cherenkov telescope array

ICRC2017
35th International Cosmic Ray Conference

Cherenkov Telescope Array: The Next Generation Gamma-ray Observatory

ICRC 2017 (Busan, Korea), 13 July 2017

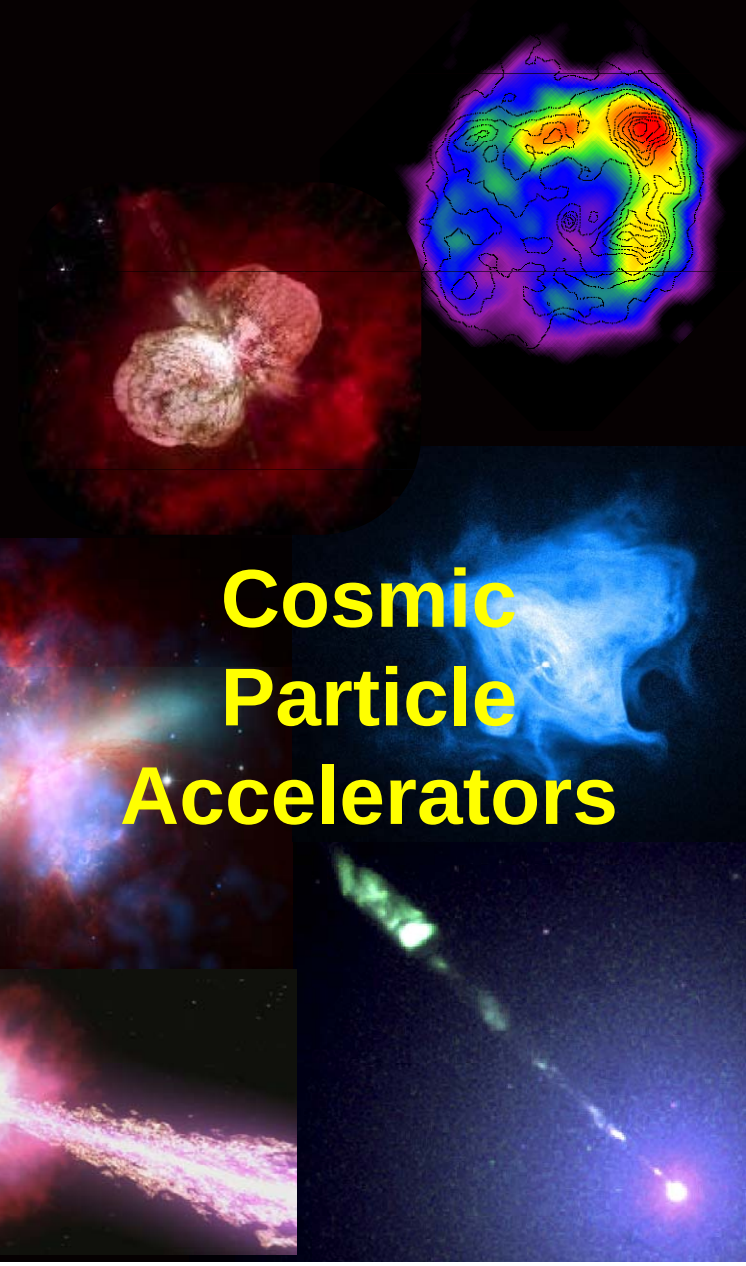
The CTA Consortium[1], represented by Rene A. Ong[2]

[1]See http://www.cta-observatory.org/consortium_authors/authors_2017_07.html
[2]University of California, Los Angeles, CA, 90095, USA

2005-2017:
VHE Astronomy Comes of Age

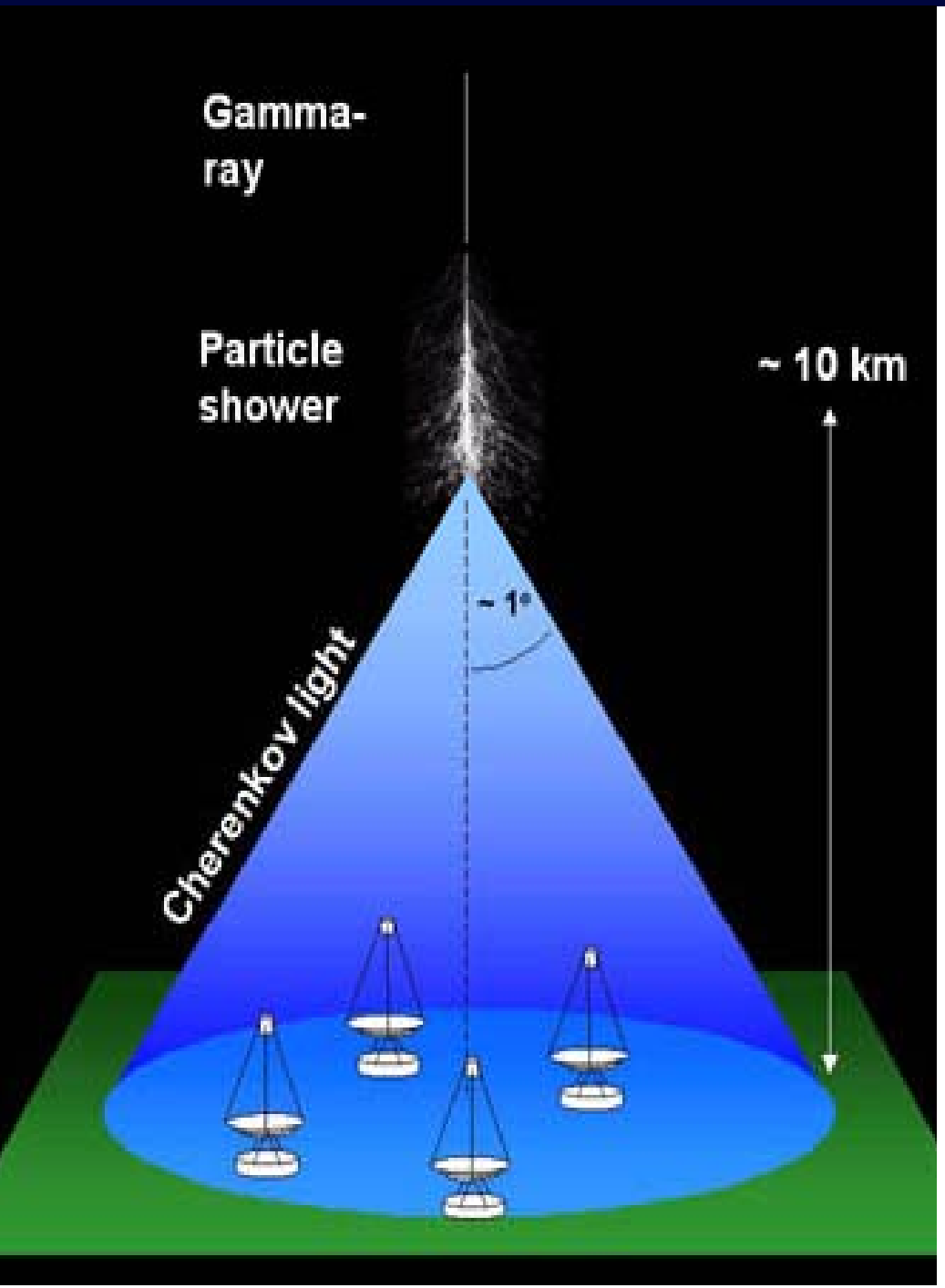
- Dominant expectation (pre-1990)
  - Will find the “cosmic ray” accelerators – probably SNRs
- Reality (2017)
  - Astonishing variety of VHE † emitters
    - Within the Milky Way
      - Supernova remnants
      - Bombarded molecular clouds
      - Stellar binaries - colliding wind & X-ray
      - Massive 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

† 0.05-50 TeV



Cosmic Particle Accelerators

Imaging Atm. Cherenkov Technique



Atm. Cherenkov showers:

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

Imaging technique:

- Excellent shower reconstruction
- Large background rejection

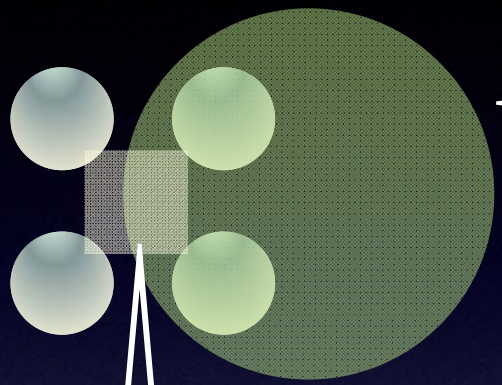
Well-demonstrated by current instruments:
H.E.S.S., MAGIC, & VERITAS

But we have not reached limit of the technique !

Further improved by:

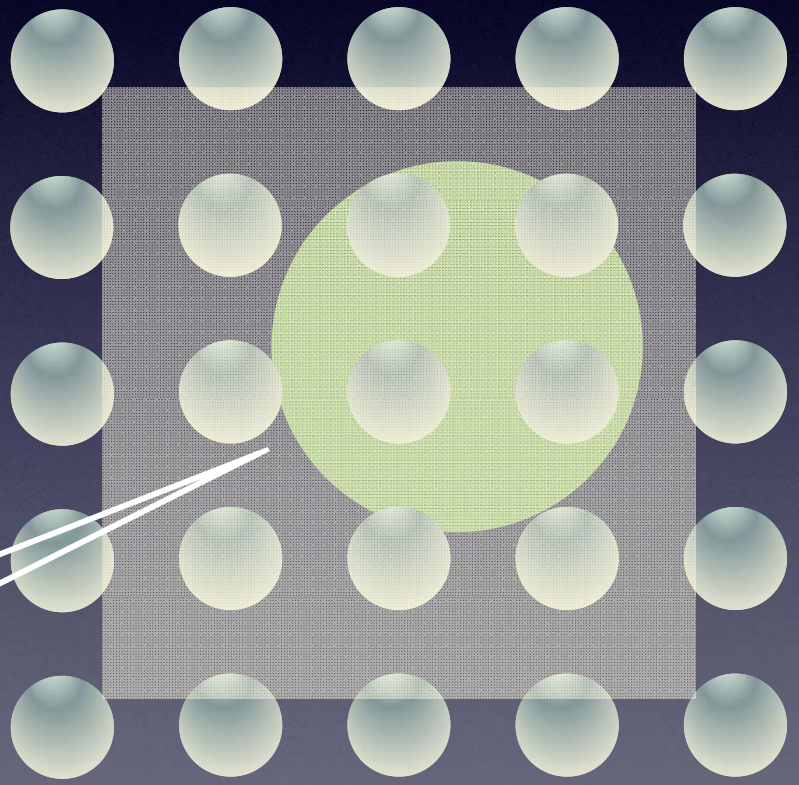
- More views of shower
- Higher resolution images
- Wider field-of-view

