cta cherenkov telescope array

RICAP 18 — 7th Roma International Conference on AstroParticle Physics

Cherenkov Telescope Array: Science Goals & Current Status

RICAP 2018 (Roma, 07 Sept 2018)

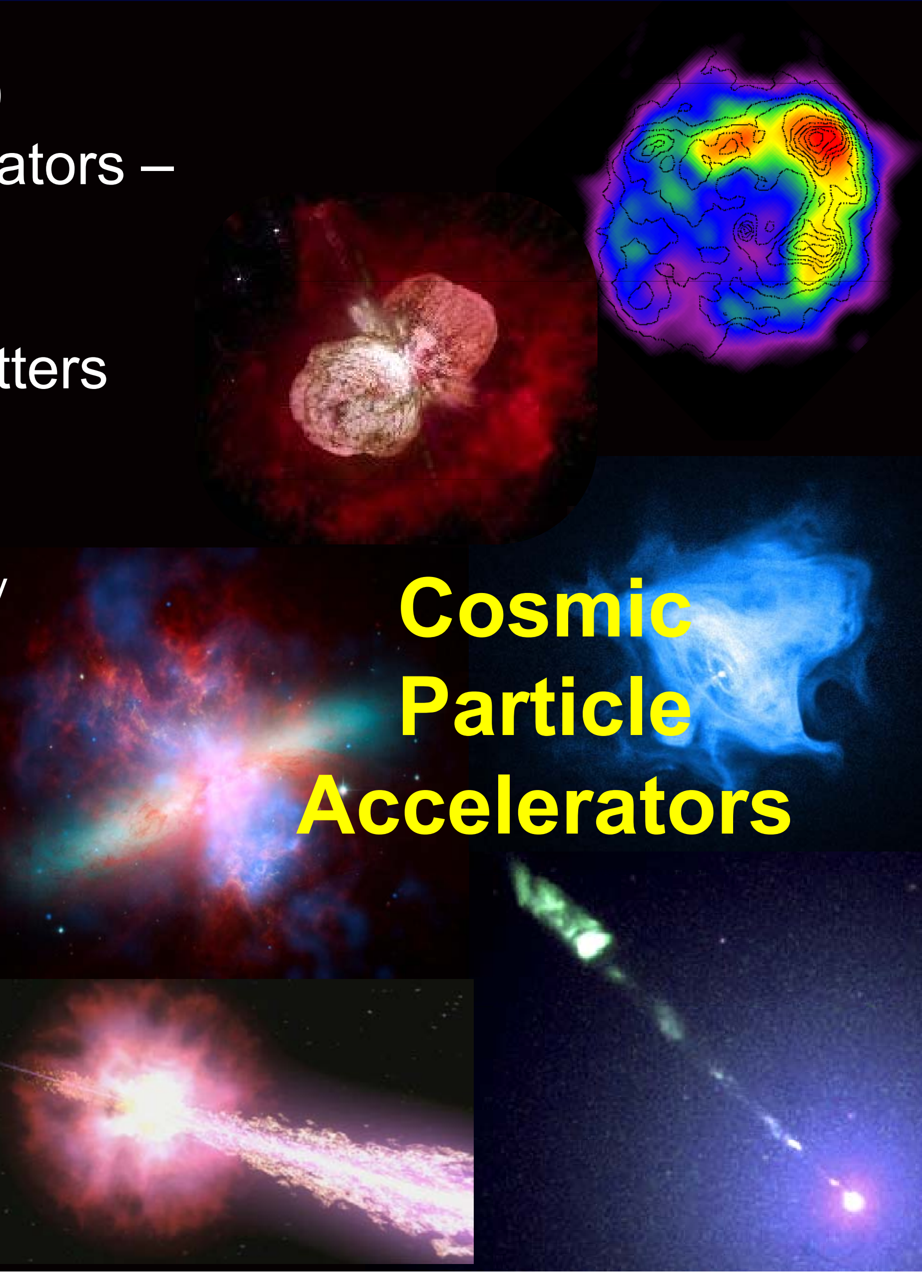
The CTA Consortium[1], represented by Rene A. Ong[2]

[1]See https://www.cta-observatory.org/consortium_authors/authors_2018_09.html

[2]University of California, Los Angeles, CA 90095, USA

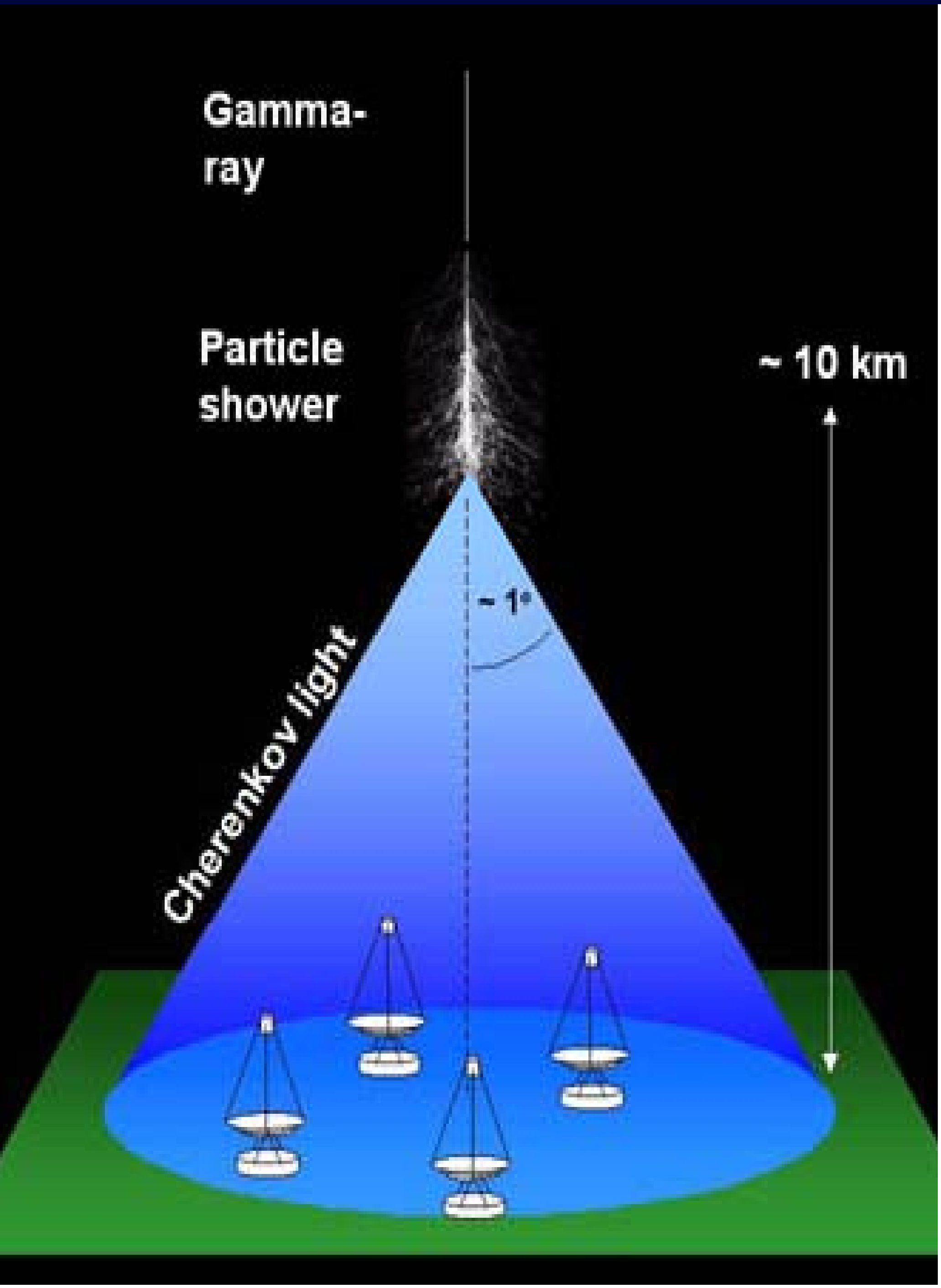
2005-2018:
VHE Astronomy Comes of Age

- Dominant expectation (pre-1990)
  - Will find the “cosmic ray” accelerators – probably SNRs
- Reality (2018)
  - Astonishing variety of VHE † emitters
    - Within the Milky Way
      - Supernova remnants
      - Bombarded molecular clouds
      - Stellar binaries - colliding wind & X-ray
      - Massive stellar clusters
      - Pulsars and pulsar wind nebulae
      - Supermassive black hole Sgr A*
      - Diffuse & extended emission
    - Extragalactic
      - Starburst galaxies
      - MW satellites
      - Radio galaxies
      - Flat-spectrum radio quasars
      - ‘BL Lac’ objects
      - Gamma-ray Bursts



† 50 GeV – 50 TeV

Imaging Atm. Cherenkov Technique



Atm. Cherenkov showers:

- V. large light pool ~250 m diameter
- Rapid time structure ~ 5 ns
- Fully calorimetric
- Fine angular structure (< 1 arc-min)

Imaging technique:

