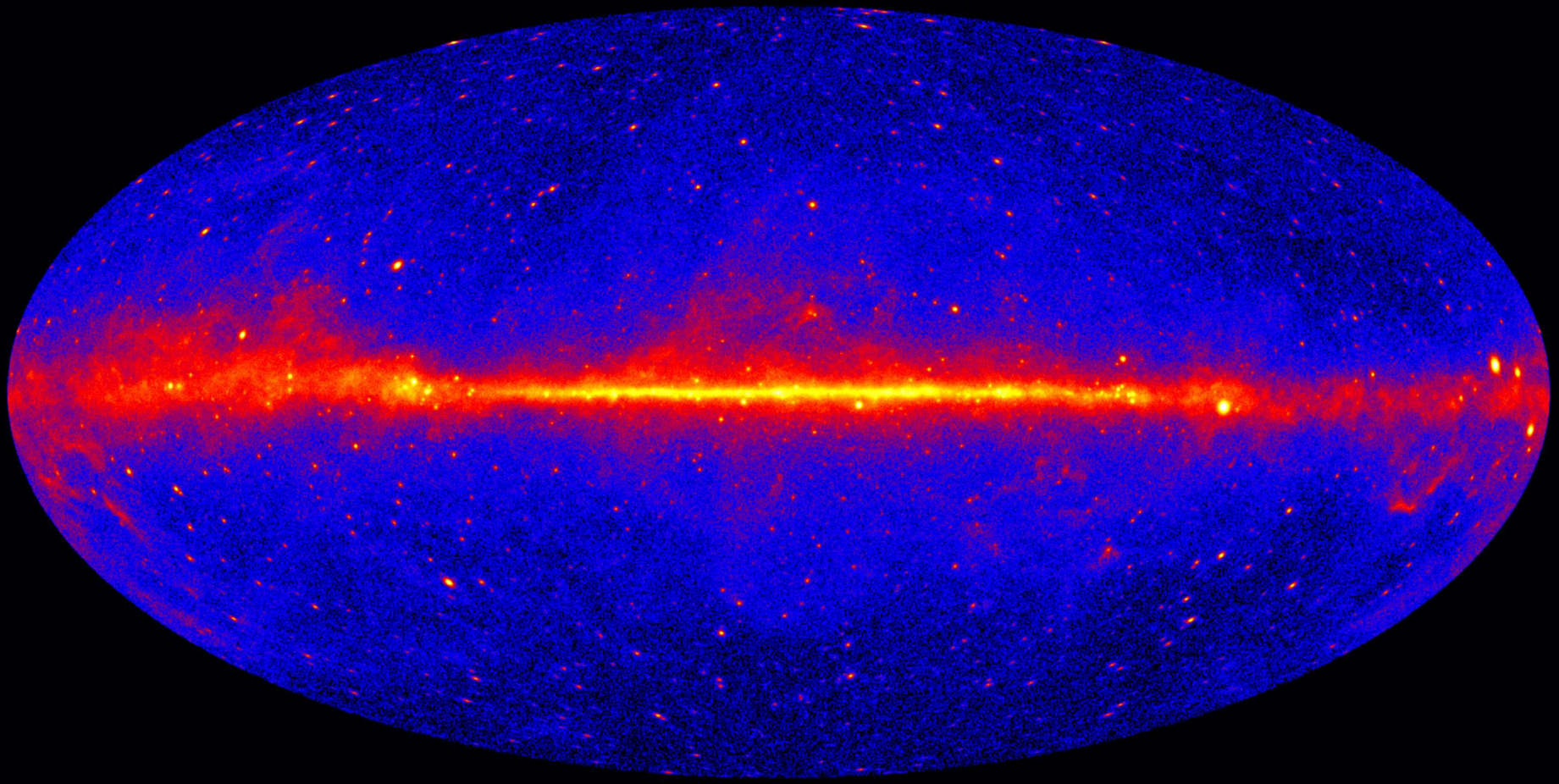
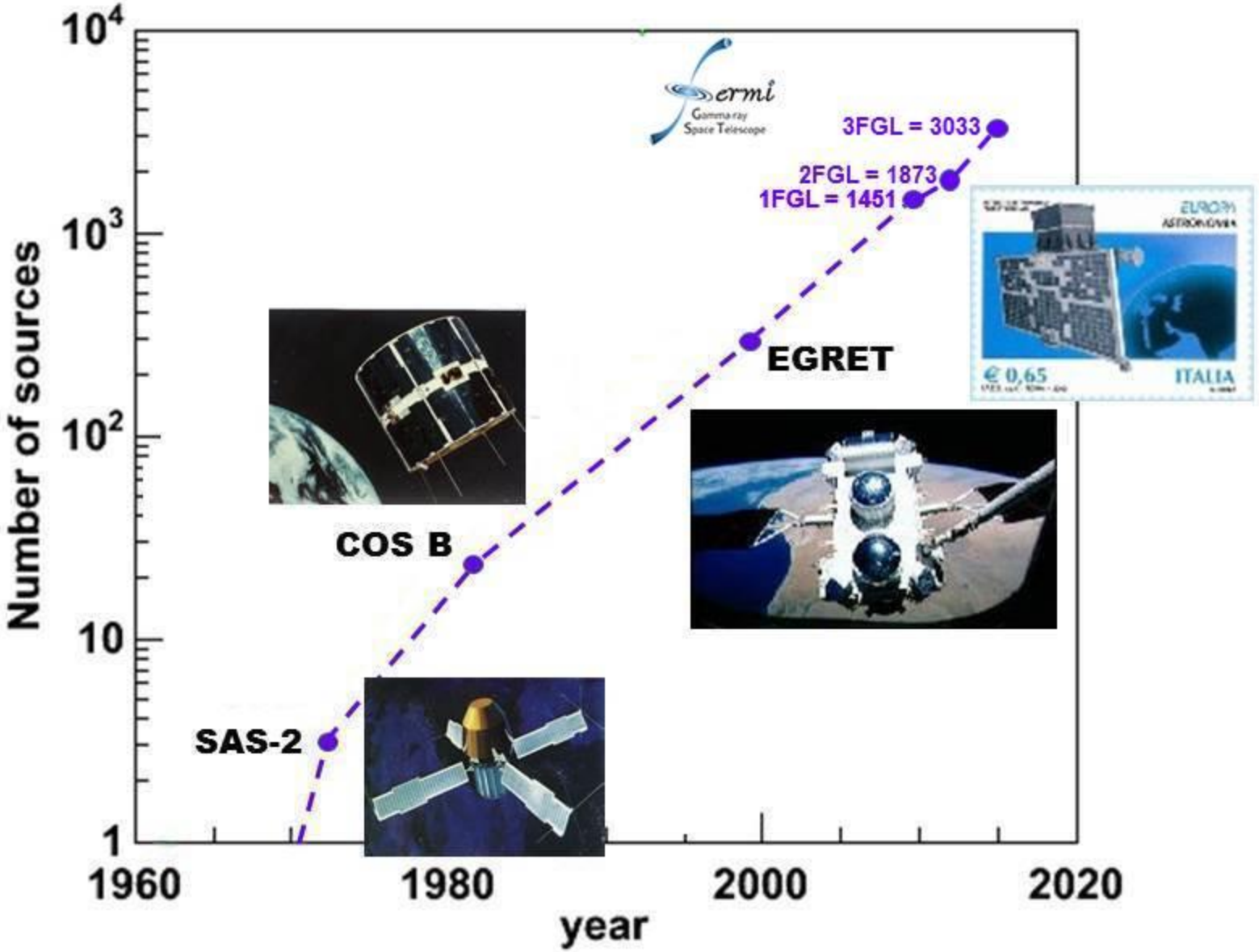
THE PATH TOWARDS THE CHERENKOV TELESCOPE ARRAY OBSERVATORY