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*

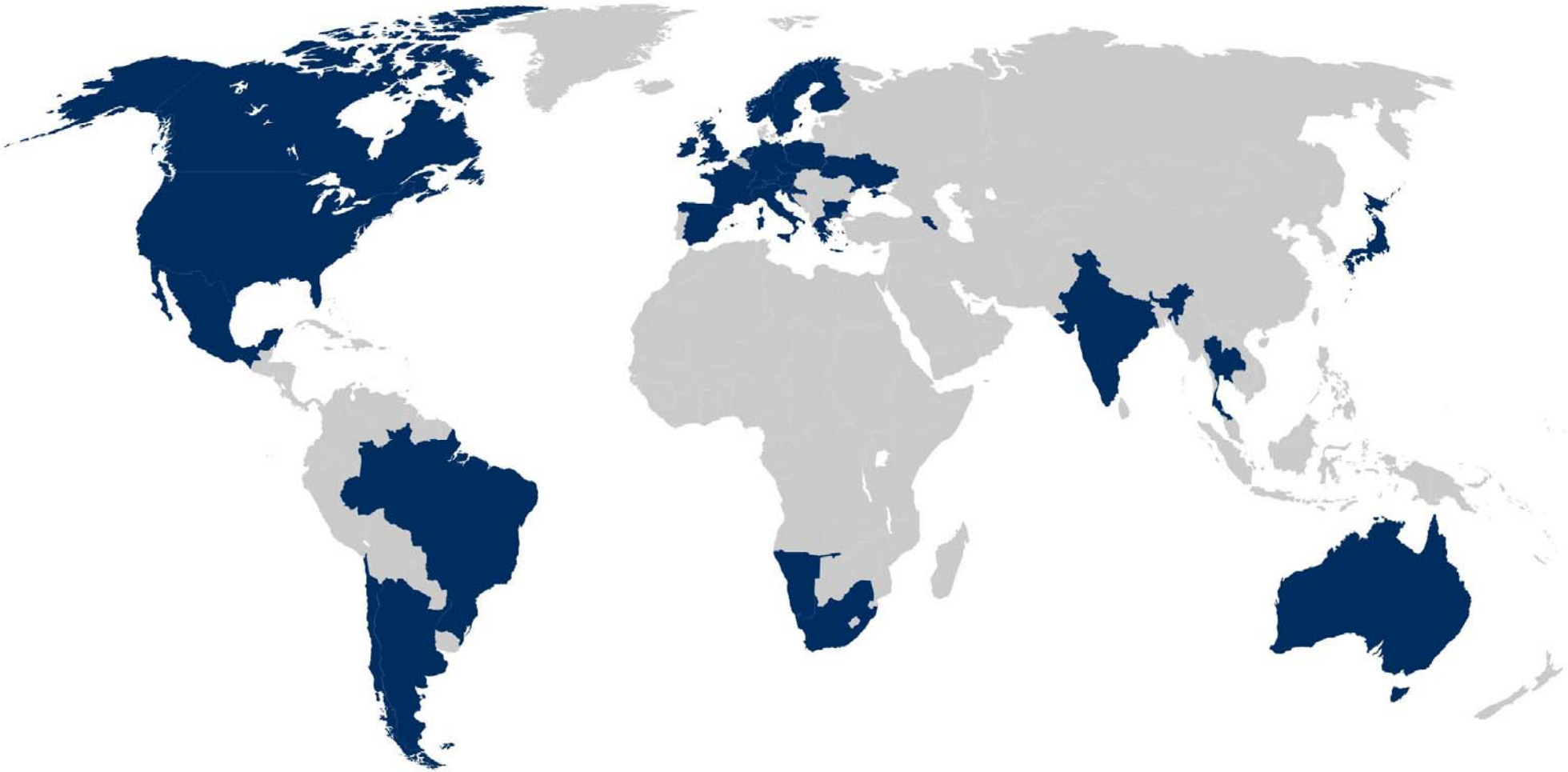
International partnerships required by scale/scope

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


cta
cherenkov telescope array

CTA Consortium

The Consortium originated CTA and will contribute to the construction of the arrays



32 countries, ~1402 scientists, ~208 institutes, ~480 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

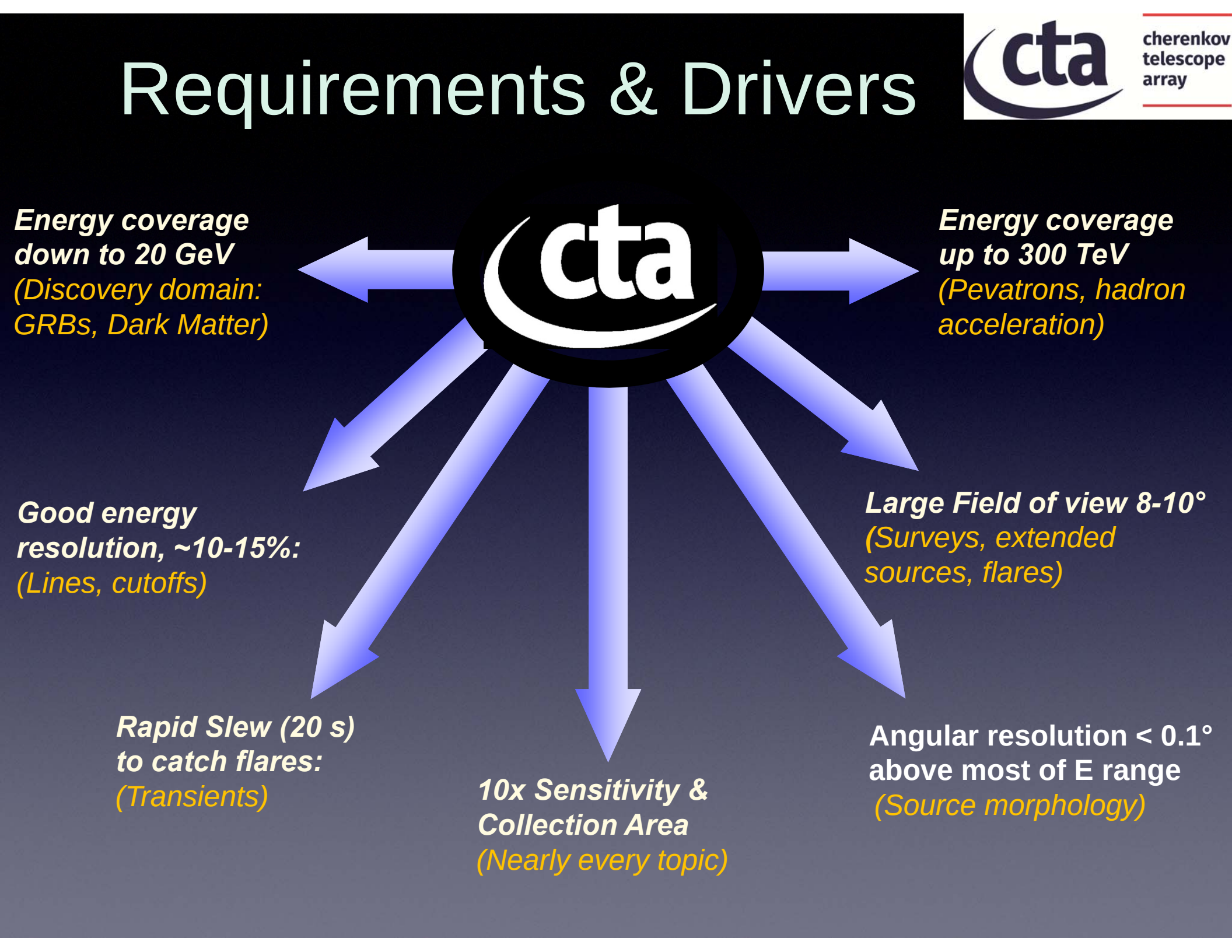
Physics frontiers – beyond the Standard Model

- 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?

→ See upcoming “Science with CTA” document

Requirements & Drivers

cherenkov telescope array



CTA Design (S array)