- Excellent shower reconstruction
- Very high background rejection

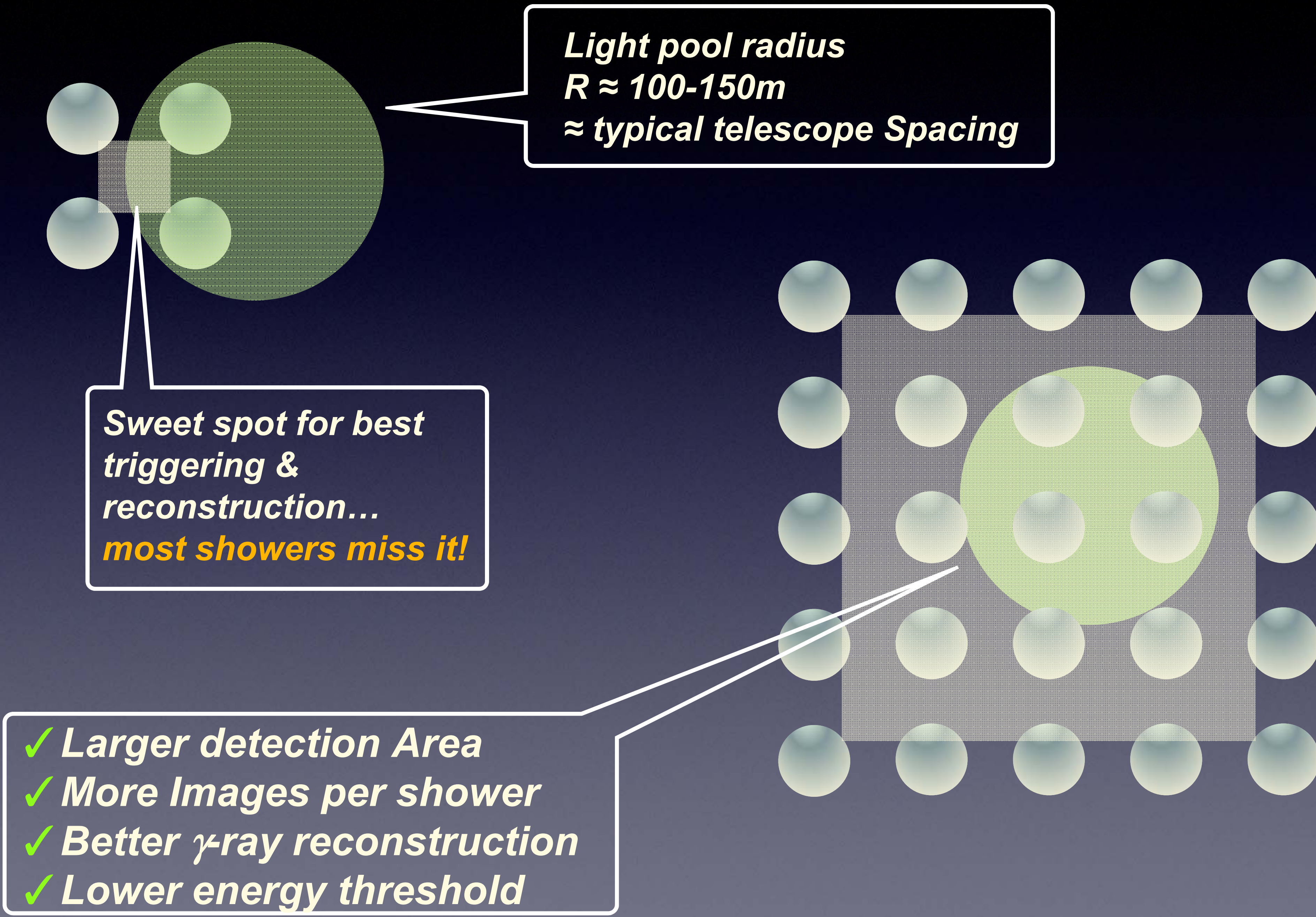
Well-demonstrated by current instruments: H.E.S.S., MAGIC, & VERITAS

But we have not reached limit of the technique !

Further improved by:

- More views of shower
- Higher resolution images
- Wider field-of-view

Larger area → More contained events, more images



Planning for the Future

cherenkov telescope array

What do we know, based on current instruments?

Great scientific potential exists in the VHE domain

- *Frontier astrophysics & important connections to particle physics*

Imaging Cherenkov technique is very powerful

- *Have not yet reached its full potential → large telescope array*

Exciting science in both Hemispheres

- *Argues for an array in both S and N*

Open Observatory gives substantial reward

- *Open data/access, MWL connections to get the best science*

International partnerships required by scale/scope

- *Challenges associated with putting pieces together (i.e. funding streams, communities, etc.)*


cta
cherenkov telescope array

CTA Consortium

cherenkov telescope array

The Consortium developed CTA and will construct the bulk of the CTA components through in-kind contributions

31 Countries
204 Institutes
1461 Members (503 FTE)

Sept 2018

CTA Main Scientific Themes

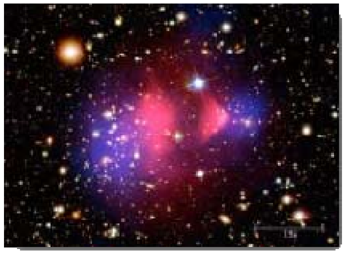
Cosmic Particle Acceleration

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

Probing Extreme Environments

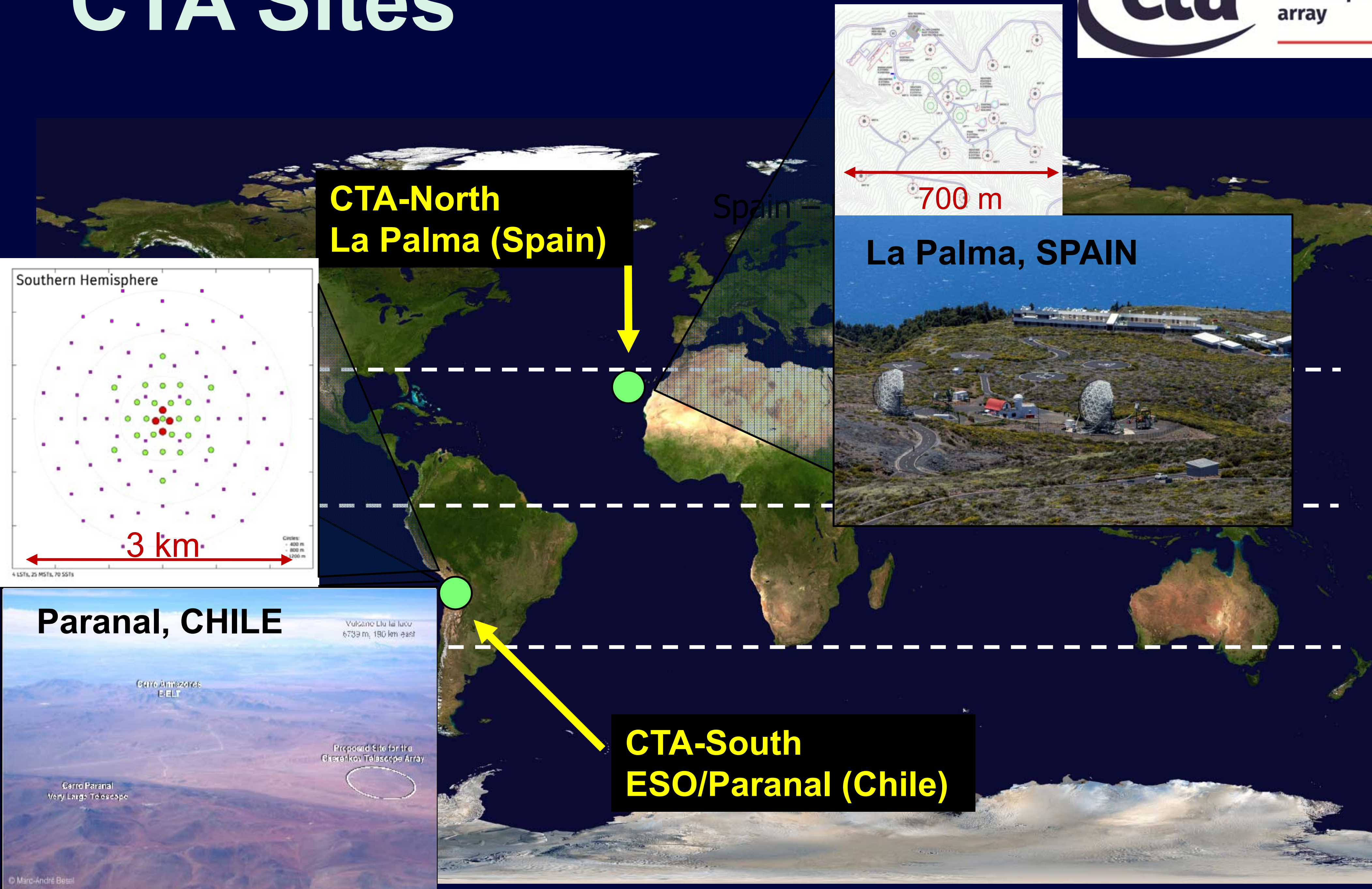
- Processes close to neutron stars and black holes
- Processes in relativistic jets, winds and explosions
- Exploring cosmic voids

Physics frontiers – beyond the Standard Model



- What is the nature of Dark Matter? How is it distributed?
- Is the speed of light a constant for high-energy photons?
- Do axion-like particles exist?