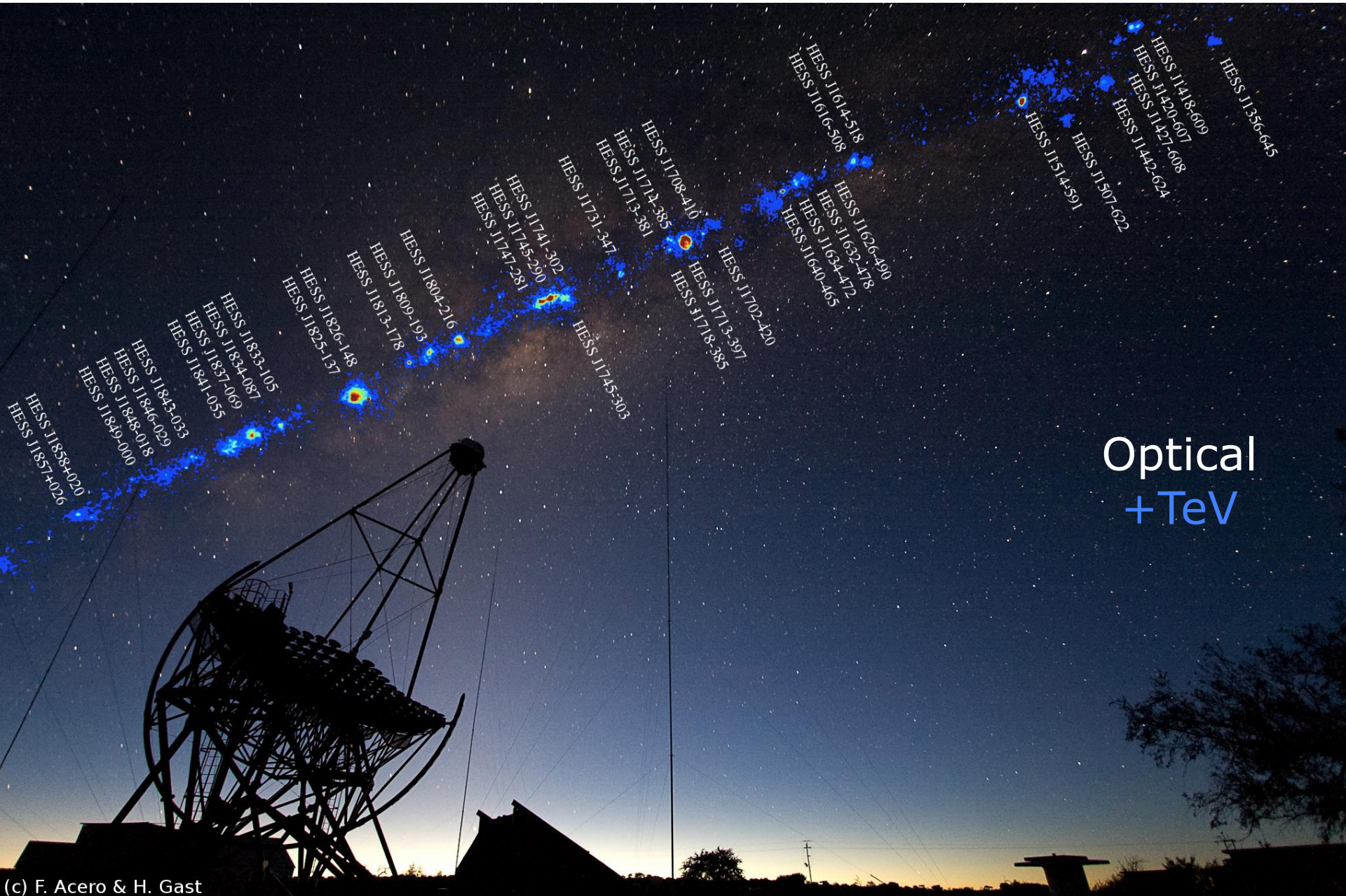
Patrizia Caraveo

5 y integration of the gamma-ray sky



4 decades of γ-ray astronomy from space




HESS J1837+026
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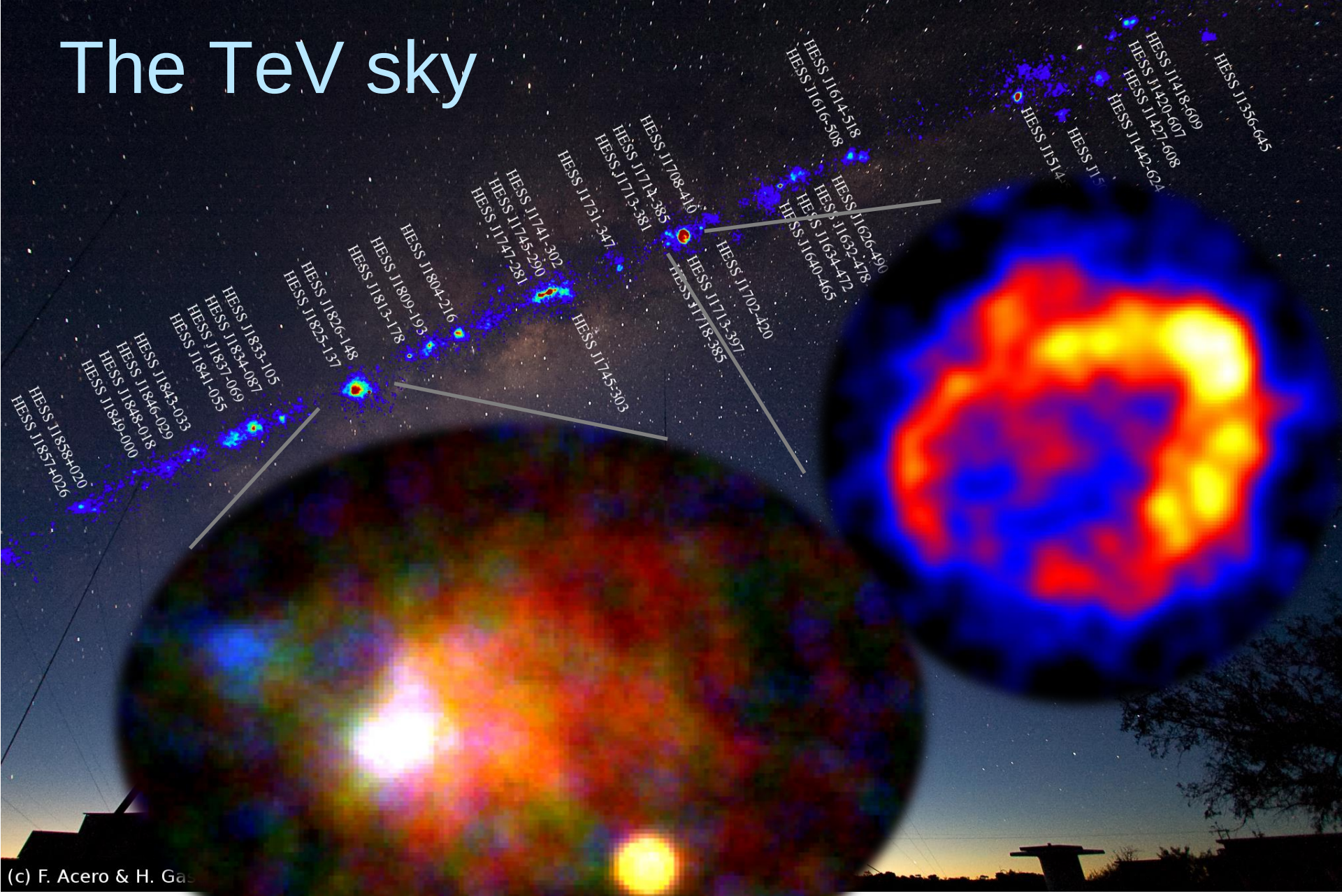
HESS J1837-069
HESS J1834-087
HESS J1833-105
HESS J1825-137
HESS J1826-148
HESS J1813-178
HESS J1809-193
HESS J1804-216
HESS J1747-281
HESS J1745-290
HESS J1741-302
HESS J1745-303
HESS J1731-347
HESS J1713-381
HESS J1714-385
HESS J1708-410
HESS J1718-385
HESS J1713-397
HESS J1702-420
HESS J1640-465
HESS J1634-472
HESS J1632-478
HESS J1626-490
HESS J1616-508
HESS J1614-518
HESS J1514-591
HESS J1507-622
HESS J1442-624
HESS J1427-608
HESS J1420-607
HESS J1418-609
HESS J1356-645
Optical
+TeV
(c) F. Acero & H. Gast

The TeV sky


HESS J1614-518
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HESS J1634-472
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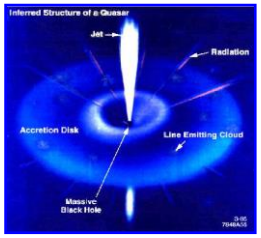
HESS J1514
HESS J1418-609
HESS J1420-607
HESS J1427-608
HESS J1442-624
HESS J1356-645
(c) F. Acero & H. Ga

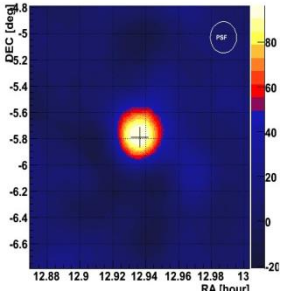
> 40, Active Galactic Nuclei (Blazars)

AGN ➔ TeV by electrons (strong correlation between
X-ray and TeV flux variability, clearly suggests a unique parent population i.e.
Electrons emitting X by syncrotron and Gamma by Inverse Compton).

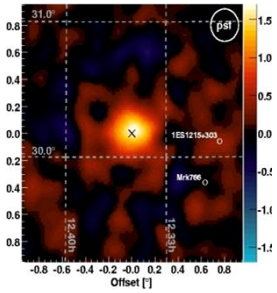


AGN ➔ emission beamed and particles acceleration in the jets

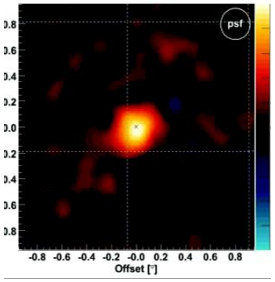
Some MAGIC discoveries of extra-galactic sources



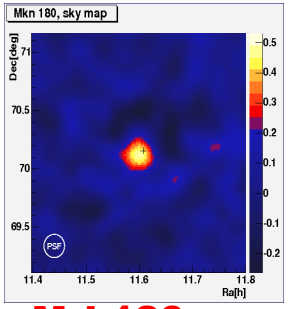
3C279
(z = 0.536)



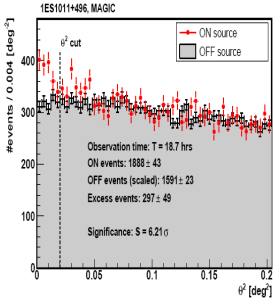
1ES1218
(z= 0.18)



PG 1553
(Z>0.25)

