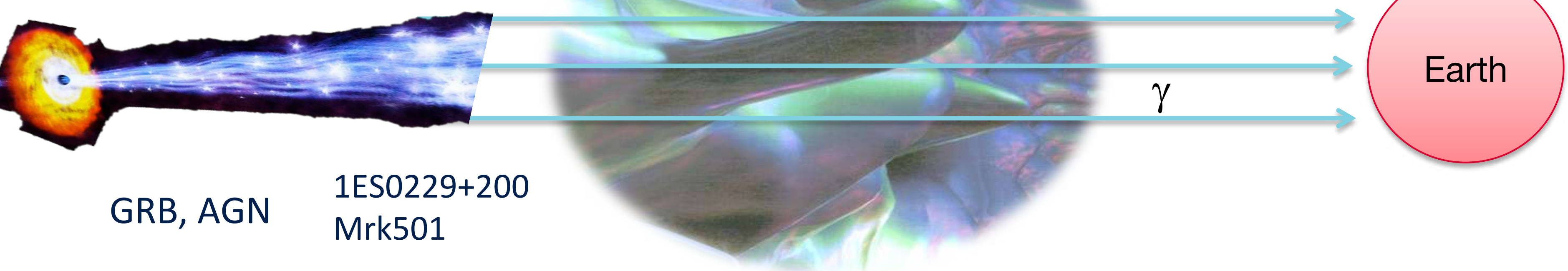
Diffuse Gamma-Ray emission from clusters z=0-5

(Hussain, Alves-Batista, de Gouveia Dal Pino & Dolag, Nature Comms. 2023, in press)

Photon propagation: LIViolation



arXiv:1101.3650
arXiv:0810.3475
arXiv:2007.16129



GRB, AGN

1ES0229+200
Mrk501

- **Quantum Gravity effects (at Planck scales):** arrival time delays between photons of different energies travelling large distances (due to *wavelength dependent refractive index of the vacuum)*
  -> **LIV - variation of light speed**

$$\boxed{\Delta t \simeq \left(\frac{\Delta E}{\xi_\alpha E_{\rm Pl}}\right)^{\alpha} \frac{L}{c}}$$

$$E_{\rm Pl} = \sqrt{\hbar c/G_{\rm N}} \simeq 1.22 \times 10^{19}\ \rm GeV$$

α~1-2 ξ_α - factor of Planck energy for QG

Mini-Array

A CTA Precursor @ Tenerife

9 SST-2M telescopes:
INAF (Italy) + Brazil, South Africa, Spain, Switzerland

3 structures: Brasil - IAG-USP (FAPESP funding)

Currently in construction
Installation **Teide Observatory (Tenerife, Canary Islands):**
2022-2025

Credits: M. Leone

ASTRI mini-array: mini but not small…

Expected performance:

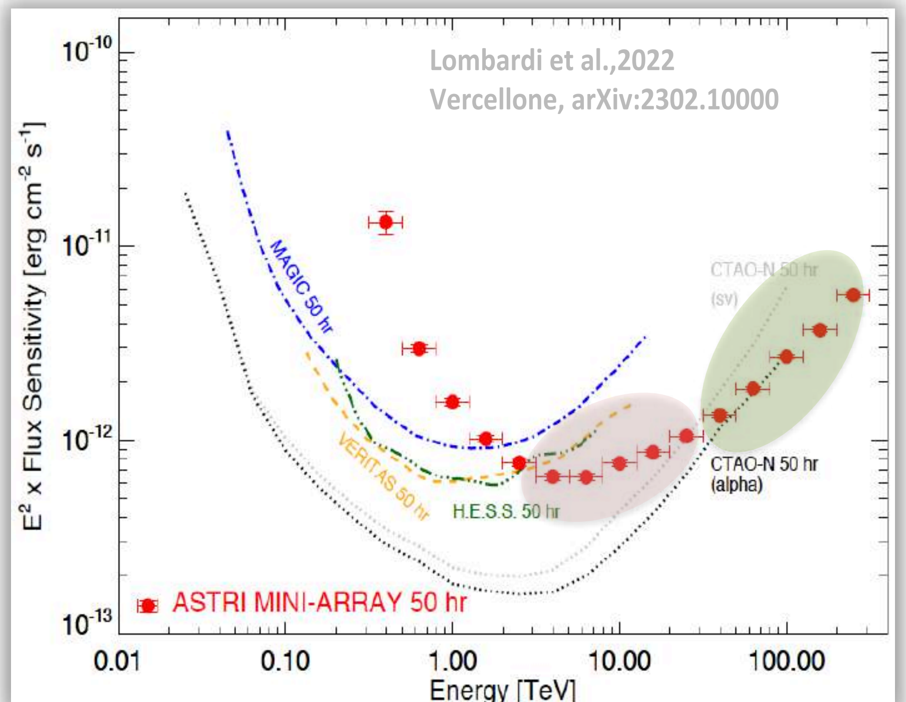
- **Sensitivity: better than current IACTs (E > 10 TeV):**
  - Extend spectra of already detected sources and measure cut-offs
  - Characterize morphology of extended sources at the highest VHE