CTA Sites



HQ: Bologna, Italy
SDMC: Zeuthen, Gemany

CTA Concept – S Array

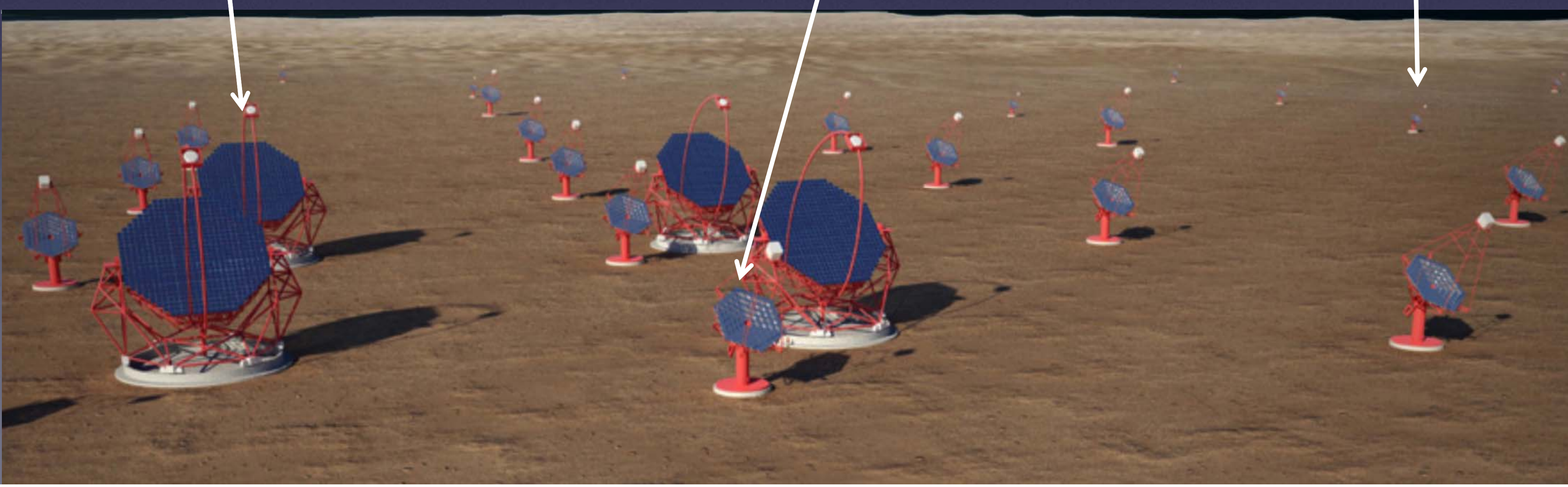
cherenkov telescope array

Science Optimization under budget constraints

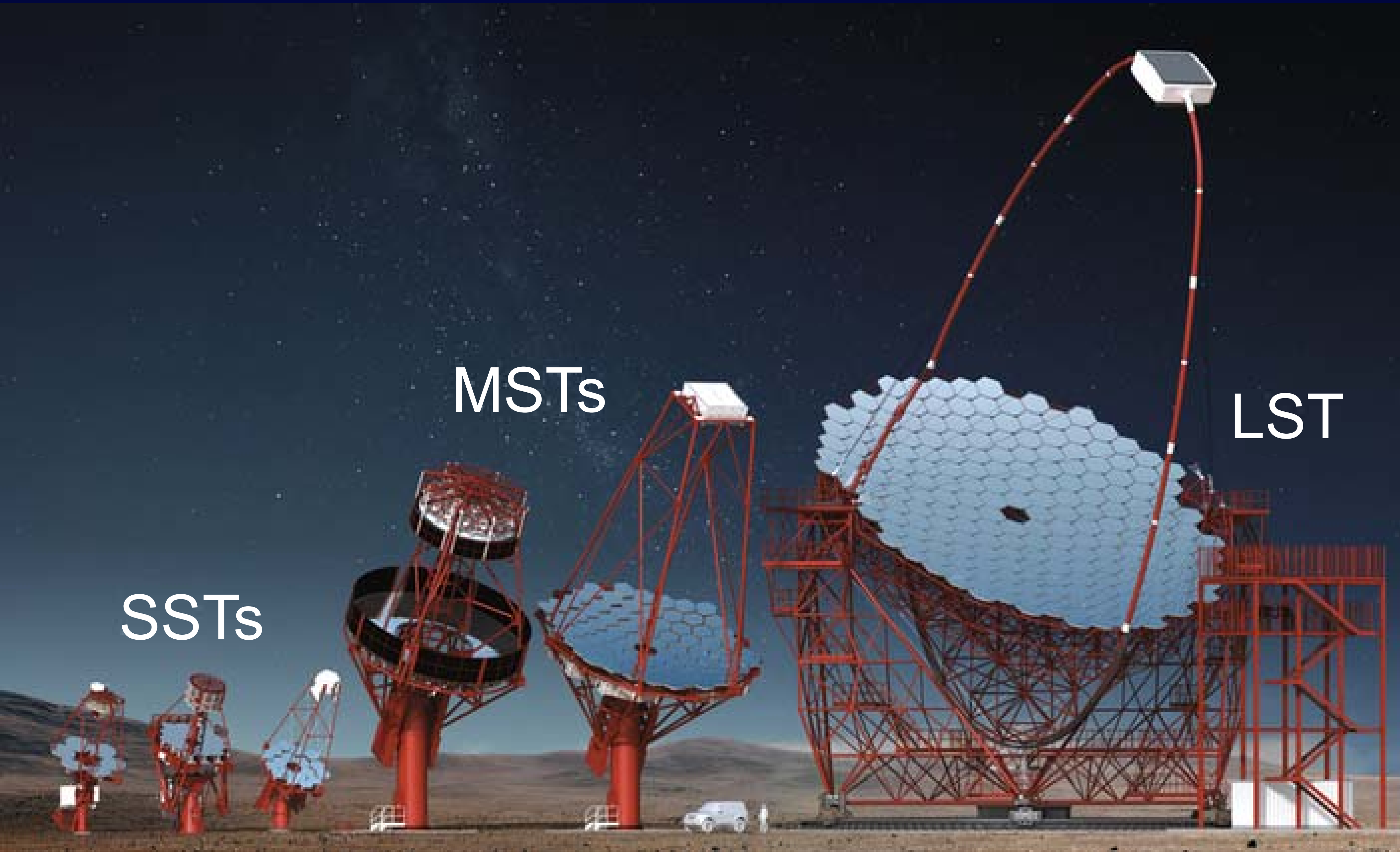
Low energies
Energy threshold 20-30 GeV
23 m diameter
4 telescopes
(LST's)

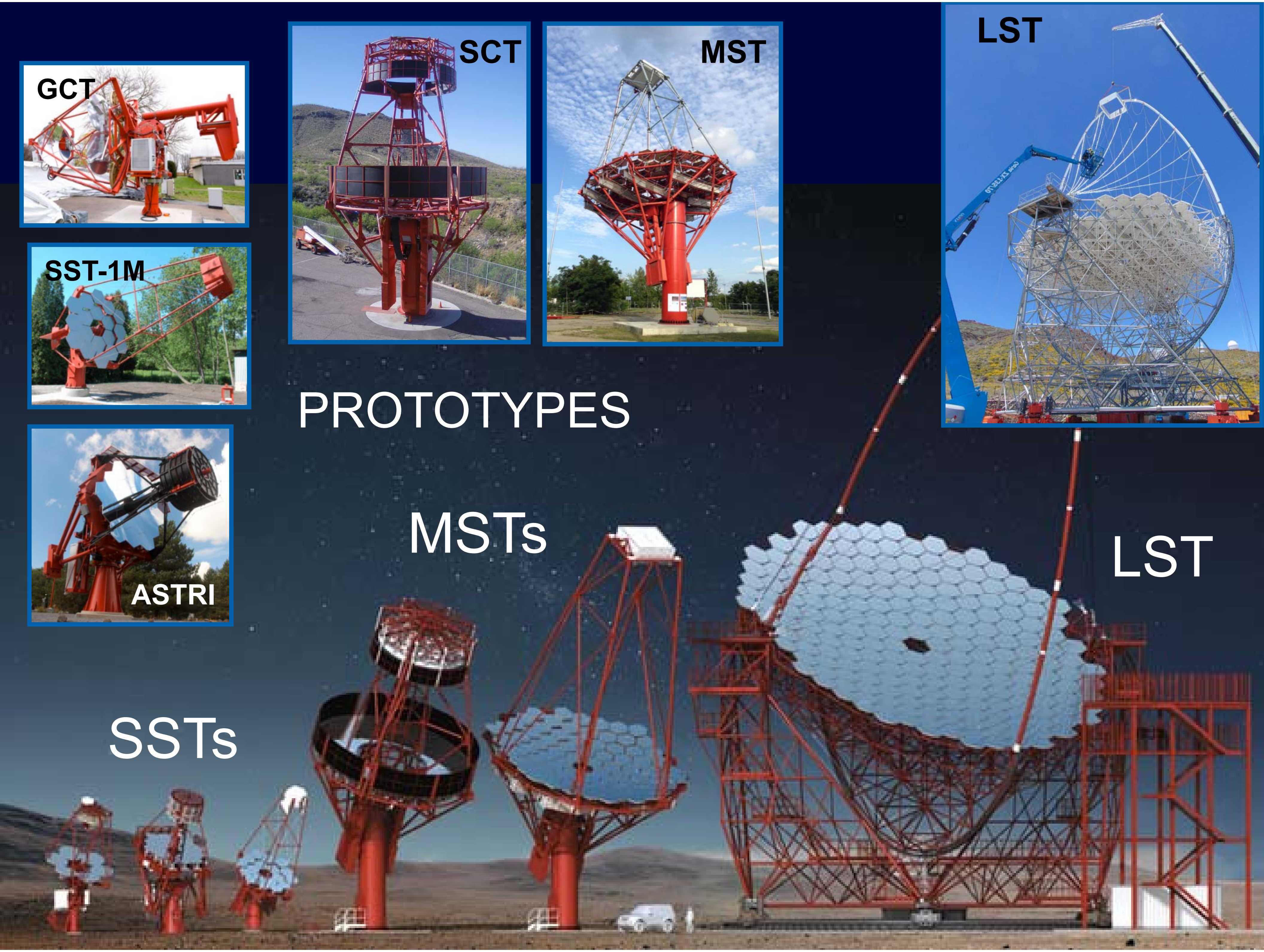
Medium energies
100 GeV – 10 TeV
9.7 to 12 m diameter
25 telescopes
(MST's/SCTs)

High energies
Up to > 300 TeV
10 km^2 eff. area @ 10 TeV
4m diameter
70 telescopes
(SST's)

