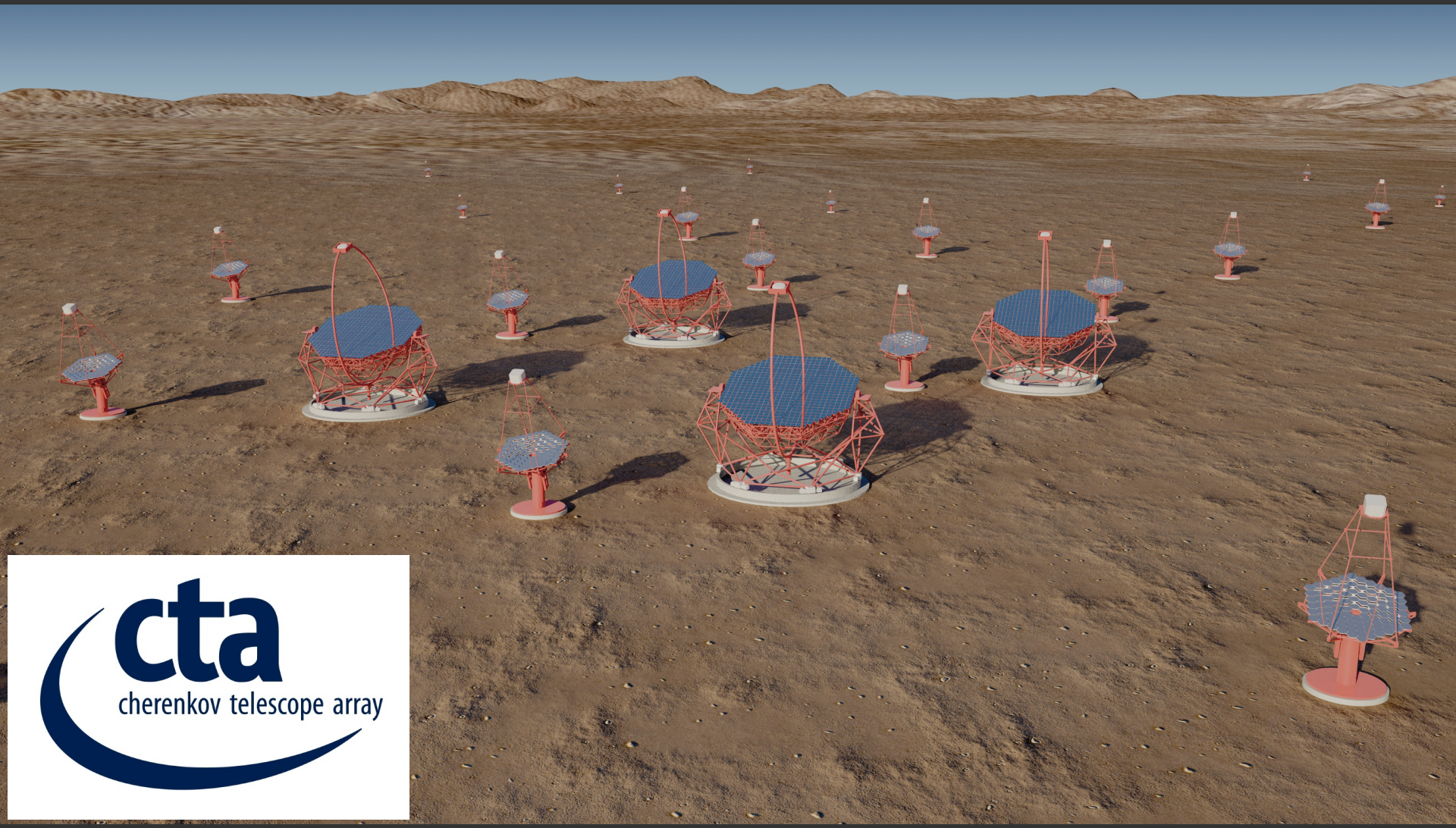
CTA – Status, Science and Australia's Role

Gavin Rowell Uni. Adelaide

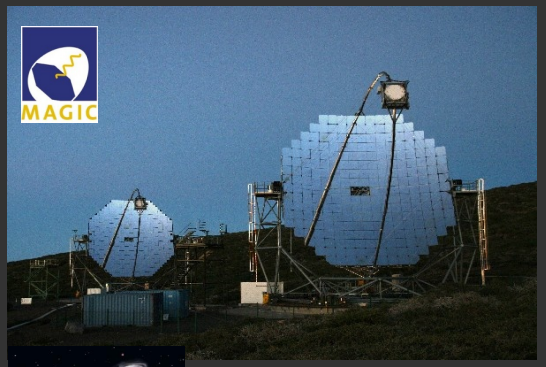


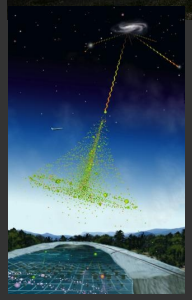
CTA-Australia Workshop 2015 Adelaide

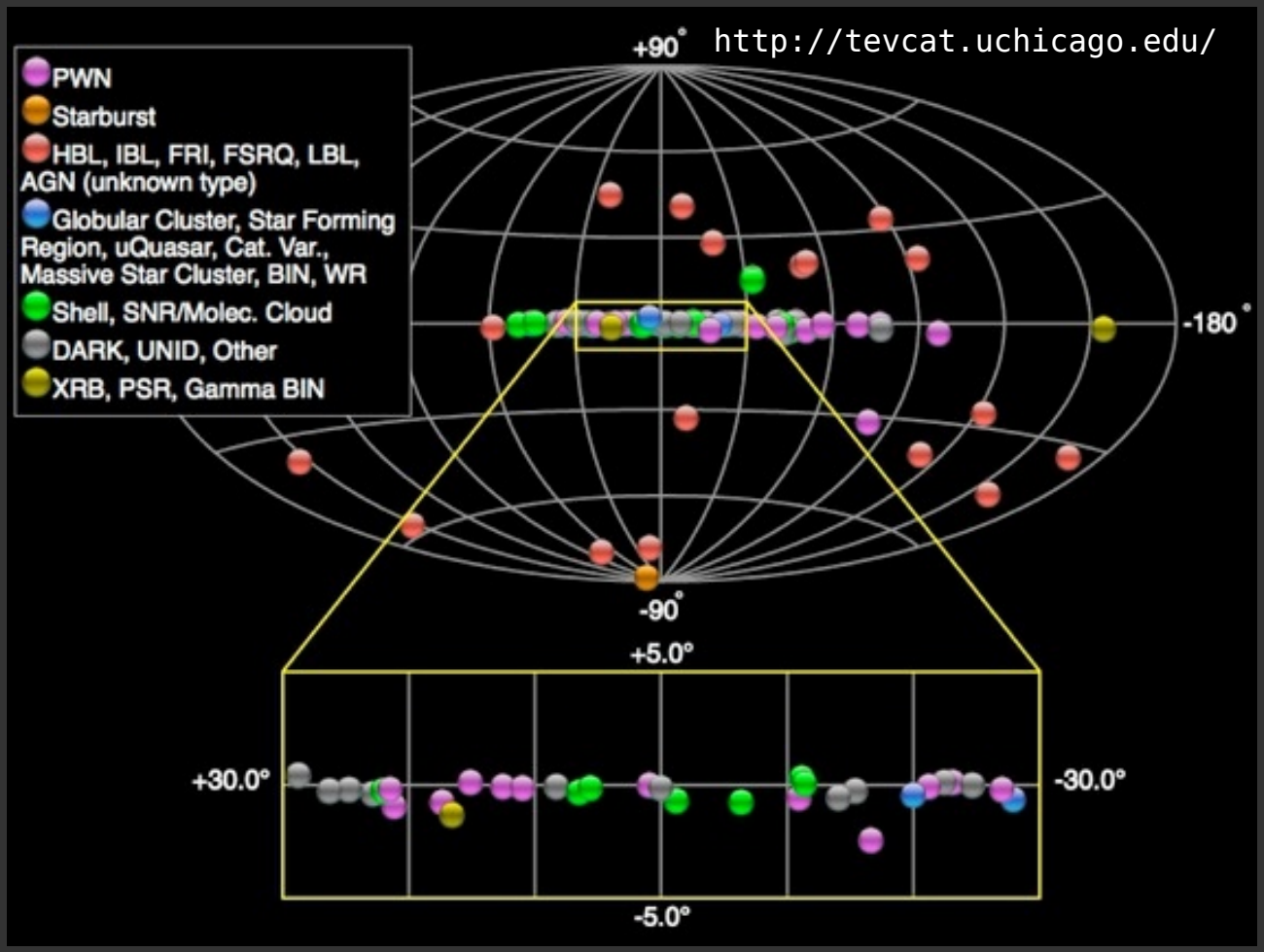
Gamma-rays (~30 GeV to ~500TeV)

Highly effective tracer of high energy particles

High impact results – 19 Nature, Science, PhysRevLett papers since 2004

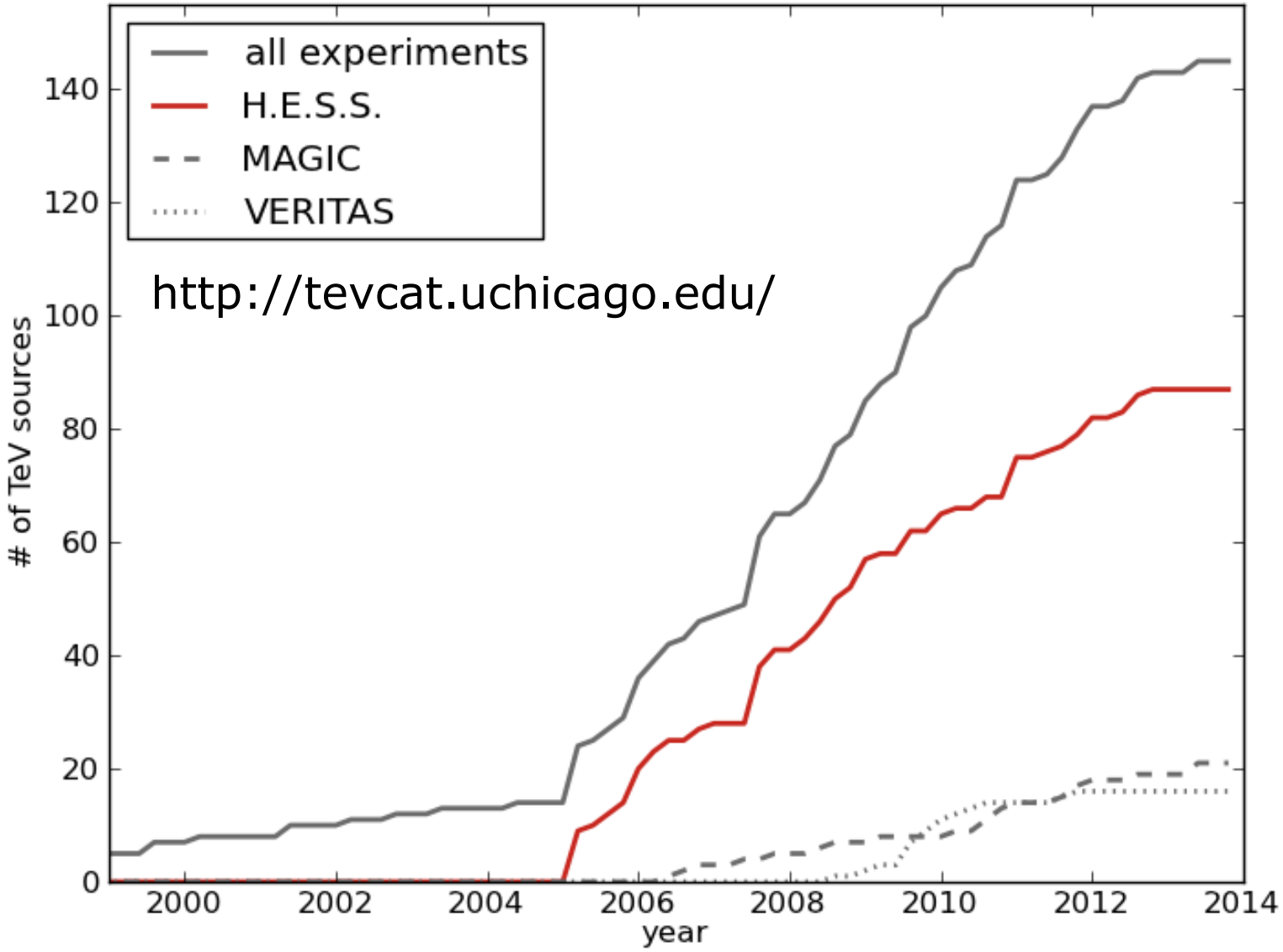






Great success with HESS, VERITAS, MAGIC, MILAGRO

→ HESS-II, MAGIC-II, VERITAS upgrade, CTA, HAWC...


all experiments
H.E.S.S.
MAGIC
VERITAS
http://tevcat.uchicago.edu/
# of TeV sources
0
20
40
60
80
100
120
140
2000
2002
2004
2006
2008
2010
2012
2014
year

The Cherenkov Telescope Array

- Huge improvement in all aspects of performance

  x10 better sensitivity, better FoV + angular resolution, wider energy coverage, collection area >few km^2, wider survey capabilities