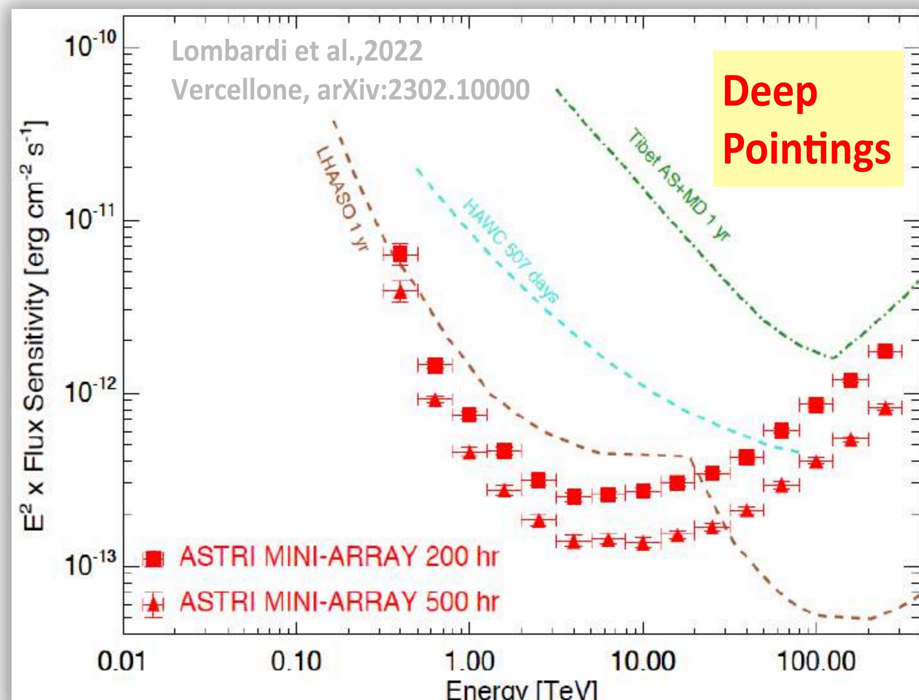
- **Energy/Angular resolution: < ~10% / < ~ 0.05° (E ~ 10 TeV)**
- **Wide FoV (≥ 10°), with homogeneous off-axis acceptance**
  - Optimal for multi-target fields, surveys, and extended sources
  - Enhanced chance for serendipity discoveries

Mini Array Performance

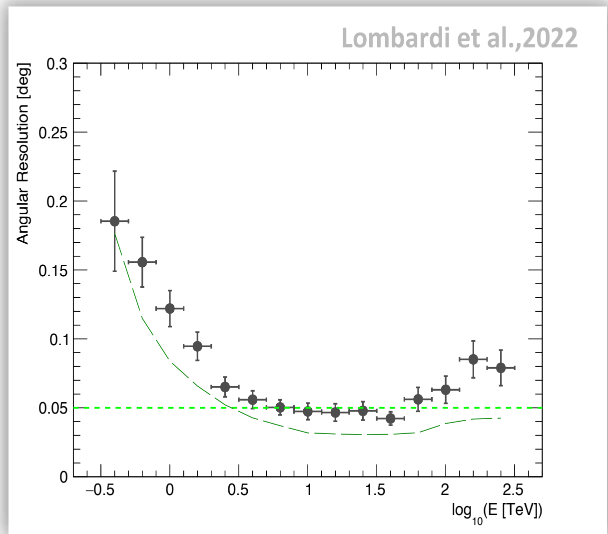
We extend current IACTs **differential sensitivity up to several tens of TeV and beyond**