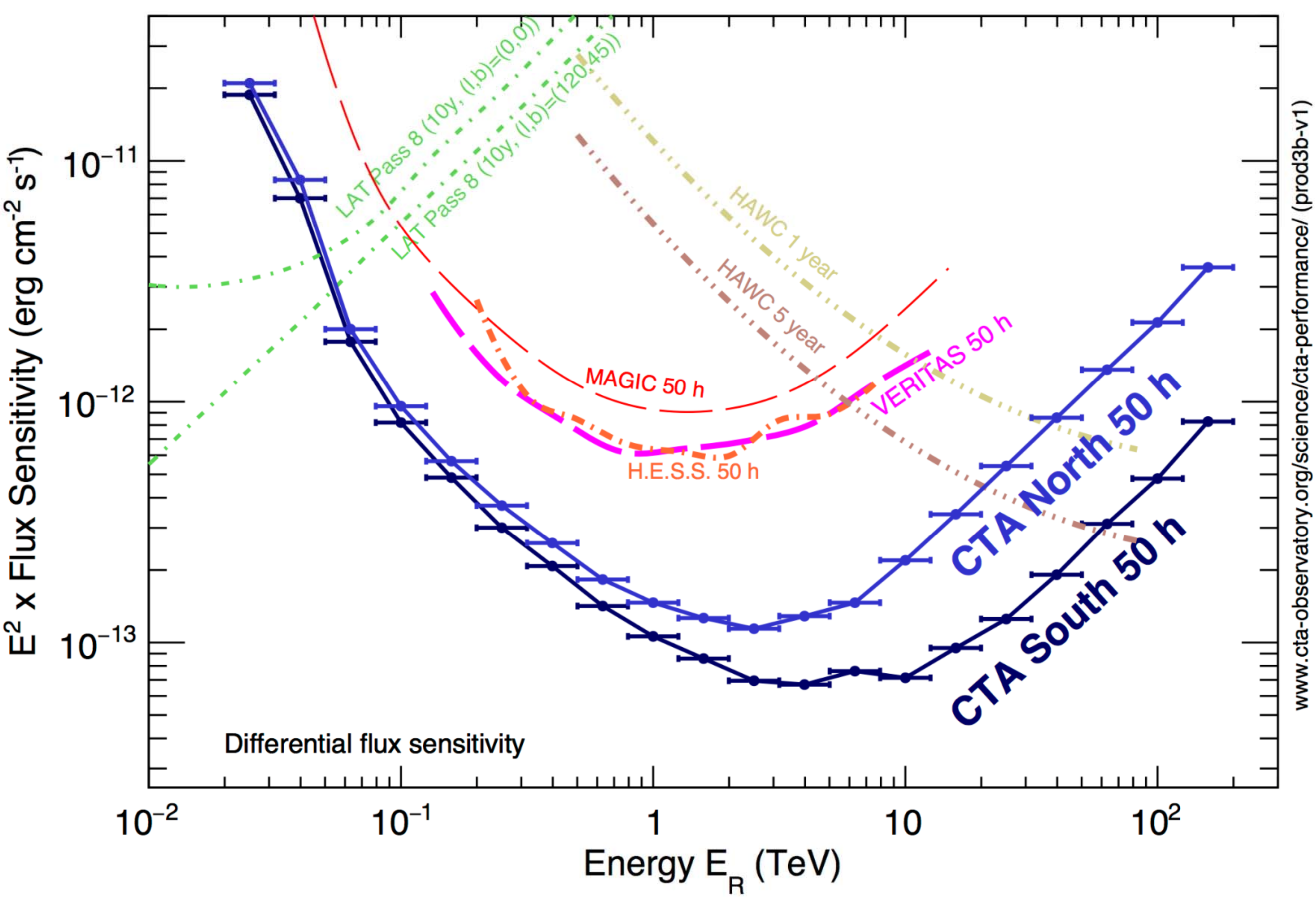


Telescope Types



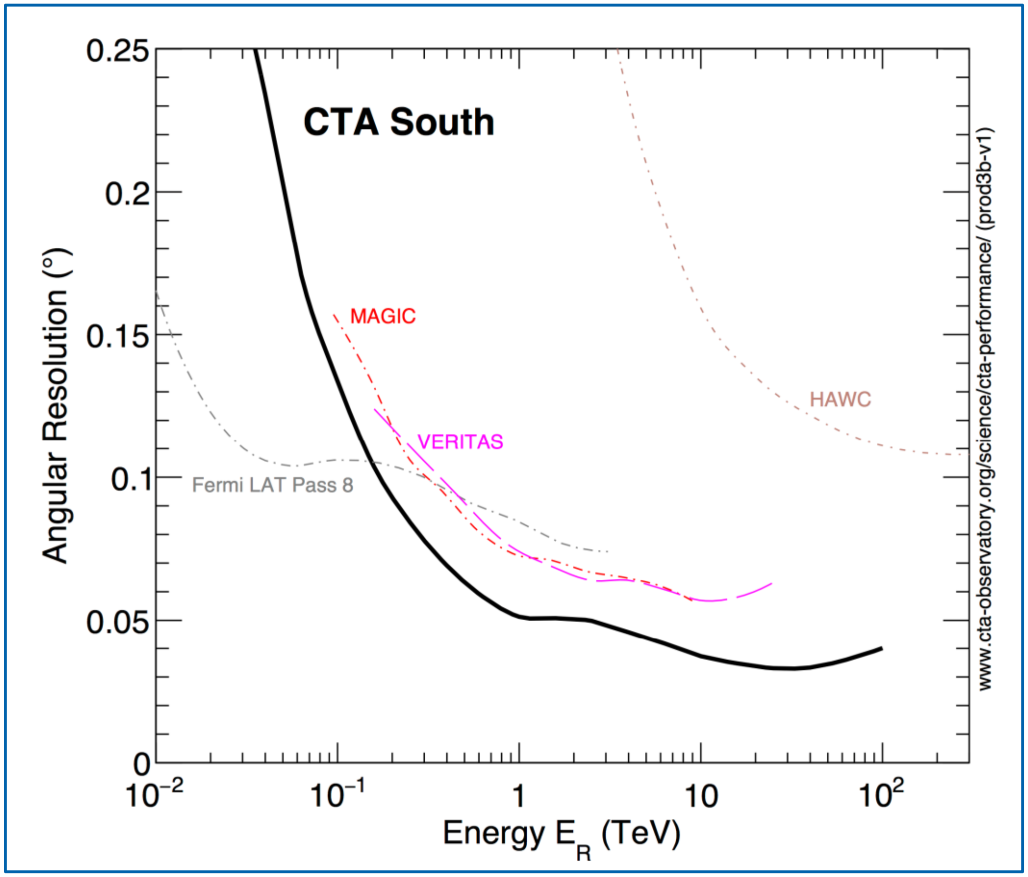

GCT
SST-1M
ASTRI
SCT
MST
LST
PROTOTYPES
MSTs
SSTs
LST

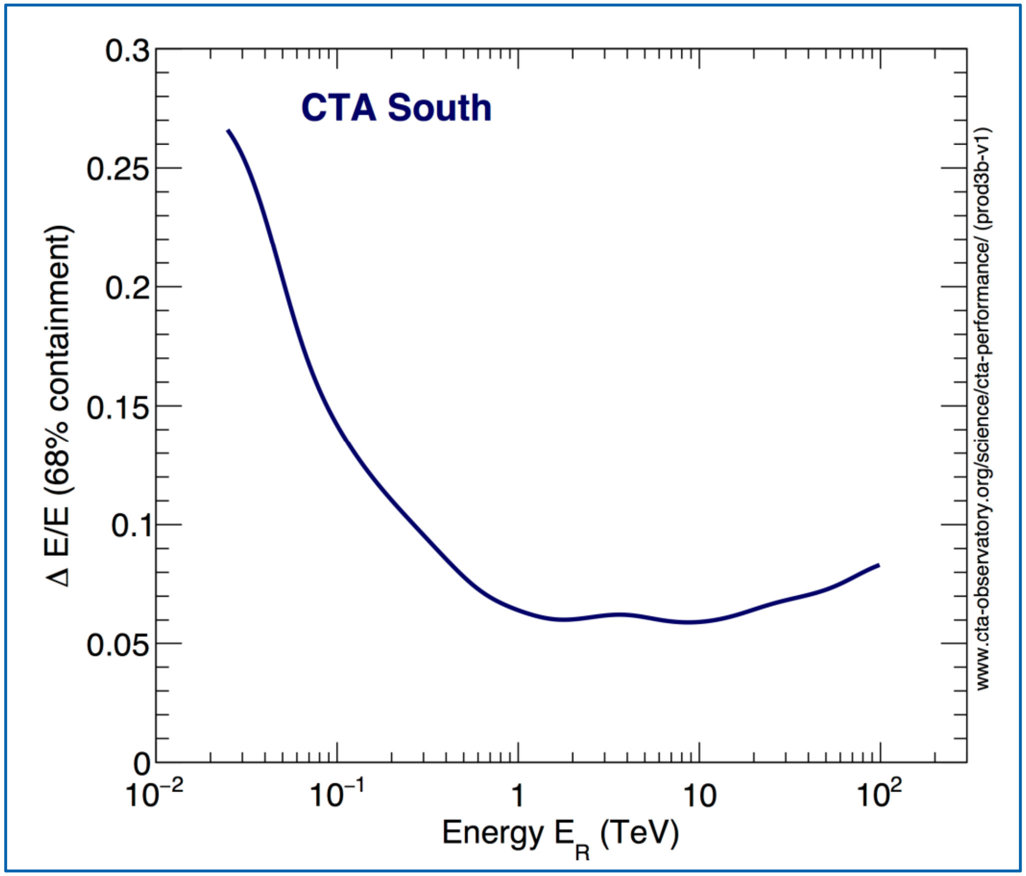
Flux Sensitivity



Major sensitivity improvement & wider energy range

Angular & Energy Resolutions





Important for resolving morphology of sources

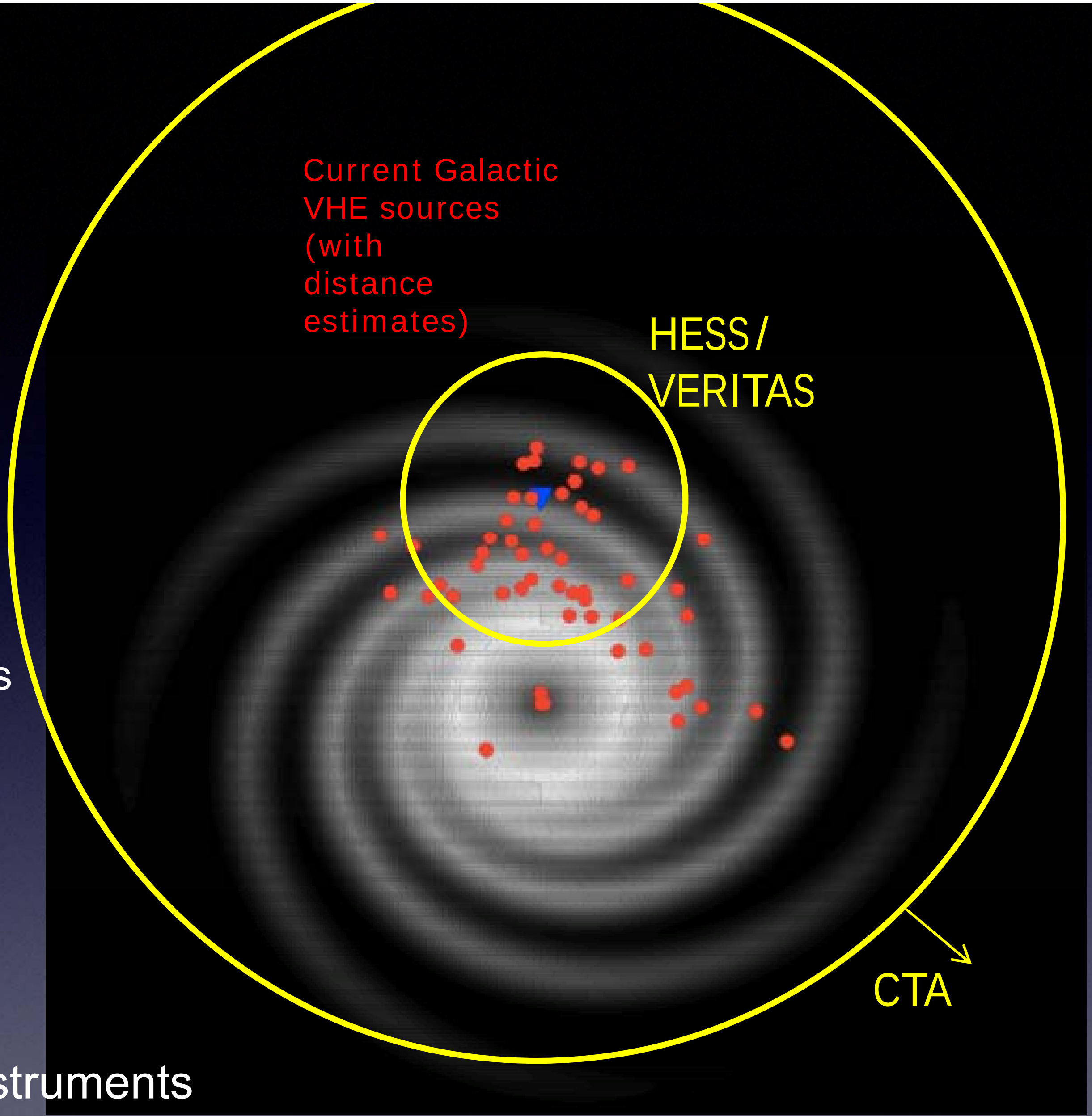
Important for spectral precision

Galactic Discovery Reach

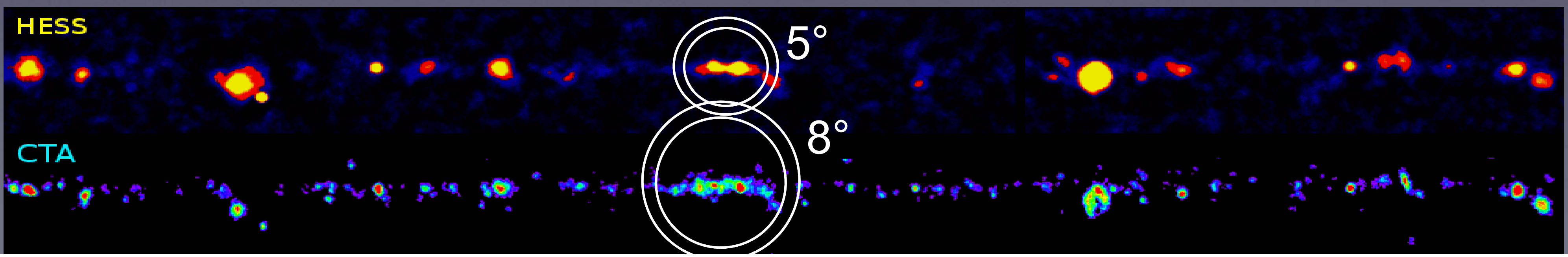