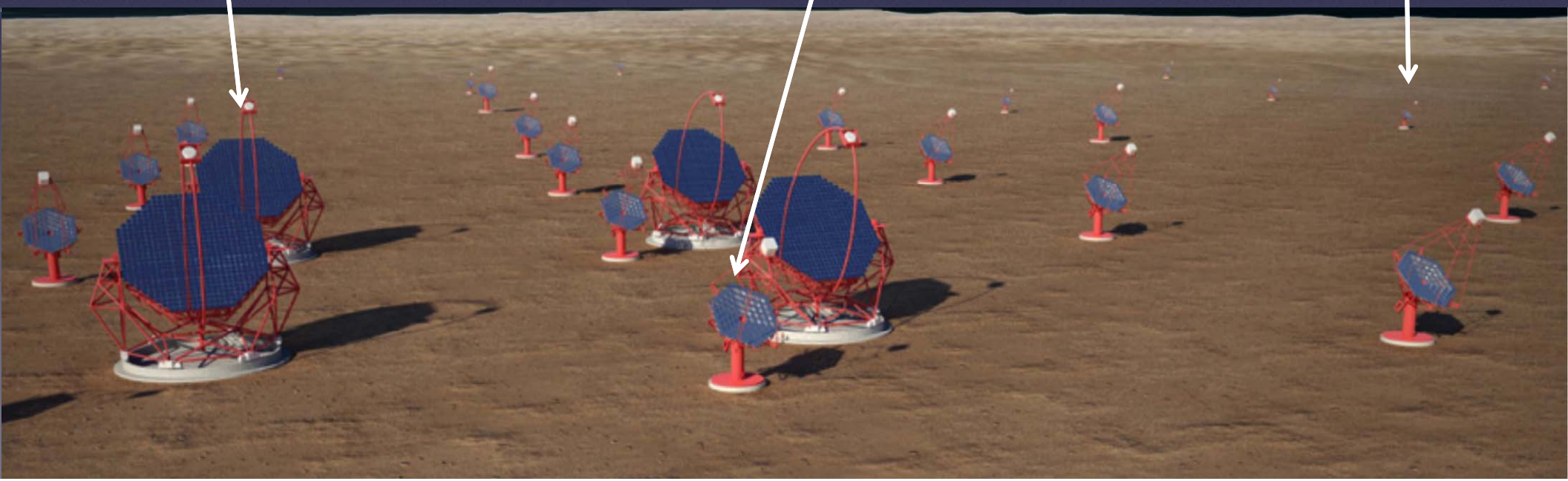
cherenkov telescope array

Science Optimization under budget constraints

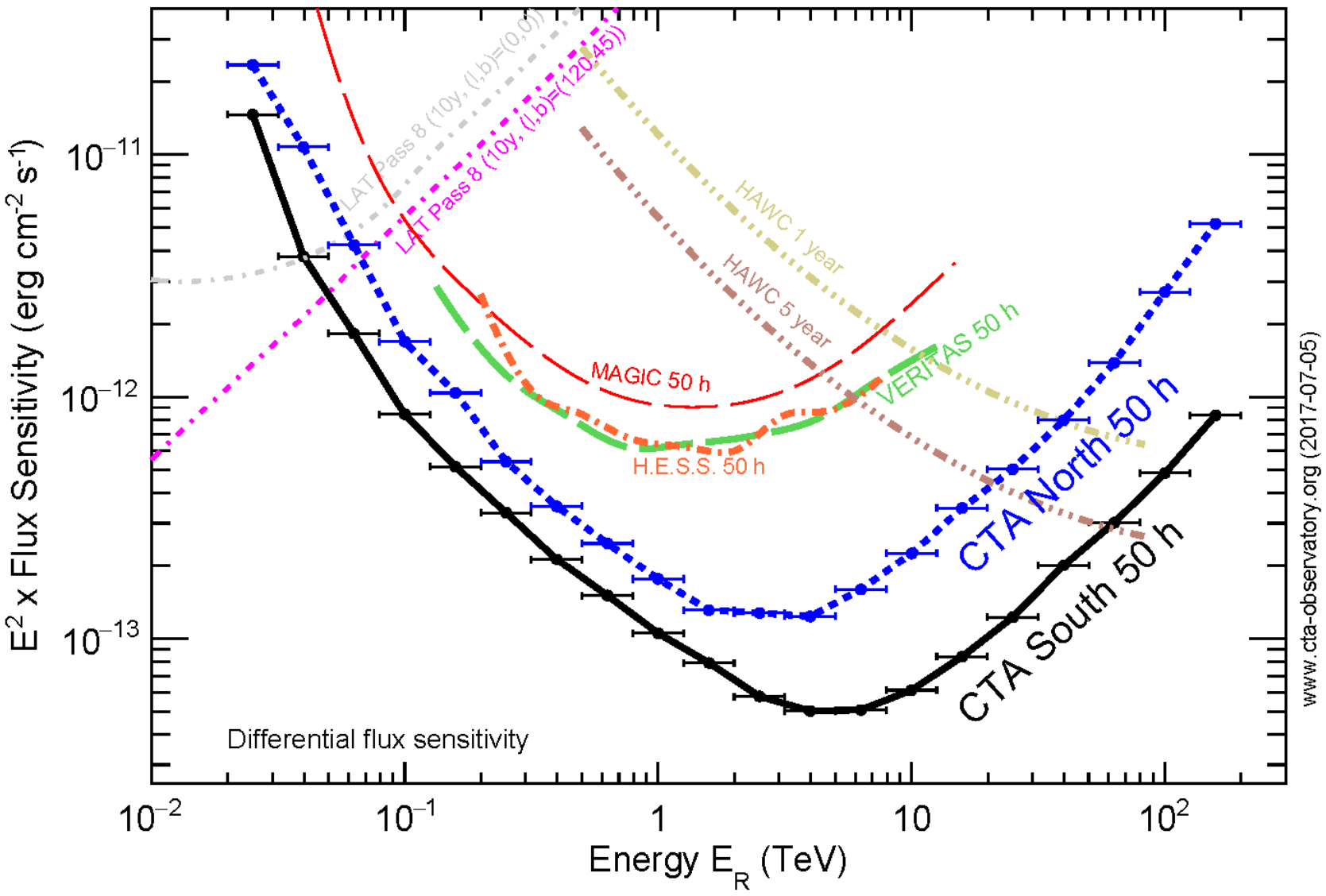
Low energies
Energy threshold 20-30 GeV
23 m diameter
4 telescopes
(LST's)

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)