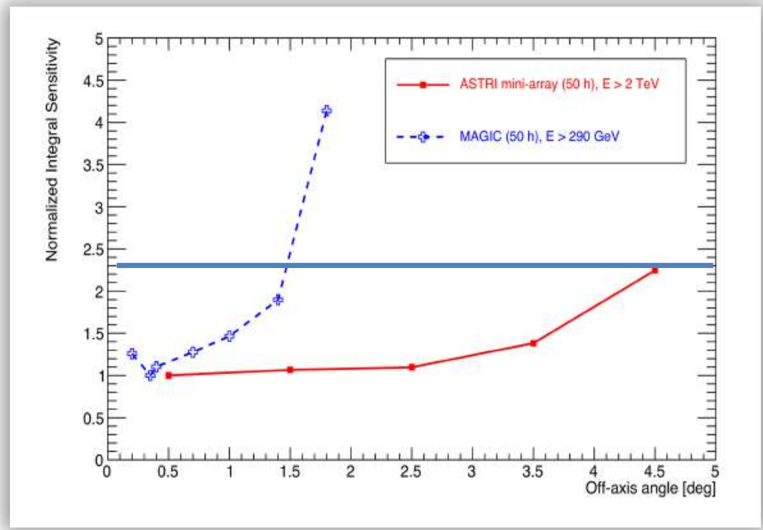
Investigate possible spectral features at VHE, such as the presence of **spectral cut-offs** or the detection of emission at several tens of TeV expected from **Galactic PeV sources**

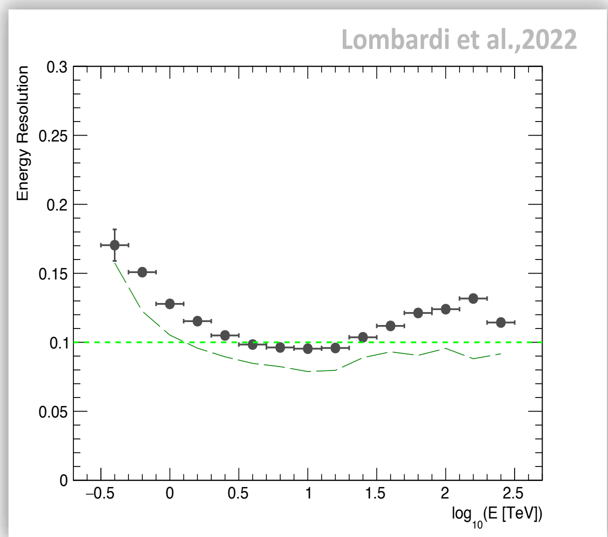




FOV, Angular and Energy Resolution







Sensitivity: better than current IACTs (E ≳ 3 TeV)

- Broad-band spectrum
- Spectral cut-off constraints

Energy/Angular resolution: ~10% / ~0.05° (E ~10 TeV)

- Extended sources morphology

10° field of view with excellent off-axis performance

- Multi-target fields
- Serendipitous discoveries

Science with the ASTRI Mini-Array

Pillar 1
The origin of cosmic rays

- Quest for PeVatrons
- Particle propagation
- PWN HE emission
- UHECR from SB galaxies

Pillar 2
Fundamental physics

- IR EBL constraints
- Probing IGMF
- Blazars & hadron beams
- Test on ALPs & LIV