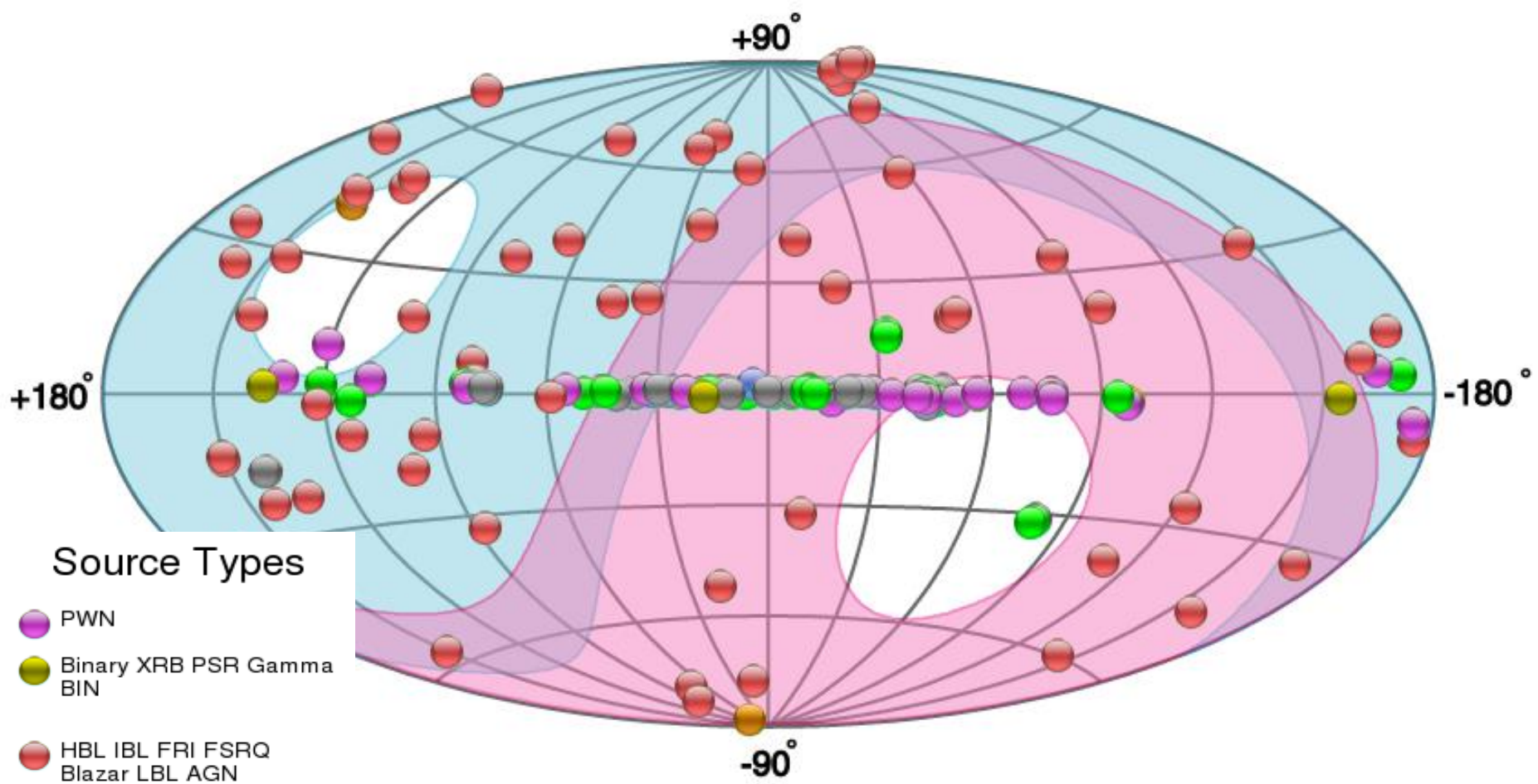


Mrk180
(z=0.045)



1ES1011
(Z=0.212

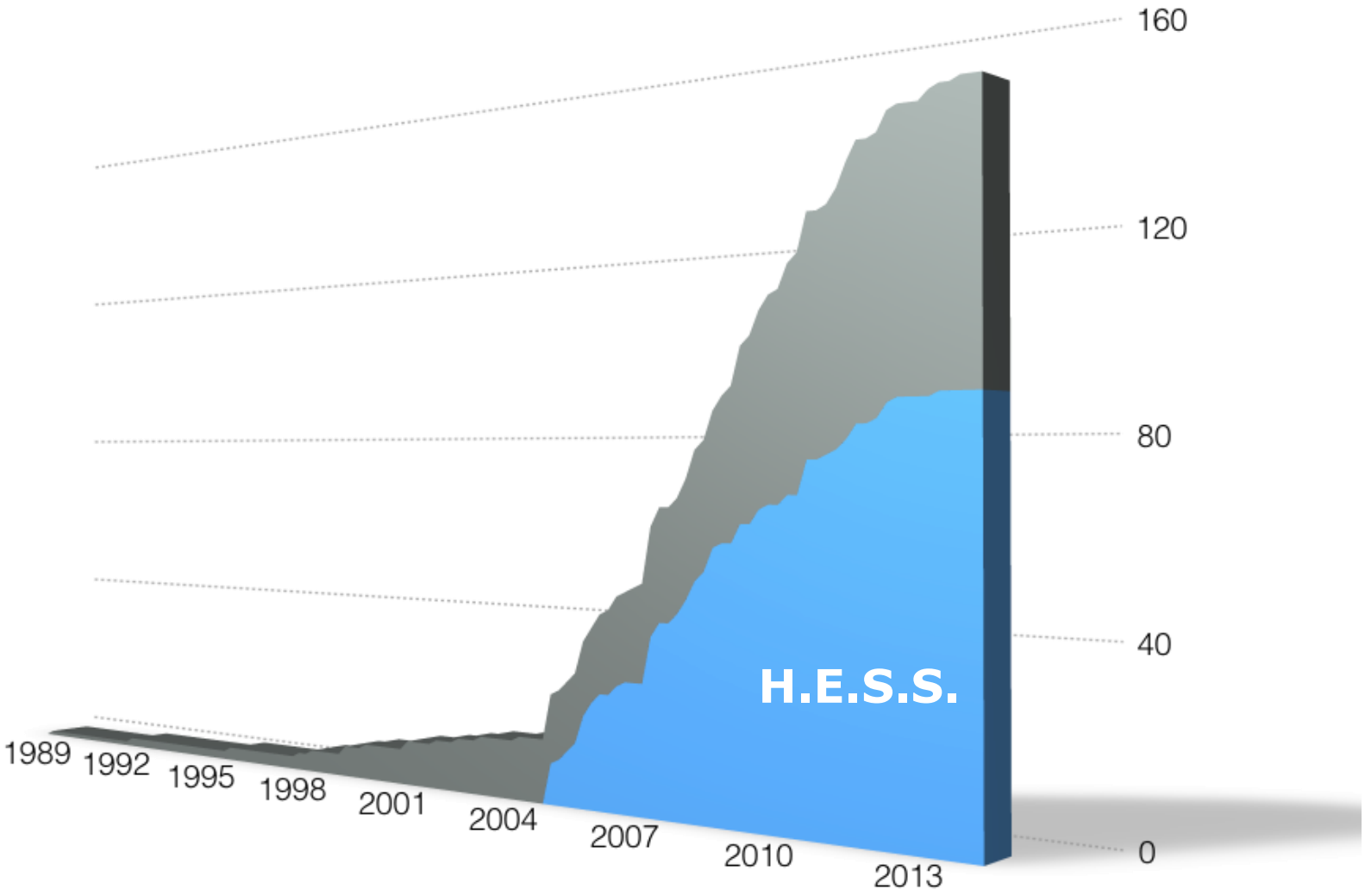
AGN ➔ spectral shape distribution
➔ Constraints on the EBL (Extragalactic Background Light) intensity

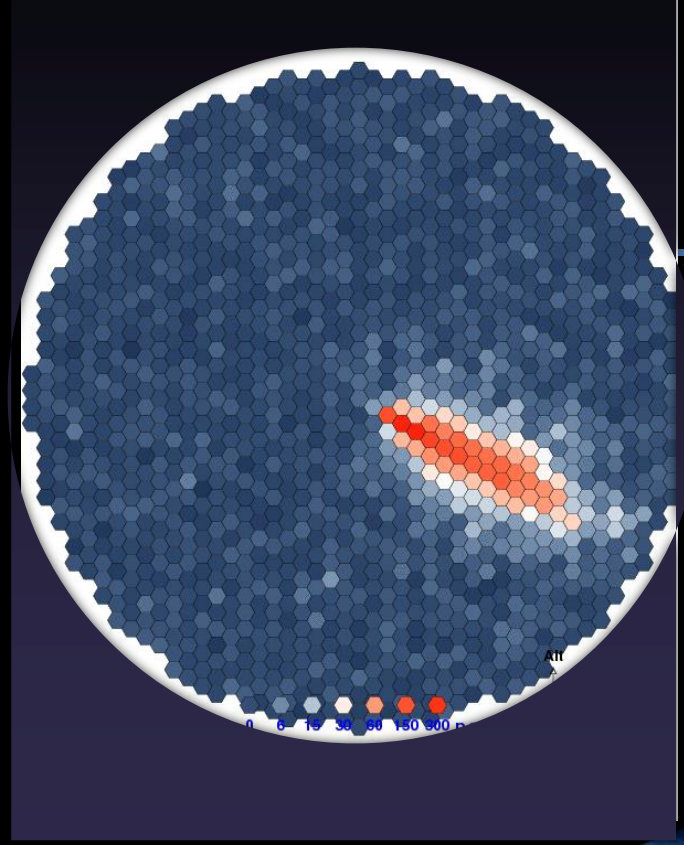


160 TeV sources

tevcat.uchicago.edu/

VHE GAMMA RAY SOURCE DISCOVERIES





“Shower”

For E=1 TeV ($E_C \cong 80$ MeV)