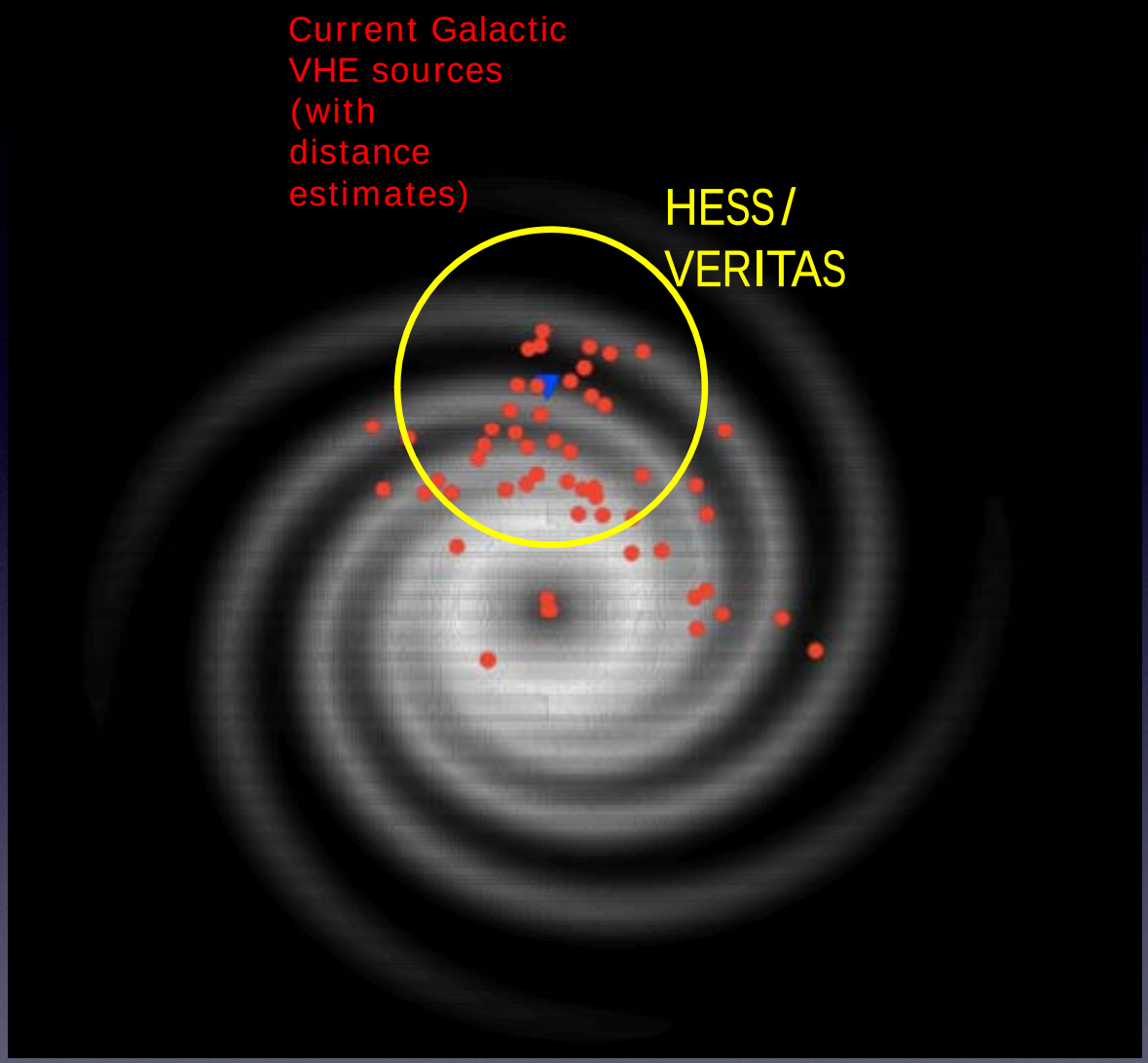


Flux Sensitivity

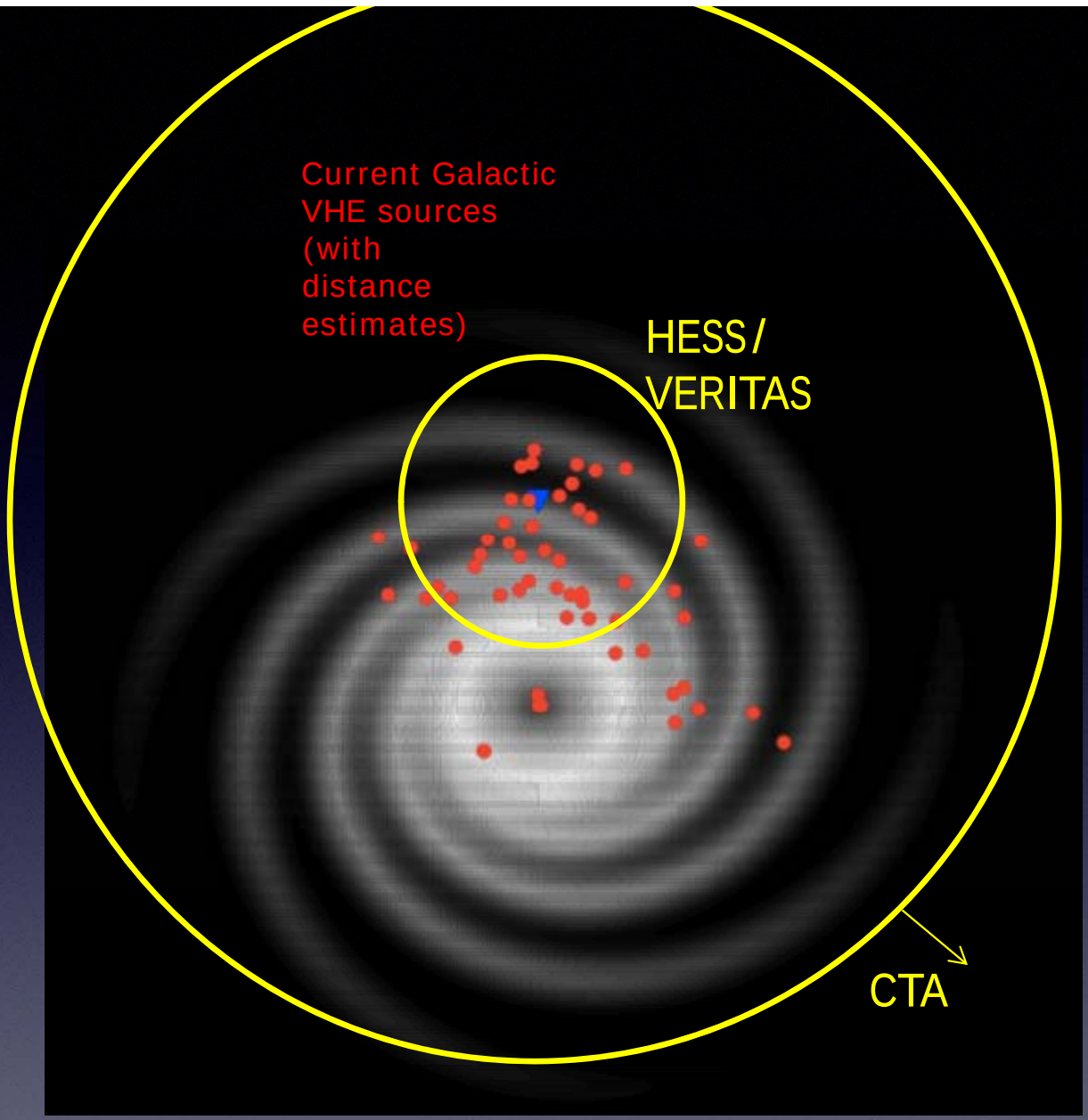


Major sensitivity improvement & wider energy range

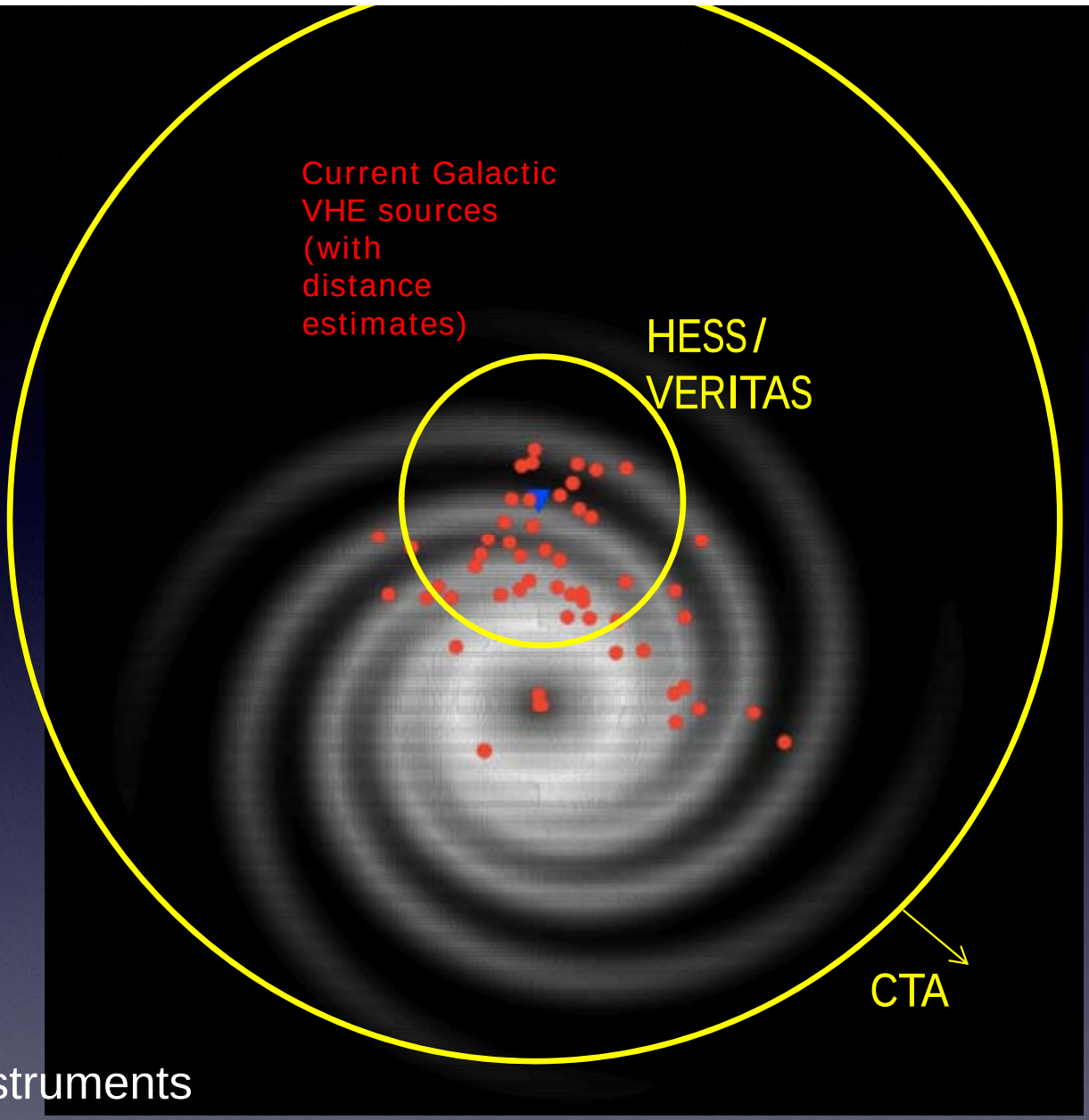
Galactic Discovery Reach



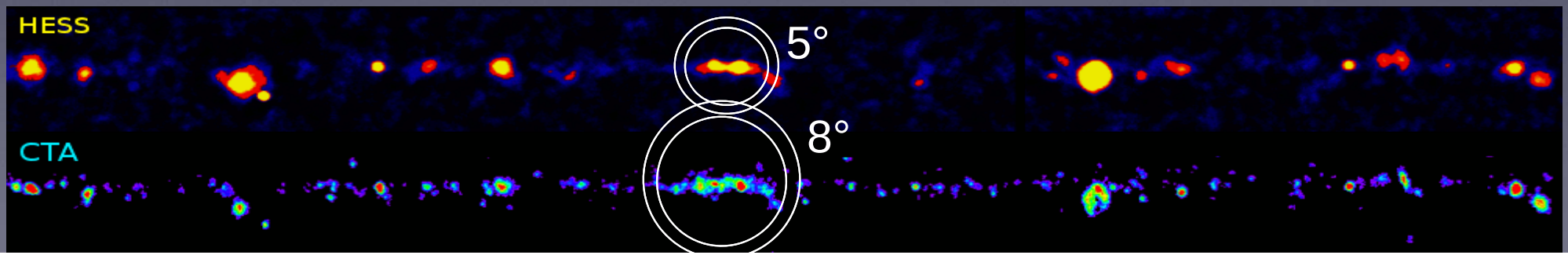
Galactic Discovery Reach



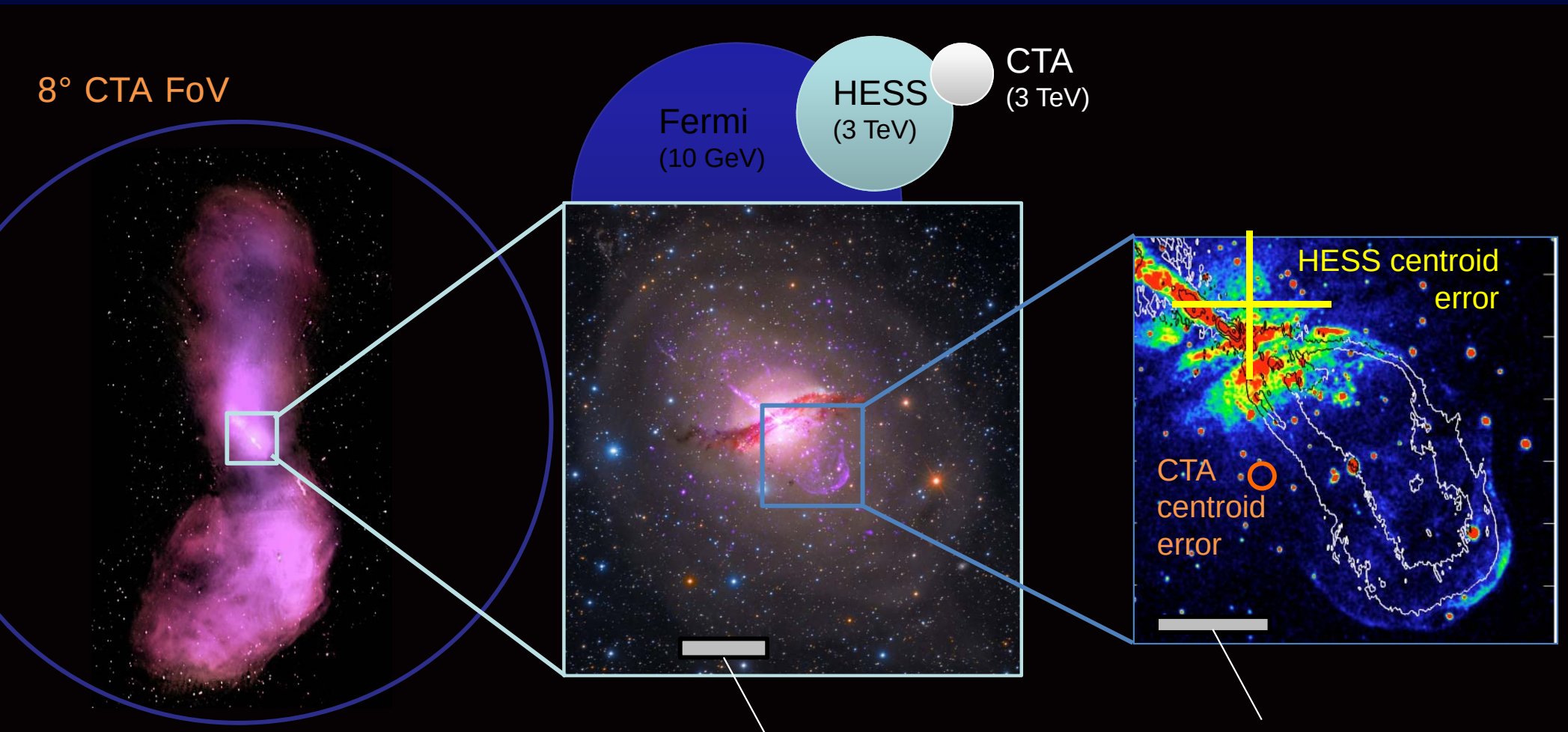
Galactic Discovery Reach



Survey speed:
x300 faster than current instruments

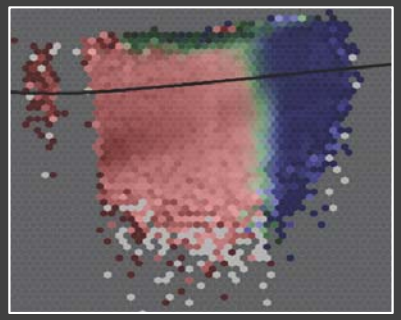


Angular Resolution

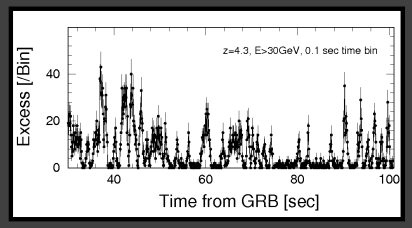


Example: Cen A

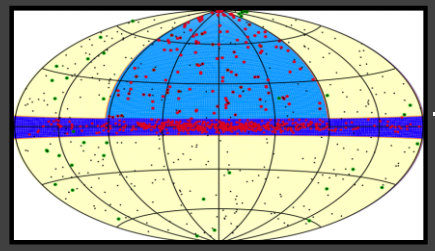
Key Science Projects (KSPs)