Time-domain

GRB, GW, ν

Synergies

MWL, Legacy

Non γ–ray

UHECR measure
SI^3

LHAASO Sources at PeV energies

Cao et al., 2021, Nature

Source name	RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326	276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545	279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338	280.75	−3.65	8.5	$0.26 -0.10^{+0.16}$	0.73(0.17)
LHAASO J1849-0003	282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745	292.25	17.75	7.4	$0.71 -0.07^{+0.16}$	0.38(0.09)
LHAASO J1956+2845	299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102	308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157	317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

The **ASTRI Mini-Array** will investigate these and future UHE sources, providing both the opportunity for **their precise identification** and important **information on their morphology and spectra**

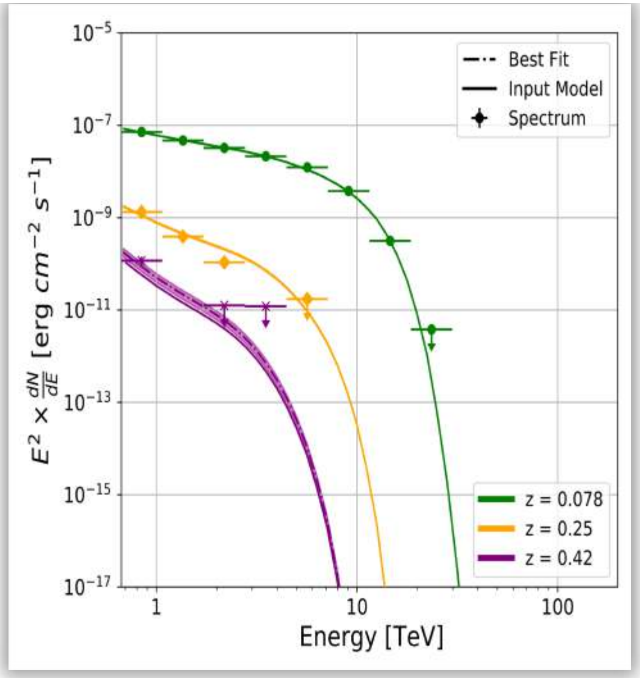
Discovery of **12 sources emitting at several hundreds of TeV**, up to 1.4 PeV

Crab aside, the majority of remaining sources represent **diffuse γ-ray structures with angular extensions up to 1°**

The **actual sources** responsible for the ultra high-energy γ-rays **have not yet been firmly localized and identified** (except for the Crab Nebula), leaving **the origin of these extreme accelerators open**

Gamma-Ray Bursts with Mini-Array

- GRBs confirmed as a new class of TeV emitters thanks to the MAGIC detection of GRB 190114C (z=0.42)
- SSC component extending into the TeV energy range
- LHAASO detection of **GRB 221009A (z=0.15) well above 10 TeV challenges the standard physics model**



Simulation of the emission from three GRB 190114C-like bursts, at three different redshifts (z = 0.078, z = 0.25 and z = 0.42)

Simulations of GRB 221009A will start very soon

The ASTRI Mini-Array

- might have detected emission from GRB 190114C
- is able to confirm afterglow emission at E >1 TeV from close (z < 0.4) GRBs if observations start within the first tens of seconds up to few minutes from the onset of the burst
- can measure the spectral cut-off, either originated by the EBL absorption or intrinsic, if greater than 1 TeV

The expected number of follow-ups on observable GRBs is about 1 per month

Mini Array - Summary

ASTRI mini-array: mini but not small…

The ASTRI Mini-Array will start **scientific observations in 2025** from the *Observatorio del Teide* with a 4 (core science) + 4 (observatory science) year programme

Its **10° field of view** will allow us to investigate both extended sources (e.g., SNRs) and crowded/rich fields (e.g., the Galactic Center) with a single pointing

Its **3’ angular resolution** at 10 TeV will allow us to perform detailed morphological studies of extended sources

Its **sensitivity extending above 100 TeV** will make it the most sensitive IACT in the energy range 5-200 TeV in the Northern hemisphere before CTAO-N