$X_{max} \cong X_0 \ln(E/E_C) / \ln 2$

$h_{max} = h_0 \ln(X_A/X_{max})$ ➡ 5 km

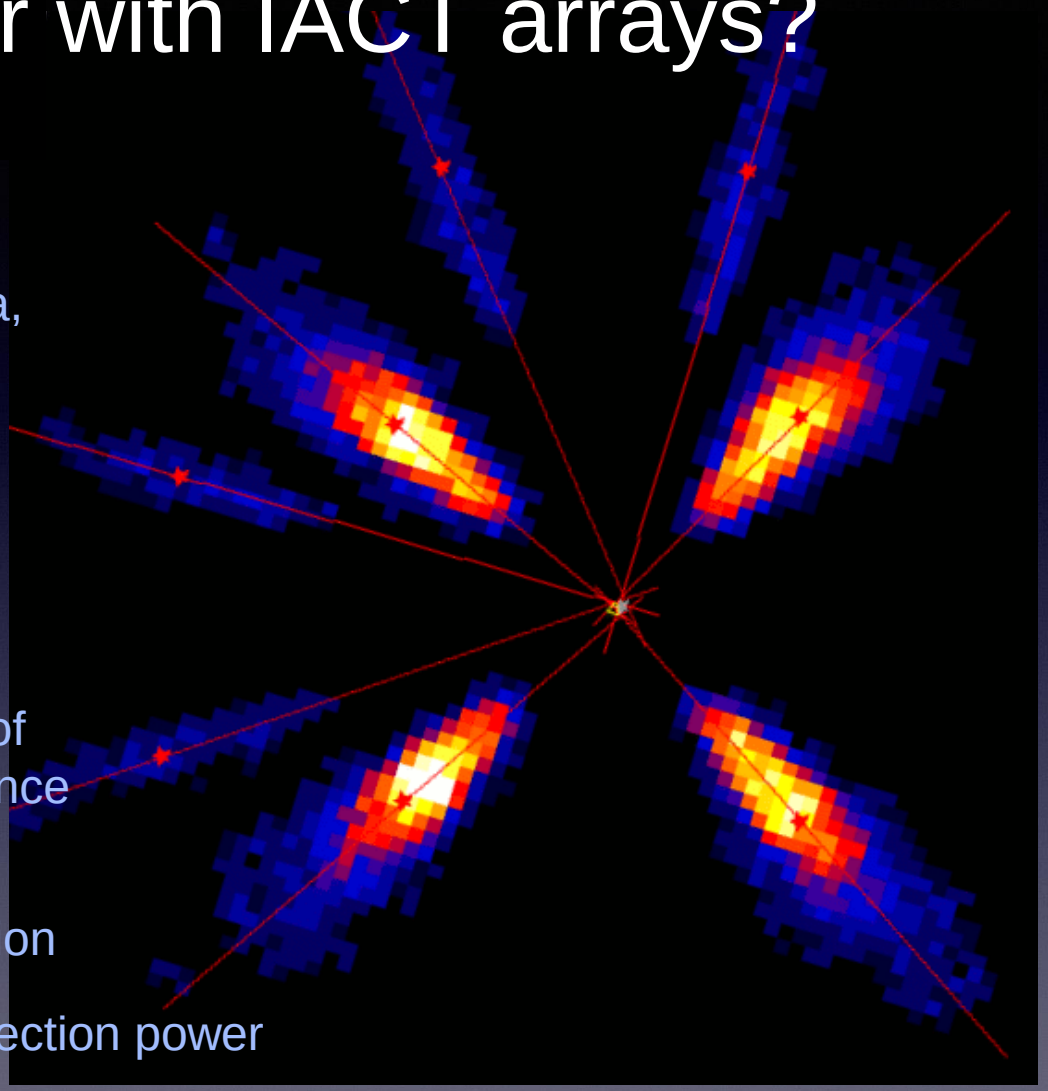
UV-optical reflecting mirrors focussing flashes of Cherenkov light produced by air-showers into ns-sensitive cameras.

140 m

How to do better with IACT arrays?

- More events
  - More photons = better spectra, images, fainter sources
    - ✓ Larger collection area for gamma-rays
- Better events
  - More precise measurements of atmospheric cascades and hence primary gammas
    - ✓ Improved angular resolution
    - ✓ Improved background rejection power

➡ More telescopes!



Simulation:
Superimposed images from 8 cameras

Major IACT Instruments

MAGIC Canary Islands 2200 m asl
2 x 17m telescopes. Magic I in operation since Oct 2003, Magic II first light shown at ICRC09

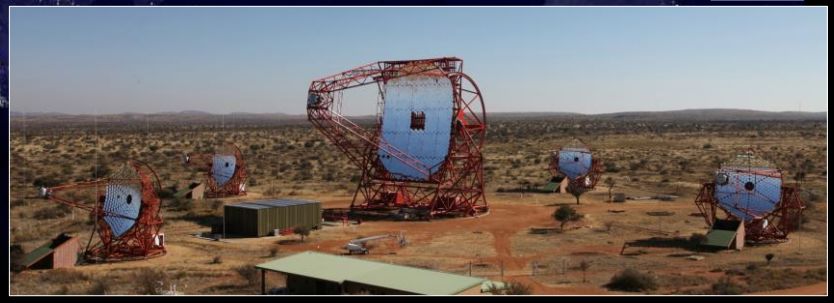
VERITAS Arizona, USA 1800 m asl
4 telescopes of 12m diameter
fully operational from fall 2007

MAGIC

VERITAS

HESS Namibia 1800 m asl
HESS I: 4 telescopes of 12m diameter
HESS II: 28 m diameter

HESS



Dec 2003: 4 telescope commissioned
Dec 2014: HESS II commissioning?


cta
cherenkov telescope array

Theme 1: Cosmic Particle Acceleration

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

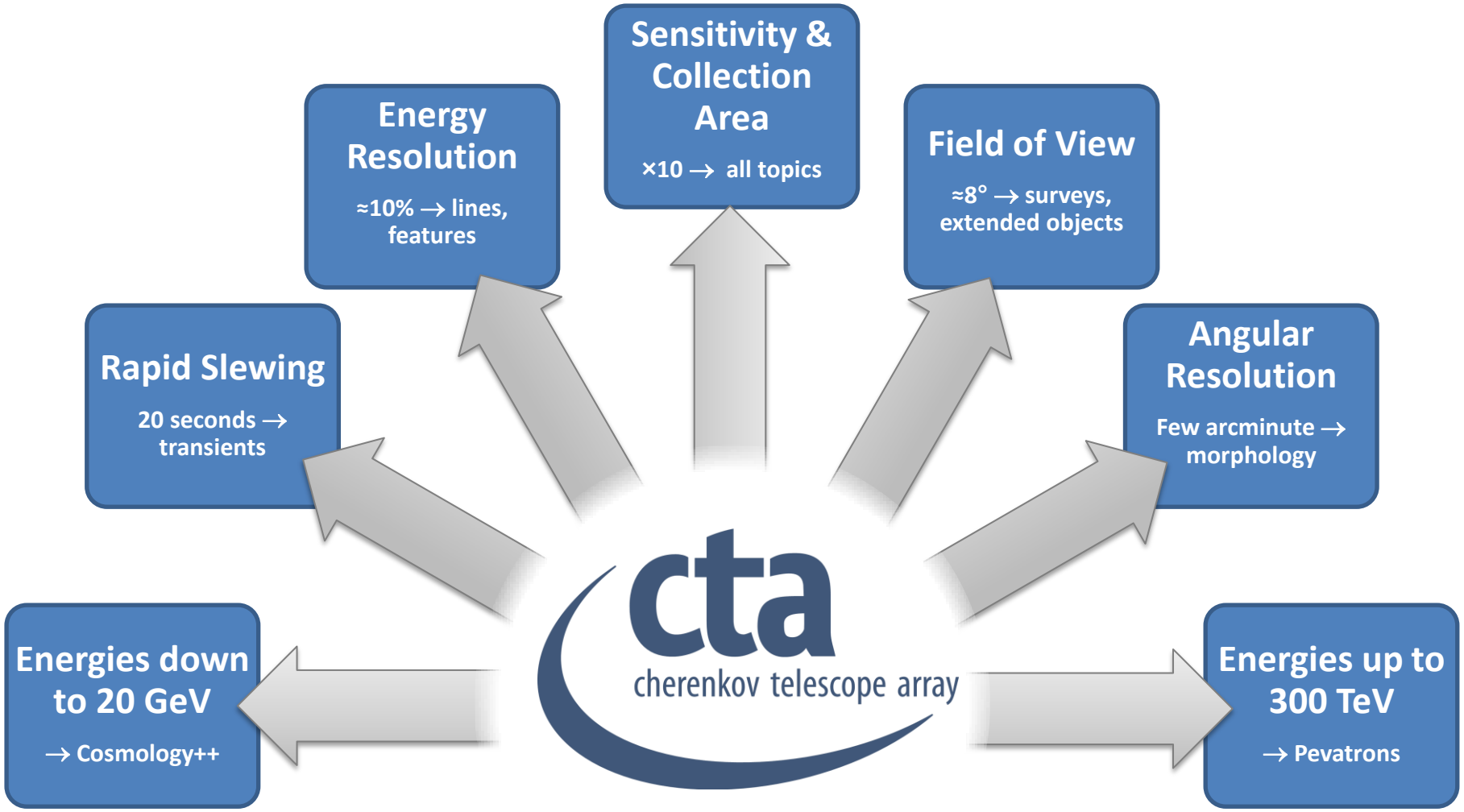
Theme 2: Probing Extreme Environments

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

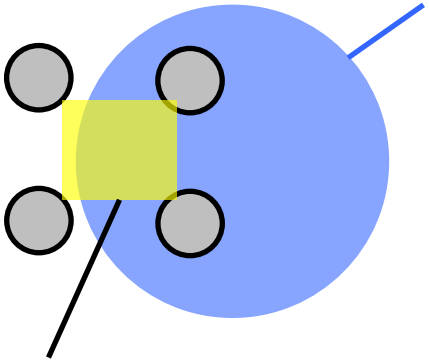
Theme 3: Physics Frontiers – beyond the SM

- 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?

