cherenkov telescope array

COSPAR 2018
42ND ASSEMBLY | 60TH ANNIVERSARY

Cherenkov Telescope Array: Overview & Galactic Science

COSPAR 2018 (Pasadena, CA, USA)
Session E1.5: Origin of Cosmic Rays

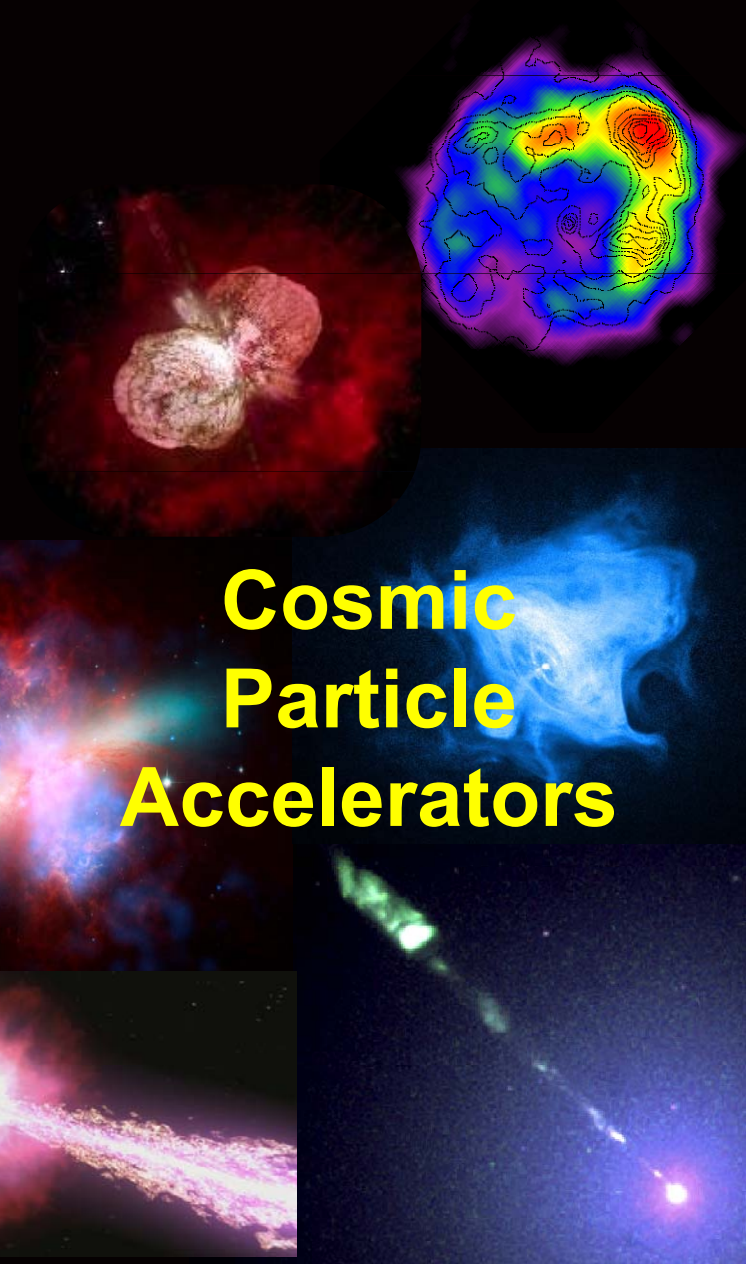
The CTA Consortium[1], represented by Rene A. Ong[2]

[1]See https://www.cta-observatory.org/consortium_authors/authors_2018_07.html
[2]University of California, Los Angeles, CA 90095, USA

2005-2018: VHE Astronomy Comes of Age

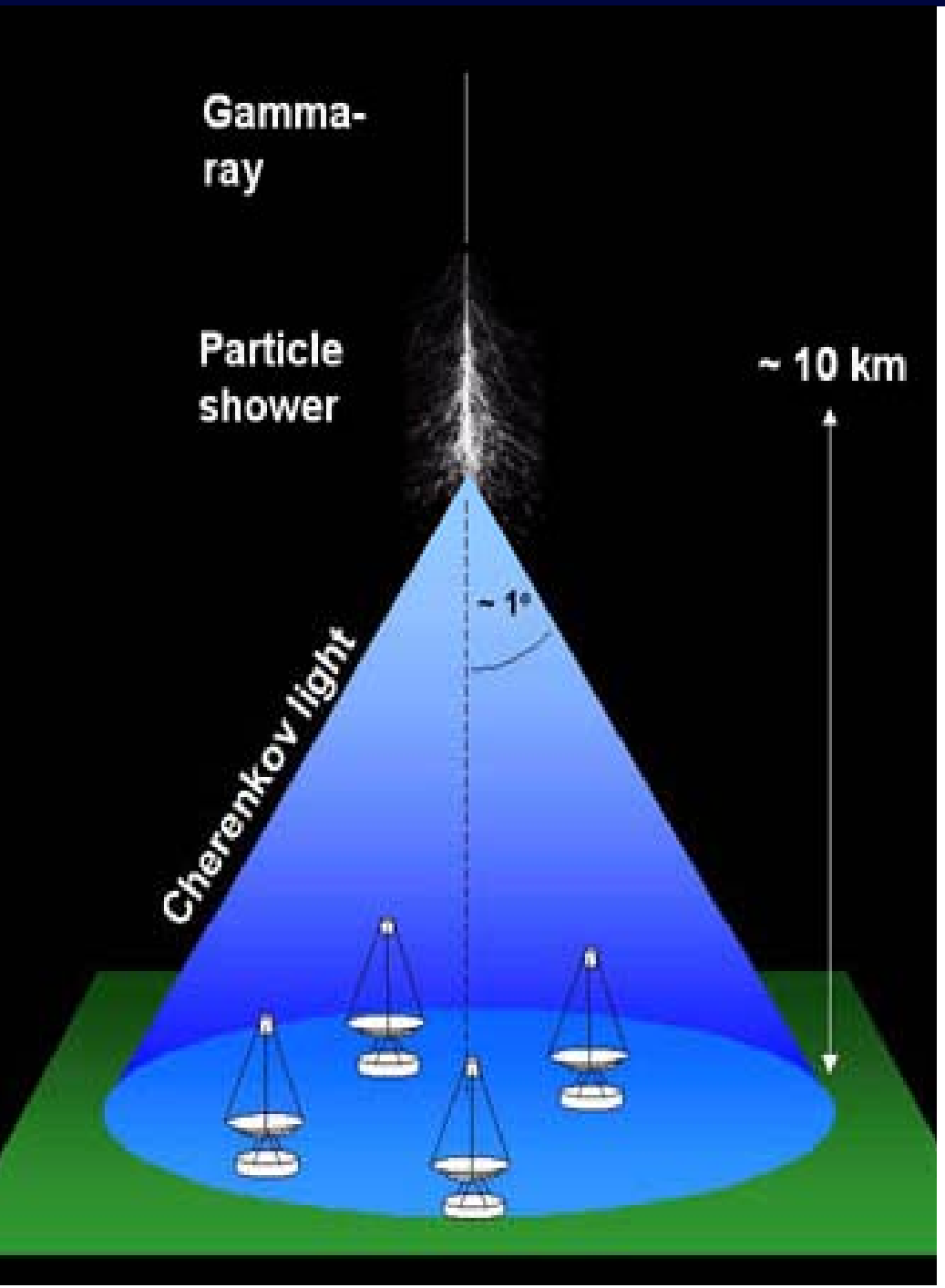
- Dominant expectation (pre-1990)
  - Will find the “cosmic ray” accelerators – probably SNRs
- Reality (2018)
  - Astonishing variety of VHE † emitters
    - Within the Milky Way
      - Supernova remnants
      - Bombarded molecular clouds
      - Stellar binaries - colliding wind & X-ray
      - Massive 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



Cosmic Particle Accelerators

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′)

Imaging technique:

- Excellent shower reconstruction
- Large background rejection

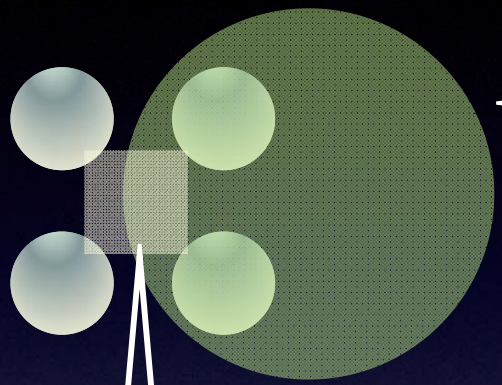
Well-demonstrated by current instruments:
H.E.S.S., MAGIC, & VERITAS

But we have not reached limit of the technique !