Young pulsars and SNRs

- have typical brightness such that current instruments can see only relatively local objects

CTA will see **whole** Galaxy



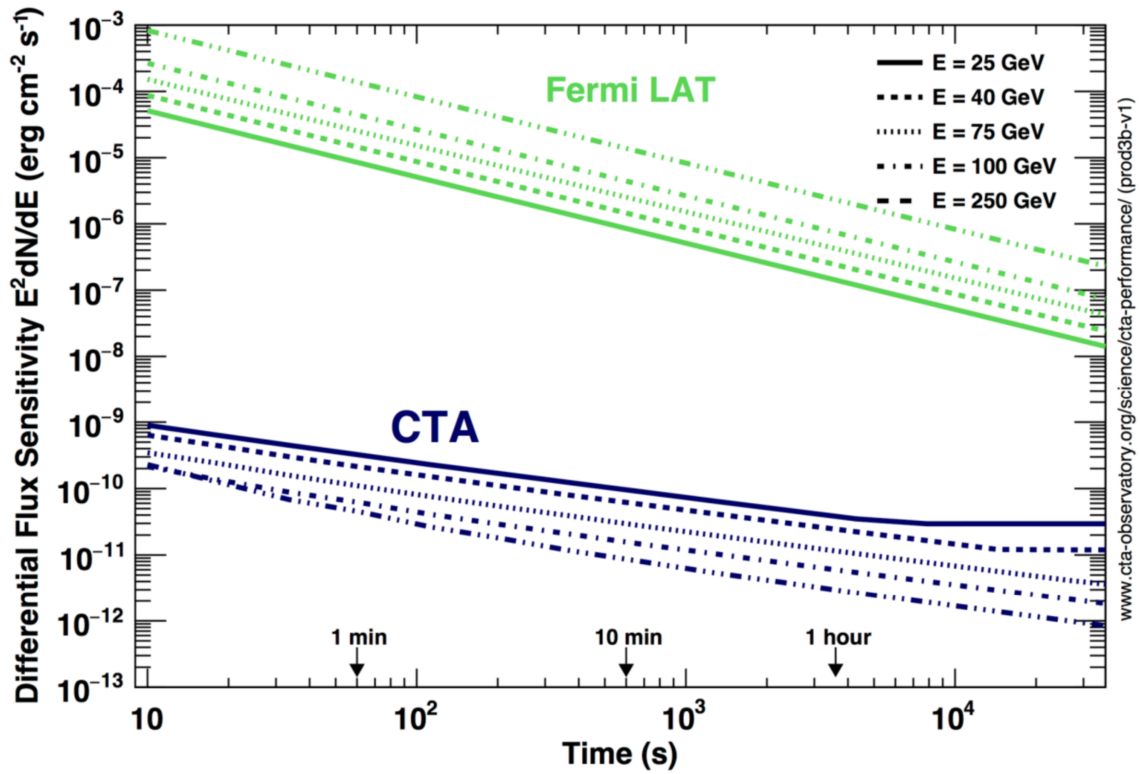
Survey speed:
x300 faster than current instruments



CTA as a Transient Factory

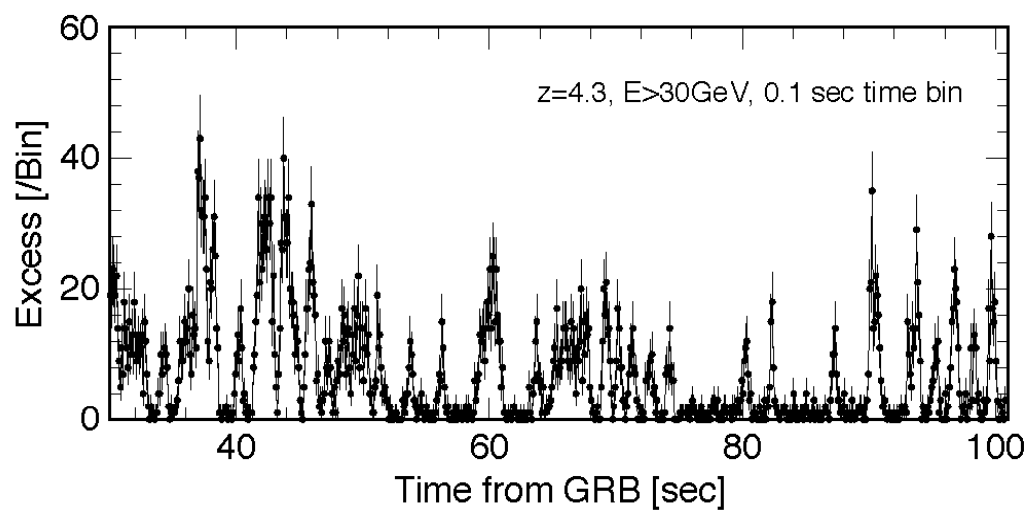
Big advantage
over Fermi and HAWC in energy range of overlap for ~min to ~ day timescales:

- Explosive transients (e.g. GRBs, GW events, etc.)
- AGN flares
- γ–ray binaries



Disadvantages:

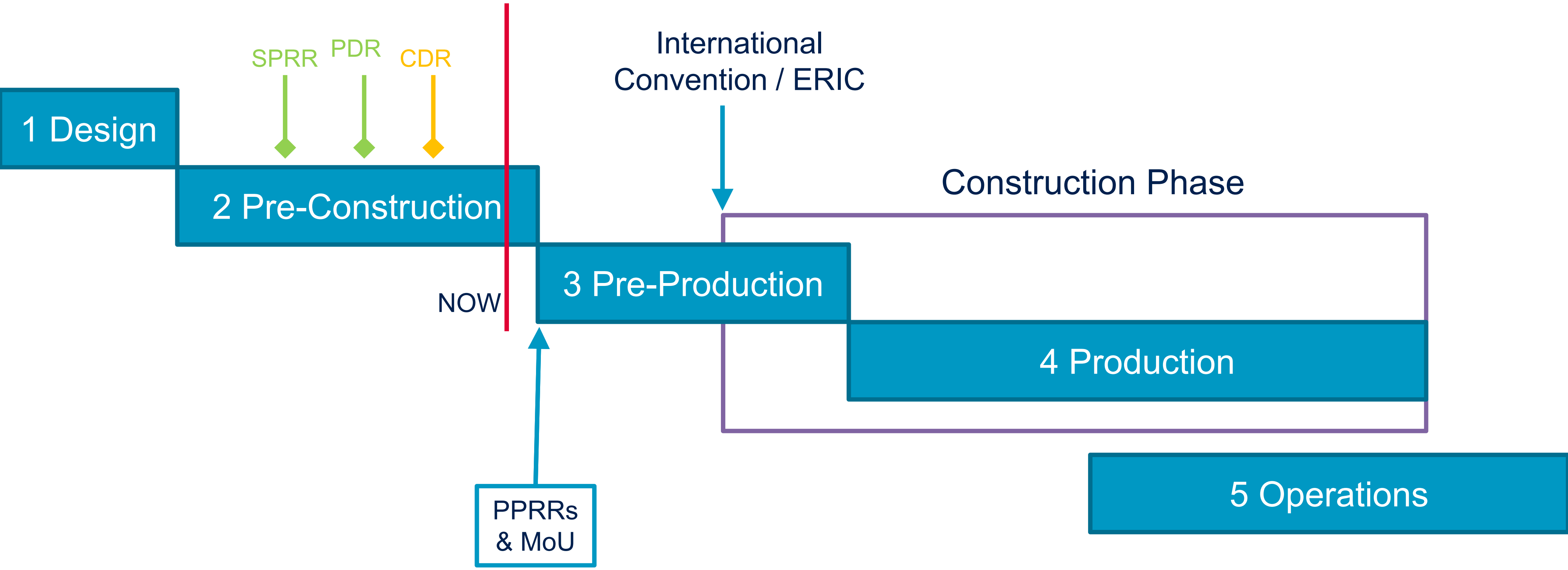
- Limited FoV (more focused on follow-ups)
- Prompt reaction is critical



GRB (z=4.3) Light curve

CTA capabilities → Key Science Project devoted to Transients

CTA Phases & Timeline



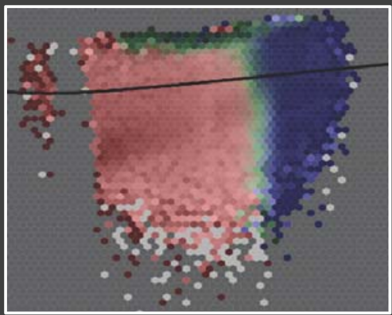
- 2017-8: Hosting agreements, site preparations start
- 2019: Start of construction
- Construction period of ~6 years
- Initial science with partial arrays possible before construction end

CTA Science Program

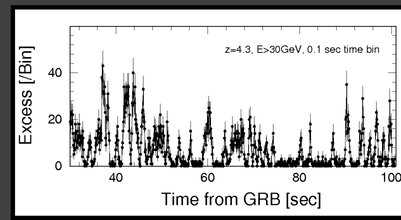
- Open observatory
- Proposals for Guest Observer Programme – essential for major community involvement
- All data on public archive after proprietary period (typically 1 year)
- ~40% time in Key Science Projects (KSPs), carried out by CTA Consortium

KSP Programme described in
Science with CTA document
arXiv:1709.07997
(soon to be published as a book)

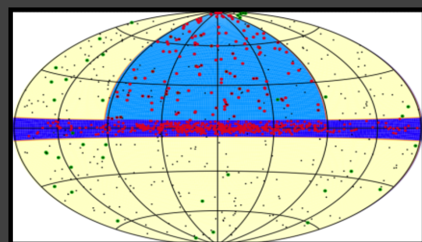
Key Science Projects (KSPs)



Dark Matter Programme

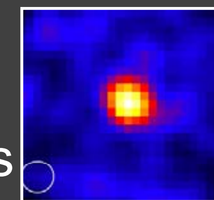


Transients



ExGal Survey

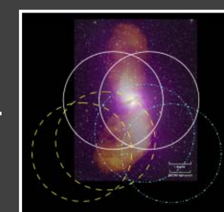
Galaxy Clusters

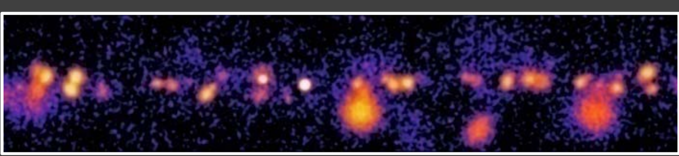


Extragalactic

Star Forming Systems

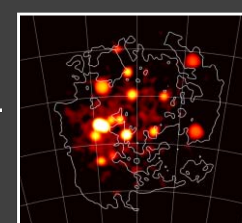
AGN





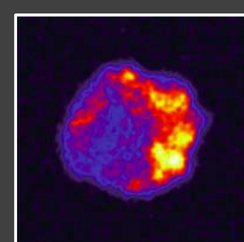
Galactic

LMC Survey

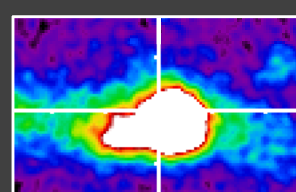


Galactic Plane Survey

PeVatrons



Galactic Centre

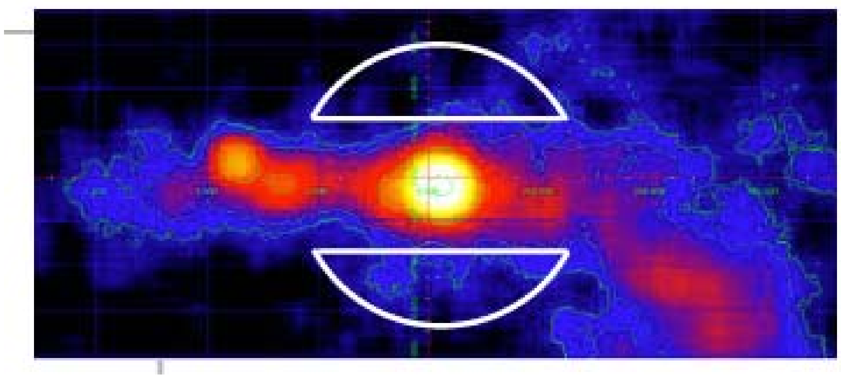


KSPs discussed here

Dark Matter Programme

Existence of DM well established

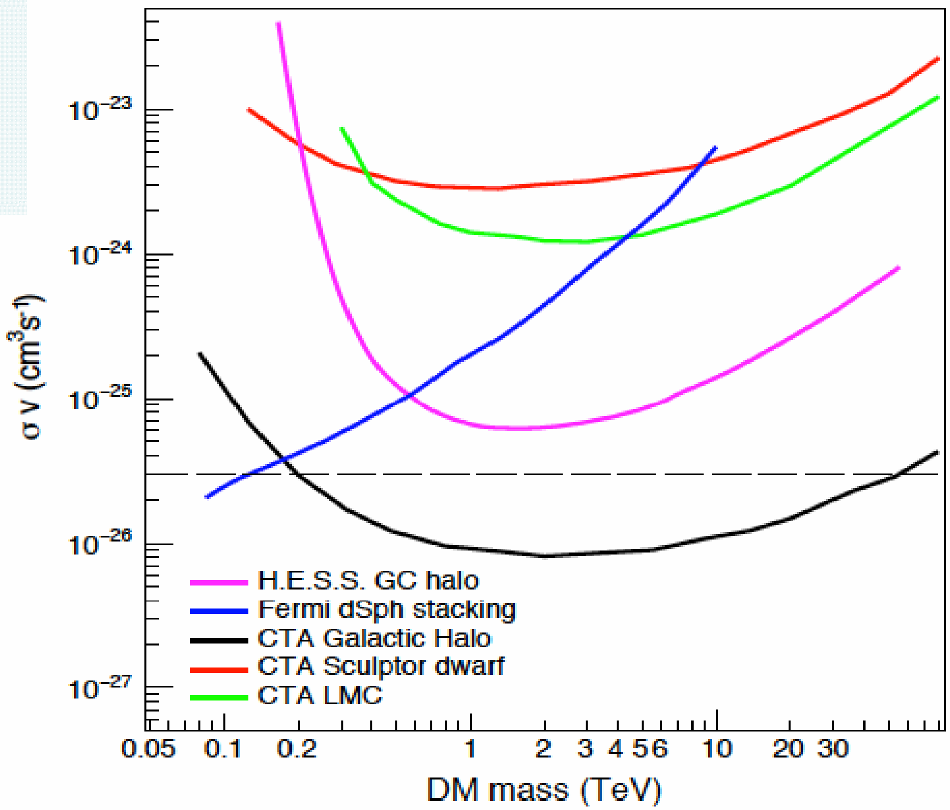
- CTA will search for DM via indirect detection technique: WIMP annihilation or decay
- Targets: GC, dSphs, LMC, G. Clusters



Programme strategy focused on a possible detection:

- Key target: <u>Galactic centre halo</u> with deep observation (O 500h) to reach relic x-section over wide mass range
- Complementary data on other targets