REQUIREMENTS & DRIVERS

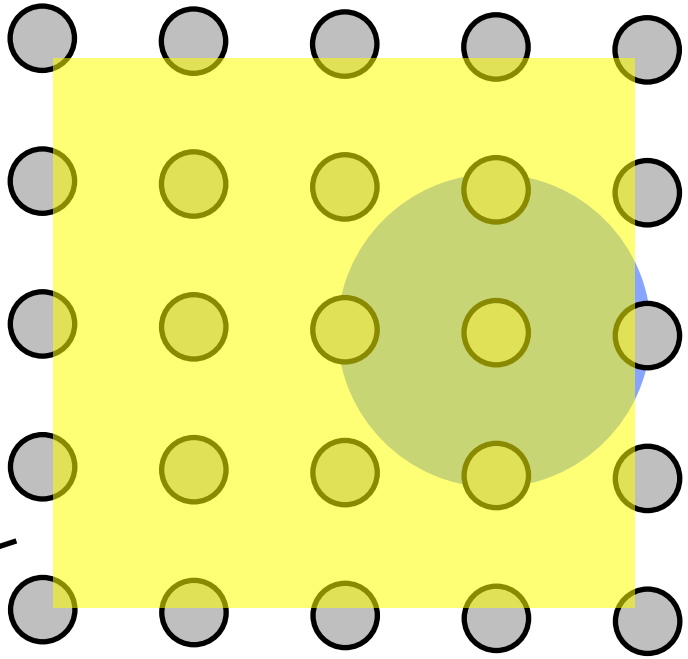


FROM CURRENT ARRAYS TO CTA



light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
most showers miss it!



large detection area
more images per shower
lower trigger threshold

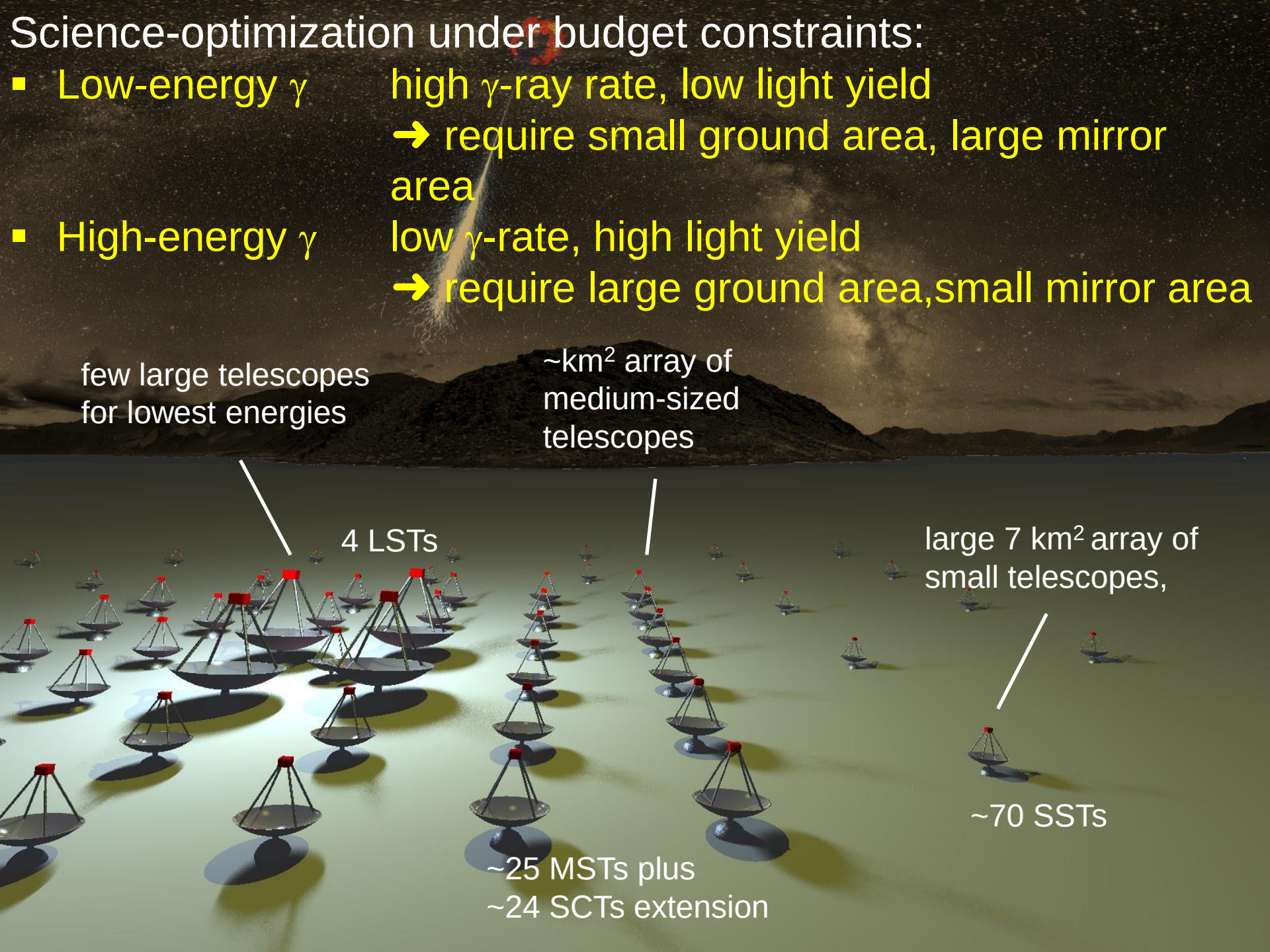
The Cherenkov Telescope Array

- A huge improvement in all aspects of performance
  - A factor ~10 in sensitivity, much wider energy coverage, much better resolution, field-of-view, full sky, …
- A user facility / proposal-driven observatory
  - With two sites with a total of >100 telescopes
- A 27 nation ~€200M project
  - Including everyone from HESS, MAGIC and VERITAS

Prototypes: 2013-15
First Science: ~2016
Completion: ~2020

Science-optimization under budget constraints:

- Low-energy γ — high γ-ray rate, low light yield
  ➜ require small ground area, large mirror area
- High-energy γ — low γ-rate, high light yield
  ➜ require large ground area,small mirror area



SOUTHERN AND NORTHERN SITES

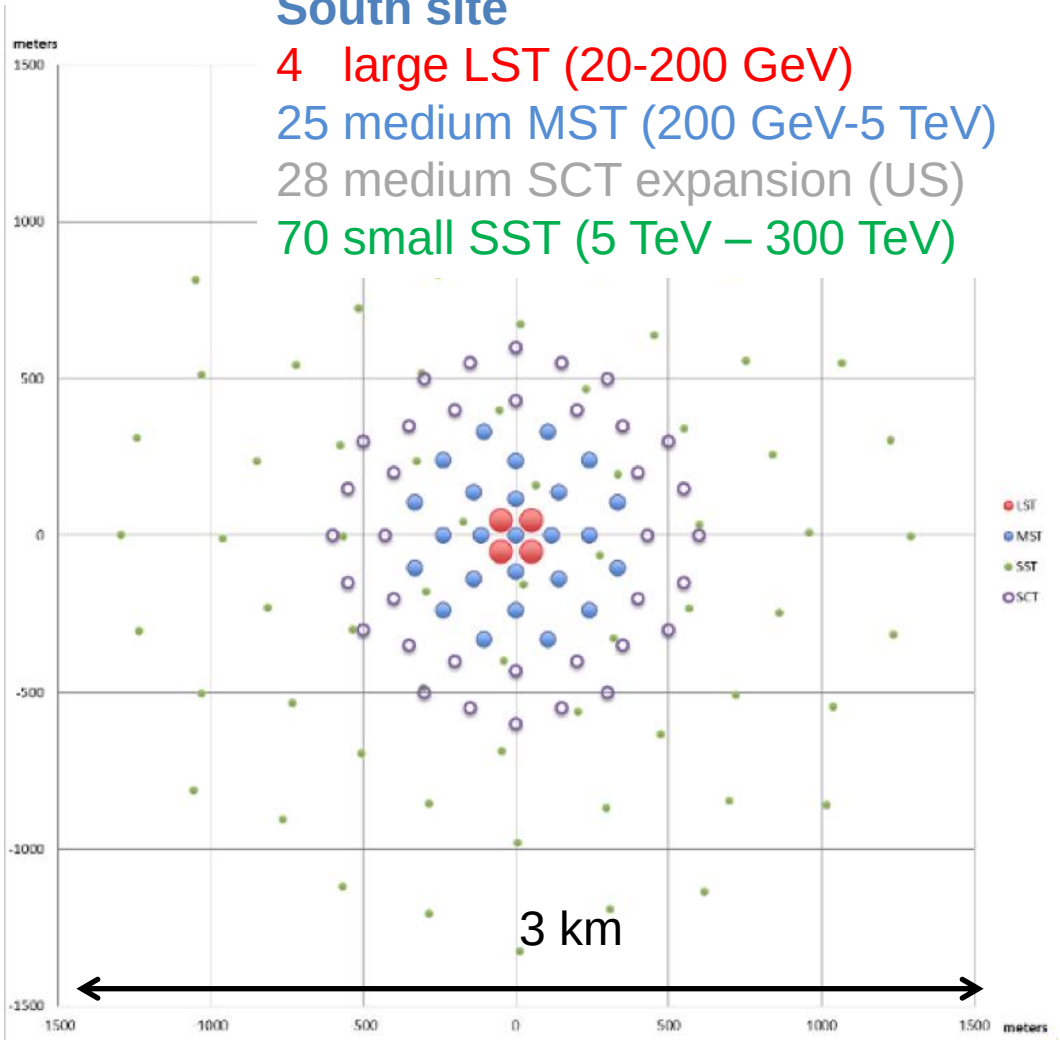
South site

4 large LST (20-200 GeV)

25 medium MST (200 GeV-5 TeV)

28 medium SCT expansion (US)

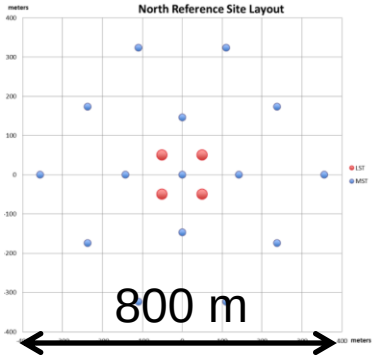
70 small SST (5 TeV – 300 TeV)