- A user facility / proposal-driven observatory

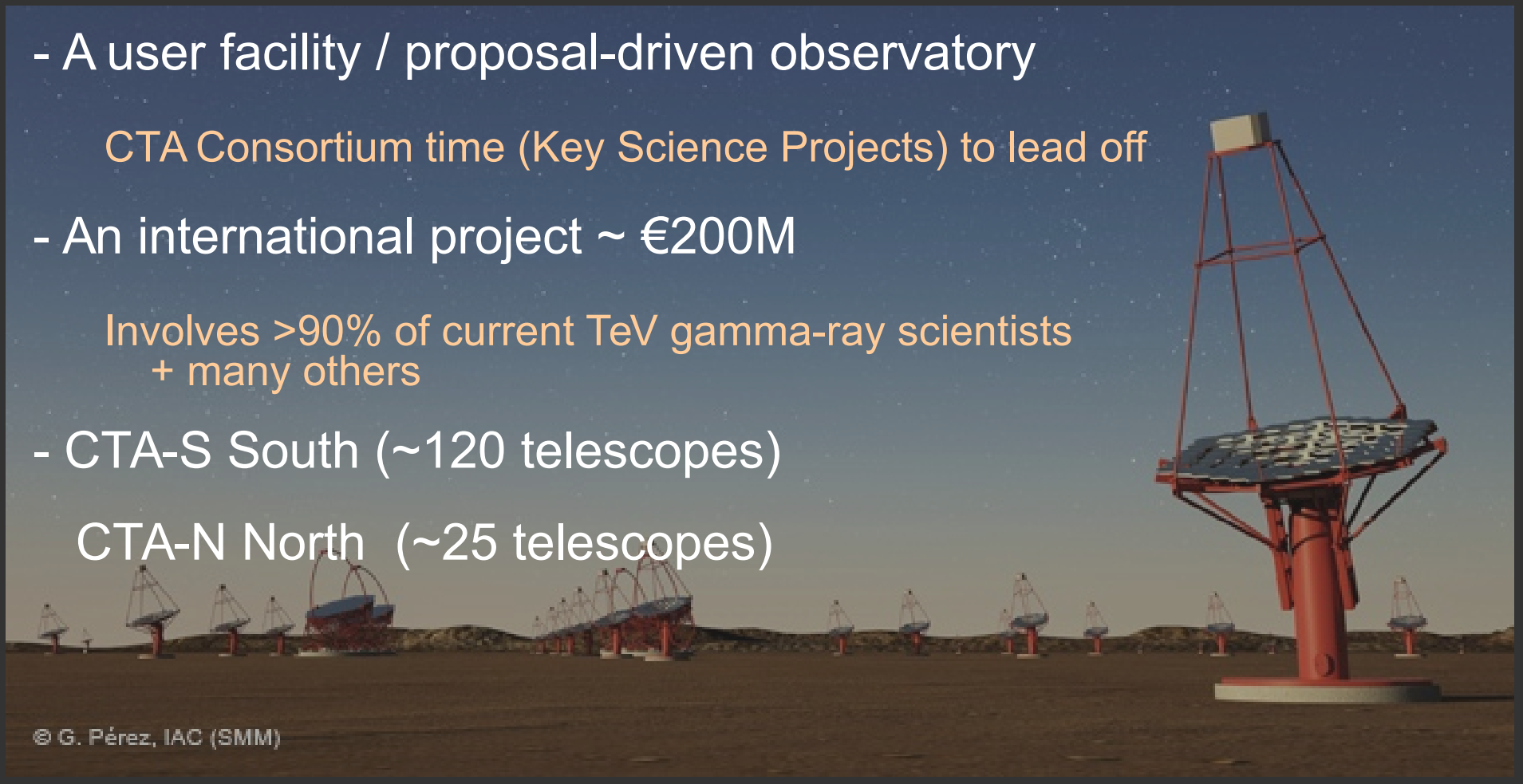
  CTA Consortium time (Key Science Projects) to lead off

- An international project ~ €200M

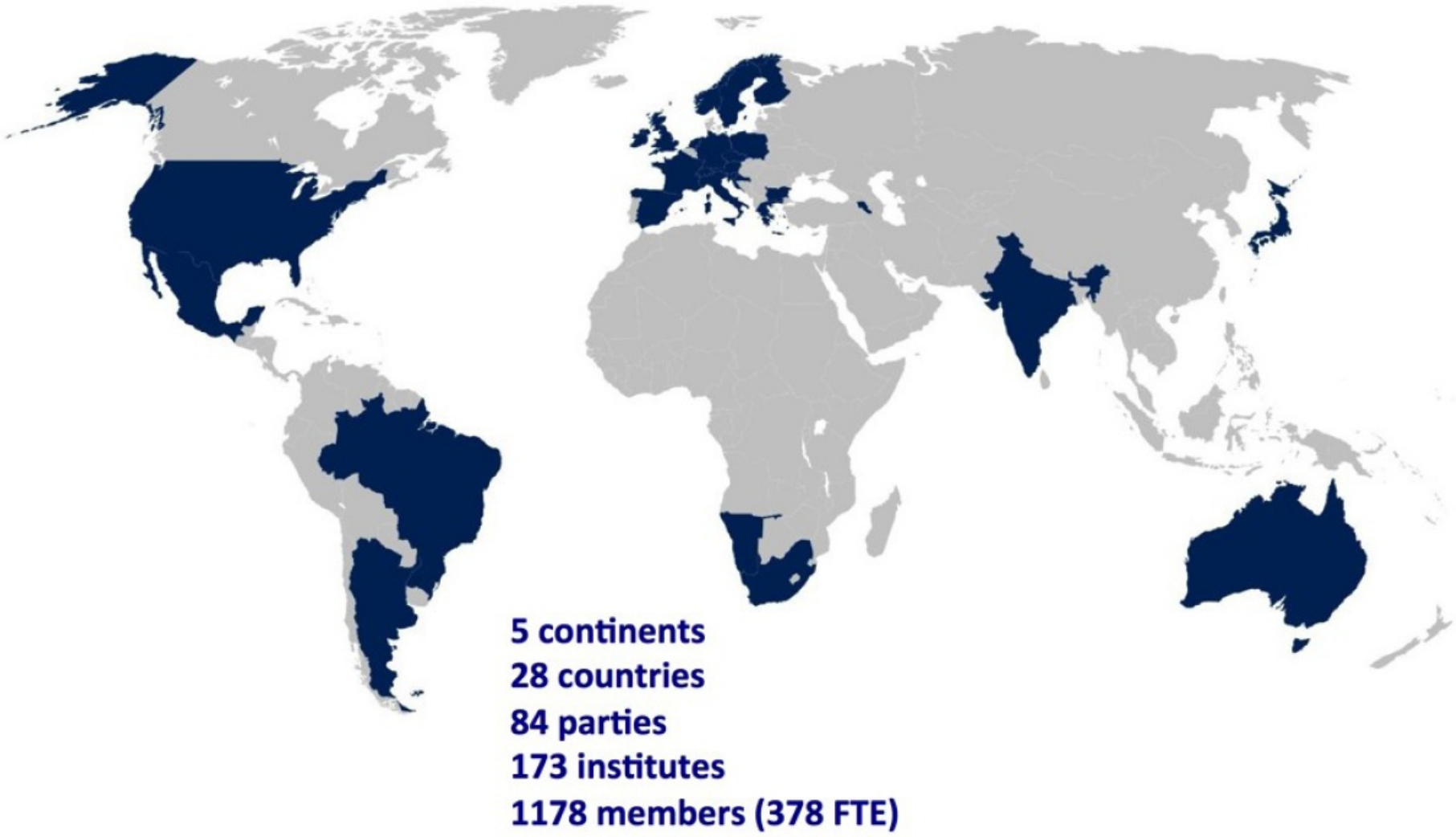
  Involves >90% of current TeV gamma-ray scientists + many others

- CTA-S South (~120 telescopes)

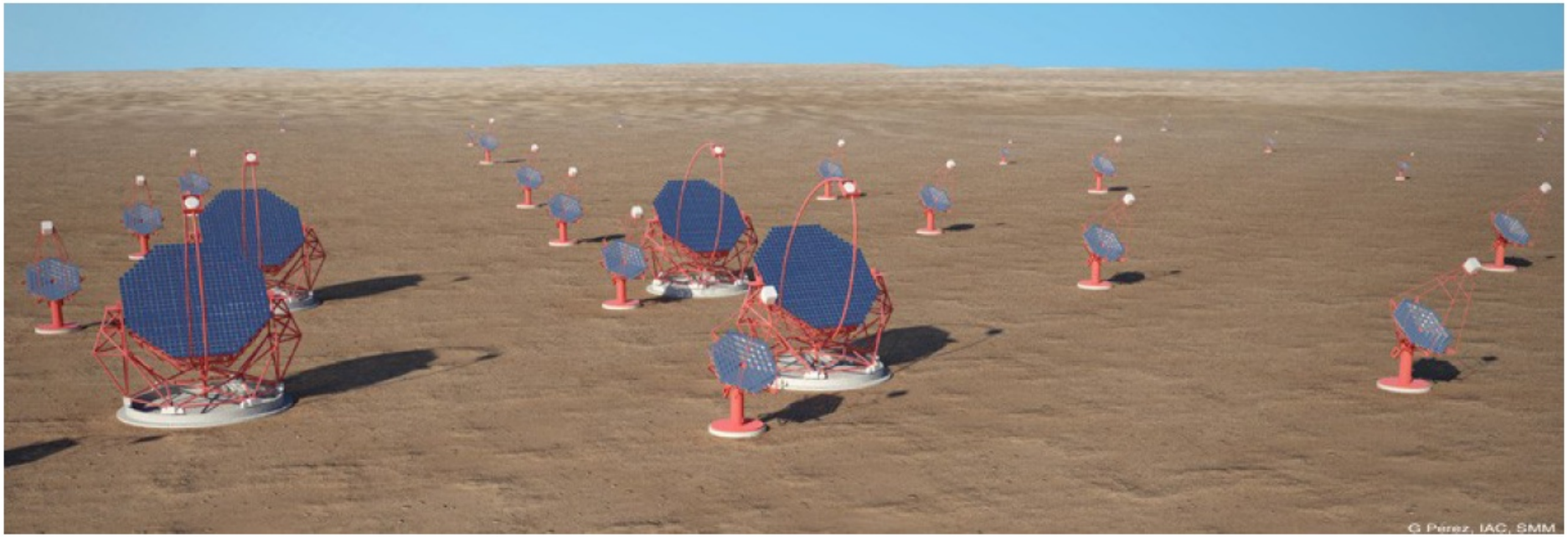
  CTA-N North (~25 telescopes)