Further improved by:

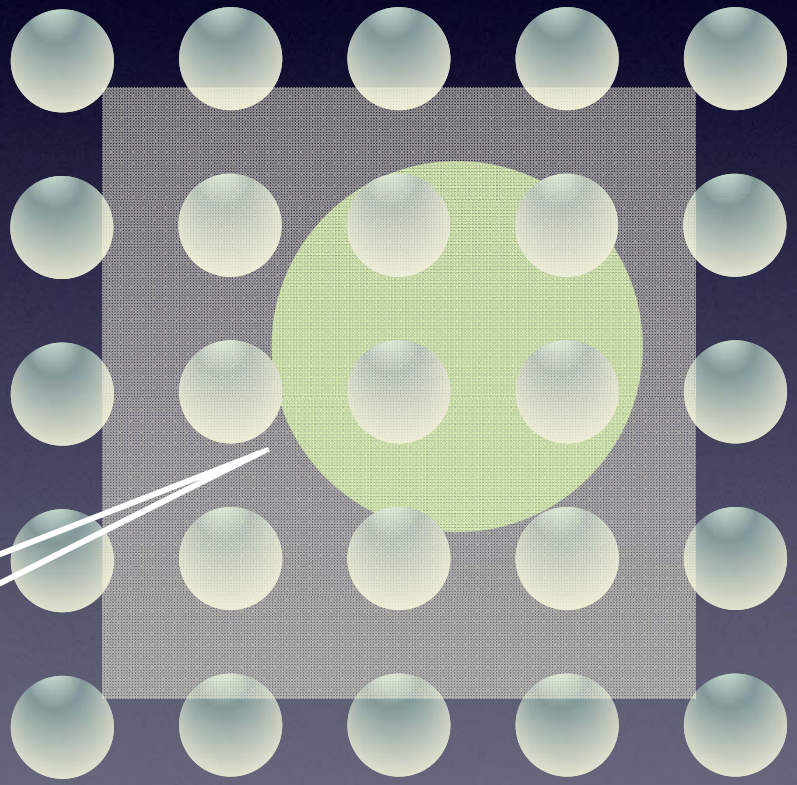
- More views of shower
- Higher resolution images
- Wider field-of-view

Larger area → More contained events, more images



Light pool radius
R ≈ 100-150m
≈ typical telescope Spacing

Sweet spot for best triggering & reconstruction…
most showers miss it!



✓ *Larger detection Area*
✓ *More Images per shower*
✓ *Better γ-ray reconstruction*
✓ *Lower energy threshold*

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*

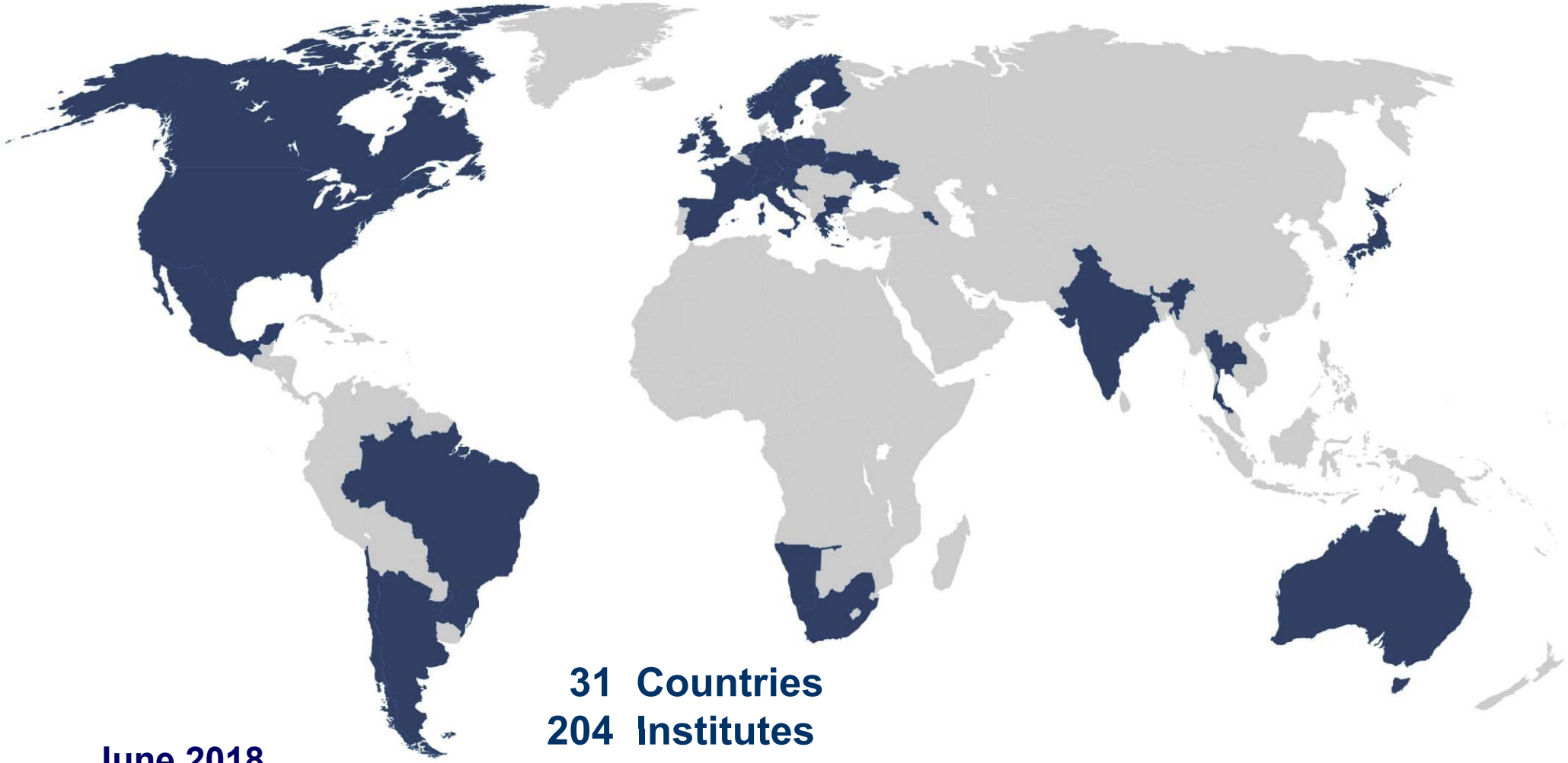
International partnerships required by scale/scope

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


cta
cherenkov telescope array

CTA Consortium

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



June 2018

31 Countries
204 Institutes
1461 Members (503 FTE)

CTA Main Scientific Themes

cherenkov telescope array

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 Main Scientific Themes

cherenkov telescope array

FOCUS FOR THIS SESSION: ORIGIN OF COSMIC RAYS

Cosmic Particle Acceleration

- How and where are particles accelerated?
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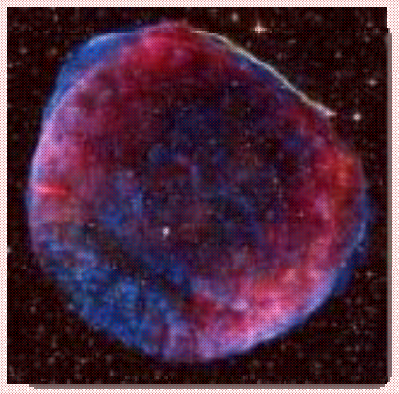