Dark Matter Programme

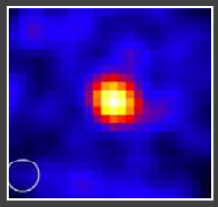


Transients



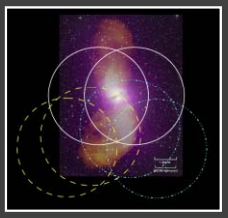
ExGal Survey

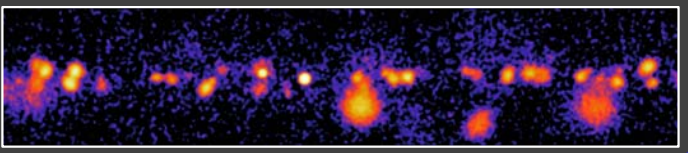
Galaxy Clusters



Star Forming Systems

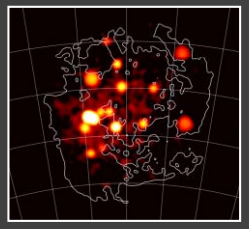
AGN



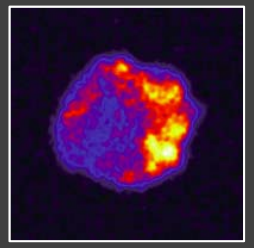


Galactic Plane Survey

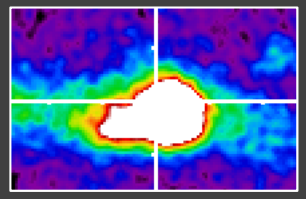
LMC Survey



PeVatrons



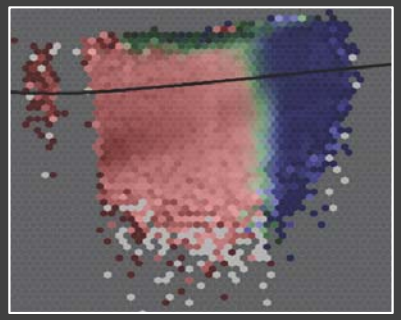
Galactic Centre



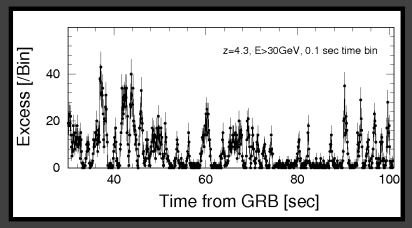
Extragalactic

Galactic

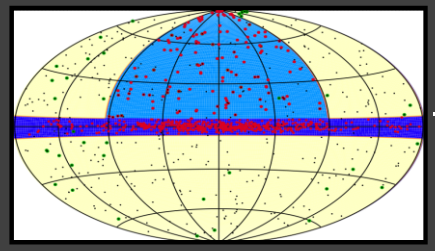
Key Science Projects (KSPs)



Dark Matter Programme

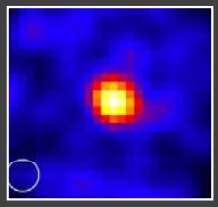


Transients



ExGal Survey

Galaxy Clusters



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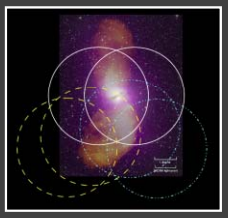
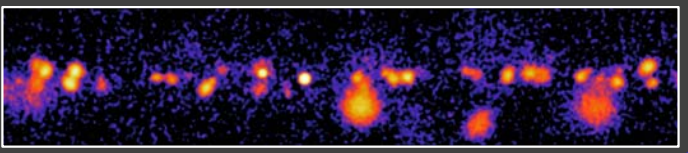


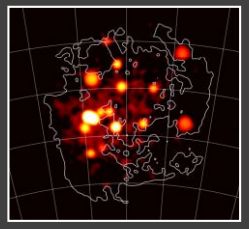
Extragalactic

Galactic

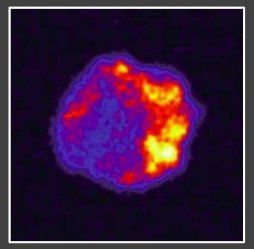


Galactic Plane Survey

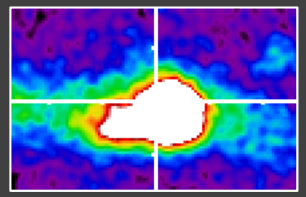
LMC Survey



PeVatrons

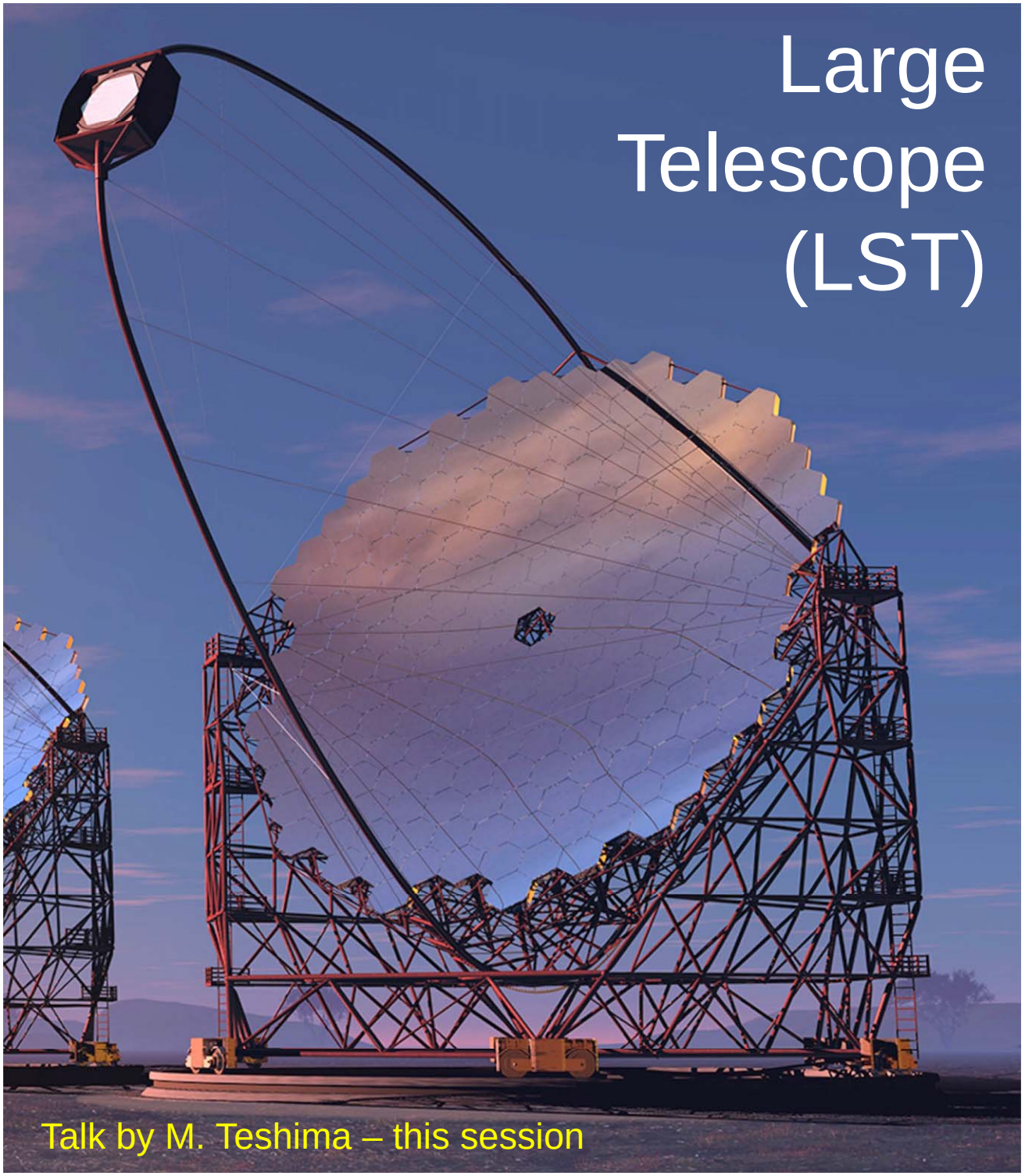


Galactic Centre



CTA Science talks:
R. Zanin 15/07 GA044
T. Hassan 18/07 GA145
A. Morselli 19/07 DM015

Large Telescope (LST)



cherenkov telescope array

23 m diameter
390 m^2 dish area
28 m focal length
1.5 m mirror facets

4.5º field of view
0.1º PMT pixels
Camera ø over 2 m

Carbon-fiber structure for 20 s positioning

Active mirror control

4 LSTs on South site
4 LSTs on North site

Prototype construction Underway (La Palma)

Medium Telescope (MST)

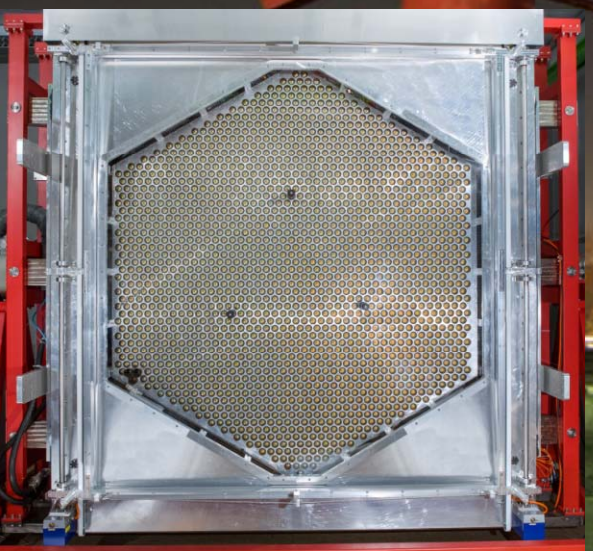
cherenkov telescope array

Prototype MST near DESY (Berlin)

100m^2 mirror dish area
16 m focal length
1.2 m mirror facets

8^o field of view
~2000 x 0.18^o PMT pixels

25 MSTs on South site
15 MSTs on North site



Prototype FlashCAM camera

Medium 2-mirror Telescope

Prototype SCT at Whipple Obs, Arizona

Schwarzschild-Couder Telescope (SCT)

9.7 m primary
5.4 m secondary
5.6 m focal length, f/0.58
50 m^2 mirror dish area
PSF better than 4.5'
across 8^o FOV

8^o field of view
11328 x 0.07^o Si-PM pixels

➜ Improved γ-ray angular resolution

Talk by V. Vassiliev
– this session

Small Sized Telescopes (SSTs)

cherenkov telescope array

- 3 different prototype designs
- 2 designs use two-mirror approaches (Schwarzschild-Couder design)
- All use Si-PM photosensors
- 8-10 m^2 mirror area, FOV > 9^o