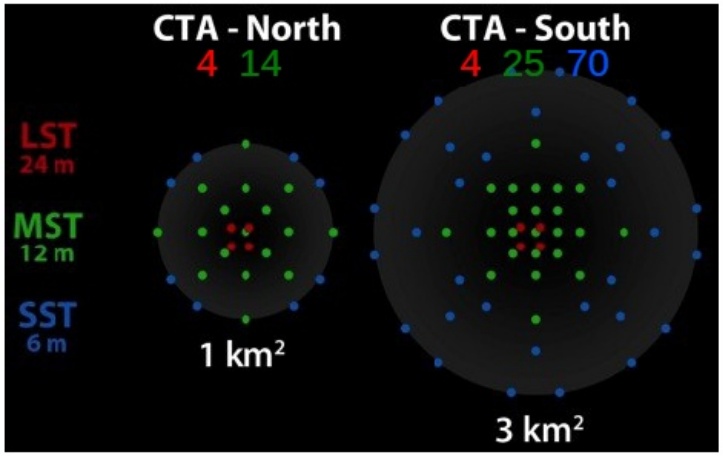


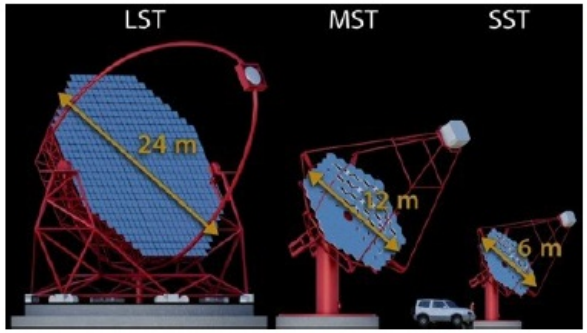
CTA Consortium July 2014



The CTA Observatory

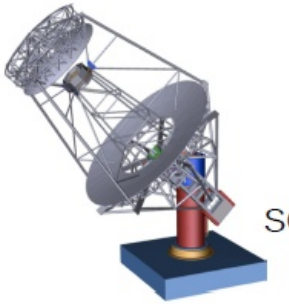




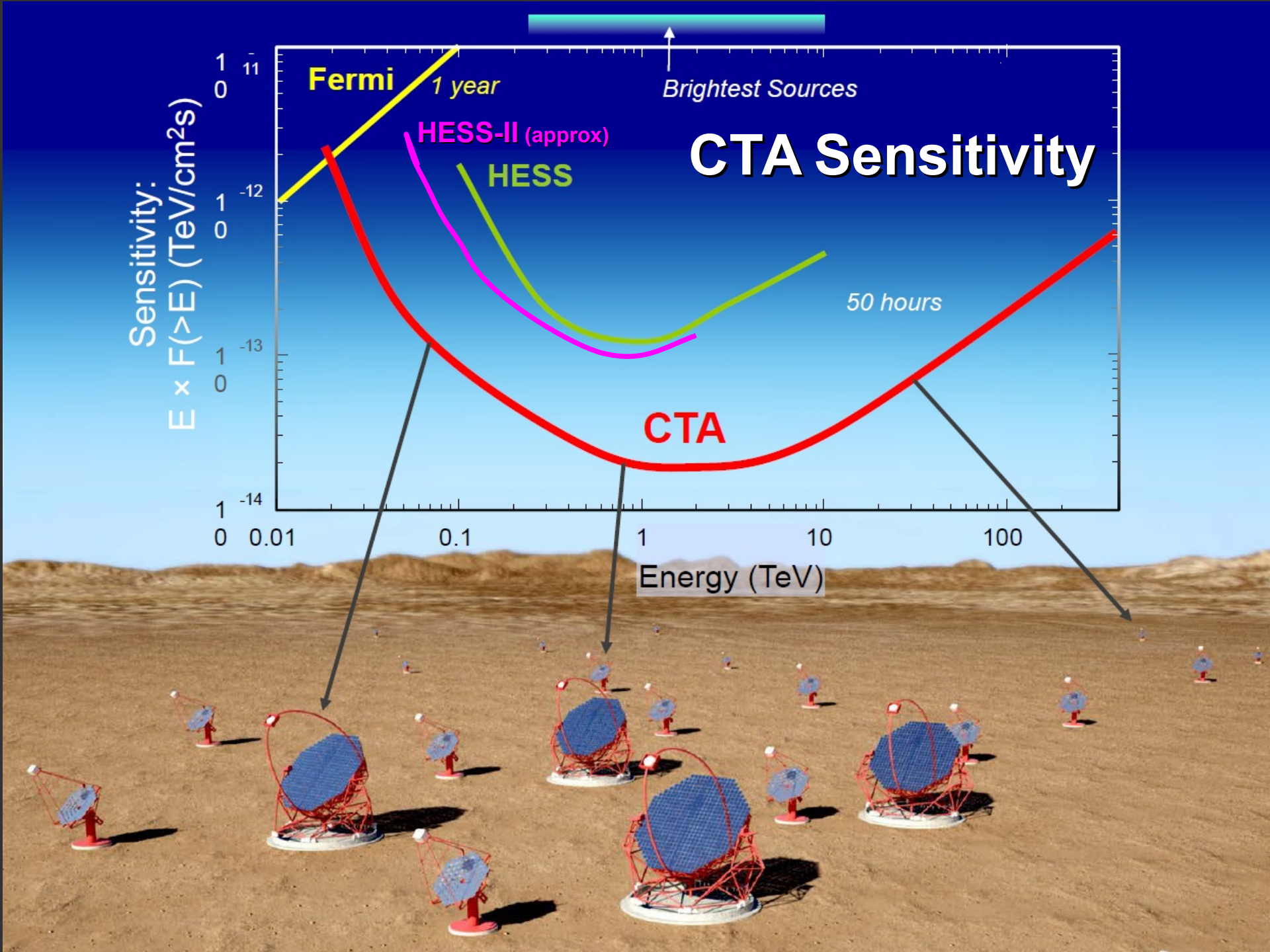


Characteristics

3 telescope classes
2 sites (South and North)
About 120 (+25) telescopes

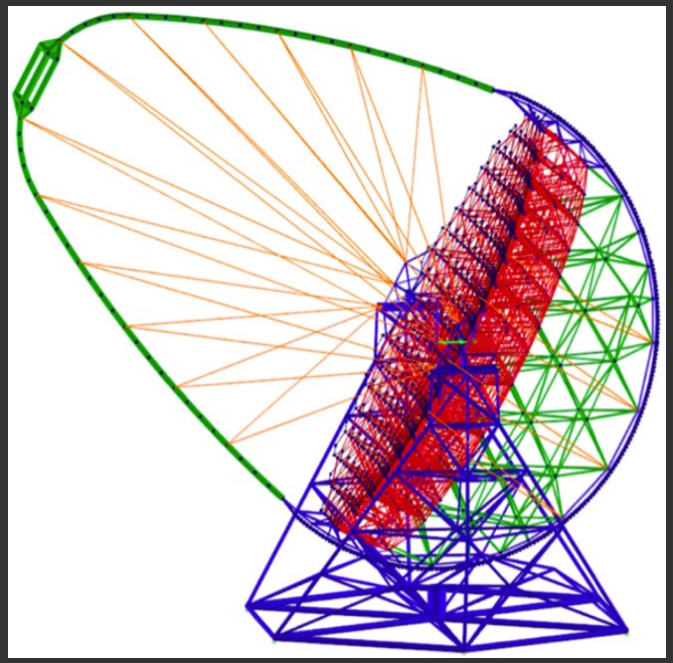


SCT

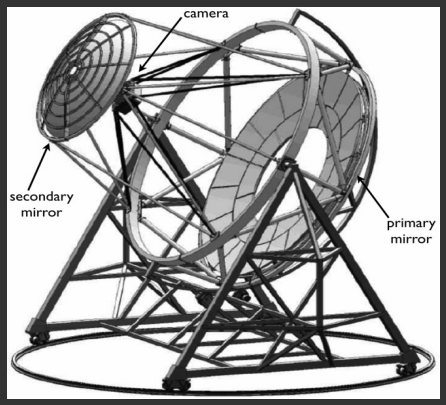

CTA Sensitivity
Fermi
1 year
Brightest Sources
HESS-II (approx)
HESS
50 hours
CTA
Sensitivity:
E × F(>E) (TeV/cm²s)
10^-11
10^-12
10^-13
10^-14
0.01
0.1
1
10
100
Energy (TeV)

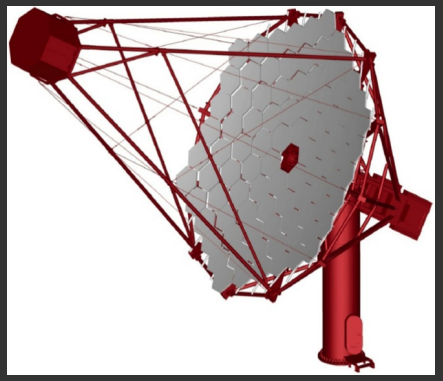
CTA – Telescopes

LST

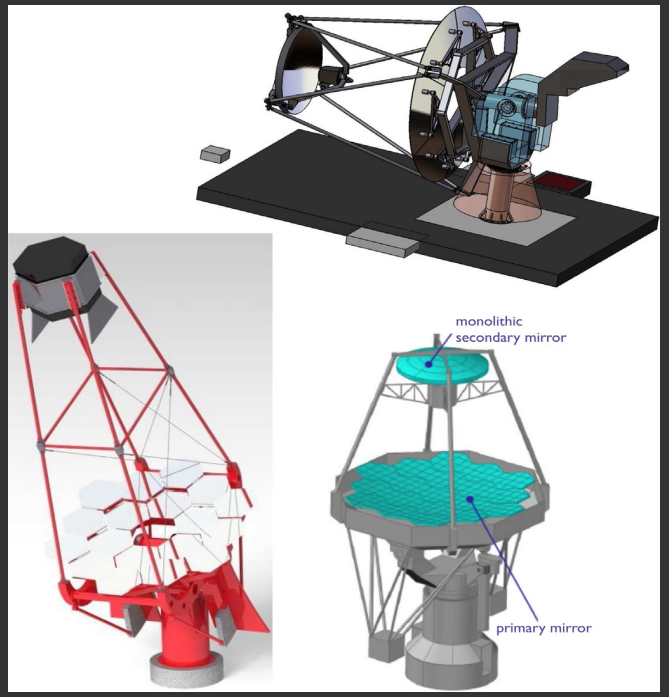


MST





SST



LST – Large Size Telescope 23m diam 4.5° FoV
MST – Medium Size Telescope 12m diam 7.5° FoV
SST – Small Size Telescope 4-6m diam 9° FoV

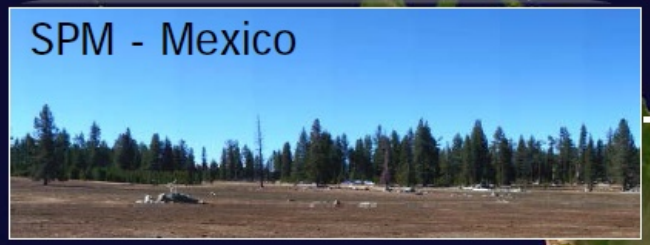
prototypes now under construction

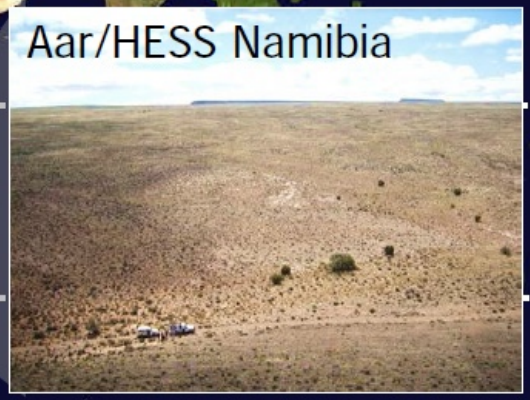
CTA Time-line & Funding

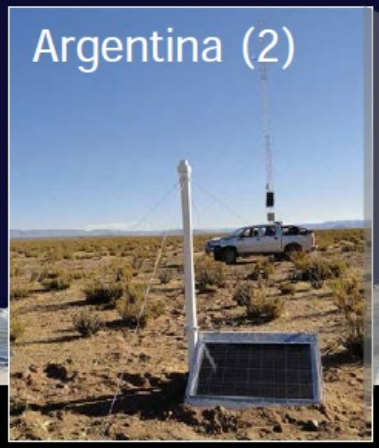
- Design Study
  - Design development 2006-9
  - CTA appears on *key roadmaps*
- Preparatory Phase > €30M funded
  - EU FP7 funded activity 2010-14
  - Preliminary Design Review 2013
  - Site Selection during 2014
  - Critical Design Rev. early 2015
- Construction Phase
  - Site development and first telescopes on site 2015/16
  - First science 2016/17
  - Completion ~2020
- Operation: aim for 30 years

Pre-production phase

CTA Sites: Candidates







CHERENKOV TELESCOPE ARRAY

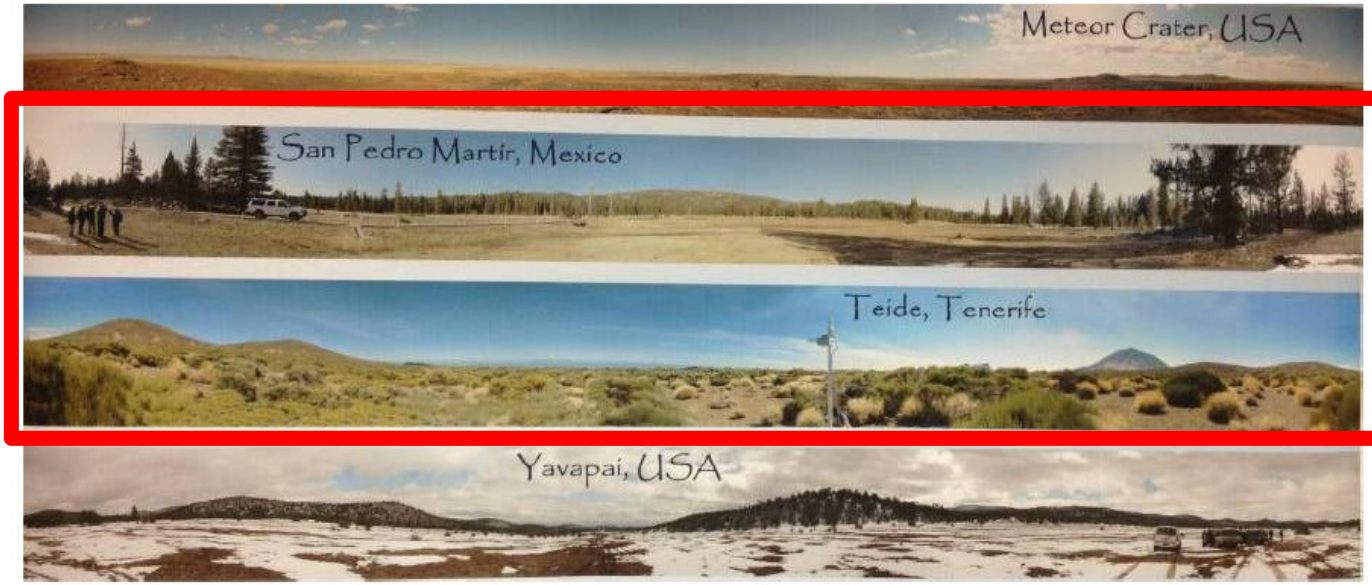
potential site locations

www.cta-observatory.org

CTA site selection

South

North



MST Prototype (DESY Berlin)

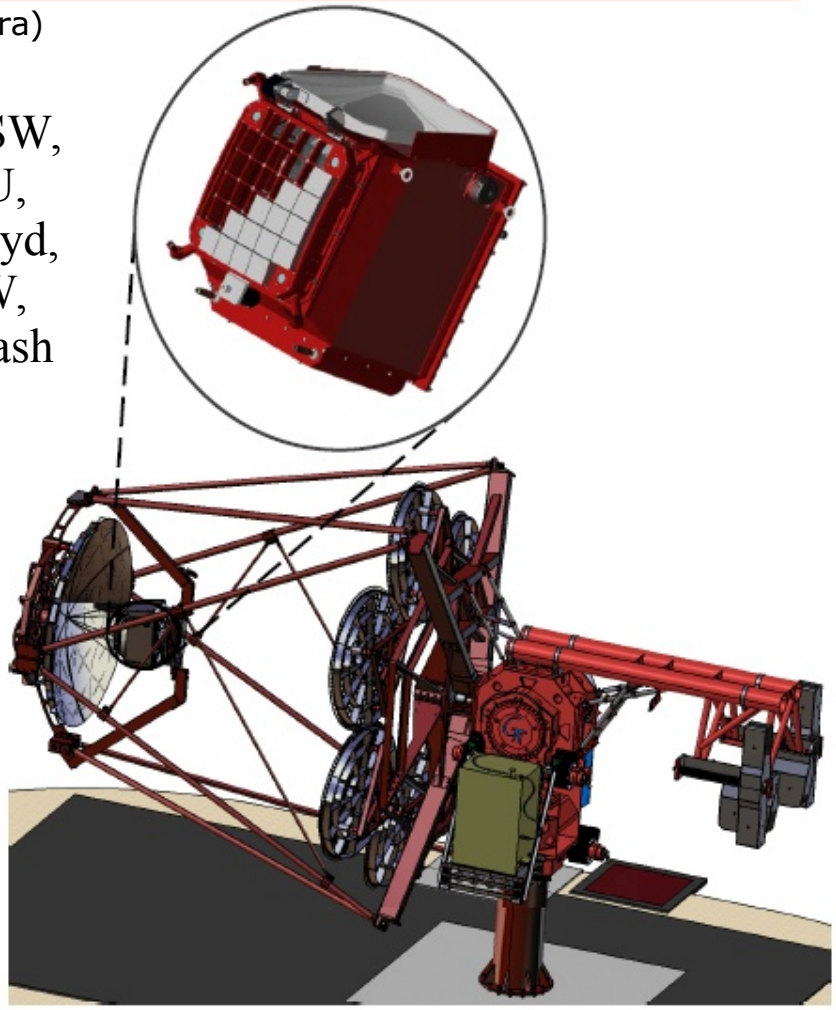
SST 1M prototype (Krakow)