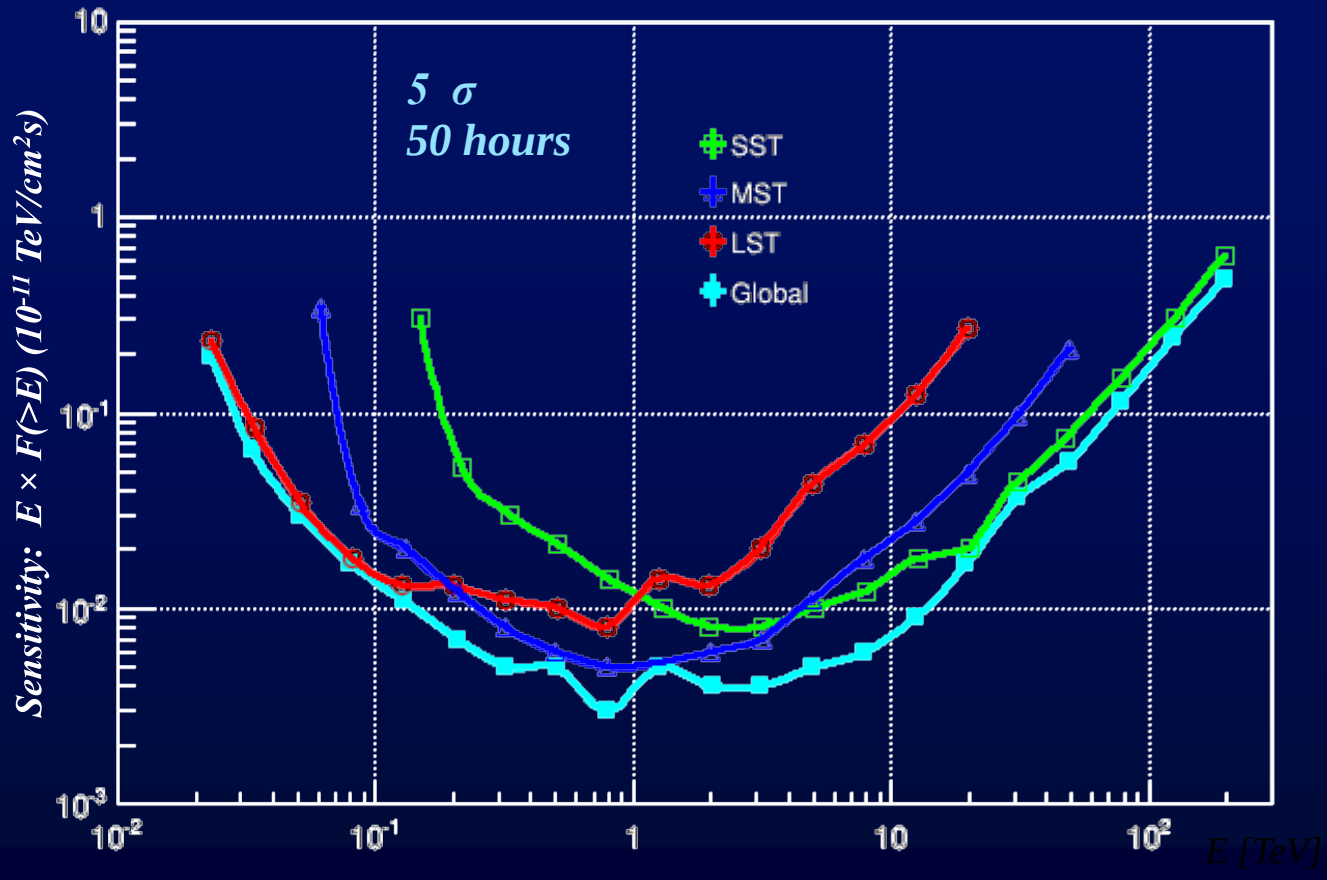
North site

4 large LST

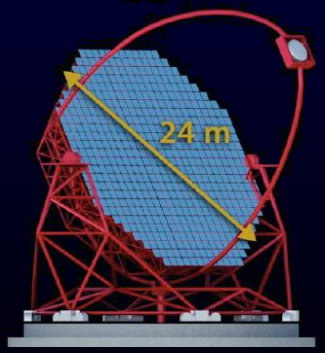
15 medium MST



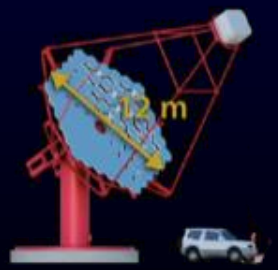
~2/3 of all current sources in Southern sky


5 σ
50 hours
SST
MST
LST
Global
Sensitivity: E × F(>E) (10-11 TeV/cm2s)
E [TeV]
10
1
10-1
10-2
10-3
10-2
10-1
1
10
102