SST-1M
Krakow, Poland

Talk by C. Alispach – this session

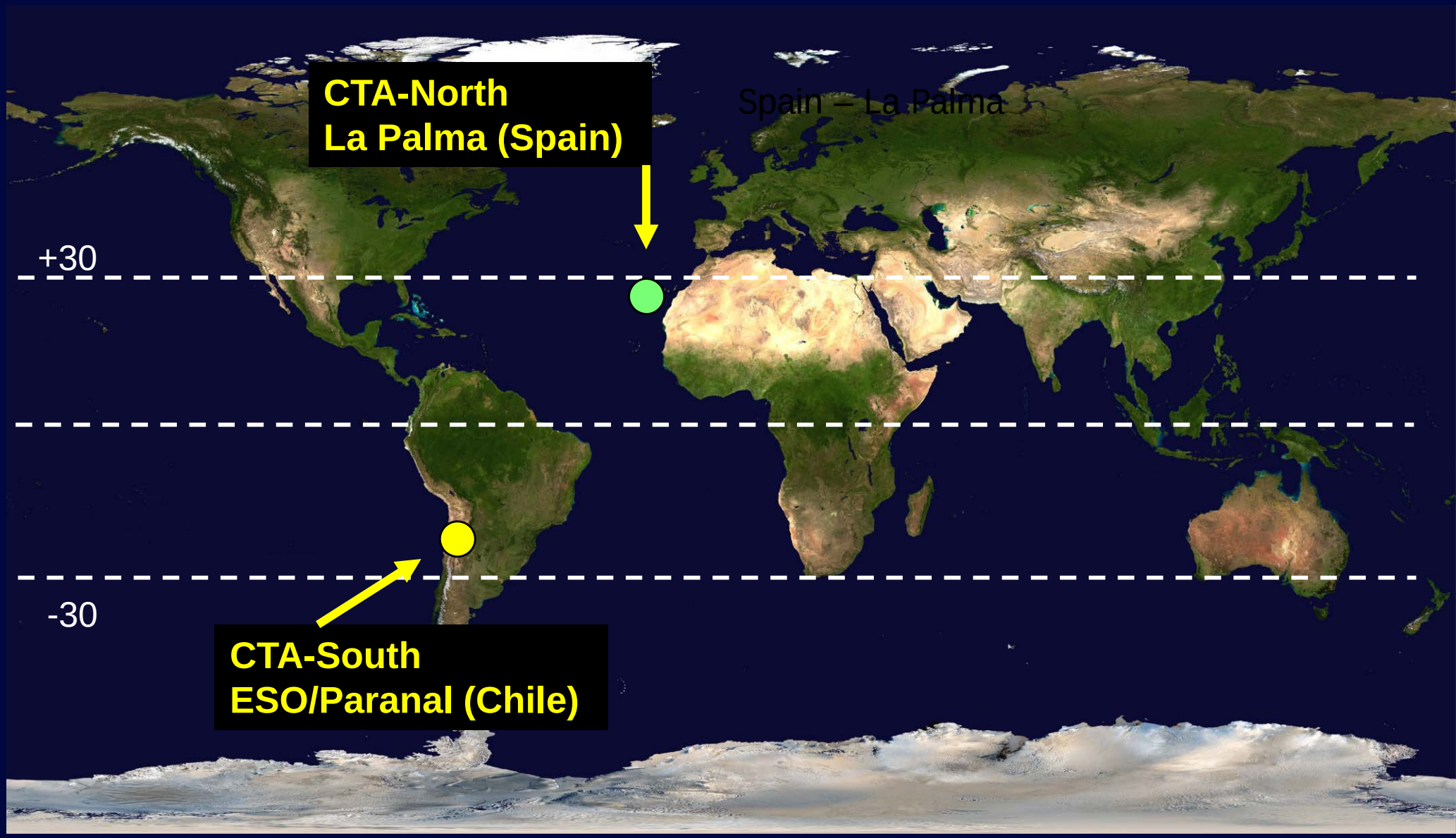
SST-2M ASTRI
Mt. Etna, Italy

Talk by M.C. Maccarone – this session

SST-2M GCT
Meudon, France

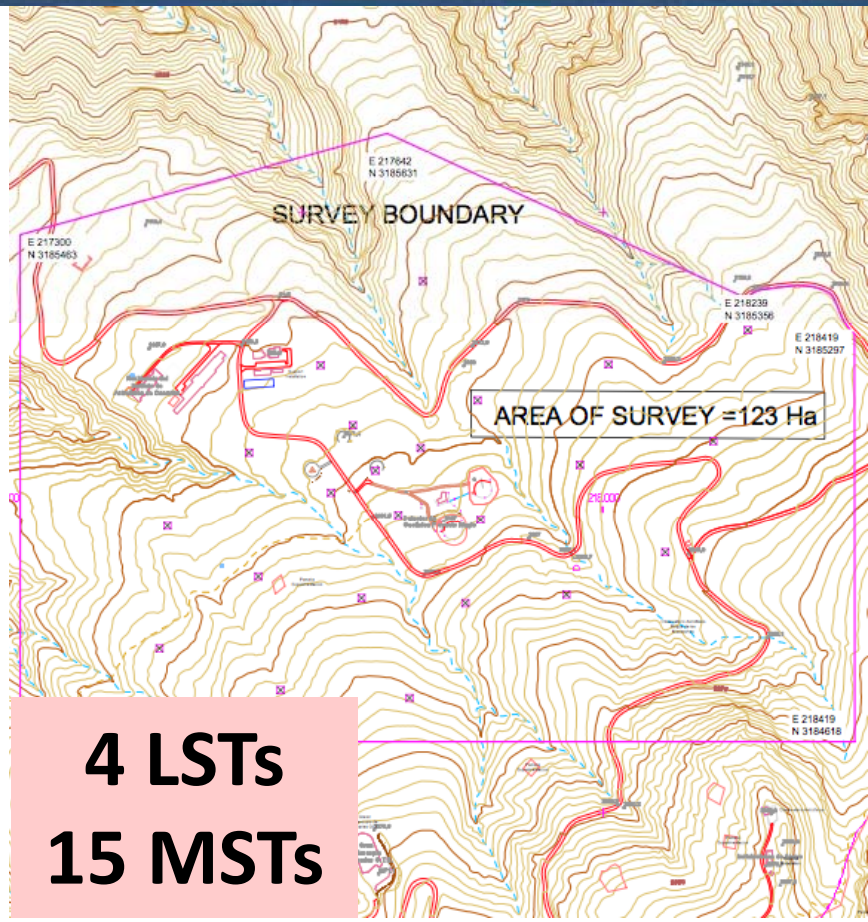
Talk by H. Sol – Monday, 13:30-15:00

CTA Sites


CTA-North
La Palma (Spain)
Spain – La Palma
+30
-30
CTA-South
ESO/Paranal (Chile)

La Palma – CTA North

- Canary Islands, Spain
- Observatorio del Roque de los Muchachos
- Existing observatory, under management by Instituto de Astrofisica de Canarias (IAC)
- Site of LST 1 & existing MAGIC telescopes
- Current work: topographical study, building concepts, tender for geotechnical study soon



4 LSTs
15 MSTs

ESO PARANAL – CTA South

- Atacama Desert, Chile, south of Cerro Paranal
- Existing observatory, under management by
  European Southern Observatory (ESO)
- Near a set of existing (VLT) and future (ELT) telescopes

ESO PARANAL – CTA South

- Atacama Desert, Chile, south of Cerro Paranal
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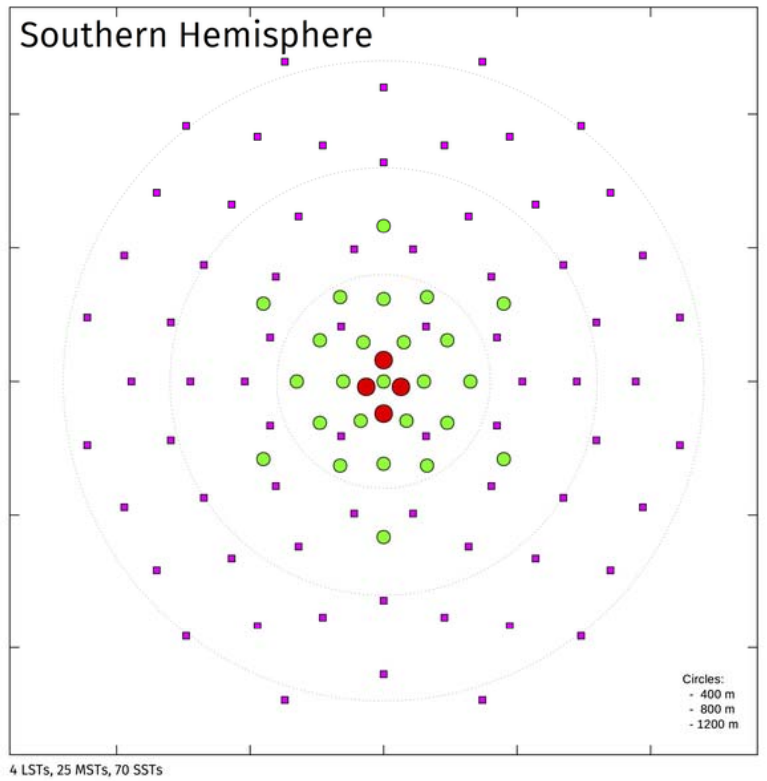
Vulcano Llullaillaco
6739 m, 190 km east

Cerro Armazones
E-ELT

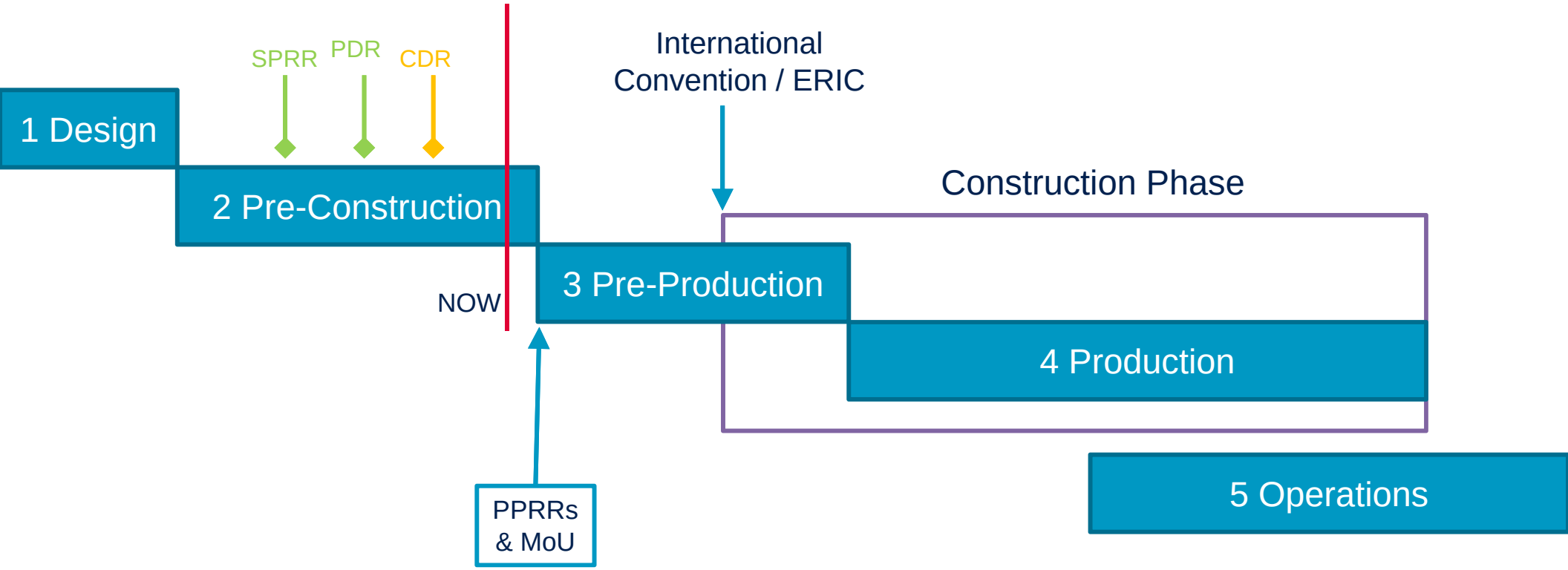
Current work: geotechnical studies (boreholes), topographical survey, concepts for roads, power, ducting, & buildings