The Gamma-ray Cherenkov Telescope group

(Compact High Energy Camera)

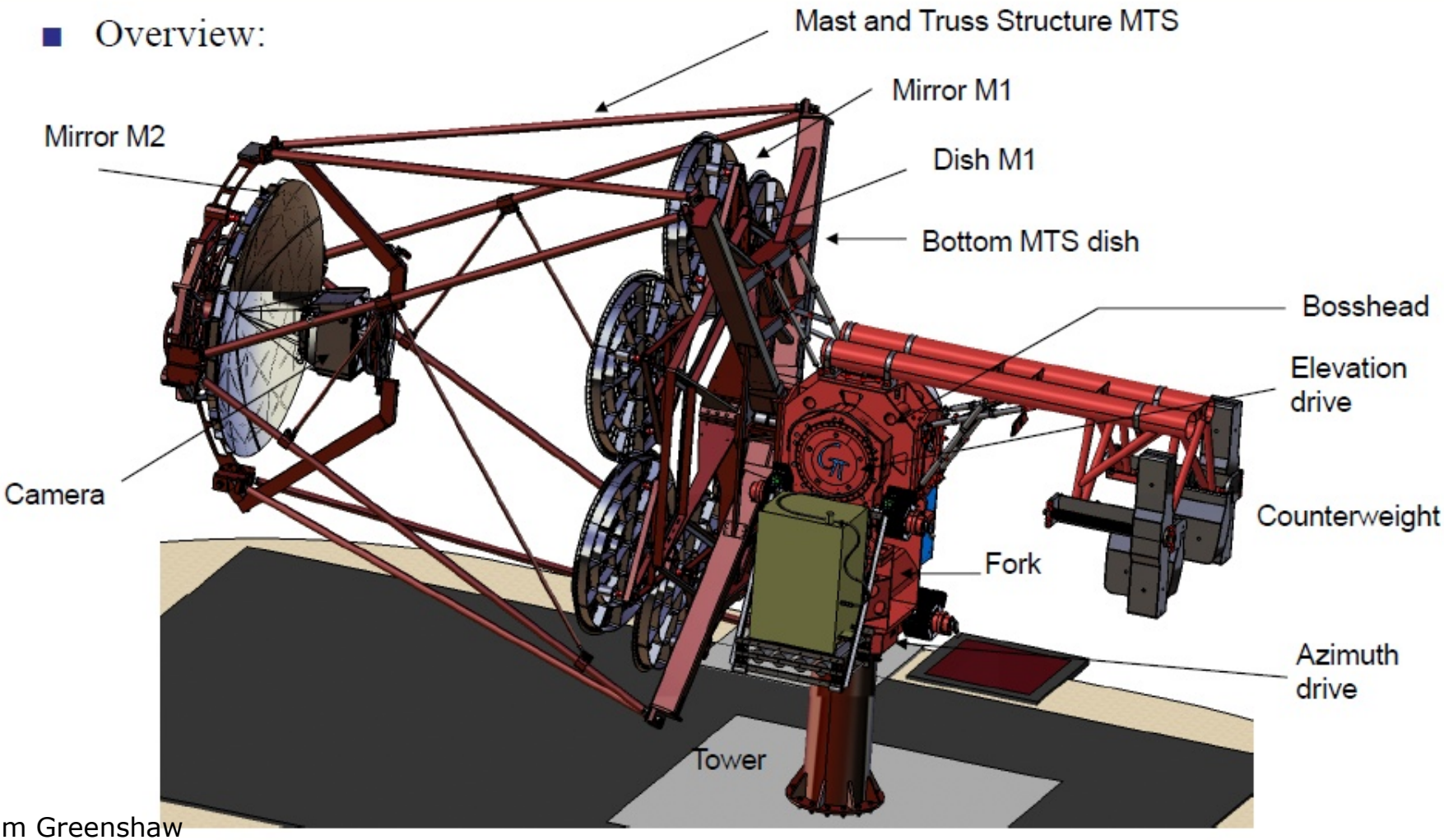
- SST-GATE and CHEC have merged to form the GCT.
- Countries (institutes) involved:
  - Australia (University of Adelaide).
  - France (Paris Observatory, CNRS-INSU, LUTH, GEPI, CPPM, University of Paris VII).
  - Germany (Max-Planck Institüt für Kernphysik, Erlangen University).
  - Japan (Nagoya University).
  - Netherlands (University of Amsterdam).
  - United Kingdom (Universities of Durham, Leicester, Liverpool, and Oxford).
- Open to others who wish to contribute!

UNSW, ANU, + U. Syd, USW, Monash



GCT status – structure

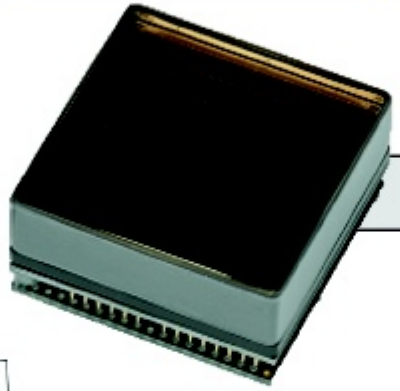
- Overview:

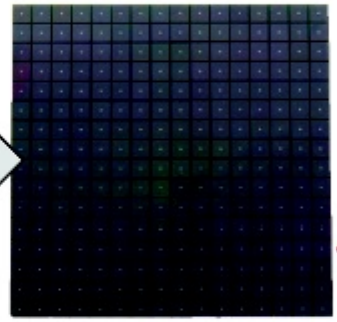


Prototyping: CHEC-S

CHEC-M | CHEC-S

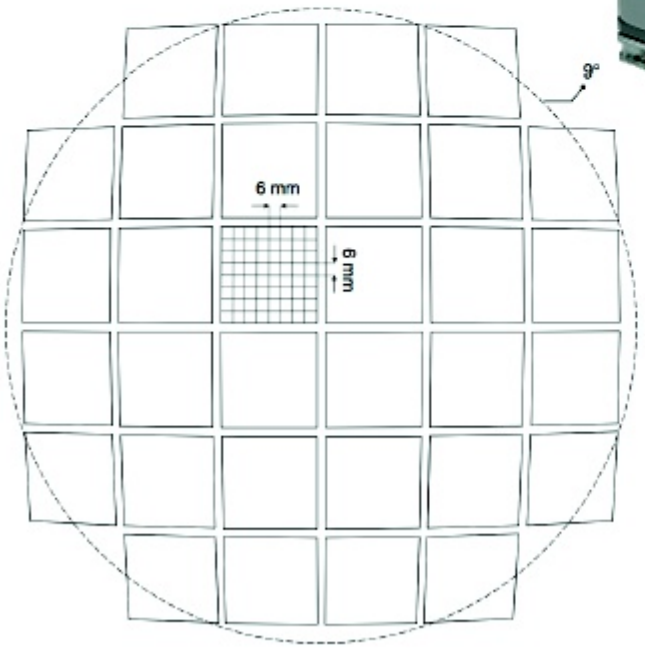
Photosensors → MAPMs → SiPMs

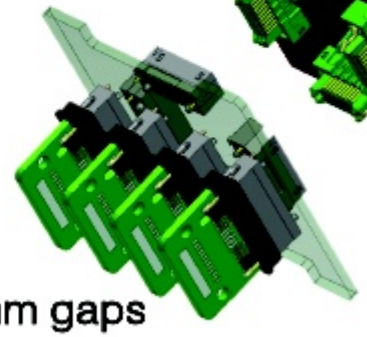




Hamamatsu

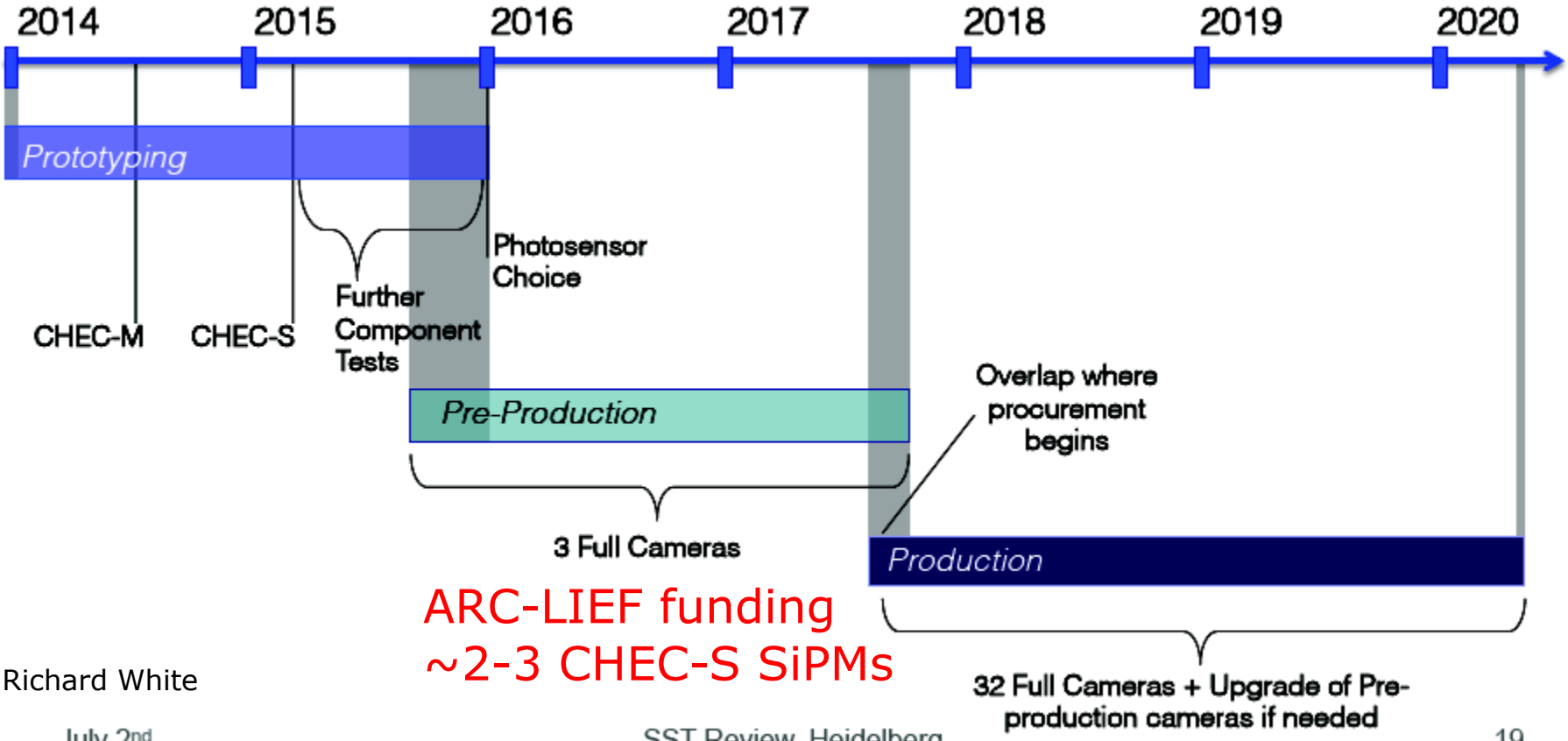
S12642-1616
256 3x3 mm² pixels
51.4 mm x 51.4 mm





32 x 64 pixel modules
2048 pixels
0.17°
~3 mm gaps → <1 mm gaps
9° FoV → ~8.6° FoV

Timeline for CHEC (& GCT)



ARC-LIEF funding
~2-3 CHEC-S SiPMs

CTA 2M-SST (ASTRI)

http://www.brera.inaf.it/astri/

- Led by INAF (Italy)

- 8 MEuro funding

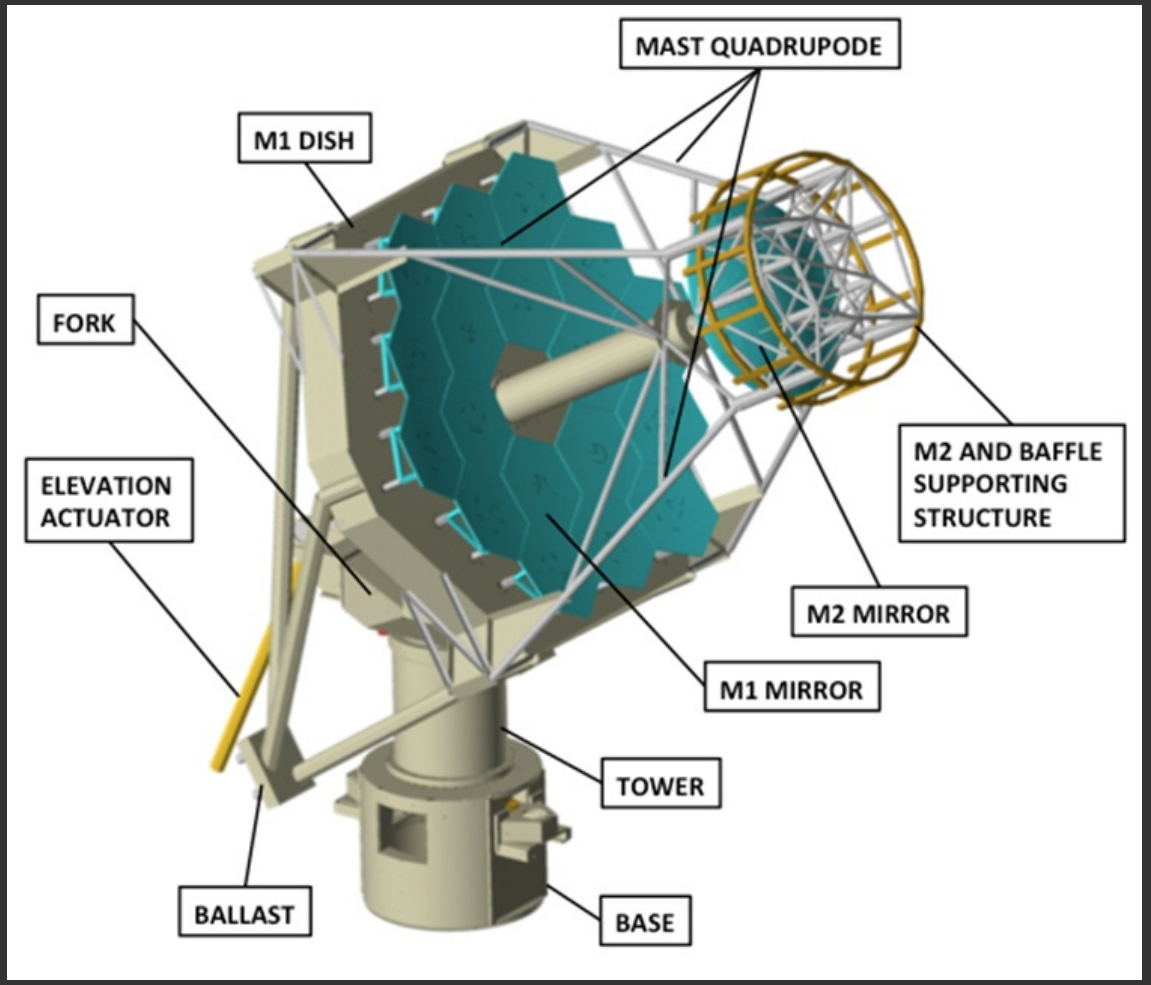
→ Mini-Array of 3-5 SSTs
Pre-Production Phase