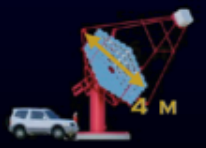
LST


24 m

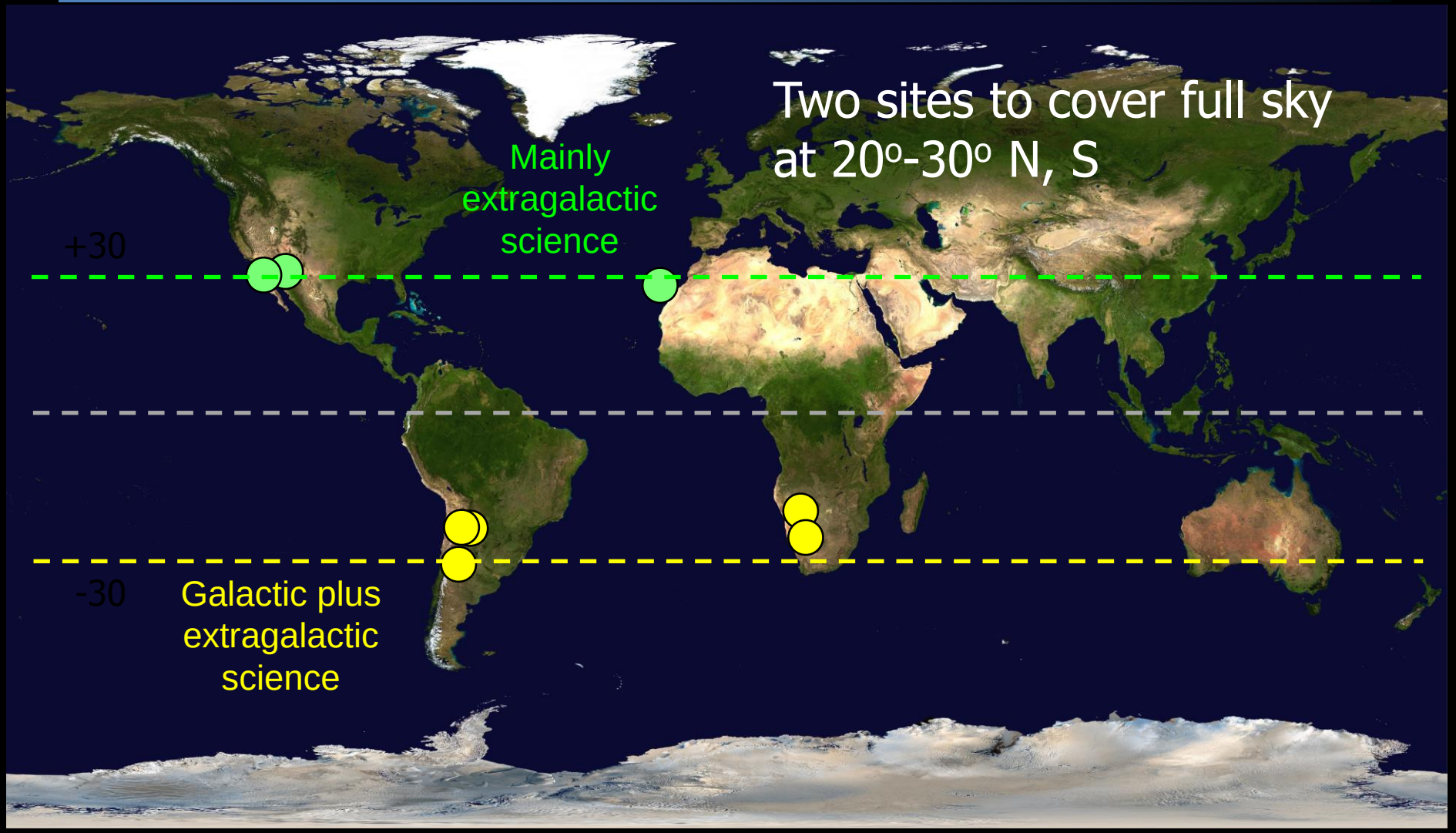
MST


12 m

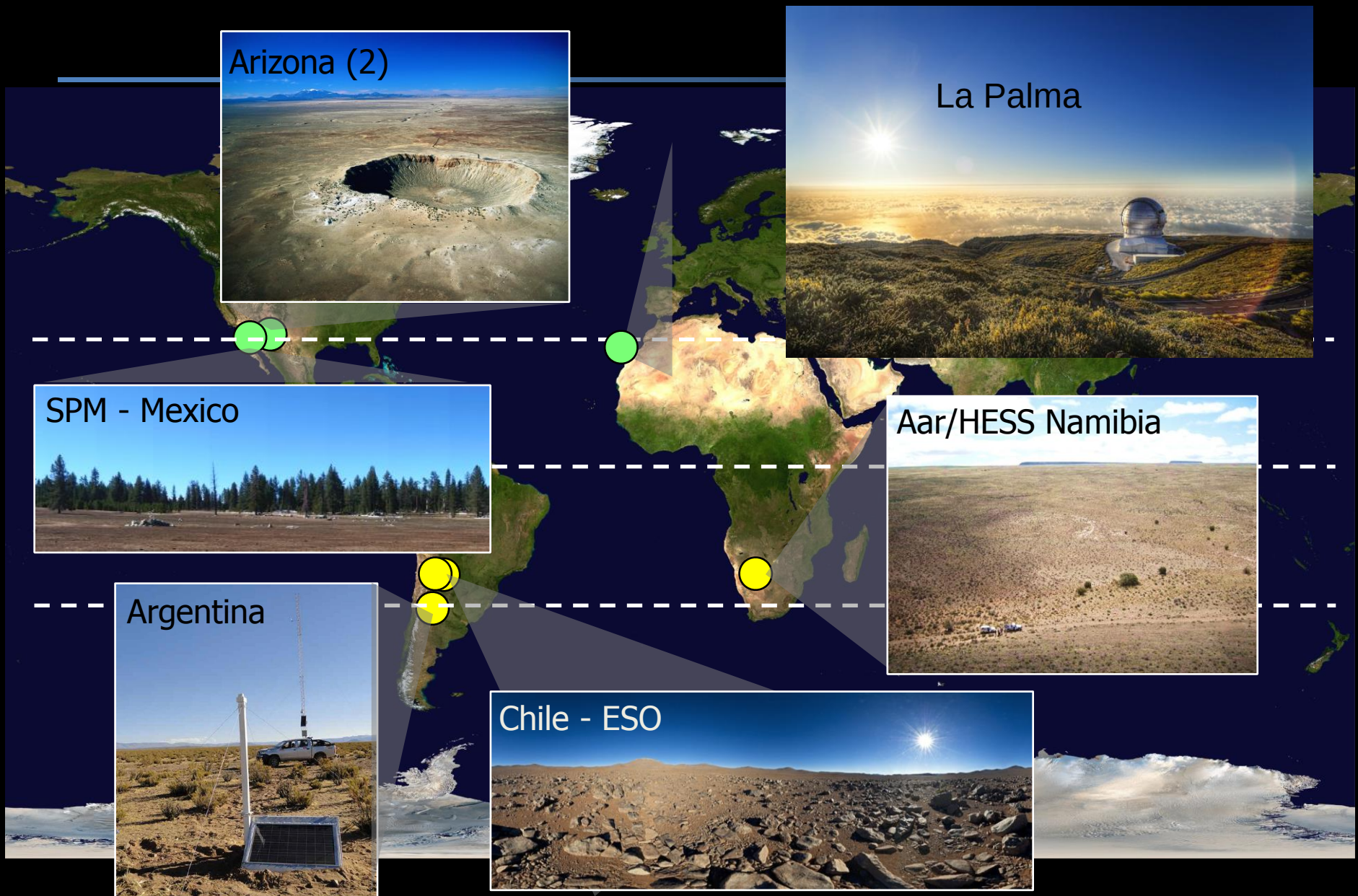
SST


4 m

CTA SITES


Two sites to cover full sky
at 20º-30º N, S
Mainly
extragalactic
science
+30
-30
Galactic plus
extragalactic
science