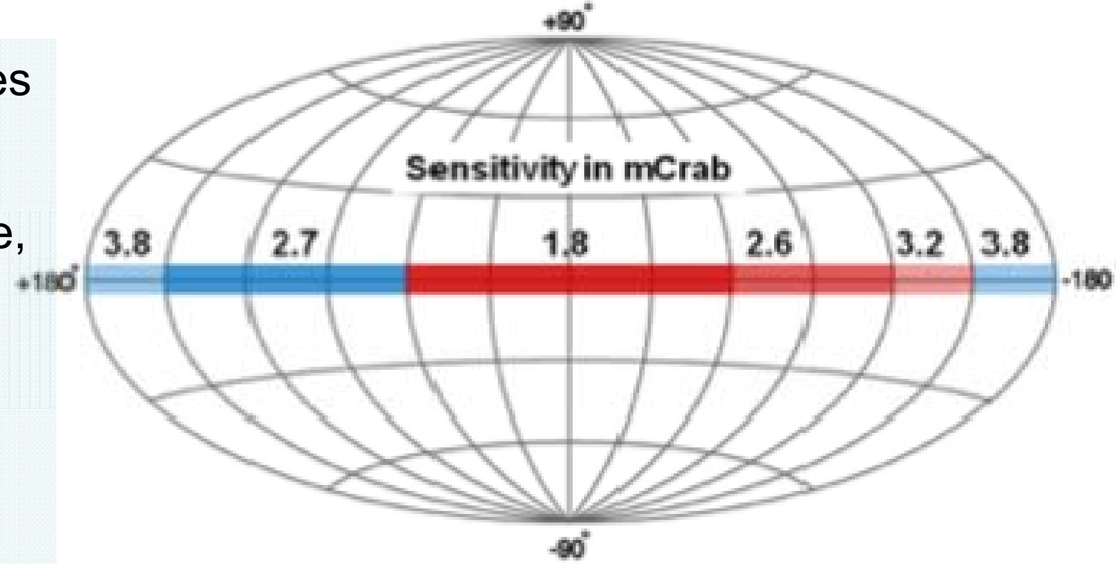
See talks by Maria I. Bernardos (LMC) & Francesco Saturni (Dwarfs), this meeting

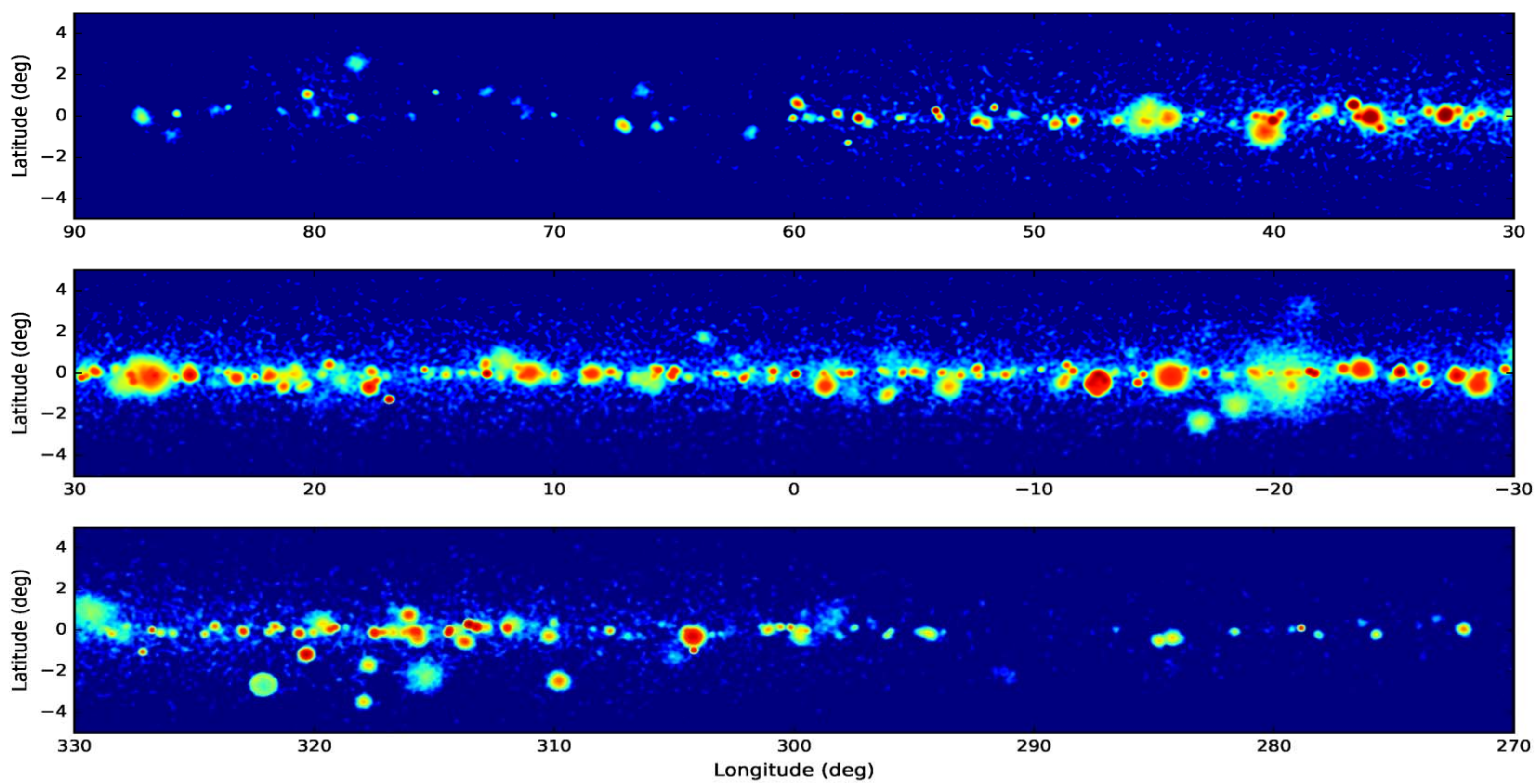


Cover WIMP masses above reach of direct detectors and the LHC

Galactic Plane Survey

- First high sensitivity survey at TeV energies
- Full-plane survey at arc-minute resolution
- Expect many100's of new sources, PWNe, SNRs and binaries → population studies
- Great potential for discovery of new phenomena
- Detailed view of diffuse γ-ray emission