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CTA Sites

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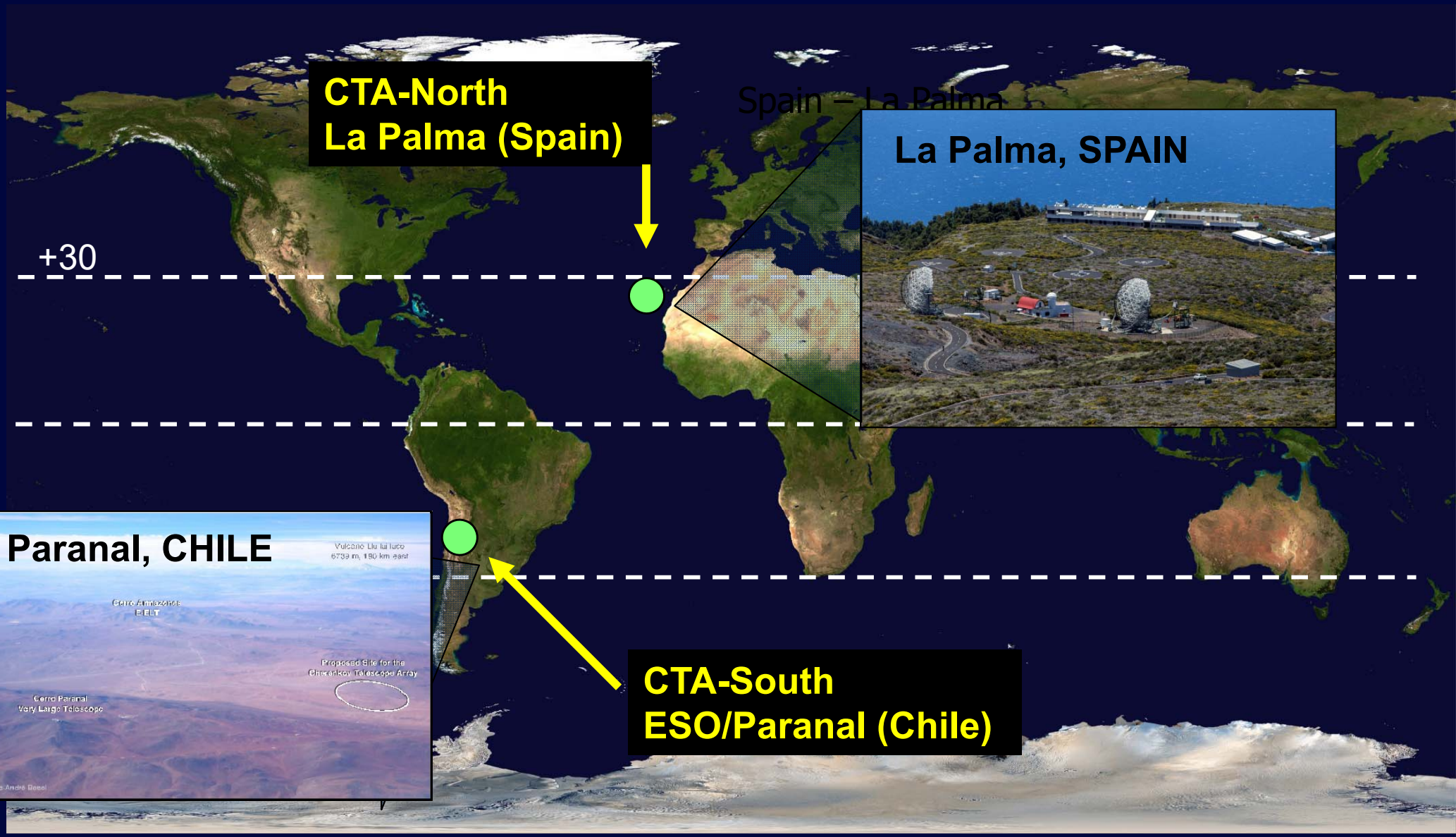


CTA Design (S array)

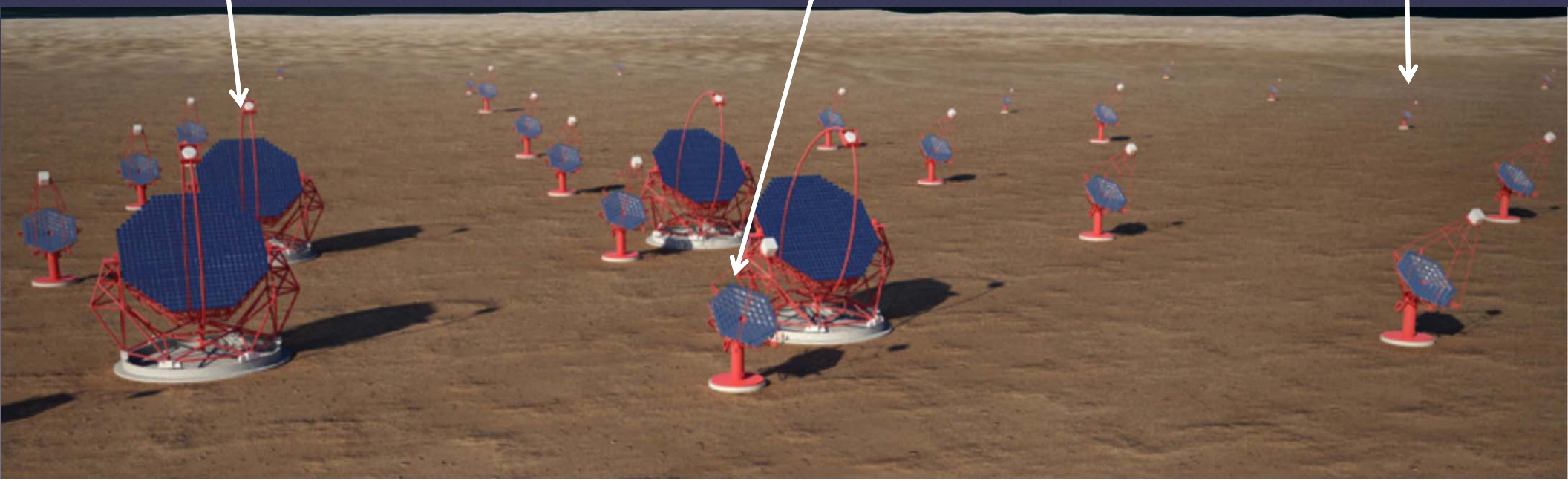
cherenkov telescope array

Science Optimization under budget constraints

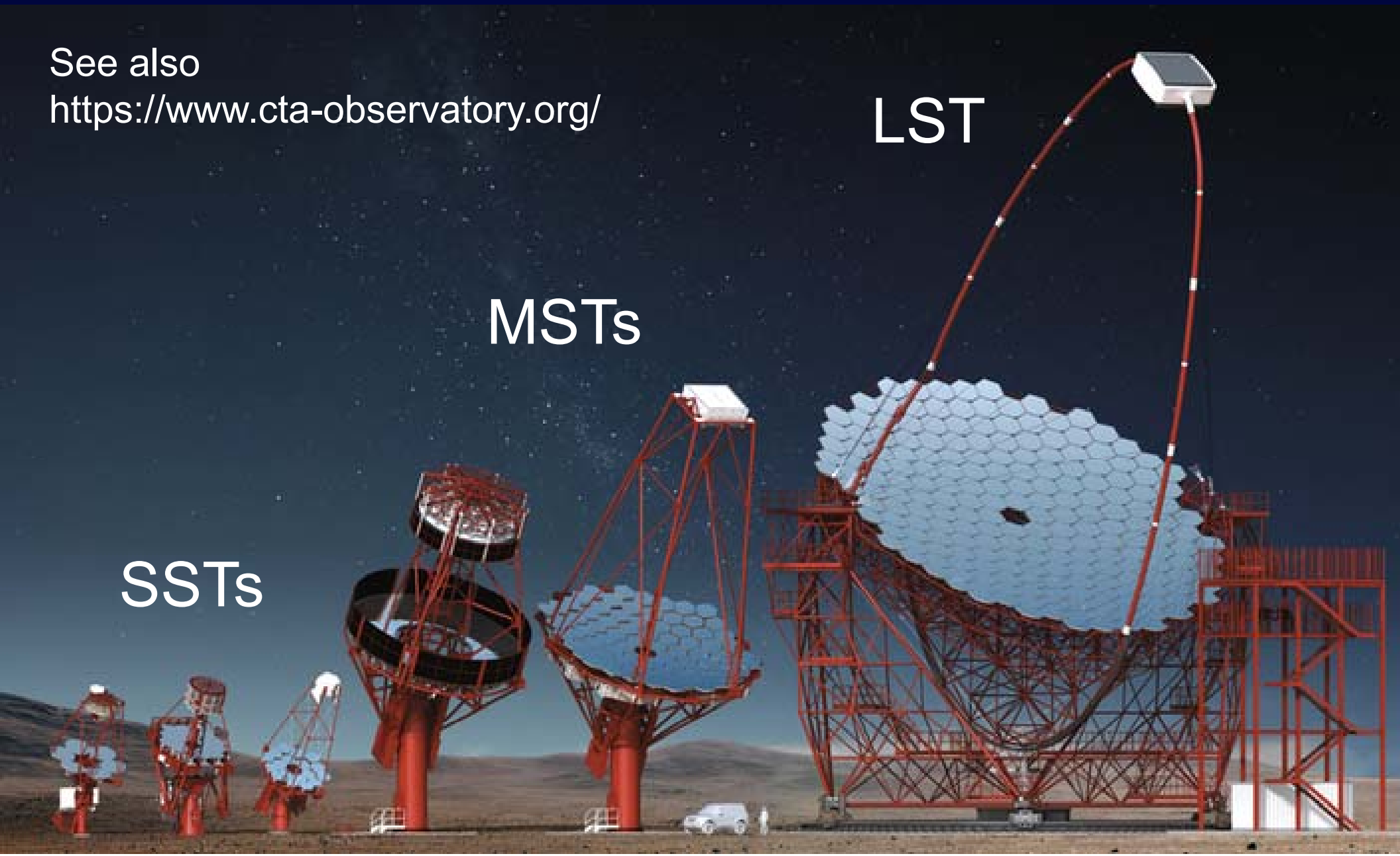
Low energies
Energy threshold 20-30 GeV
23 m diameter
4 telescopes
(LST's)