- SST prototype 2014

- SCT optics

- Mini-array 2016/17 at CTA-South Site

- Several Camera Development Groups



Inauguration of the ASTRI SST-2M Prototype (Catania)

2014 September 24th

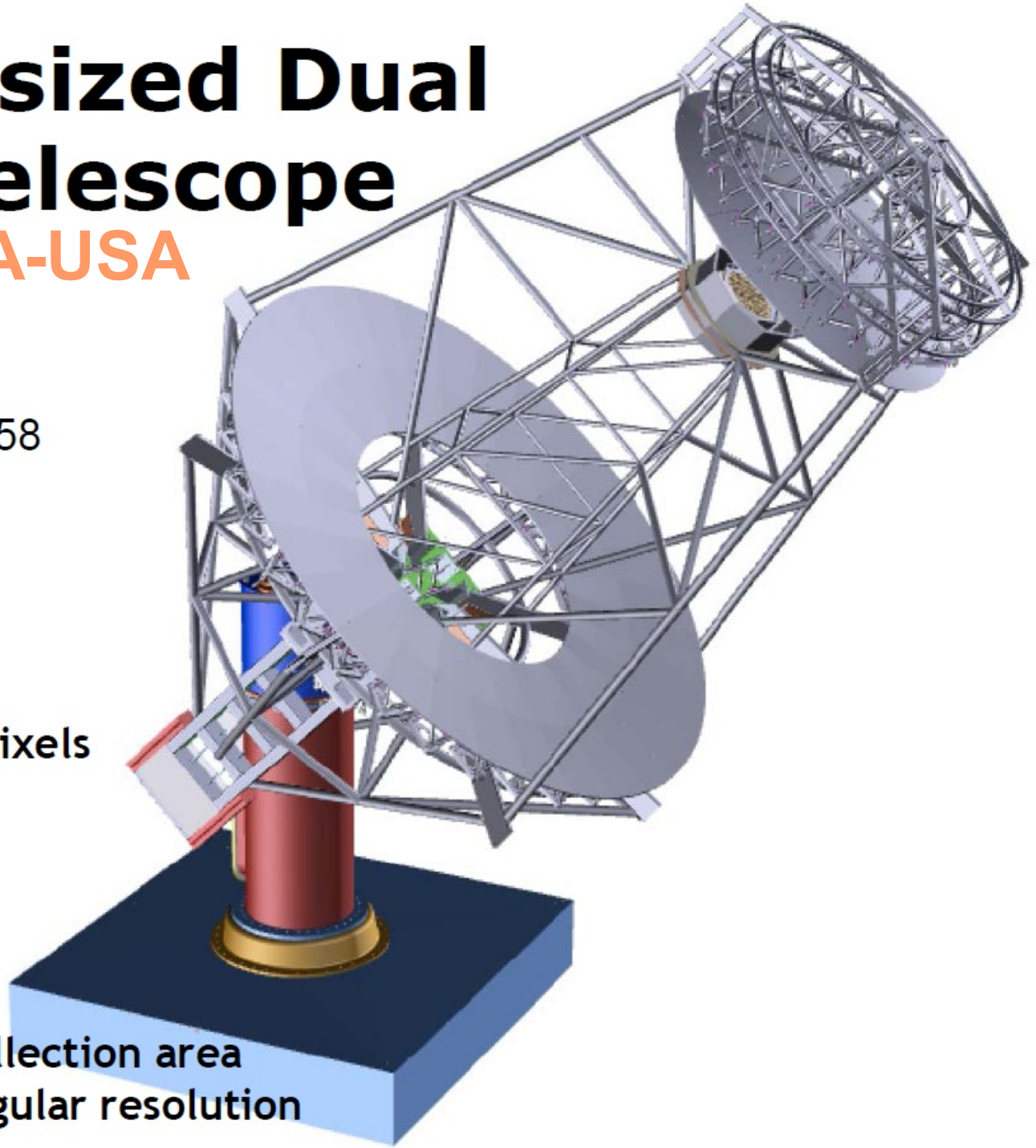
Medium-sized Dual Mirror telescope

Led by CTA-USA

9.7 m primary
5.4 m secondary
5.6 m focal length, f/0.58
40 m^2 eff. coll. area
PSF better than 4.5'
across 8° fov

8° field of view
11328 x 0.07° SiPM pixels
Target readout ASIC

Extend South array by adding 24 SCTs

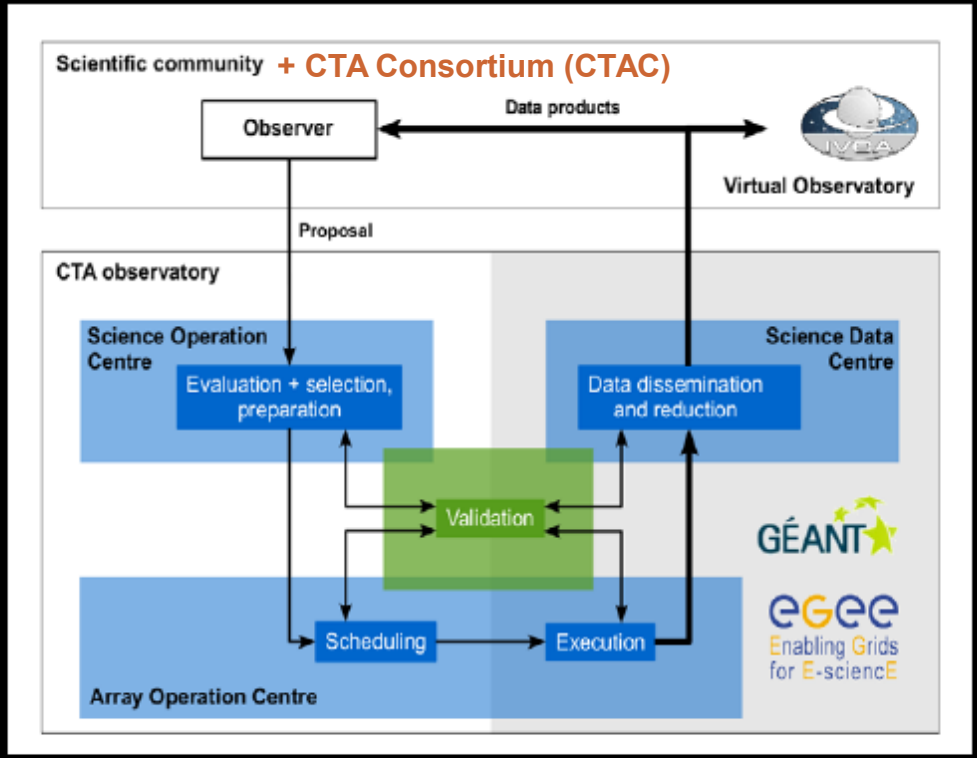


➜ increased γ-ray collection area
➜ improved γ-ray angular resolution

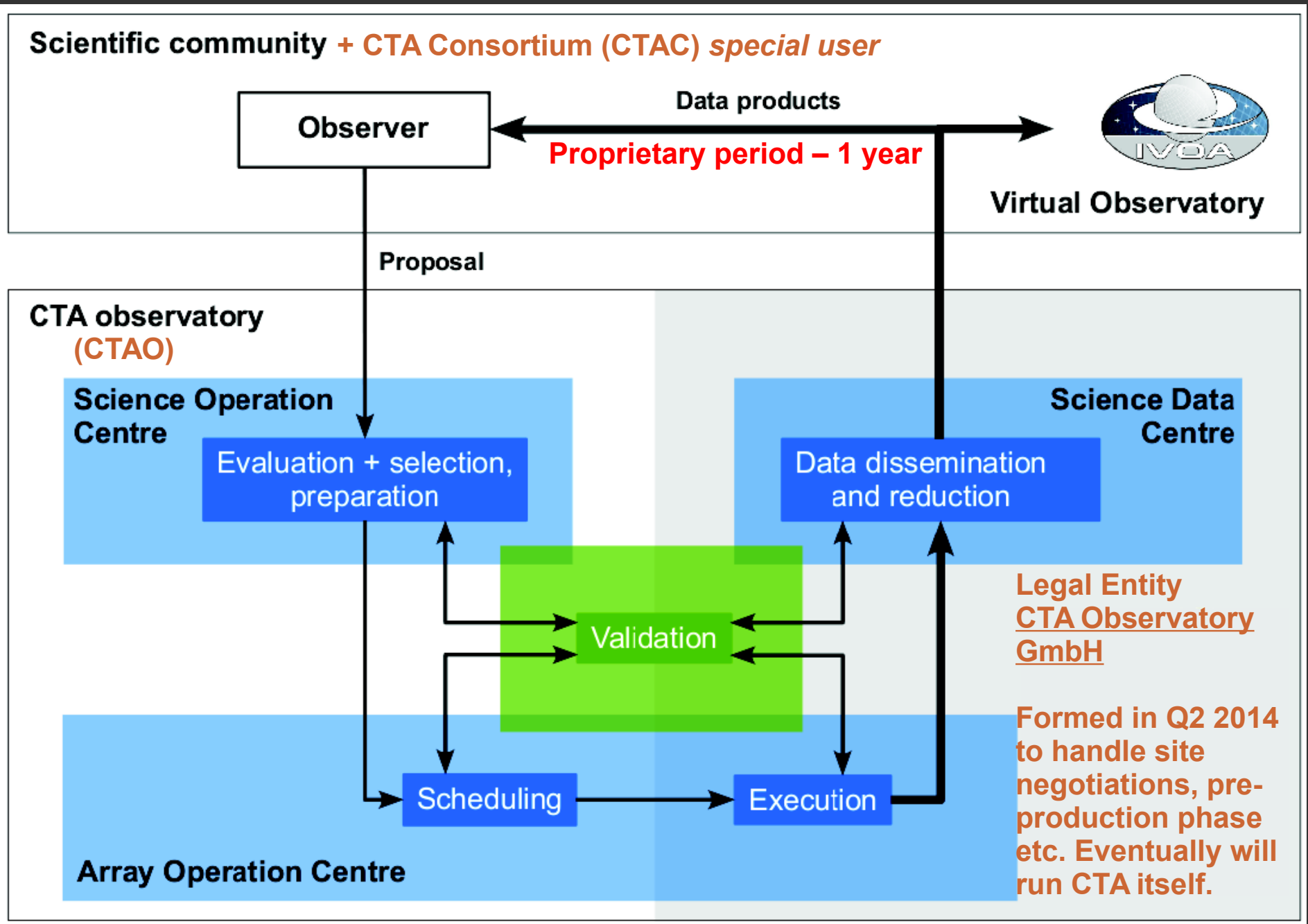
Observatory Operation

- CTA will operate like other major astronomical facilities
  - Calls for proposals, proprietary period, data archive, high level data products in FITS, user support, …
- Early science
  - Science verification phase followed by Key Science Projects + open* time (small at first but growing during construction)
  - Consortium guaranteed time ⅓-½ over 10 years

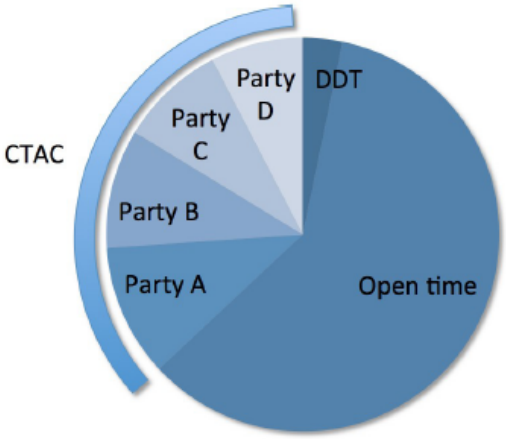
*probably limited to scientists from contributing countries



- **CTA Consortium (CTAC)**
  - 'Special' CTA user (including us!)
  - Carries out Key Science Projects
  - Access to pre-construction operations and cutting edge analysis tools


Scientific community + CTA Consortium (CTAC) special user
Observer
Data products
Proprietary period – 1 year
IVOA
Virtual Observatory
Proposal
CTA observatory
(CTAO)
Science Operation Centre
Evaluation + selection, preparation
Science Data Centre
Data dissemination and reduction
Validation
Scheduling
Execution
Array Operation Centre
Legal Entity
CTA Observatory GmbH
Formed in Q2 2014 to handle site negotiations, pre-production phase etc. Eventually will run CTA itself.