Brazil in the construction of SSTs for CTA-South

cta
cherenkov telescope array

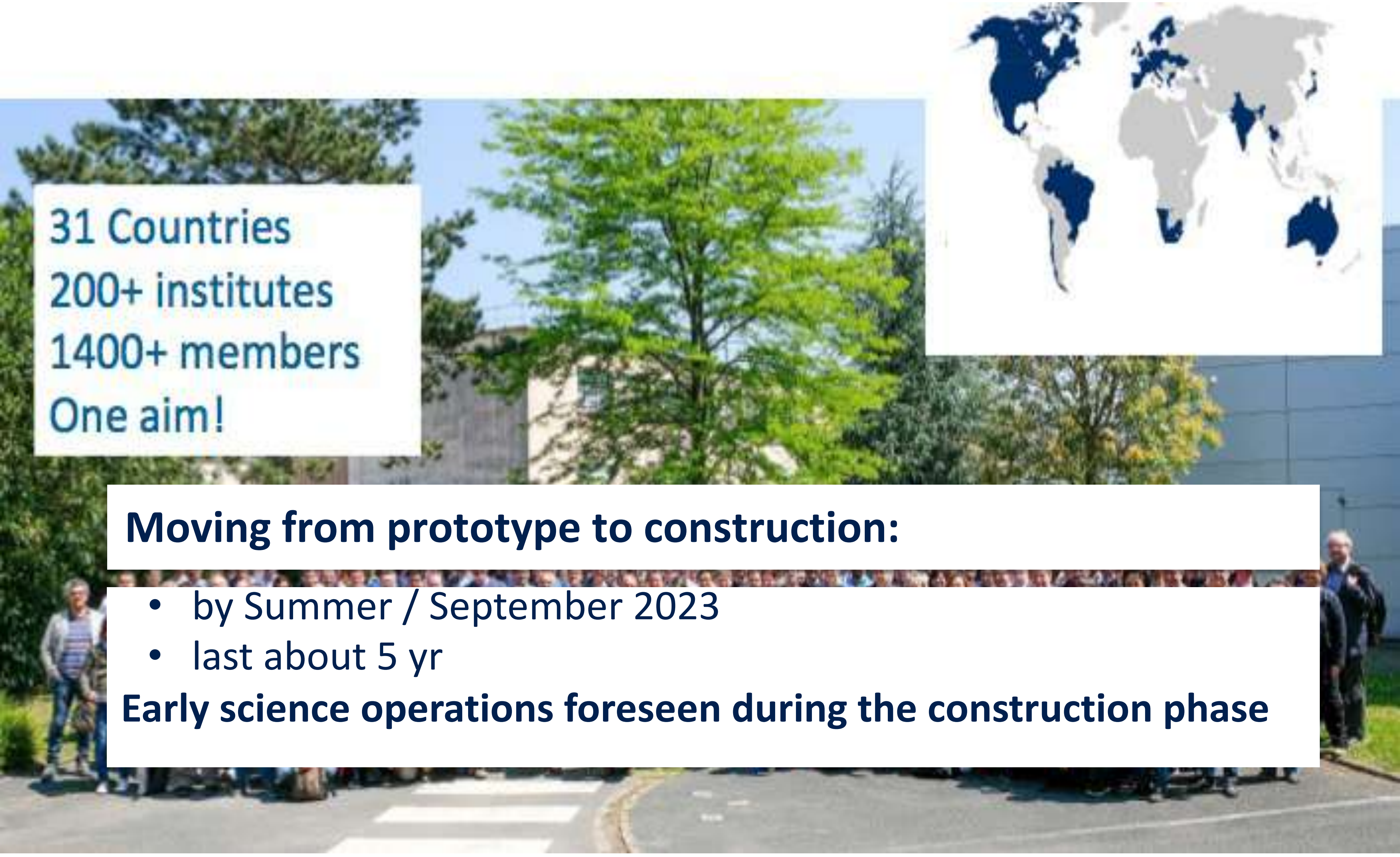
Brasil in the SST-CTA Program:

Currently: ~60 members in CTA-Br (~29 -> in SST–CTA from IAG-USP, EACH-USP, Mackenzie, UFABC, IFUSP, CBPF)