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

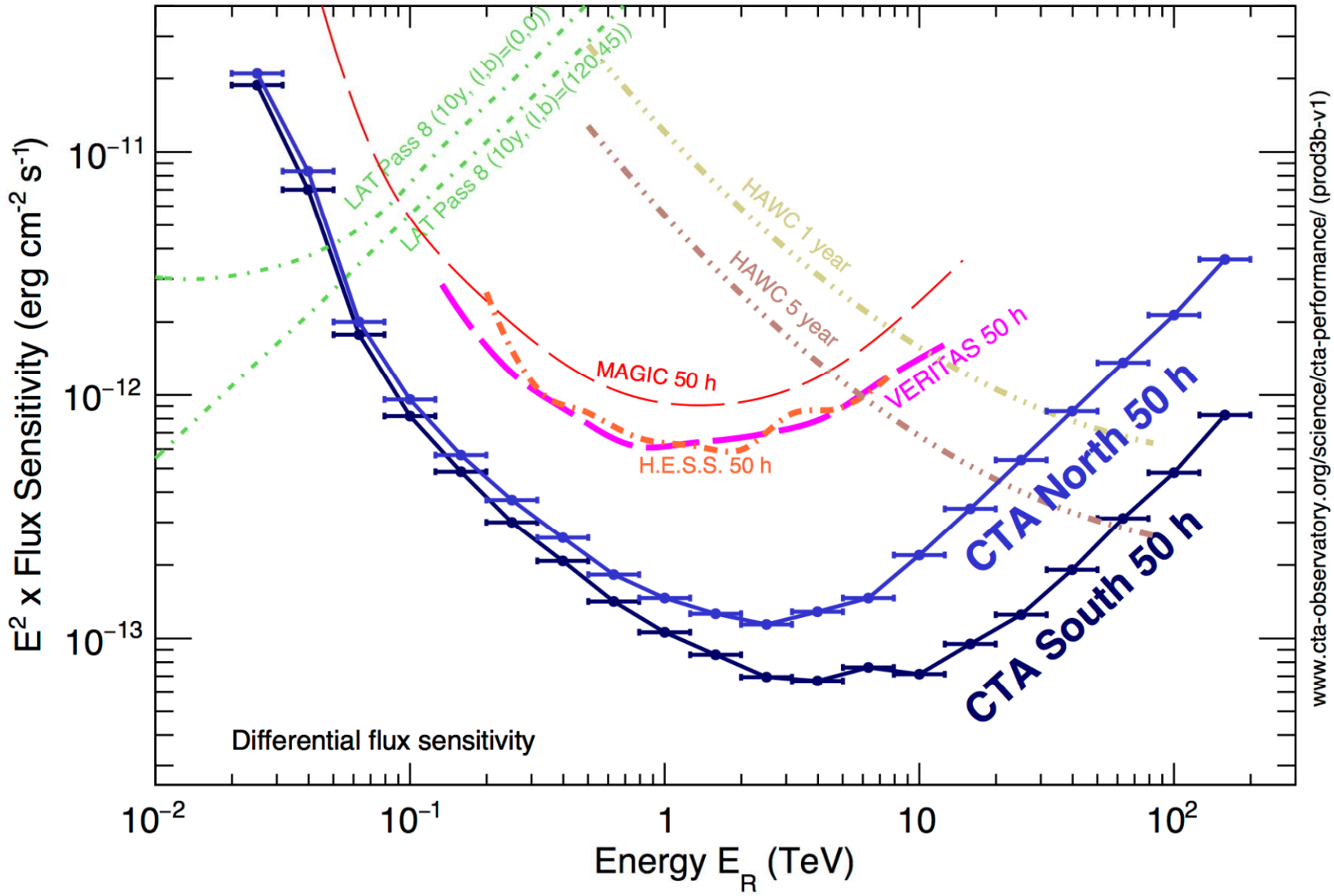
High energies
Up to > 300 TeV
10 km^2 eff. area @ 10 TeV
4m diameter
70 telescopes
(SST's)