CTA observing time



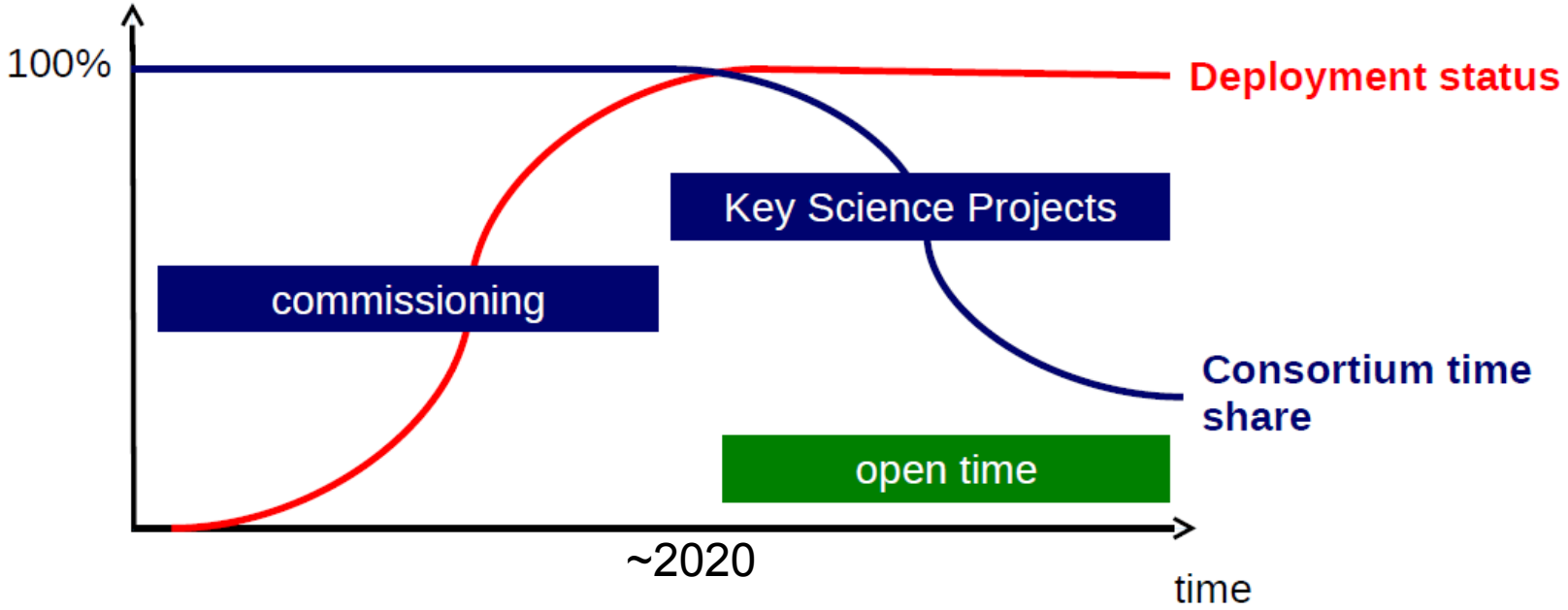
Current model

Contributing parties pool their time:

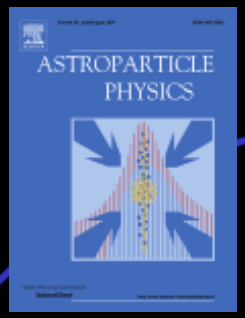
- Open time (accessible to scientists in contributing countries)
- CTA Consortium time (legacy Key Science Projects)
- Director's Discretionary Time

All data will become public to worldwide community after some proprietary period

(cf. C. Boisson)



CTA Science



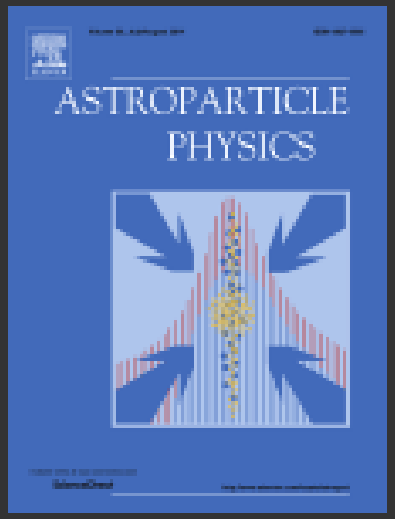
Special Issue Vol 43,
Pg 1-356 (Mar 2013)

- e.g. Galactic objects
  - Newly born pulsars and the supernova remnants
    - have typical brightness such that HESS etc can see only relatively local (typically at a few kpc) objects
  - CTA will see **whole** Galaxy
- Survey speed ~300×HESS

Extragalactic
AGN z>0.5, GRBs, Star-bursts, Gal. clusters, AGN haloes..

Astro-particle
Dark matter, Lorentz invariance....

Optical
Intensity Interferometry



Special Issue Vol 43, Pg 1-356 (Mar 2013)

A New Era in Gamma Ray Astronomy with the Cherenkov Telescope Array

Editorial:

A New Era in Gamma-Ray Astronomy with the Cherenkov Telescope Array
J. Hinton, S. Sarkar, D. Torres and J. Knapp

Part A:

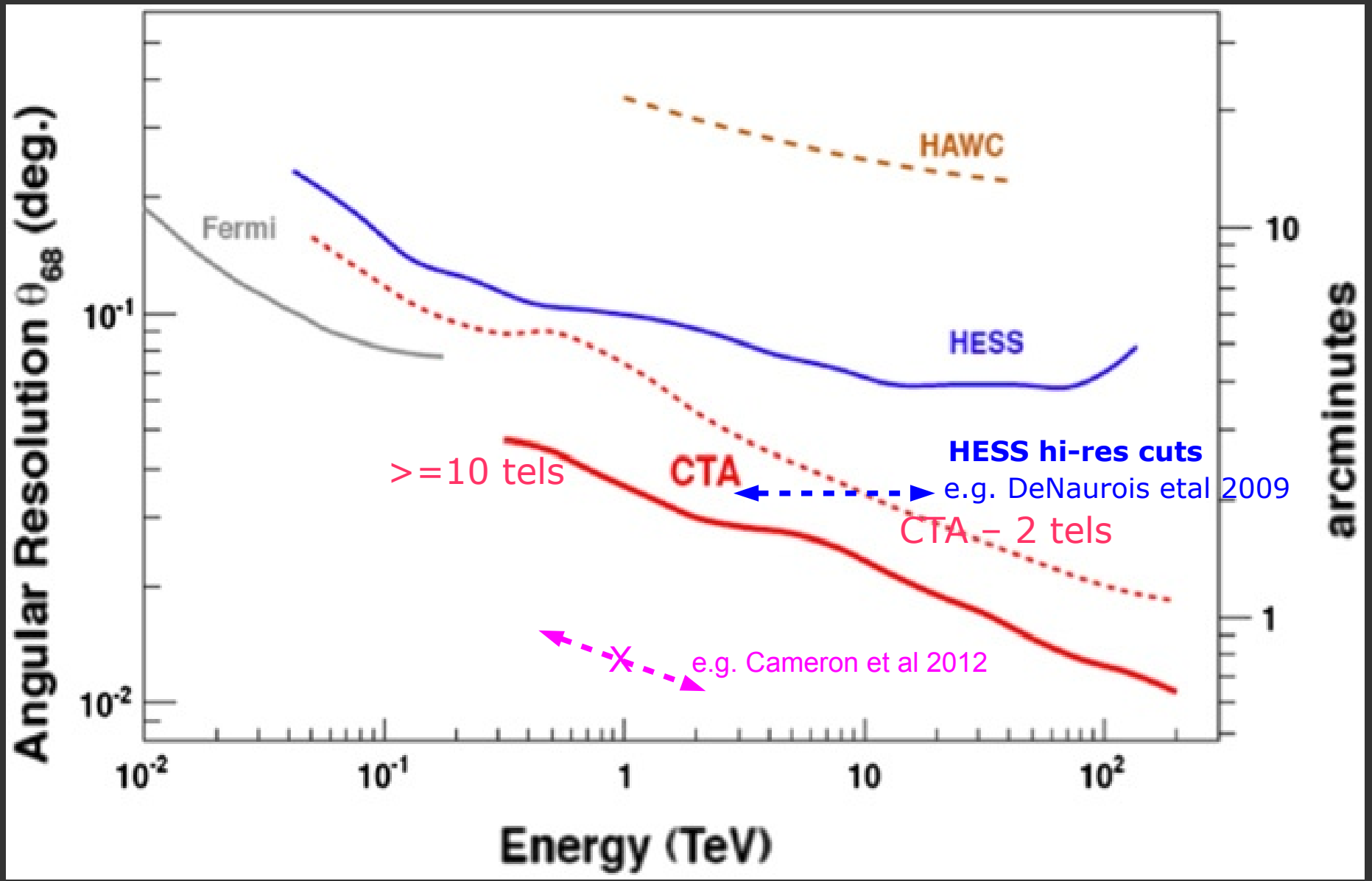
1. Introducing the CTA Concept
   The CTA Consortium
2. Evolution of ground-based gamma-ray astronomy from the early days to the Cherenkov telescope arrays
   A.M. Hillas
3. Dark matter and imaging air Cherenkov arrays
   L. Bergström
4. Probes of Lorentz violation
   J. Ellis, N.E. Mavromatos
5. Cosmic ray acceleration
   A.R. Bell
6. Gamma rays from supernova remnants
   F. Aharonian
7. High energy γ-ray emission from compact galactic sources in the context of observations with the next generation Cherenkov Telescope Arrays
   W.Bednarek
8. Studies of active galactic nuclei with CTA
   A. Reimer, M. Boettcher
9. The extragalactic background light and the gamma-ray opacity of the universe
   E. Dwek, F. Krennrich
10. Gamma ray bursts
    P. Meszaros
11. Multiwavelength Astronomy and CTA: X-rays
    T. Takahashi, Y. Uchiayama, L. Stawarz
12. Pionic photons and neutrinos from cosmic ray accelerators
    F. Halzen
13. Multi messenger astronomy and CTA: TeV cosmic rays and electrons
    P. Picozza, M.Boezio

Part B:

1. Monte Carlo design studies for the Cherenkov Telescope Array
   K. Bernlöhr et al. for the CTA Consortium
2. Dark matter and fundamental physics with the Cherenkov Telescope Array
   M. Doro et al. for the CTA Consortium
3. Active Galactic Nuclei under the scrutiny of CTA
   H. Sol et al. for the CTA Consortium
4. Potential of EBL and cosmology studies with the Cherenkov Telescope Array
   D. Mazin et al. for the CTA Consortium
5. Gamma-Ray Burst Science in the Era of the Cherenkov Telescope Array
   S. Inoue et al. for the CTA Consortium
6. Gamma-ray signatures of cosmic ray acceleration, propagation, and confinement in the era of CTA
   F. Acero et al. for the CTA Consortium
7. Prospects for observations of pulsars and pulsar wind nebulae with CTA
   E. Oña-Wilhelmi et al. for the CTA Consortium
8. Binaries with the eyes of CTA
   J.M. Paredes et al. for the CTA Consortium
9. Surveys with the Cherenkov telescope array
   G. Dubus et al. for the CTA Consortium
10. Optical intensity interferometry with the Cherenkov Telescope Array
    Dravins et al. for the CTA Consortium
11. Comparison of Fermi-LAT and CTA in the region between 10100 GeV
    S. Funk, J.A. Hinton for the CTA Consortium

Angular Resolution (HESS, CTA..)

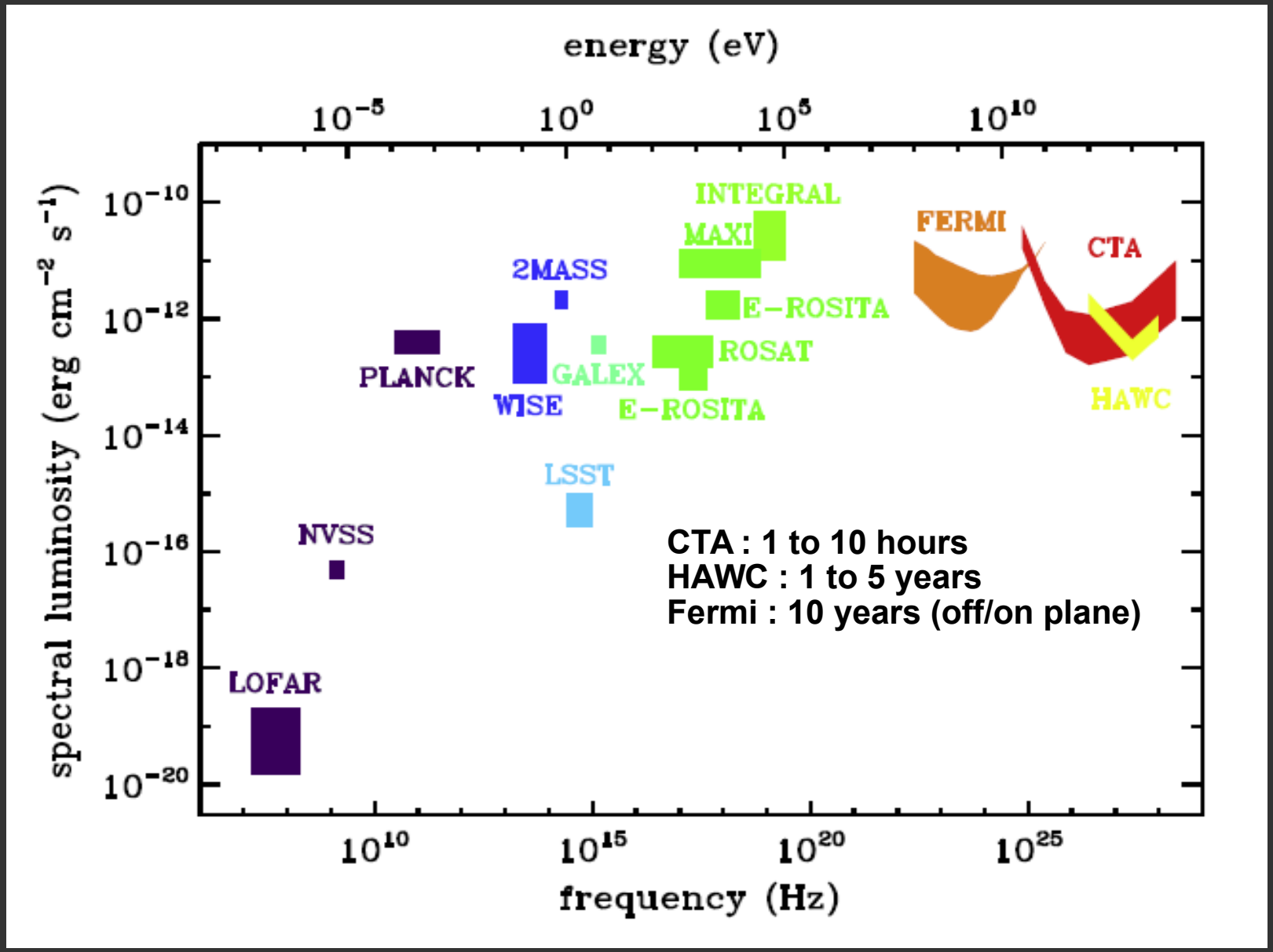
Acharyara etal 2013



CTA MST-SCTs with small pixels and/or hi-res cuts → even better!