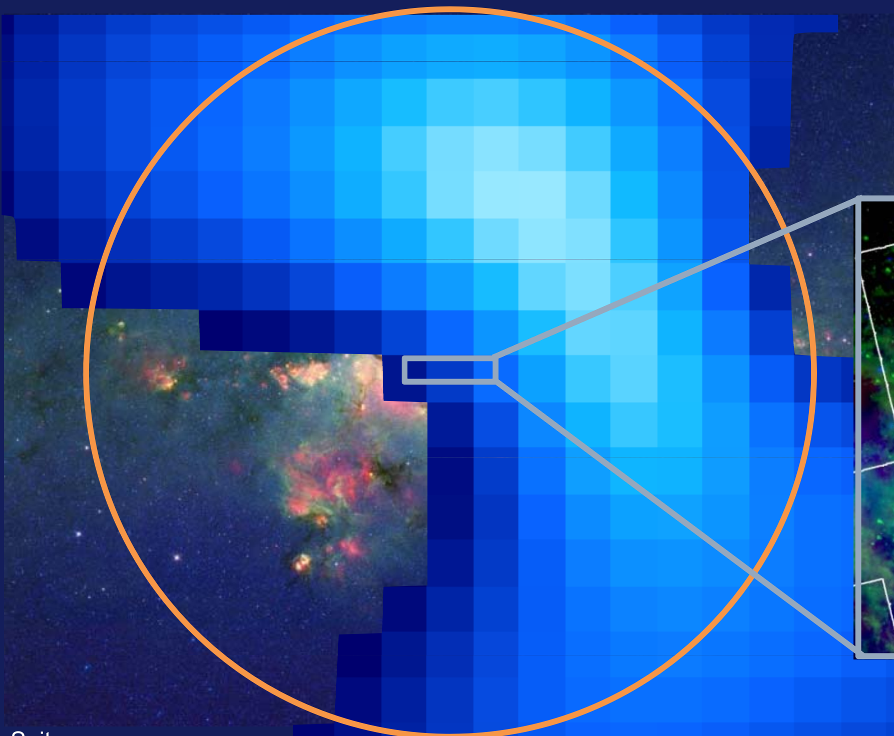




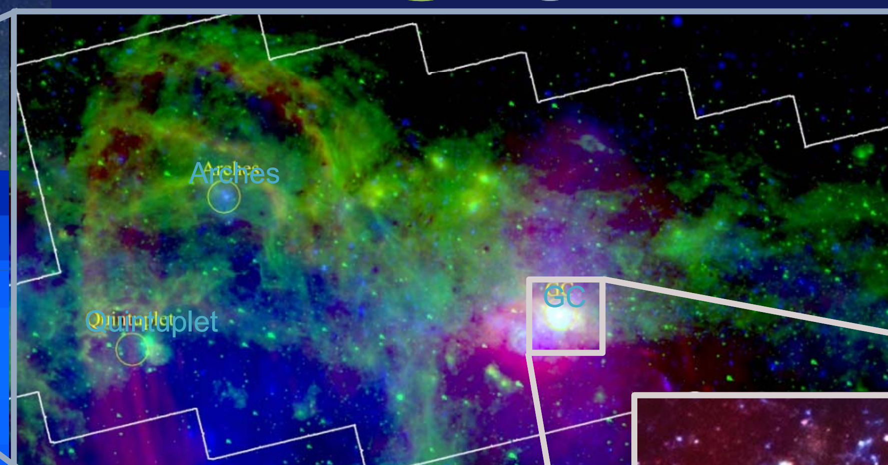
Galactic Centre

Slide courtesy of L. Tibaldo

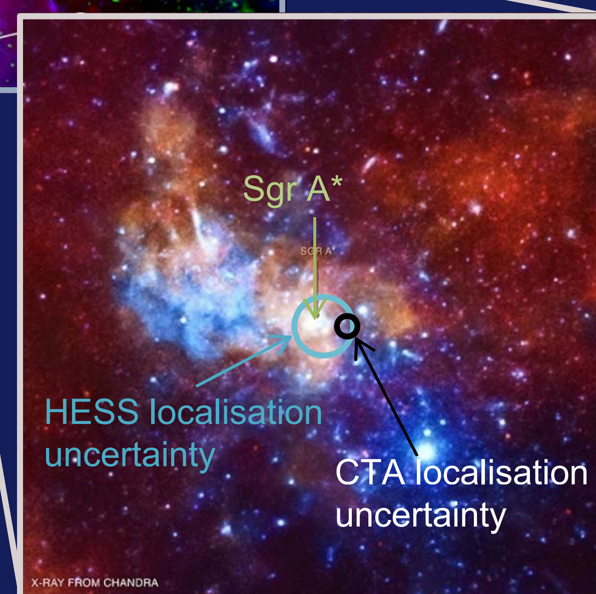
8° CTA FoV



Spitzer
Credit: NASA/JPL Caltech
+ *Fermi* bubbles
Ackermann+ 2017 ApJ 840 43A



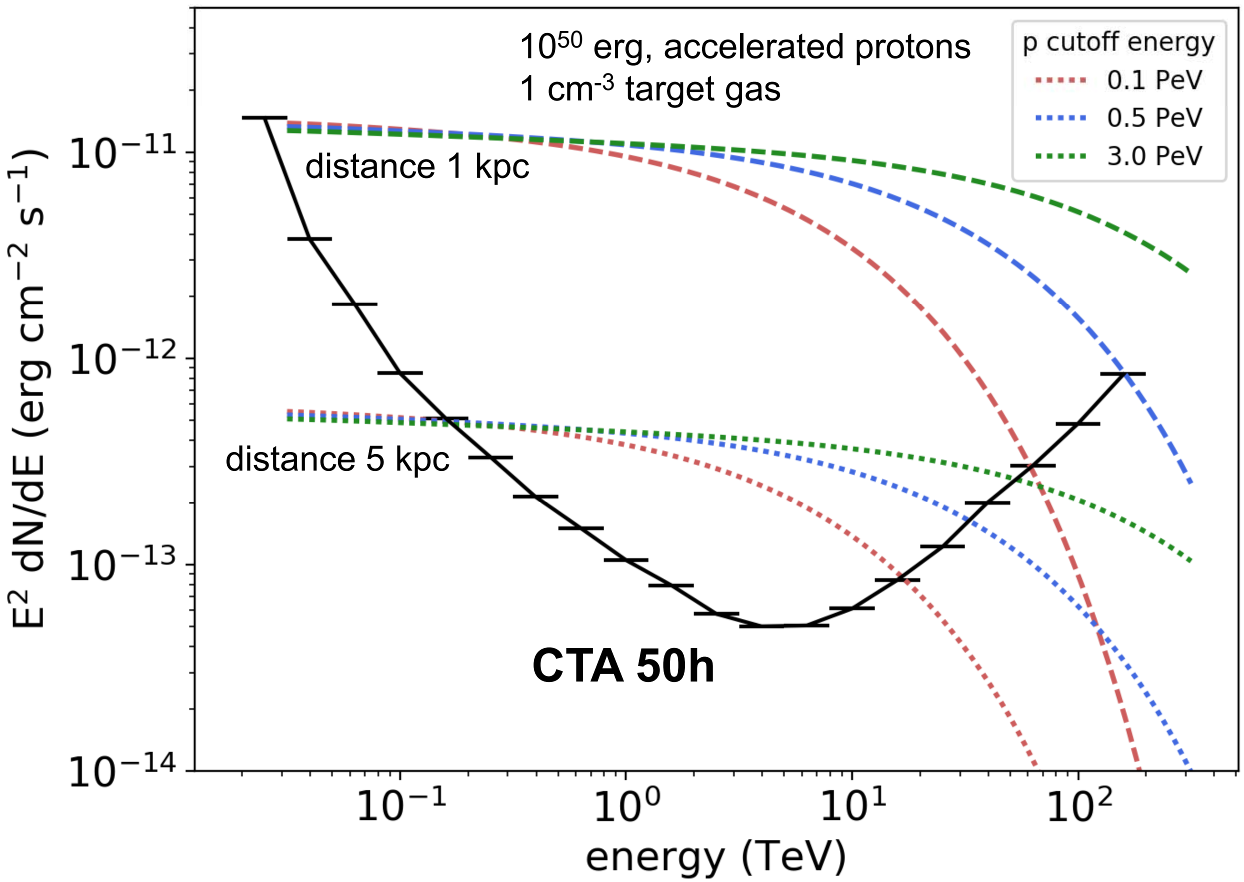
VLA + Spitzer + Chandra
Wang+ 2010 MNRAS 492 895



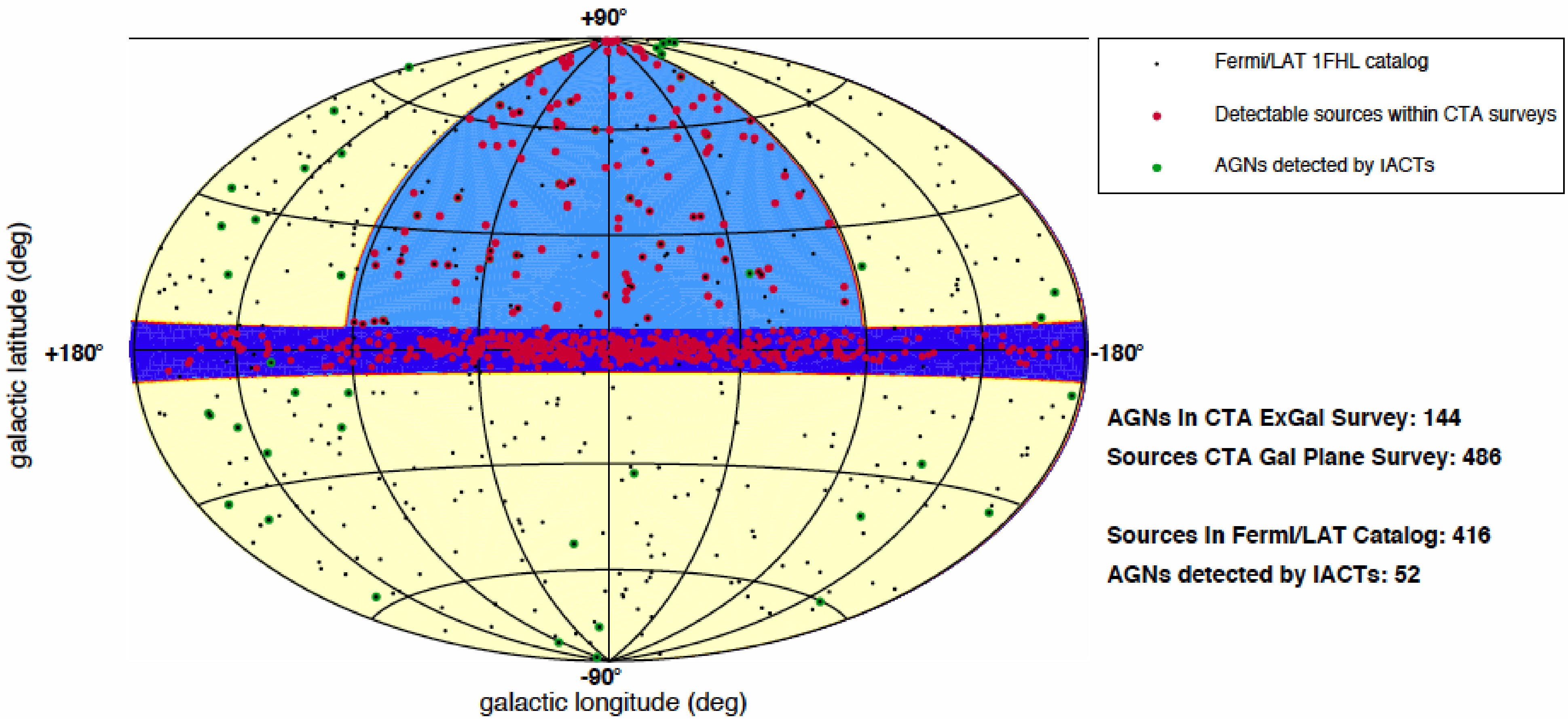
- wealth of VHE diffuse emission & sources, including the only known PeVatron
- giant particle outflow (*Fermi* bubbles)
- ideal region for dark matter searches

PeVatron Search

- **What sources accelerate hadrons to the knee?**
  - SNRs are standard paradigm, but only a handful provide strong evidence for hadronic acceleration so far, and only up to ~ 10 TeV.
- **Search for PeVatrons (beyond the GC) via the > 100 TeV spectrum**
  - Use GPS as finder and follow-up 5 brightest sources with no cut-off
  - Electrons' emission suppressed above 100 TeV (Klein-Nishina)
  - MWL information critical for identification



Extragalactic Survey



- Survey of ¼ sky to limiting sensitivity of 5 mCrab
- Connects to Galactic plane survey & covers Coma, Virgo, Cen A, & Fermi bubbles (N)
- Unbiased determination of blazar luminosity function
- Possibility of divergent pointing strategy: excellent for transients

Summary

cherenkov telescope array

- **VHE γ-ray astronomy is now a major research field**

  Great scientific potential and the power of the atmospheric Cherenkov technique → **CTA**

- **Cherenkov Telescope Array (CTA)***

  Outstanding sensitivity & resolution over wide energy range
  Open observatory with all data released to public
  Status: sites selected, full prototypes, close to construction start

- **Far reaching Key Science programme:**

  - *Dark Matter*: *sensitive search for DM, focused on discovery*
  - *Galactic plane survey (GPS): 1st at high resolution & v. high sensitivity*
  - *Galactic Centre: rich region imaged by CTA at arc-min resolution*
  - *PeVatron search: identify sources of PeV cosmic rays*
  - *Extragalactic survey: blind survey of ¼ sky to 5 mCrab sensitivity*
  - *Transients: comprehensive program of transient follow-up*

***We gratefully acknowledge financial support from the agencies and organizations listed here: http://www.cta-observatory.org/consortium_acknowledgments.**