Telescope Types

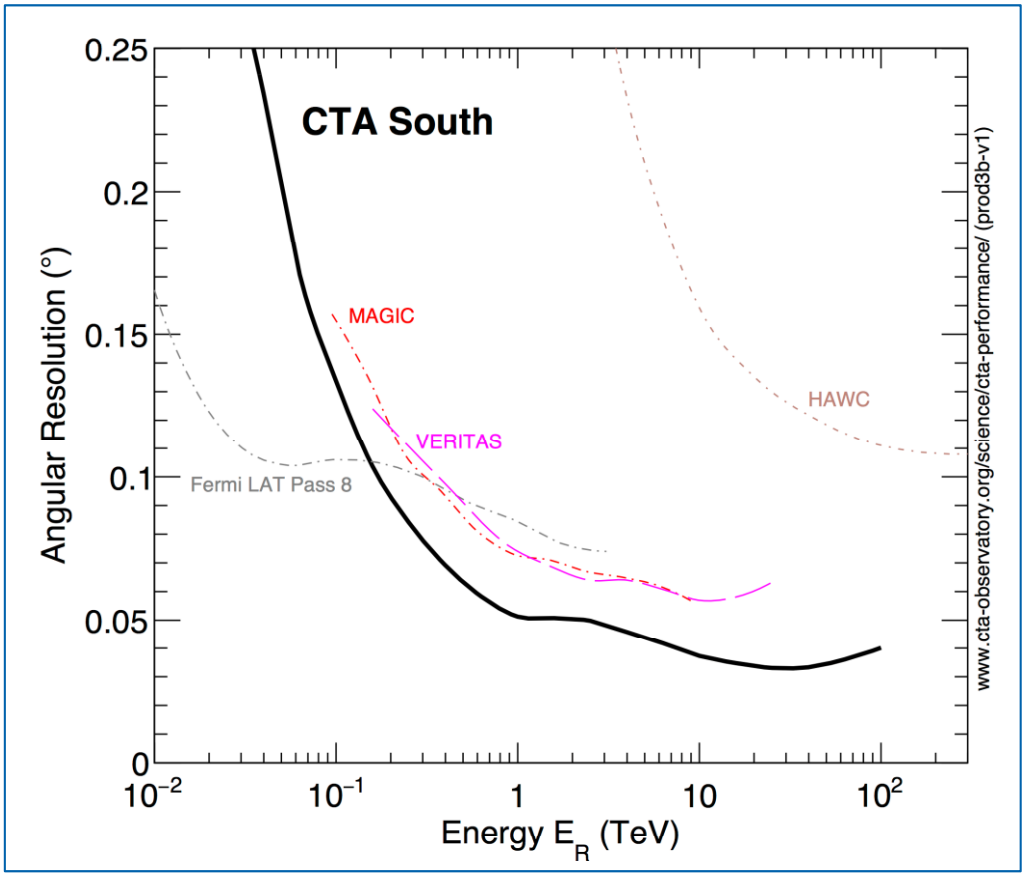


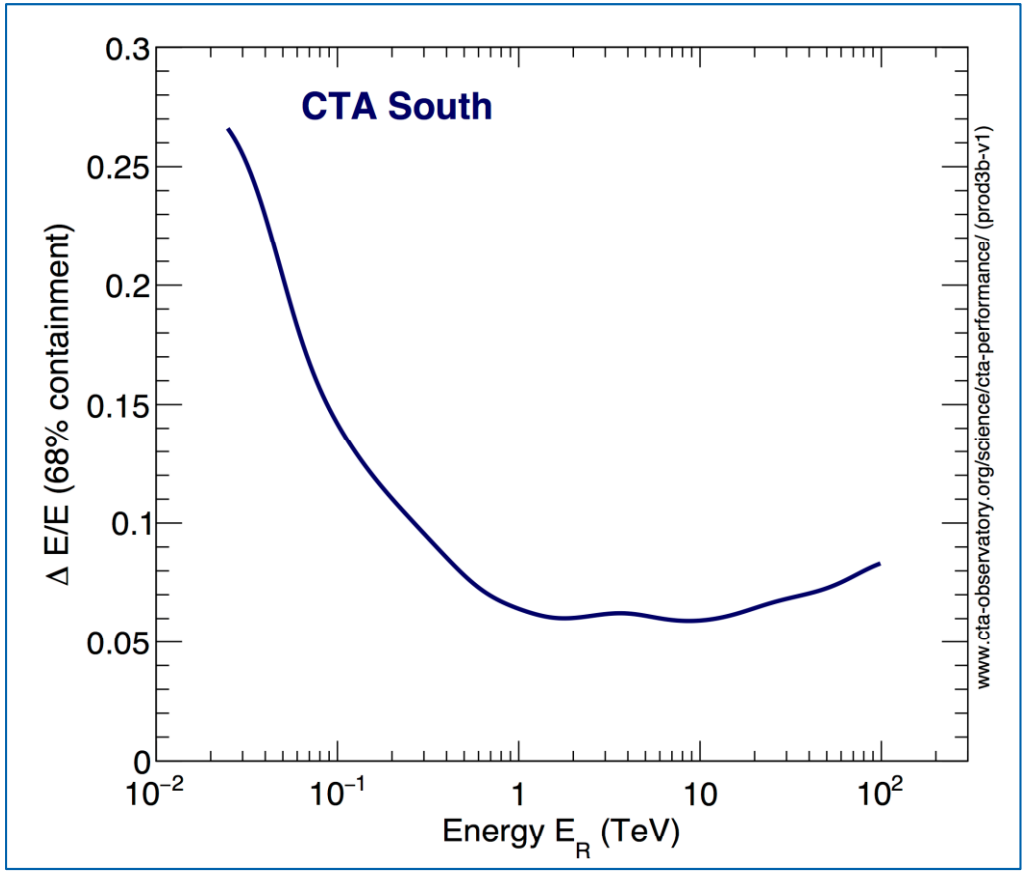
Flux Sensitivity



Major sensitivity improvement & wider energy range

Angular & Energy Resolutions

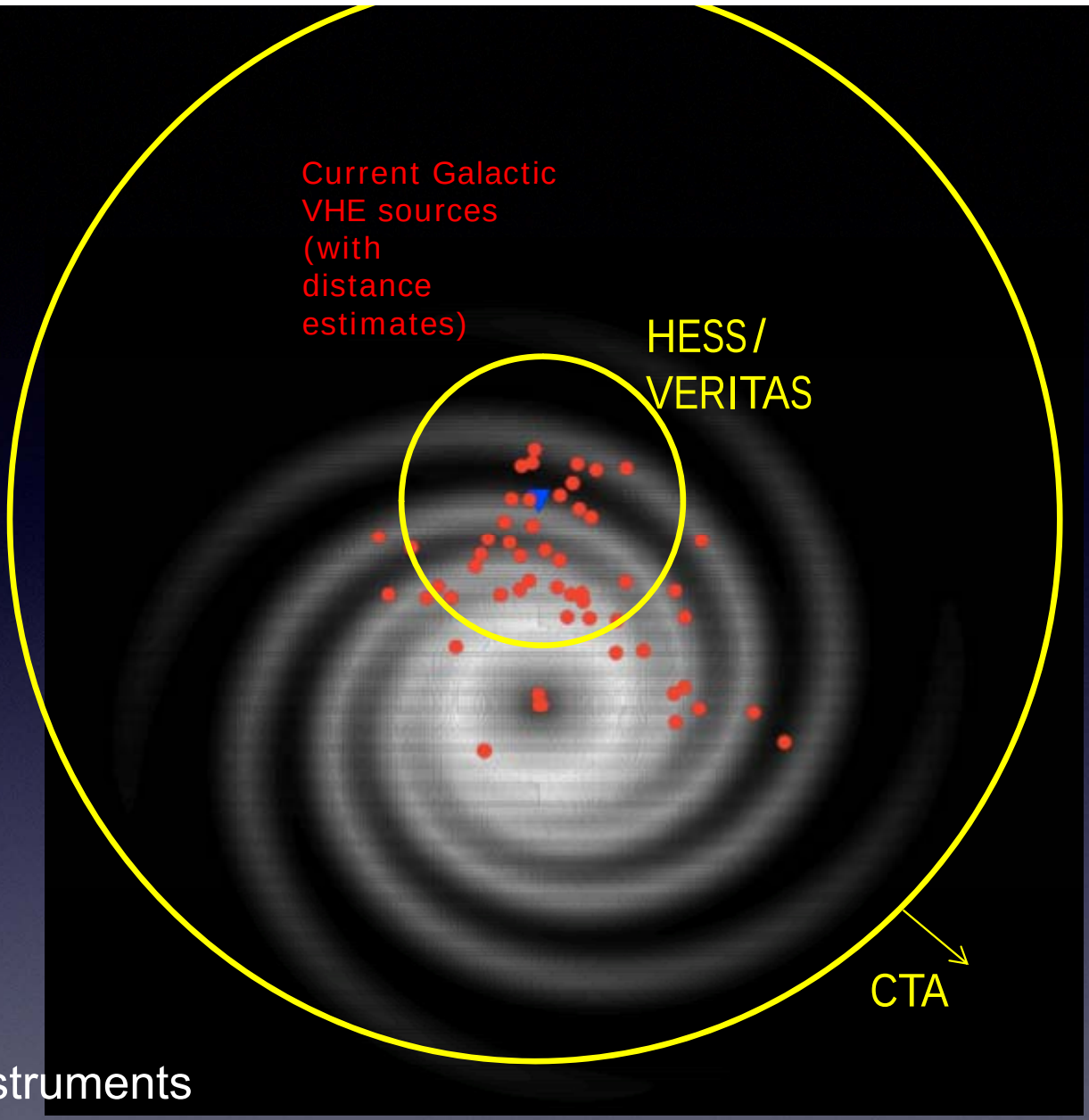




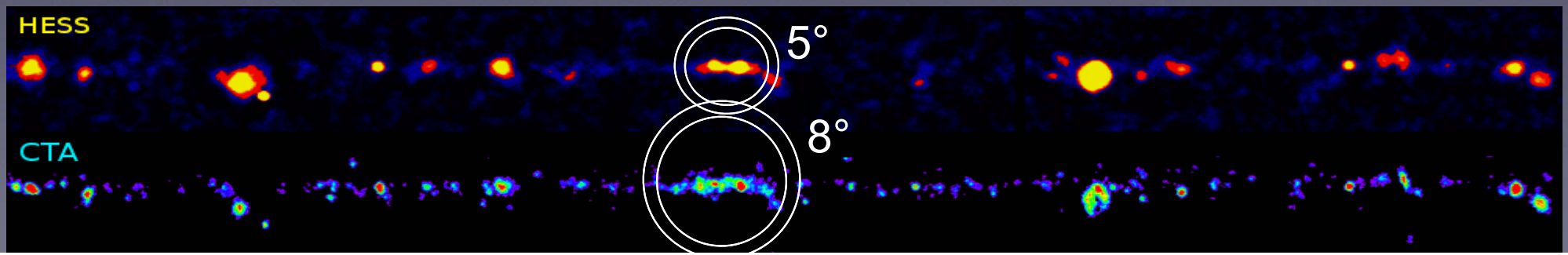
Important for resolving morphology of Galactic sources