Cerro Paranal
Very Large Telescope



4 LSTs
25 MSTs
70 SSTs

CTA Phases & Timeline



- 2016-7: Hosting agreements, site preparations start
- 2018: Start of construction
- Funding level at ~65% of required for *baseline implementation*
  → start with *threshold implementation*
  → additional funding & telescopes needed to complete baseline CTA
- Construction period of ~6 years
- Initial science with partial arrays possible before construction end

Summary

- **We've learned a lot from previous/present experiments**

  With many discoveries, VHE γ-ray astronomy has become a major and exciting field of research

  Outstanding science 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

- CTA prototyping/design is largely completed; now ready to develop both sites and enter pre-production of telescopes

- **In next decade, CTA will provide data of a quality not yet seen in the HE/VHE γ-ray band**

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

CTA Talks at ICRC 2017

cherenkov telescope array

GA Parallel, Friday, July 14: 16:30-18:30

Rene Ong	GA325	Cherenkov Telescope Array: The Next Generation Gamma-ray Observatory
Masahiro Teshima	GA202	Large Size Telescope of the Cherenkov Telescope Array
Cyril Alispach	GA300	Performance of a small size telescope (SST-1M) camera for gamma-ray astronomy with the Cherenkov Telescope Array
Maria Concetta Maccarone	GA022	ASTRI for the Cherenkov Telescope Array
Vladimir Vassiliev	GA051	Prototype 9.7m Schwarzschild-Couder telescope for the Cherenkov Telescope Array: Project Overview
Jan Ebr	GA077	Atmospheric calibration of the Cherenkov Telescope Array

GA Parallel, Saturday, July 15: 13:30-15:00

Roberta Zanin	GA044	Observing the Galactic Plane with the Cherenkov Telescope Array

GA Parallel, Monday, July 17: 13:30-15:00

Helene Sol	GA123	Observing the sky at extremely high energies with CTA: Status of the GCT project

GA Parallel, Tuesday, July 18: 16:30-18:30

Tarek Hassan	GA145	Extragalactic source population studies at very high energies in the Cherenkov Telescope Array era

GA Parallel, Wednesday, July 19: 16:30-18:30

David Kieda	GA094	Stellar Intensity Interferometric Capabilities of IACT Arrays

DM Parallel, Wednesday, July 19: 16:30-18:30

Aldo Morselli	DM015	The Dark Matter Programme of the Cherenkov Telescope Array

CTA Posters at ICRC 2017 I

[CRI097] A Monte Carlo simulation study for cosmic-ray chemical composition measurement with Cherenkov Telescope Array
Board #: 147
Presented by Michiko OHISHI on 18 Jul 2017 at 15:00

[GA019] Design, development and characterization of a calibration system for the camera of the Large Size Telescope proposed for CTA
Board #: 173
Presented by Michele PALATIELLO on 13 Jul 2017 at 15:00

[GA021] Atmospheric monitoring and array calibration in CTA using the Cherenkov Transparency Coefficient
Board #: 179
Presented by Stanislav STEFANIK on 13 Jul 2017 at 15:00

[GA023] Tools and Procedures for the CTA Array Calibration
Board #: 185
Presented by Maria Concetta MACCARONE on 13 Jul 2017 at 15:00

[GA024] Sun/Moon photometer for Cherenkov Telescope Array \u2013 first results
Board #: 240
Presented by Jakub JURYSEK on 13 Jul 2017 at 15:00

[GA039] Performance of the Cherenkov Telescope Array
Board #: 150
Presented by Gernot MAIER on 13 Jul 2017 at 15:00

[GA040] Raman LIDARs for atmospheric calibration in CTA
Board #: 230
Presented by Georges VASILEIADIS on 13 Jul 2017 at 15:00

[GA041] Control Software for a Small-Size Telescope (SST-1M) proposed for the Cherenkov Telescope Array
Board #: 188
Presented by Roland WALTER on 13 Jul 2017 at 15:00

[GA042] End-to-end data acquisition pipeline for the Cherenkov Telescope
Board #: 187
Presented by Roland WALTER on 13 Jul 2017 at 15:00

CTA Posters at ICRC 2017 II

[GA059] Studies of the nature of the low-energy, gamma-like background for Cherenkov Telescope Array
Board #: 214
Presented by Julian SITAREK on 13 Jul 2017 at 15:00

[GA061] Towards final characterization and performance of the GCT prototype telescope structure for CTA
Board #: 176
Presented by Cedric PERENNES on 13 Jul 2017 at 15:00

[GA102] Searching for PeVatrons in the CTA Galactic Plane Survey
Board #: 149
Presented by Cyril TRICHARD on 13 Jul 2017 at 15:00

[GA131] A Compact High Energy Camera (CHEC) for the GCT of CTA
Board #: 183
Presented by Harm SCHOORLEMMER on 13 Jul 2017 at 15:00

[GA136] Prototype 9.7m Schwarzschild-Couder telescope for the Cherenkov Telescope Array: status of the optical system
Board #: 209
Presented by Daniel NIETO on 13 Jul 2017 at 15:00

[GA141] Baseline telescope layouts of the Cherenkov Telescope Array
Board #: 233
Presented by Paolo CUMANI on 13 Jul 2017 at 15:00

[GA146] Exploring deep learning as an event classification method for the Cherenkov Telescope Array
Board #: 210
Presented by Daniel NIETO on 13 Jul 2017 at 15:00

[GA147] A Trigger Interface Board to manage trigger and timing signals in CTA Large-Sized Telescope and Medium-Sized Telescope camera
Board #: 208
Presented by Marcos LOPEZ on 13 Jul 2017 at 15:00

[GA155] ASTRI SST-2M prototype and mini-array simulation chain, data reduction software, and archive in the framework of the CTA
Board #: 184
Presented by Maria Concetta MACCARONE on 13 Jul 2017 at 15:00

CTA Posters at ICRC 2017 III

[GA158] A pointing solution for the medium size telescopes for the Cherenkov Telescope Array
Board #: 186
Presented by Domenico TIZIANI on 13 Jul 2017 at 15:00

[GA185] Studying cosmological gamma-ray propagation with the Cherenkov Telescope Array
Board #: 099
Presented by Florian GATÉ on 13 Jul 2017 at 15:00

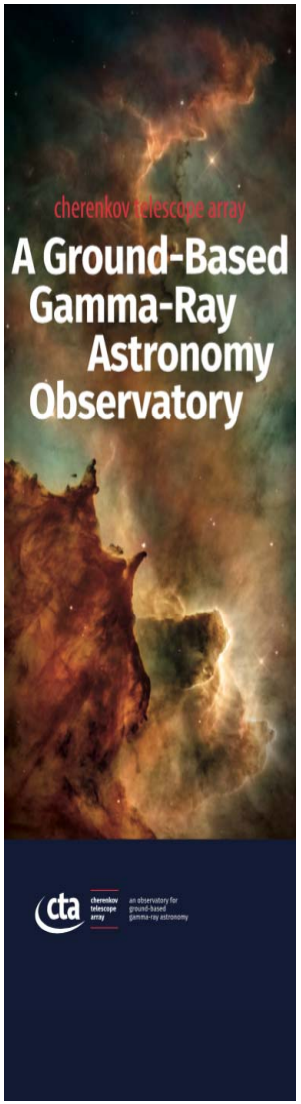
[GA279] Gammapy - high level data analysis for extragalactic science cases with the Cherenkov Telescope Array
Board #: 118
Presented by Julien LEFAUCHEUR on 13 Jul 2017 at 15:00

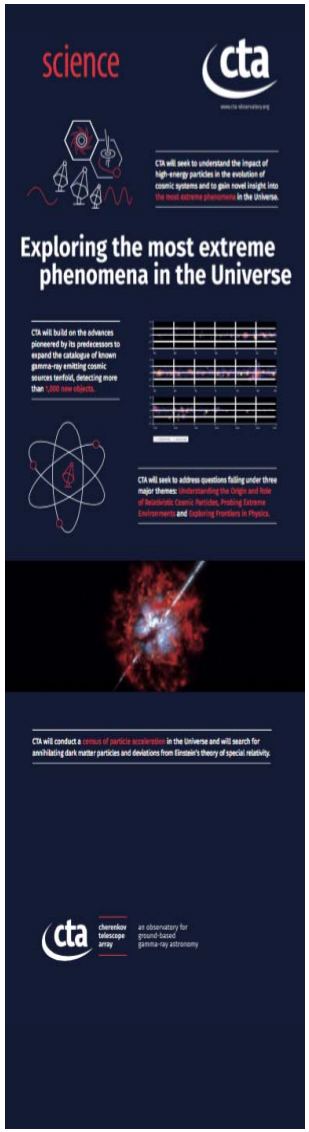
[GA284] The ARCADE Raman Lidar and atmospheric simulations for the Cherenkov Telescope Array
Board #: 231
Presented by Laura VALORE on 13 Jul 2017 at 15:00

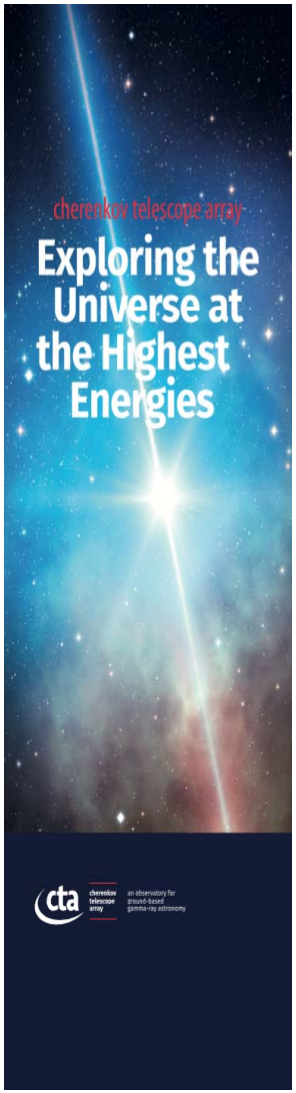
[GA166] Development of a strategy for calibrating the novel SiPM camera of the SST-1M telescope proposed for the Cherenkov Telescope Array
Board #: 238
Presented by Imen AL SAMARAI on 13 Jul 2017 at 15:00

[GA278] Gammapy - A prototype for the CTA science tools
Board #: 215
Presented by Matteo CERRUTI on 13 Jul 2017 at 15:00

Visit the CTA Exhibit!