CTA Survey Sensitivity

Dubus etal 2013



KEY SCIENCE PROJECTS

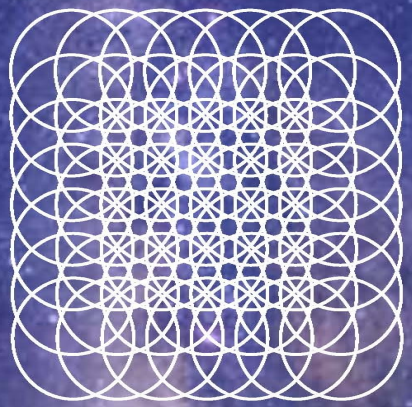
1. CTA Galactic Plane Survey
2. CTA Extragalactic Survey
3. Exploring extreme particle acceleration in the Galaxy
4. Probing DM with precision measurements of the Galactic Center
5. CTA studies on active galaxies
6. On the connection between cosmic rays and the star-formation process
7. Observations of clusters of galaxies
8. Observations of the LMC
9. Observations of the Cygnus region
10. Observation of Galactic DM dominated targets
11. Observations of transient phenomena

Some merging or down-selection to take place...

CTA observation modes

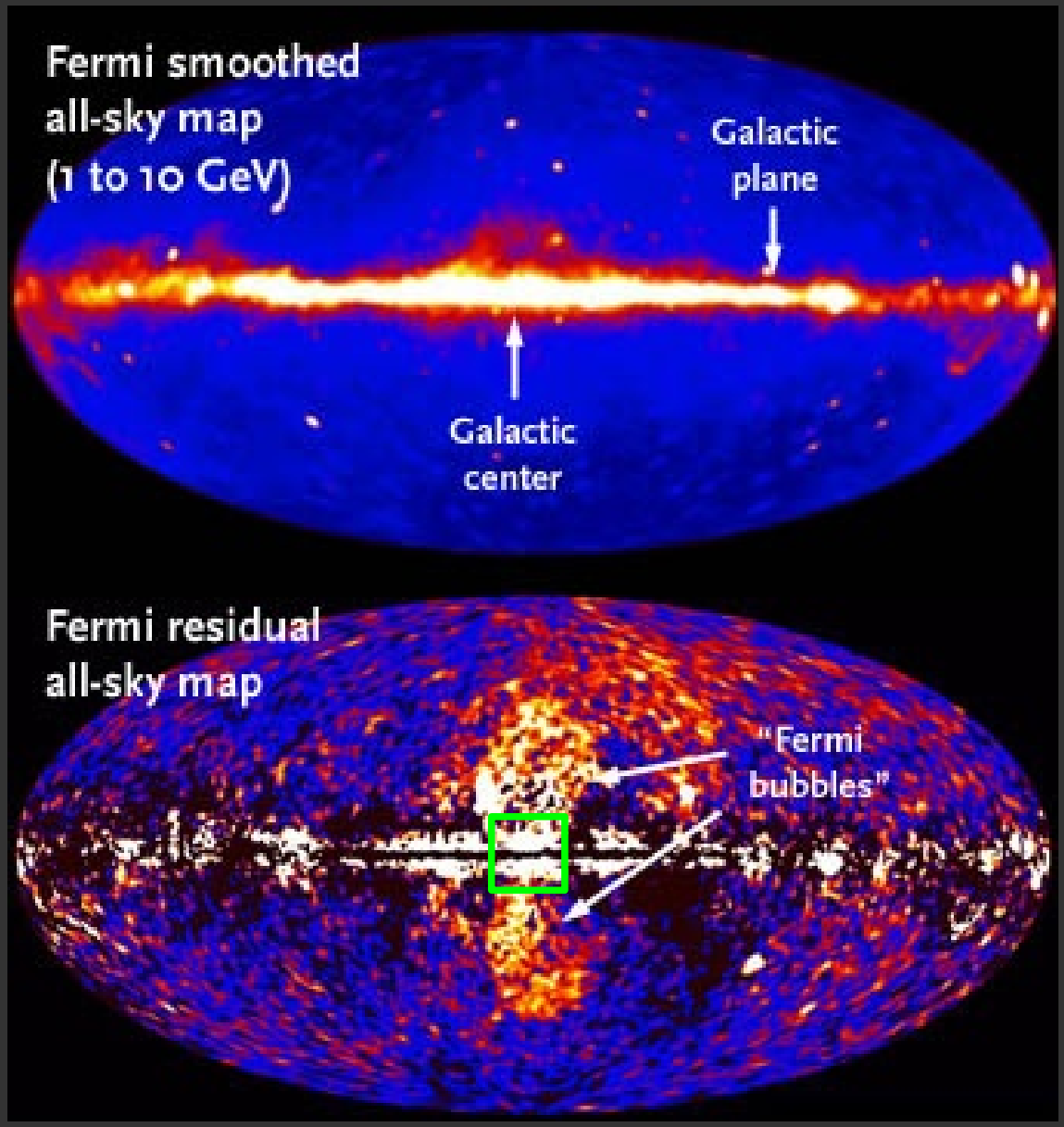
CTA FoV

LST/MST/SST – 4.5°/7.5°/9°

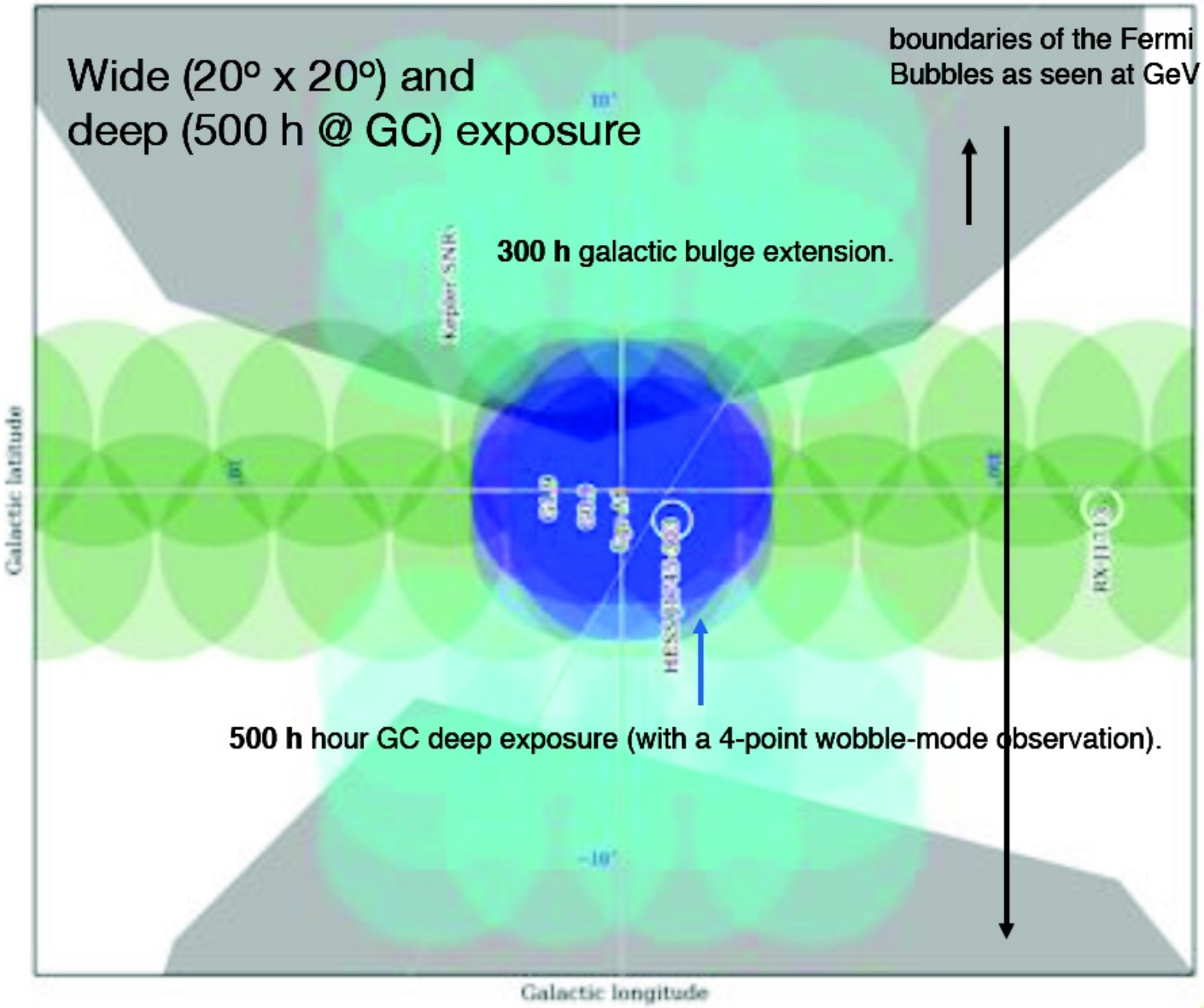


Survey mode:
Full sky at current
sensitivity in ~1 year

WH

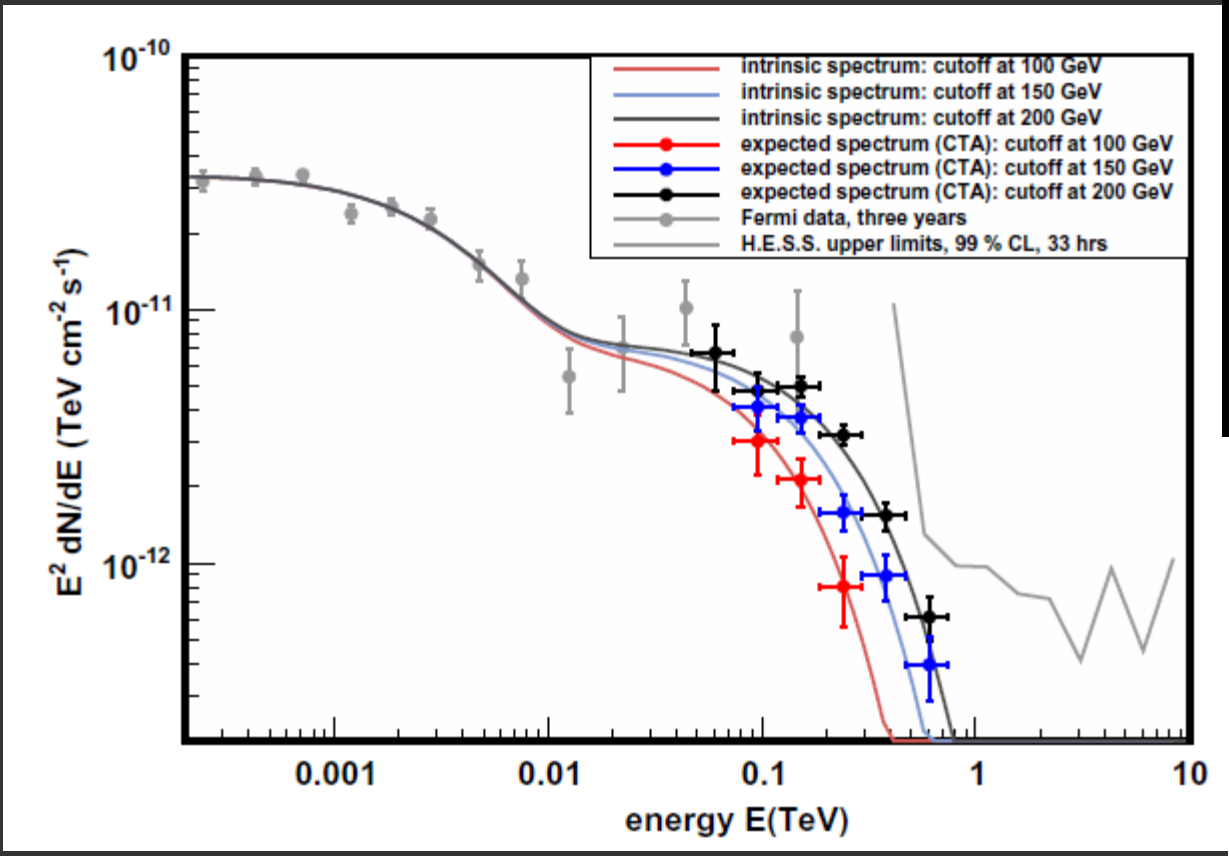

Fermi smoothed
all-sky map
(1 to 10 GeV)
Galactic
plane
Galactic
center
Fermi residual
all-sky map
"Fermi
bubbles"