Important for spectral precision

Galactic Discovery Reach



Survey speed:
x300 faster than current instruments



CTA Science Program

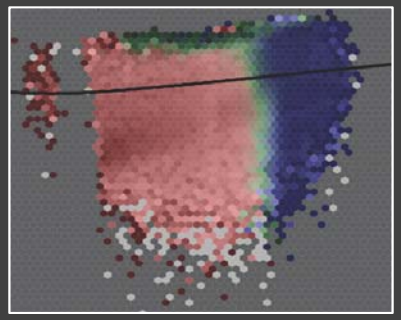
- Open observatory
- Proposals for Guest Observer Programme – essential for major community involvement
- All data on public archive after proprietary period (typically 1 year)
- ~40% time in Key Science Projects (KSPs), carried out by CTA Consortium

KSP Programme described in *Science with CTA* document

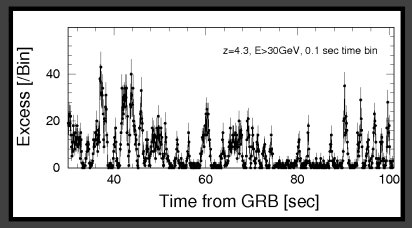
arXiv:1709.07997

(soon to be published as a book)

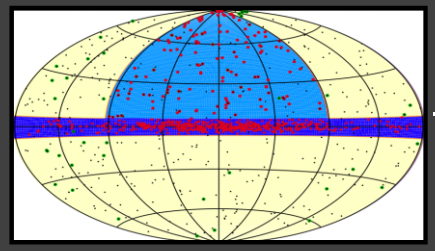
Key Science Projects (KSPs)



Dark Matter Programme

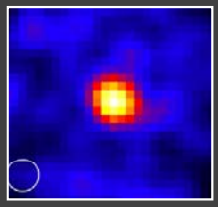


(Extragalactic CRs) Transients



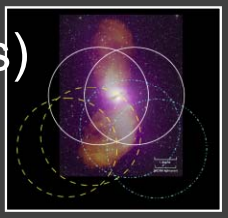
ExGal Survey

Galaxy Clusters



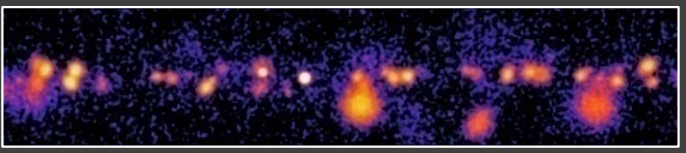
Star Forming Systems

(Extragalactic CRs) AGN

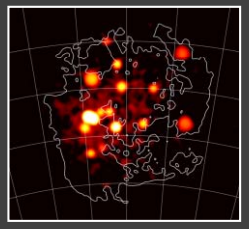


Extragalactic

Galactic

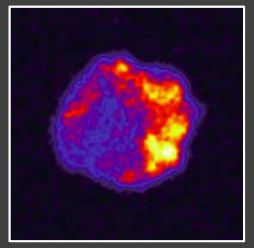


LMC Survey

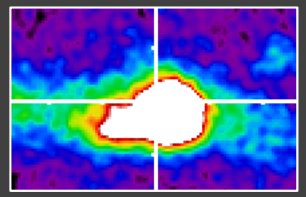


Galactic Plane Survey

PeVatrons



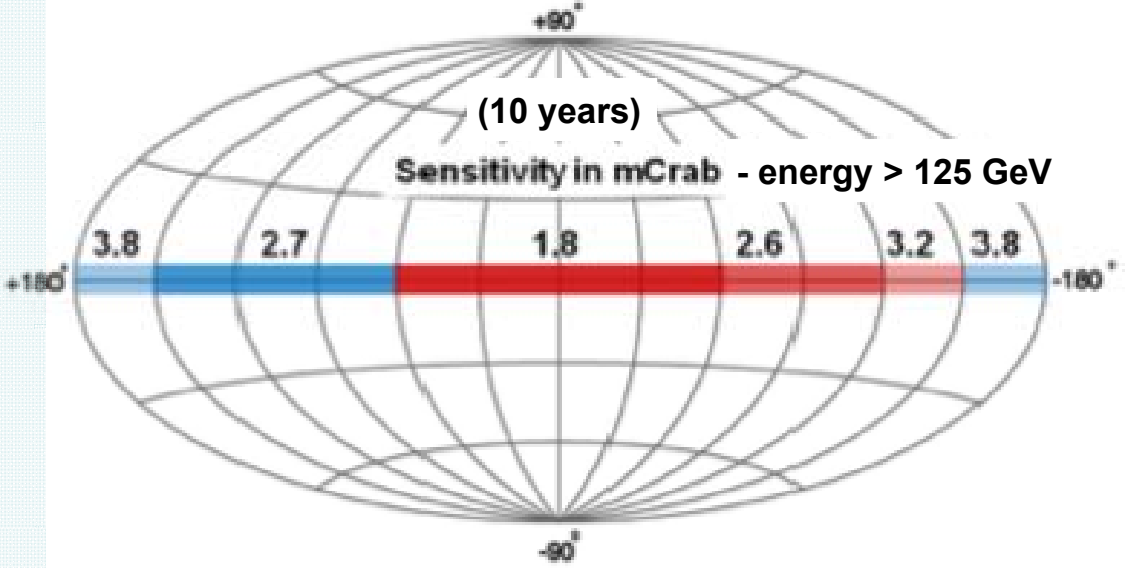
Galactic Centre

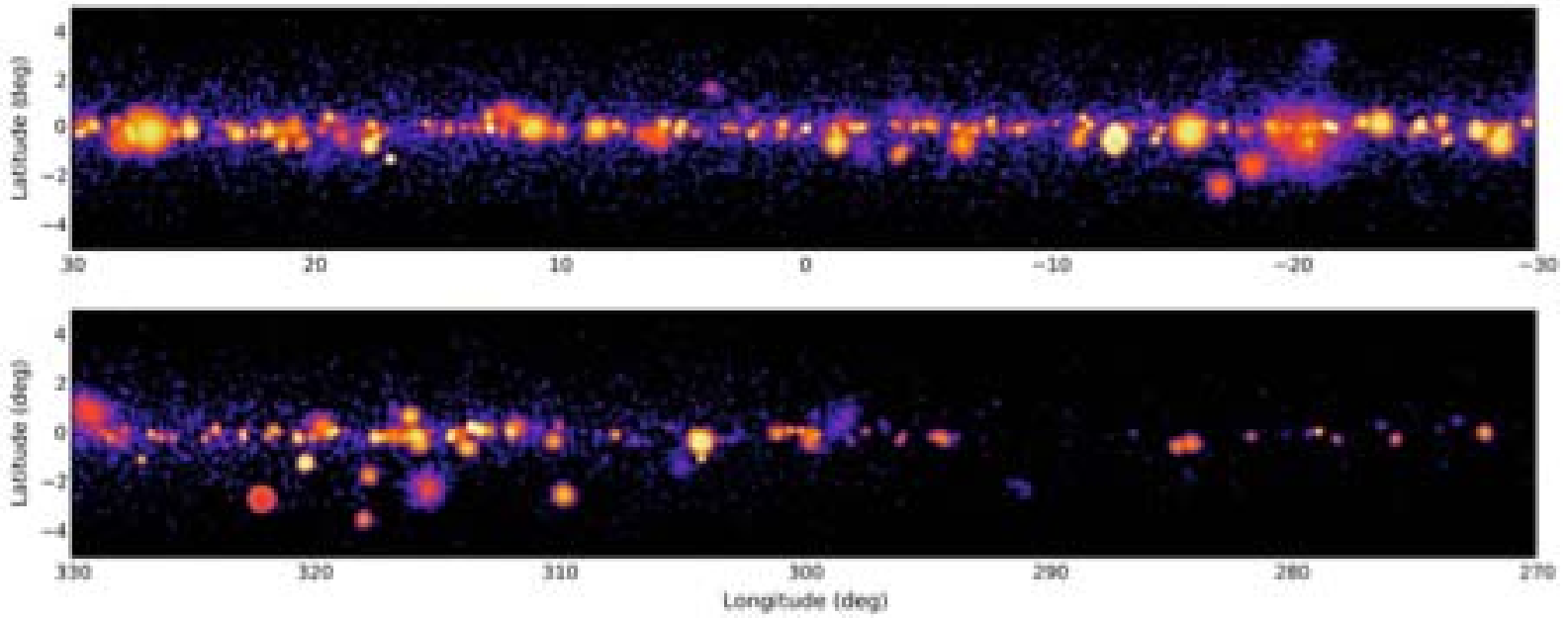


KSPs most relevant for this session

Galactic Plane Survey

- First very high sensitivity survey at TeV energies
- Full-plane survey at arc-minute angular resolution
- Expect (many) 100's of new sources, especially PWNe, SNRs and binaries → population studies (origin of CR's)
- Great potential for discovery of new phenomena
- Detailed view of diffuse γ-ray emission