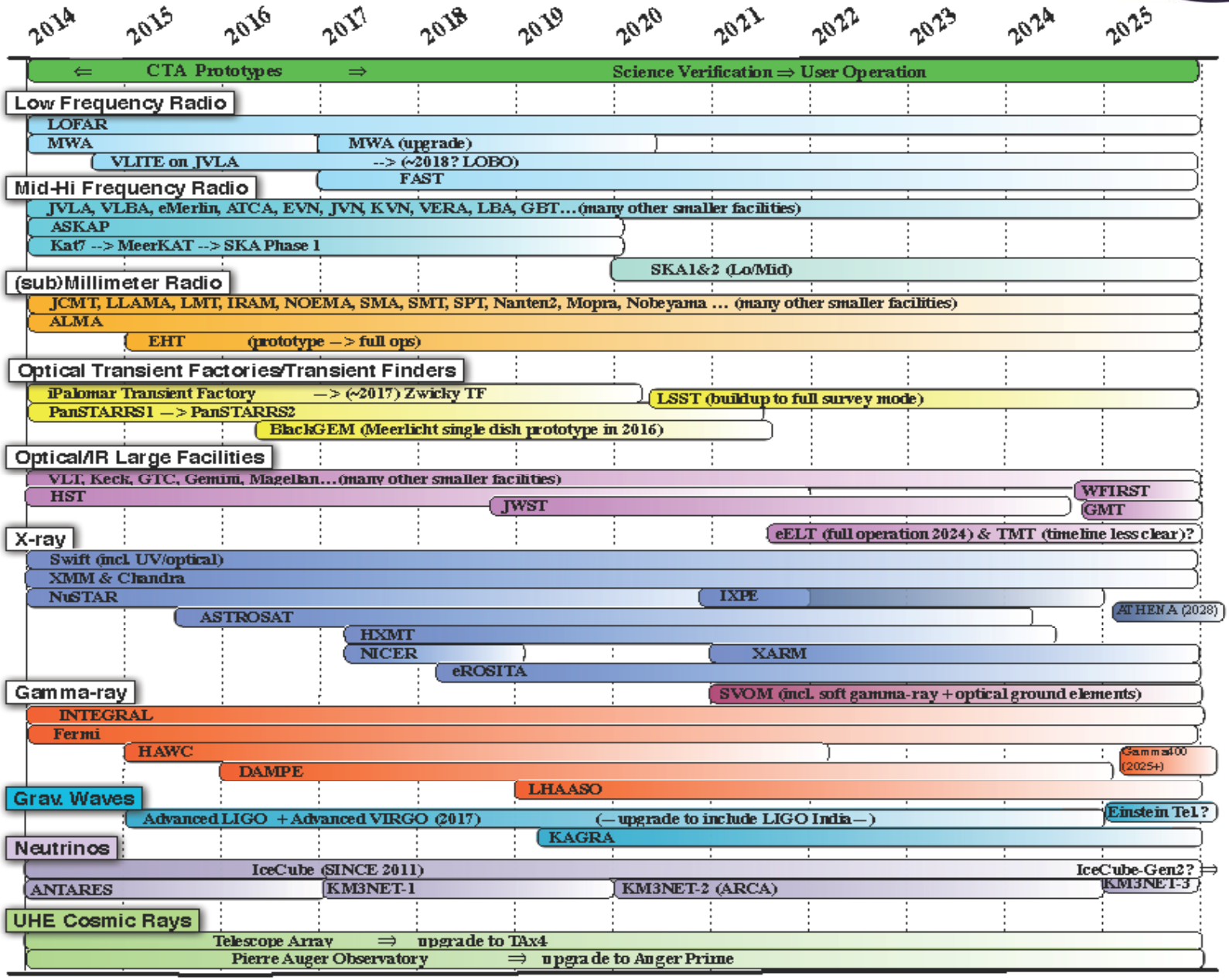






BACKUP

Important MWL/MM Synergies



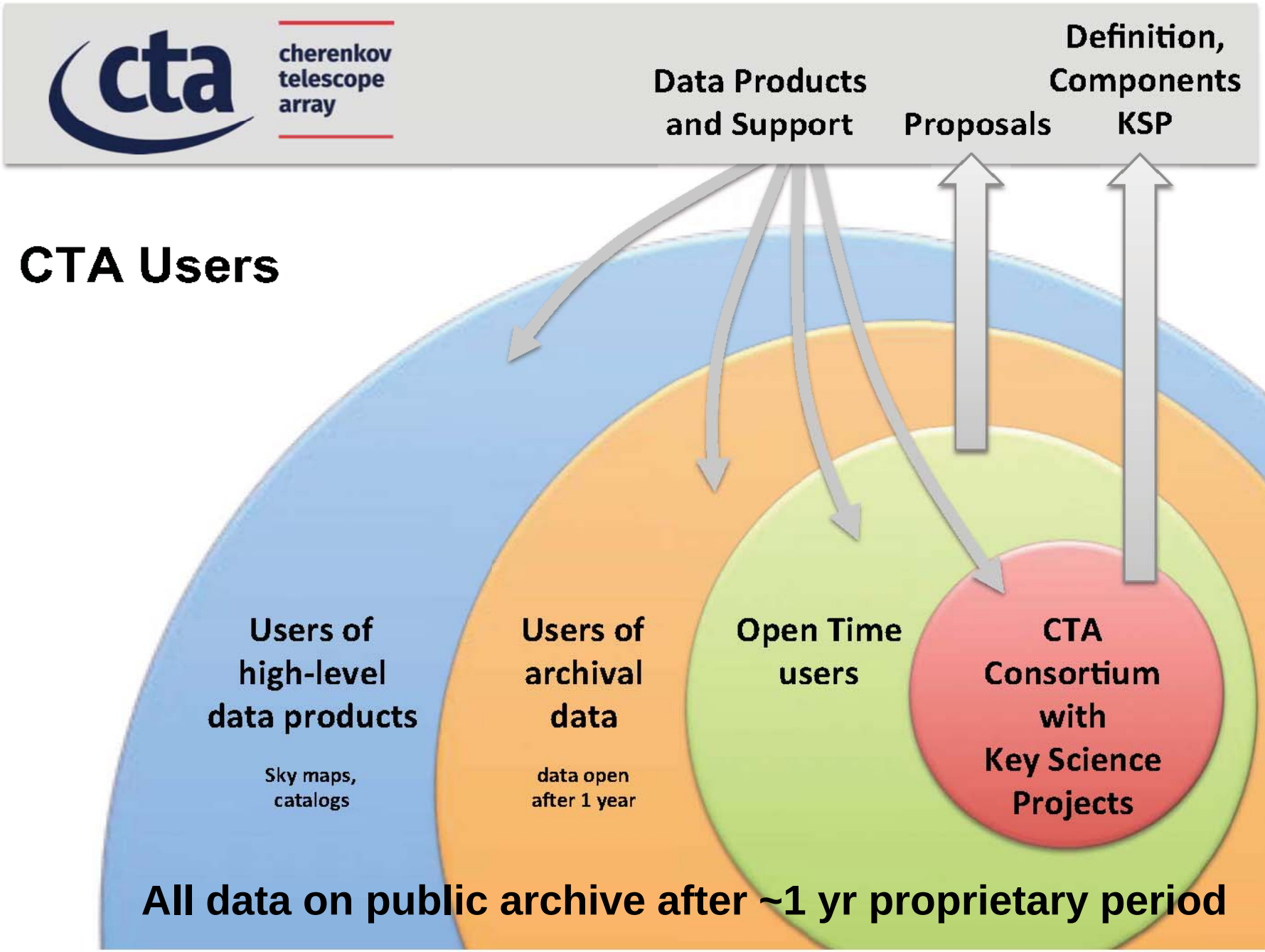
Caveat: Observatory timelines are very uncertain; this represents a notional picture based on available information

Science with CTA

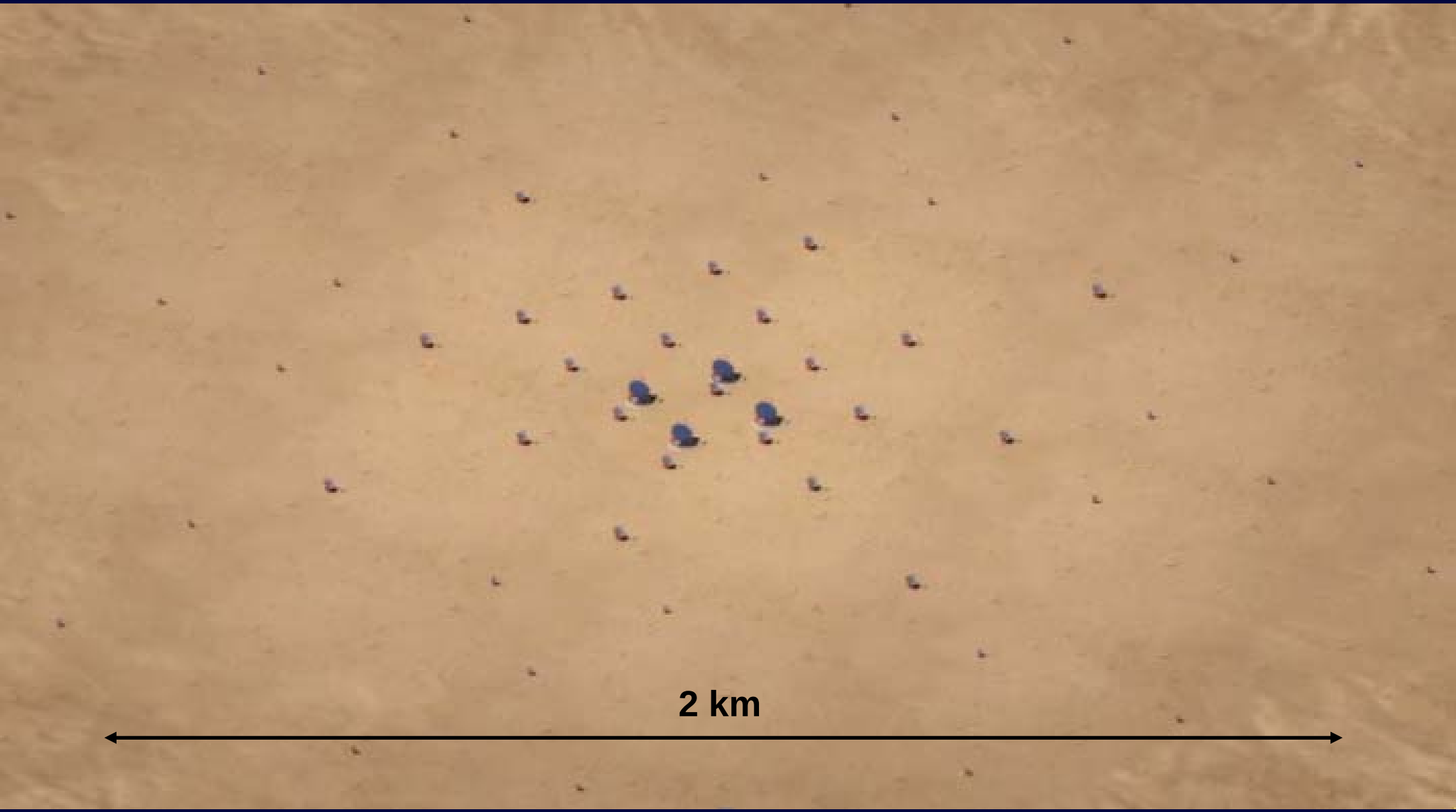
200 page document describing core CTA science

Will soon be put on axViv and become a regular book

CTA: An Open Observatory



CTA South Array



Telescope Types