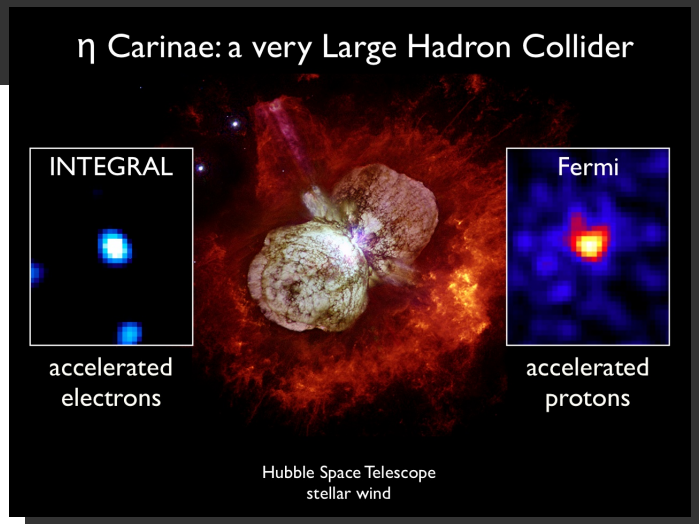
KSP OBSERVATION STRATEGY

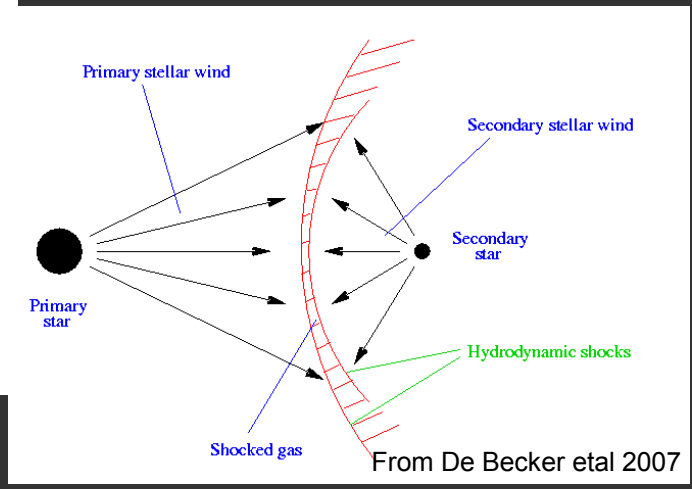


CTA simulated observations (10hr) of Eta Carinae. (Colliding wind binary system)

Paredes et al 2013



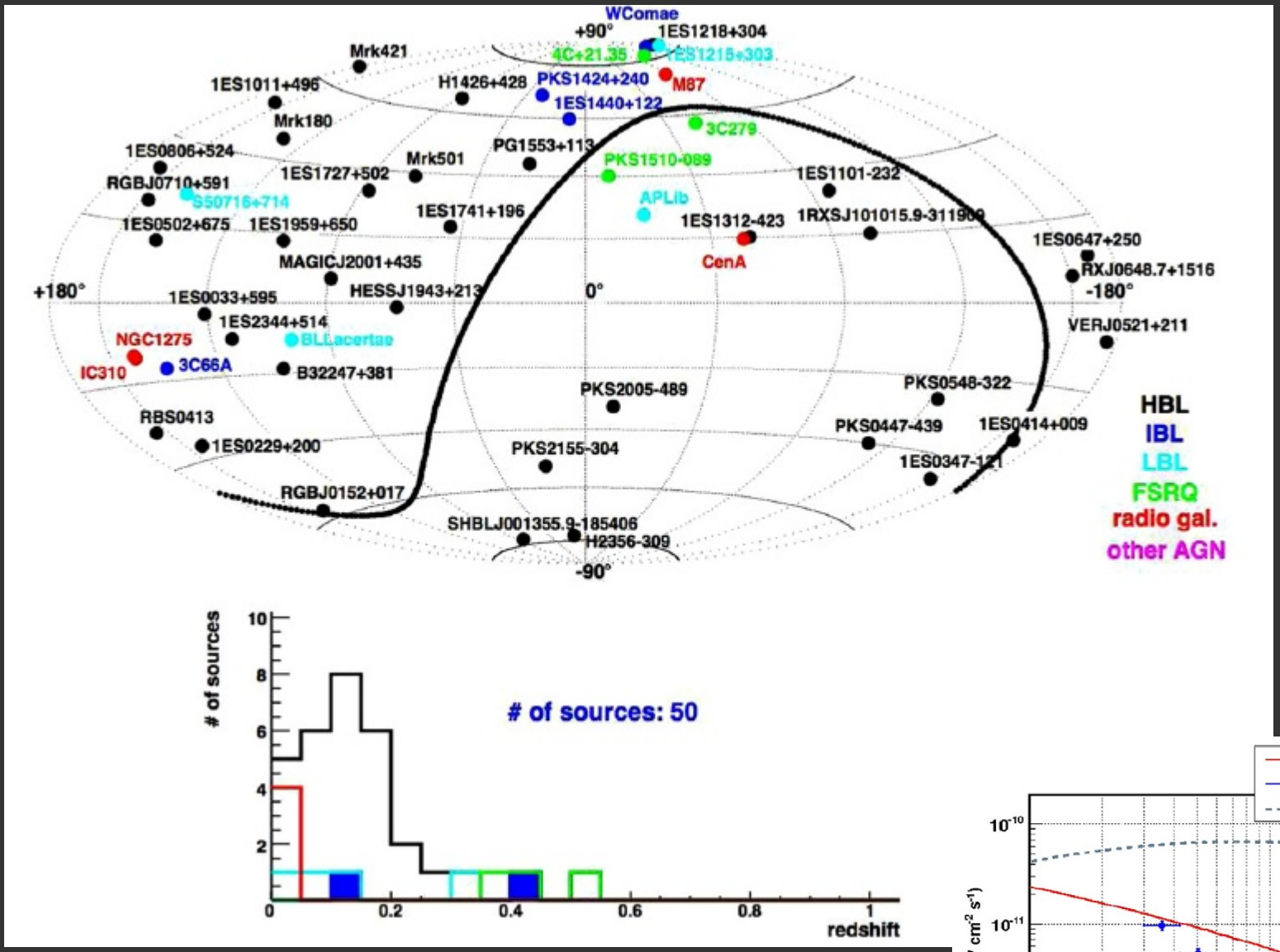


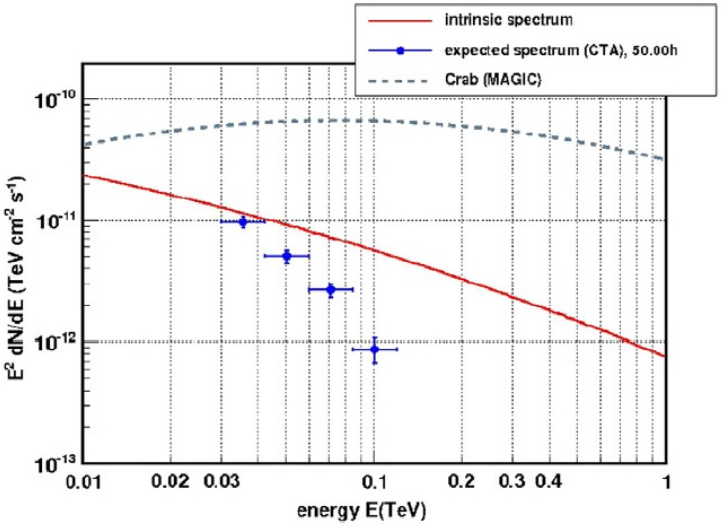


From De Becker etal 2007

Extragal. AGN etc.

Sol etal 2013





Simulation of CTA detection of the Fermi blazar 2FGLJ1504.3+1029 at redshift z=1.839 in a quiescent state.

CTA: Australia's Roles.
We play to our strengths!

CTA Hardware & Array Design
- Array layout and analysis techniques (E>10 TeV)
- Camera hardware (for small telescopes) ARC LIEF ($465k)
- Atmospheric characterisation (LIDAR, cloud monitoring)
- Effect of clouds on Cherenkov images

Multi-wavelength Support
- ISM surveys/studies (Mopra, ASKAP, HEAT)
- Radio continuum studies (ASKAP, MWA, SKAMP, SKA....)
- X-ray astronomy (e-ROSITA, XMM, Chandra)

Theory
- Theoretical high energy astrophysics
  (e.g. Galactic Centre, AGN jets/outflows)
- Astro-particle physics – Dark matter properties

CTA – Australia

Institution	Personnel (+ FTE)	Expertise	CTA Work Package(s)
University of Adelaide	Gavin Rowell (0.1), Res.Assoc.[1] (0.1), PhD student[2] (0.1), Bruce Dawson (0.05), Roger Clay (0.1), Neville Wild (technician 0.05), Martin White (0.05), David Ottaway (0.05), Peter Veitch (0.05),	γ-ray, millimetre, CR, neutrino astronomy, astrophysics theory, particle physics, LIDAR systems, atmospheric monitoring, detectors, electronics	MC, PHYS, OBS, ATAC, SITE, FPI
University of New South Wales	Michael Burton (0.1), Catherine Braiding (0.1)	millimetre, sub-millimetre, infrared astronomy, antarctic astronomy	PHYS, ATAC, OBS
University of Sydney	Anne Green (0.05), Sean Farrell (0.05)	radio astronomy	PHYS, OBS
Australian National University	Geoff Bicknell (0.1), Roland Crocker (0.1)	γ-ray, neutrino astrophysics theory	PHYS, OBS
Monash University	Duncan Galloway (0.05), Csaba Balazs (0.05)	X-ray astronomy, particle and astroparticle physics	PHYS, OBS
University of Western Sydney	Miroslav Filipovic (0.05), Nick Tothill (0.05)	γ-ray, X-ray, radio astronomy	PHYS, OBS

1. Research Associate commencing from Sept. 2013 for $\geq$4 months.
2. Based on current in-kind contributions from 2 PhD students.

Table 1: Australian Consortium for CTA Associated Party Membership. FTE estimates are for 2013+.

CTA – Australia: Funding

- ARC LIEF 2015: $270k ARC +$195k Uni.
  - Si-PMs + camera hardware for pre-production phase
  - CHEC-S commissioning support (Oct/Nov 2015)
  - Travel to CTA meetings
  - Pay for this meeting
  - CTA-Oz to Regular Party status
    (Letter to CTA Spokesperson with updated FTE and funding prospects – next week!)

- NCRIS 2015/16 $95k request via AAL
  (for travel, CTA-Oz meetings, commissioning)

- Future: To discuss here!

  LIEF2 - Next hardware purchase. More Si-PMs for SSTs?)
  NCRIS++ As above, membership fees (CTAO GmbH)
  ARC-DPs – postdocs (linked to KSPs)

CTAO GmbH

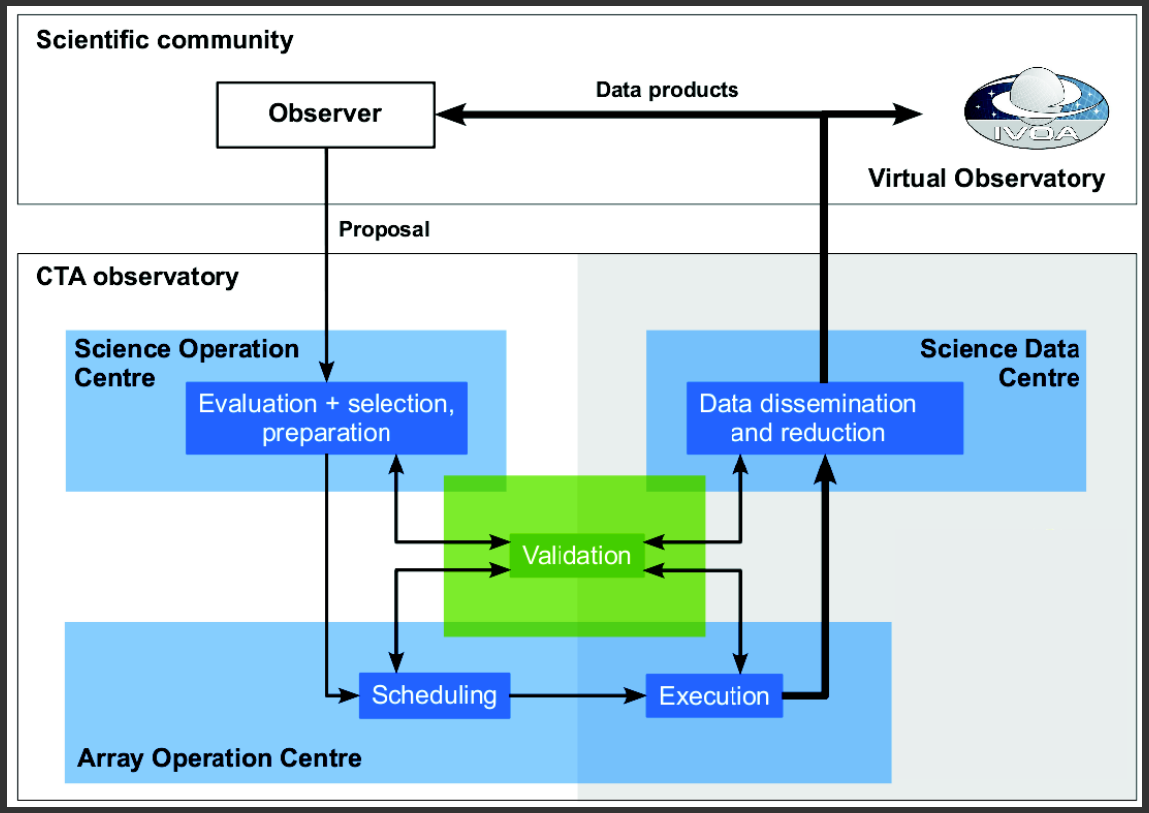
Formed in Q2 2014
- site negotiations
- coordinate construction
- interface with users
- running CTA

CTAO Costs

CTAC parties purchase 'shares' in CTAO min 2%

Currently 2%
→ 40kEuro/yr

Will increase as telescopes are built.



CTAO Share Purchase

Need legal entity to purchase shares.
AAL can in principle take on this role.

Benefit: Membership of Resource Board
→ major operational decisions


Thank you.....
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