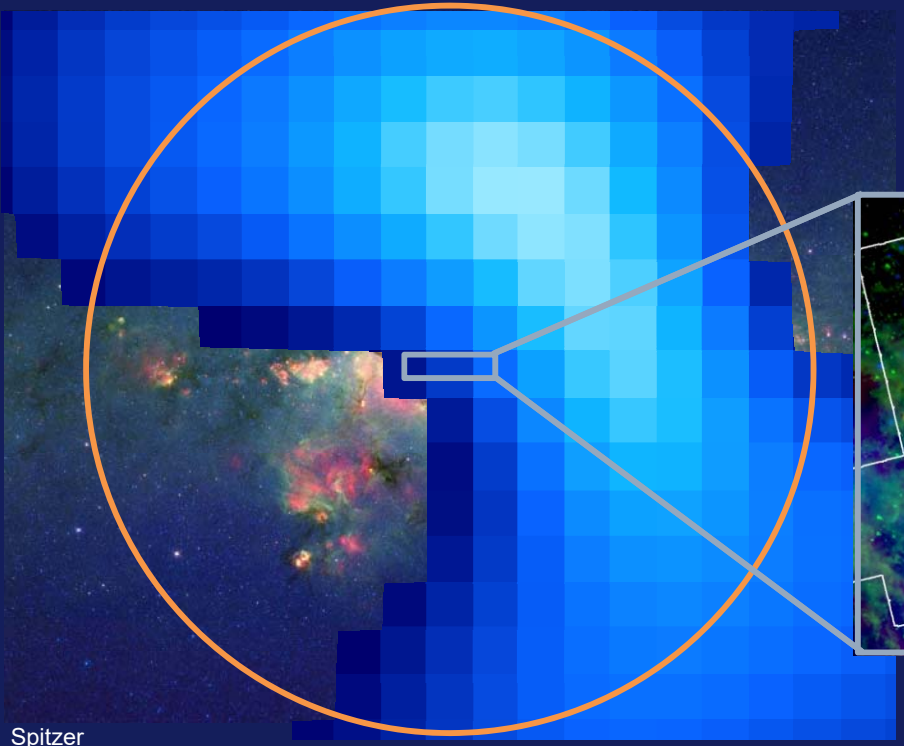




Galactic Centre

Slide courtesy of L. Tibaldo

8° CTA FoV

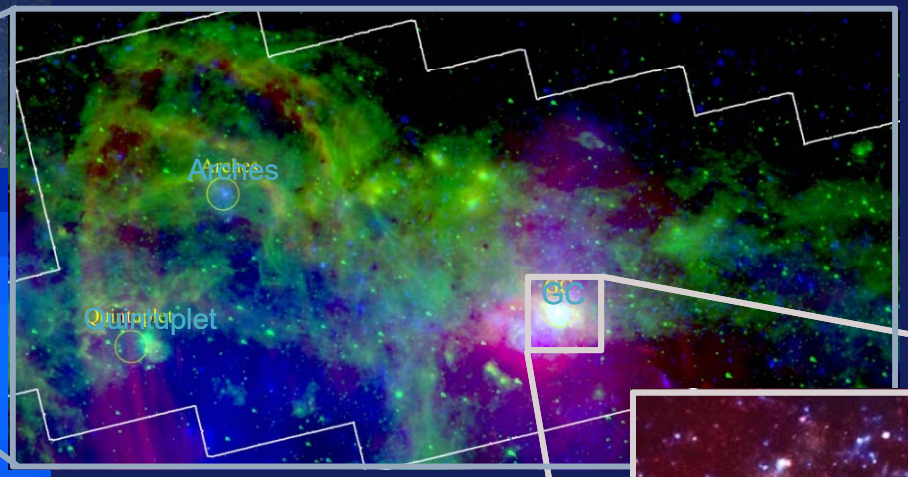


Spitzer
Credit: NASA/JPL Caltech
+ *Fermi* bubbles
Ackermann+ 2017 ApJ 840 43A

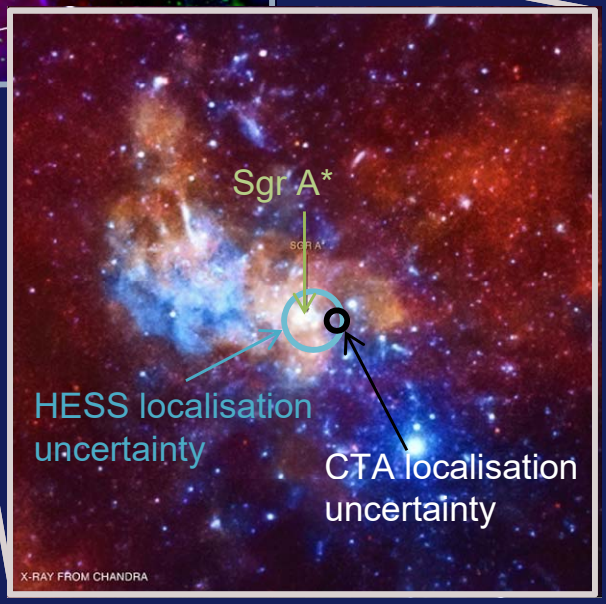
Fermi PSF (50 GeV)

HESS PSF (3 TeV)

CTA PSF (3 TeV)



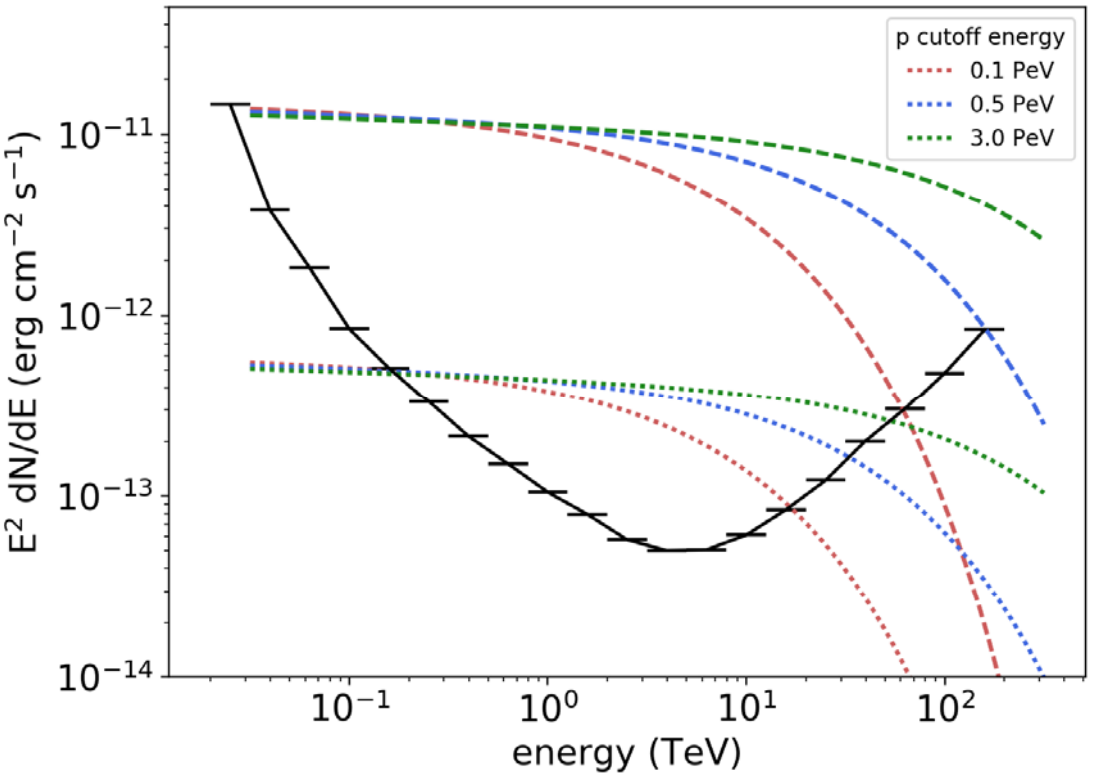
VLA + Spitzer + Chandra
Wang+ 2010 MNRAS 492 895