Aim: production in Brazil **of optical support of the 40 (ASTRI based) SST structure**s of CTA-South array (**α-configuration**) (FAPESP)

CTA Observatory is coming

CTA Observatory is coming

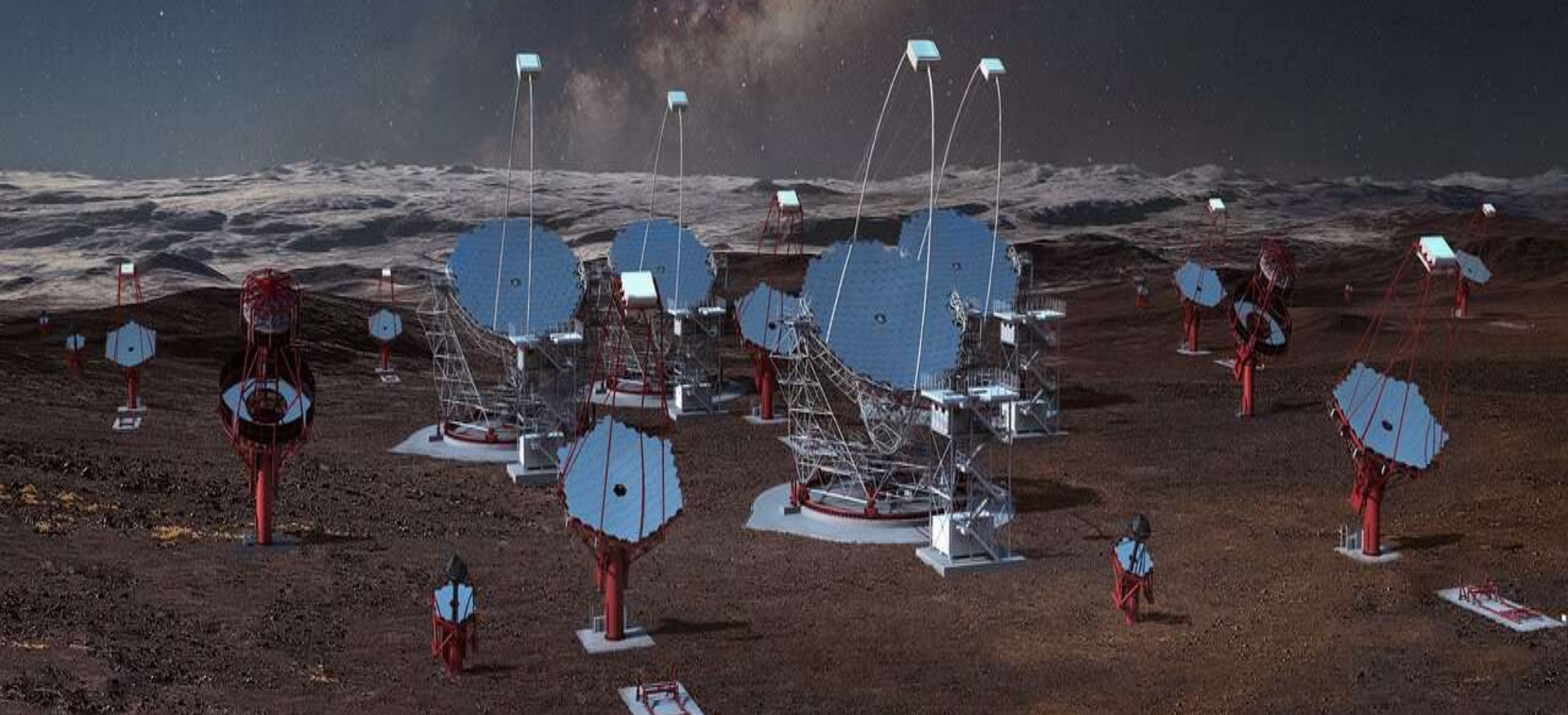


31 Countries
200+ institutes
1400+ members
One aim!

Moving from prototype to construction:

- by Summer / September 2023
- last about 5 yr

Early science operations foreseen during the construction phase



…in the mean time

Thank you