- 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 hadron 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



Star Forming Systems

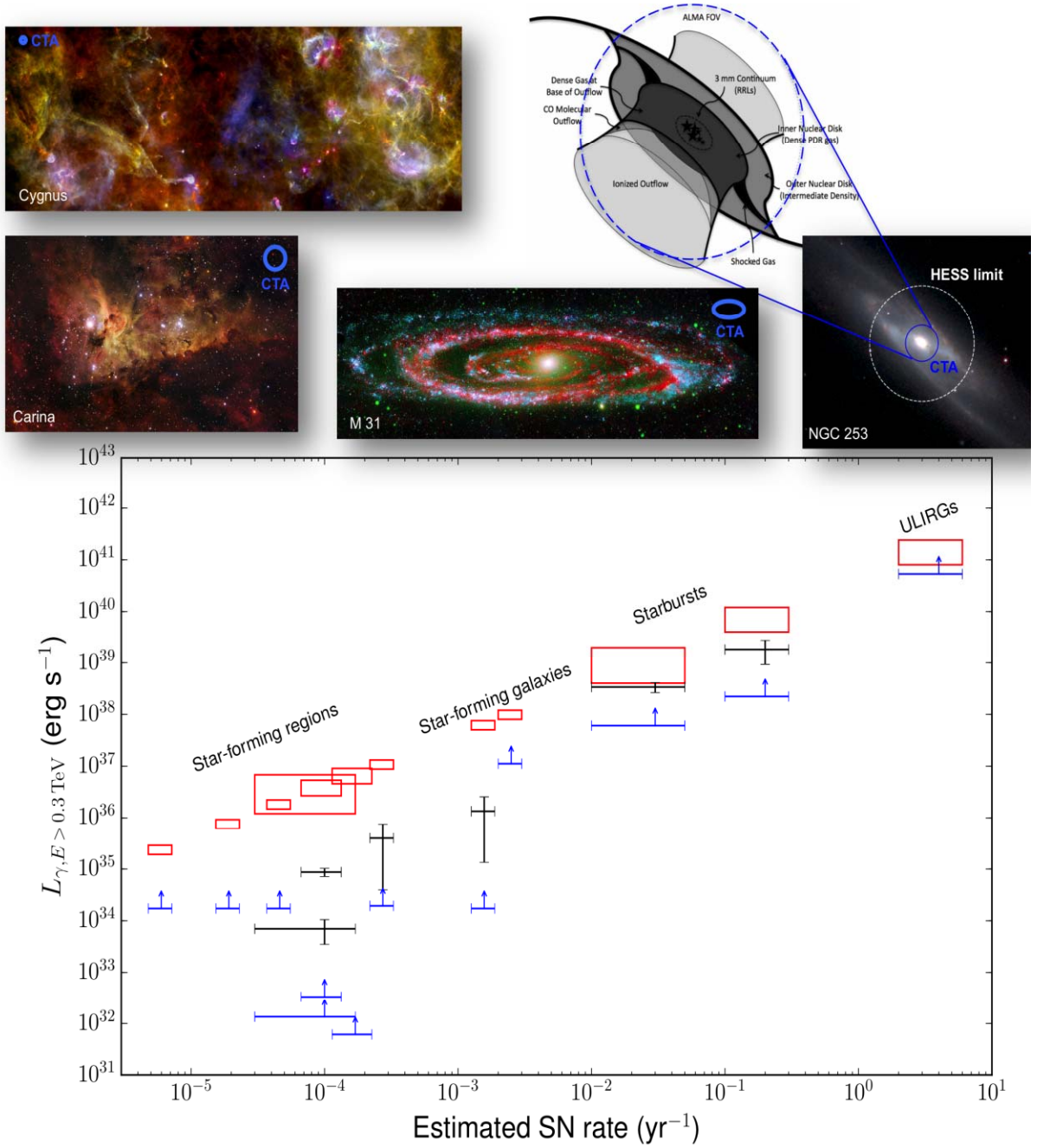
cherenkov telescope array

Key Questions:

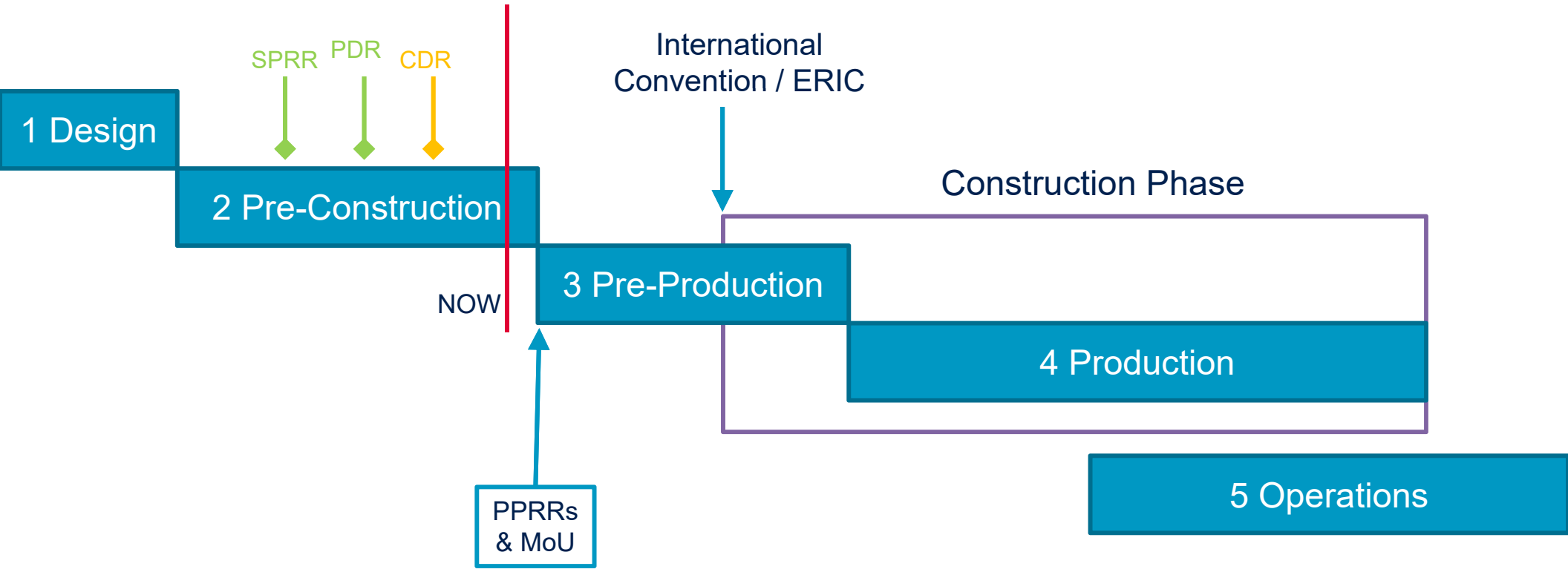
- What is the impact of CRs on the ISM and how do they propagate?
- What is the relation between star formation (SF) and particle acceleration in systems of all scales?

Motivated by connections seen in FIR, GeV γ-rays and, now TeV γ-rays.

Methodology: deep observations of a set of characteristic objects at different scales.



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

Summary

- **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

  Far-reaching key science program

  Open observatory with all data released to public

- **Probing CR origin with CTA**

  - *Galactic plane survey (GPS): first v. high sensitivity, high angular resolution survey at very high energies*
  - *Galactic Centre: rich region imaged by CTA at arc-min resolution*
  - *PeVatron search: directly identify sources producing hadronic particles at PeV energies*
  - *Star forming systems: connection between SF and particle acceleration*

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