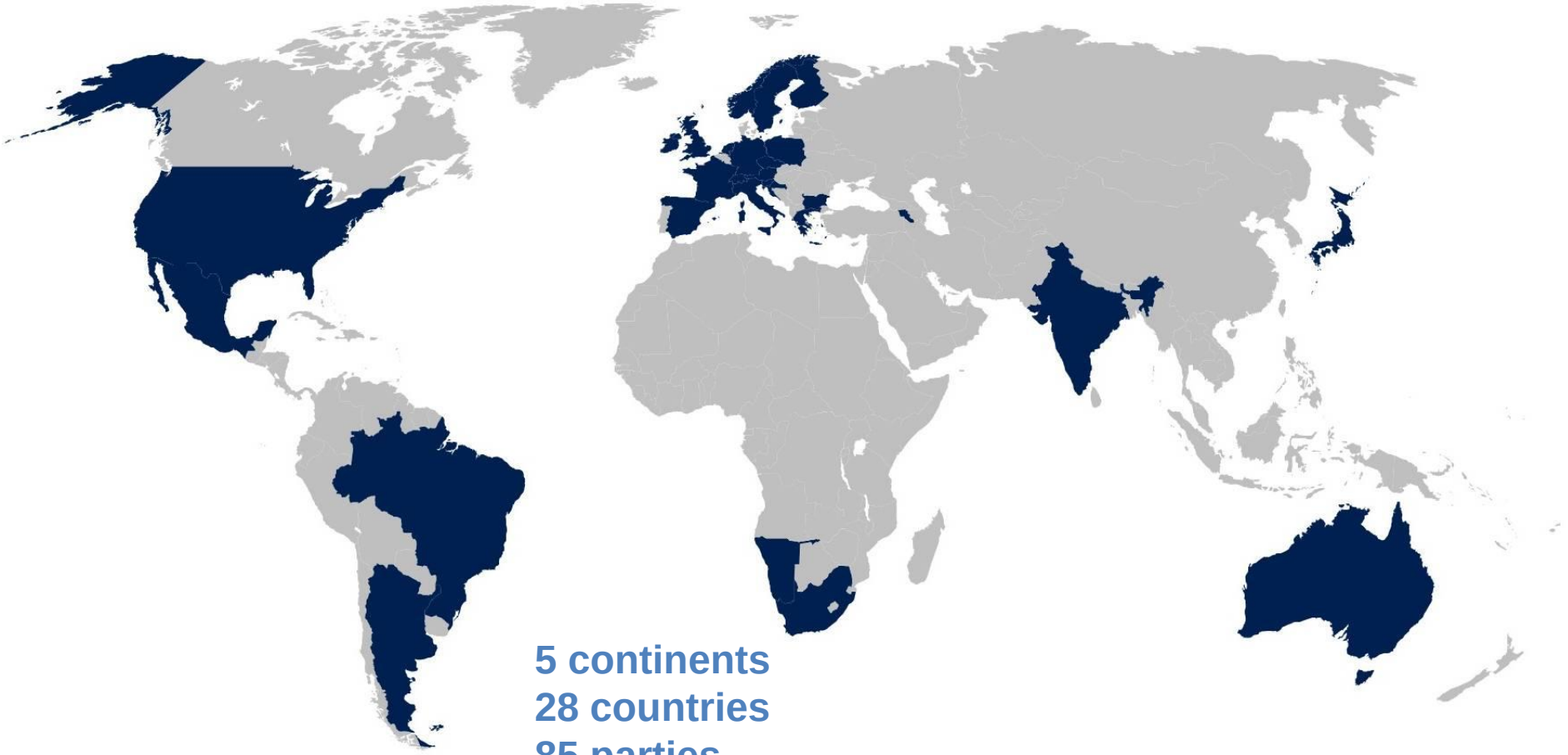
CTA SITES: CANDIDATES



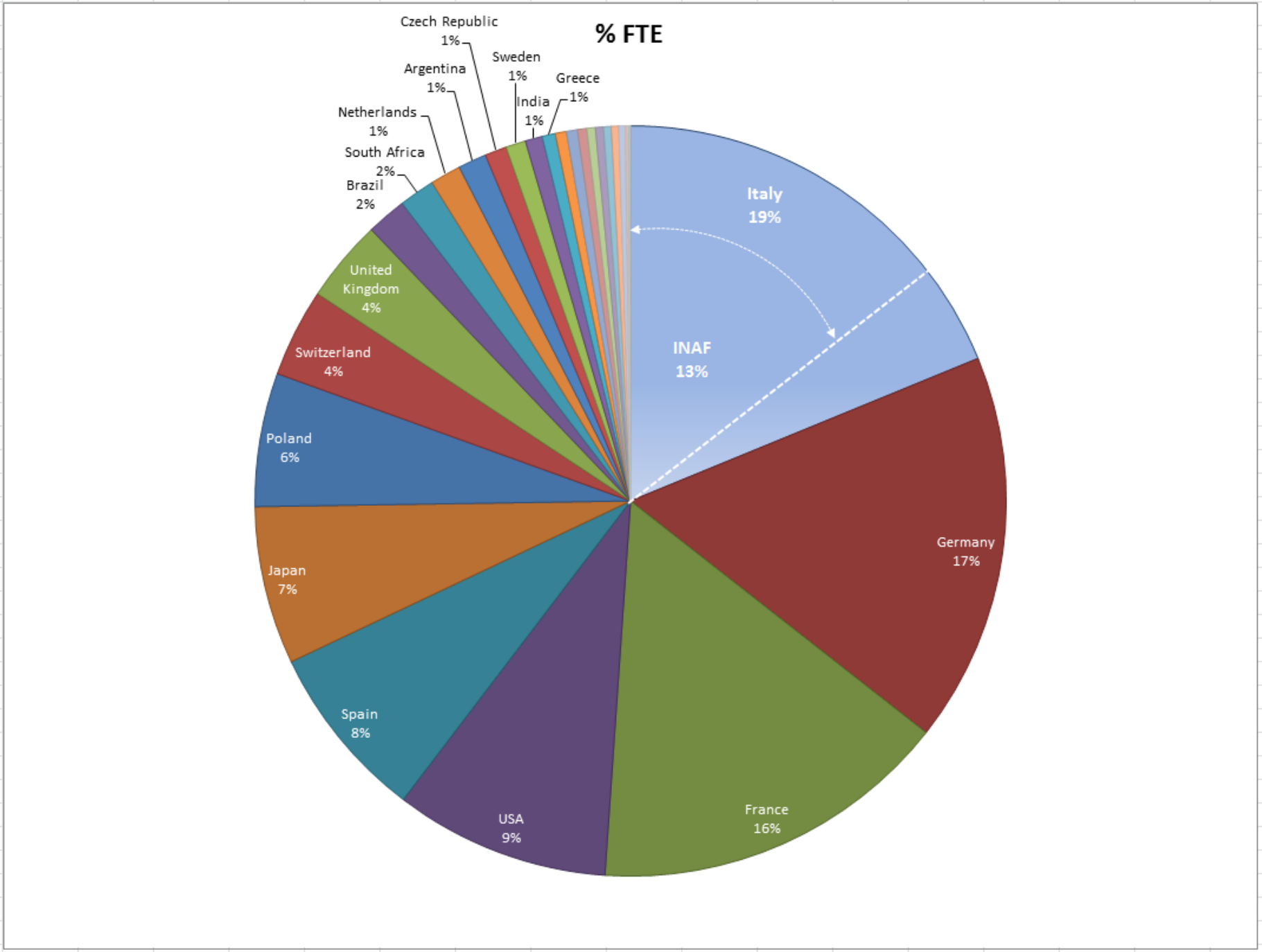
CTA CONSORTIUM

Spokesperson	**Werner Hofmann (Heidelberg)**
Co-spokesperson	**René Ong (UCLA)**

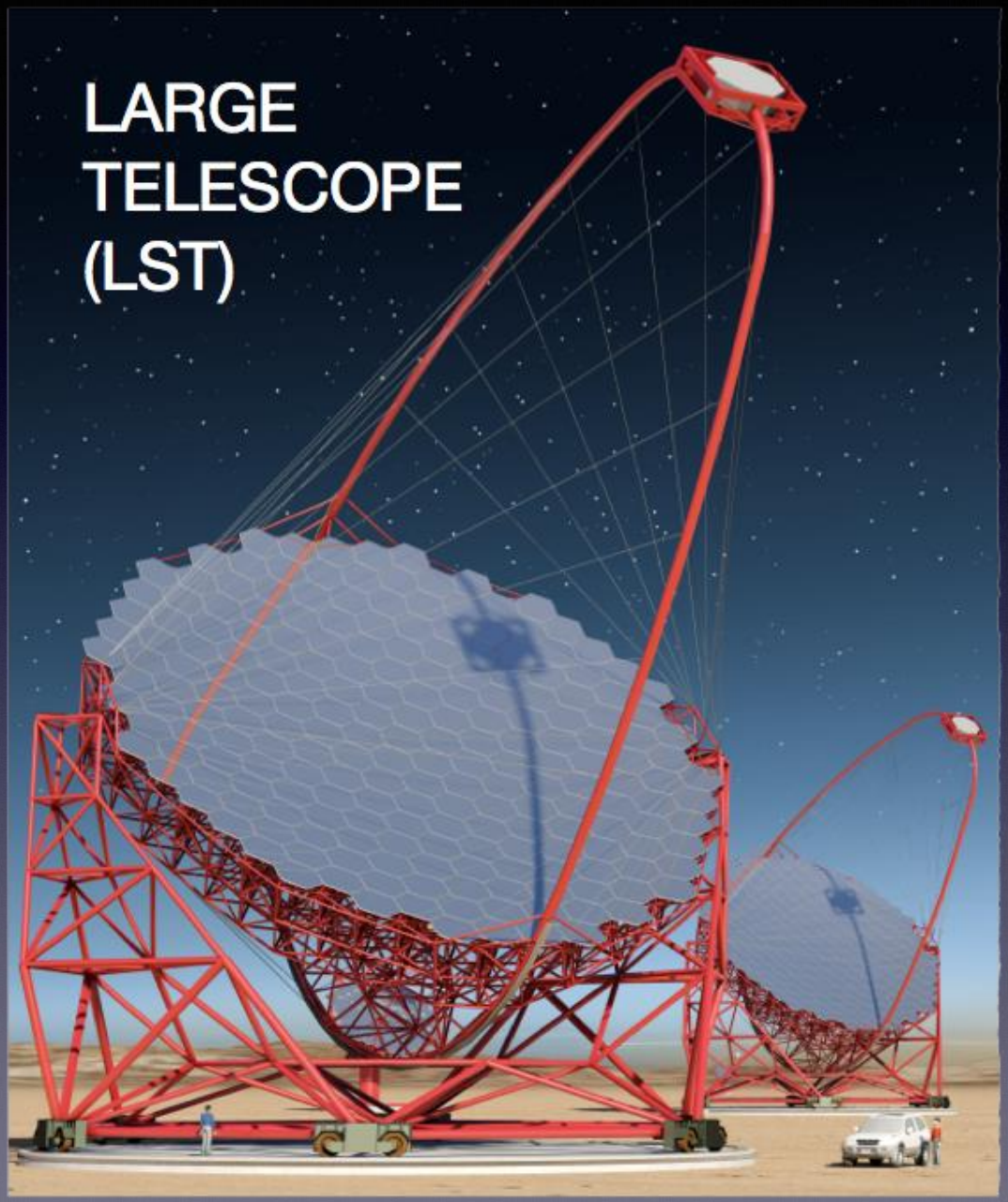
CONSORTIUM MEMBERSHIP



5 continents
28 countries
85 parties
176 institutes
1193 members (390 FTE)


% FTE
Czech Republic 1%
Sweden 1%
Argentina 1%
Greece 1%
India 1%
Netherlands 1%
South Africa 2%
Brazil 2%
Italy 19%
United Kingdom 4%
INAF 13%
Switzerland 4%
Poland 6%
Germany 17%
Japan 7%
Spain 8%
USA 9%
France 16%

TECHNICAL DESIGN & PROTOTYPING



Optimized for Energies > 100 GeV

23 m diameter

389 m^2 dish area

28 m focal length

1.5 m mirror facets

4.5° field of view

0.1° pixels

Camera Ø over 2 m

Carbon-fibre structure for 20 s positioning

Active mirror control

4 LST on South site

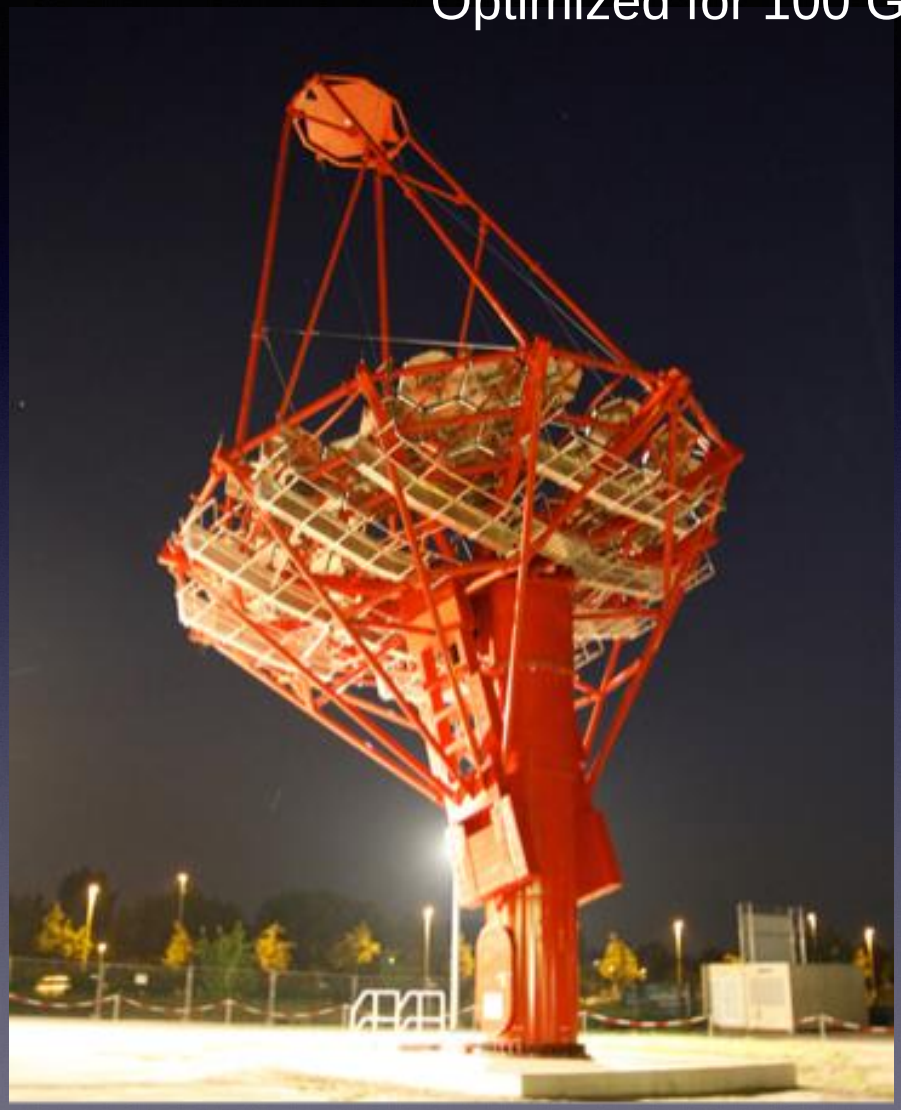
4 LST on North site

Prototype 1st telescope

cta
cherenkov telescope array

Medium Size Telescope

Optimized for 100 GeV - 10 TeV Range



MST Prototype in Berlin

12 m diameter

100 m2 dish area

16 m focal length

1.2 m mirror facets

8° field of view

0.18° pixels (~2000 pixels)

Camera Ø over 1.5 m

Active mirror control

25 MST on South site

15 MST on North site

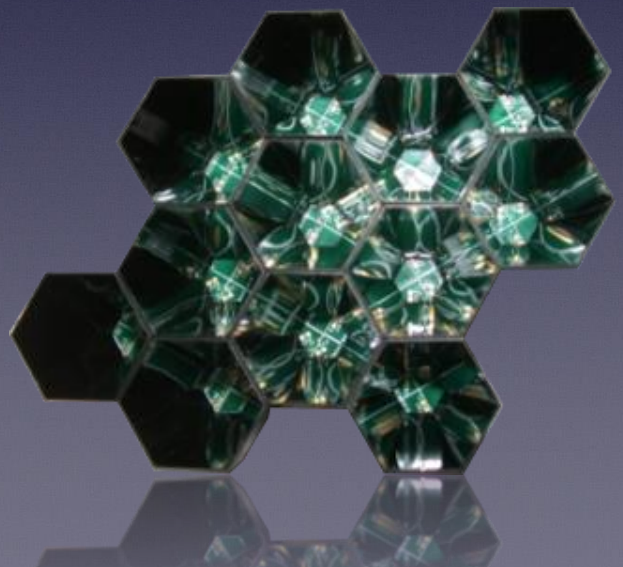
cta
cherenkov telescope array

Small Size Telescope (SSt-1M)

Optimize for Energy range above 10 TeV

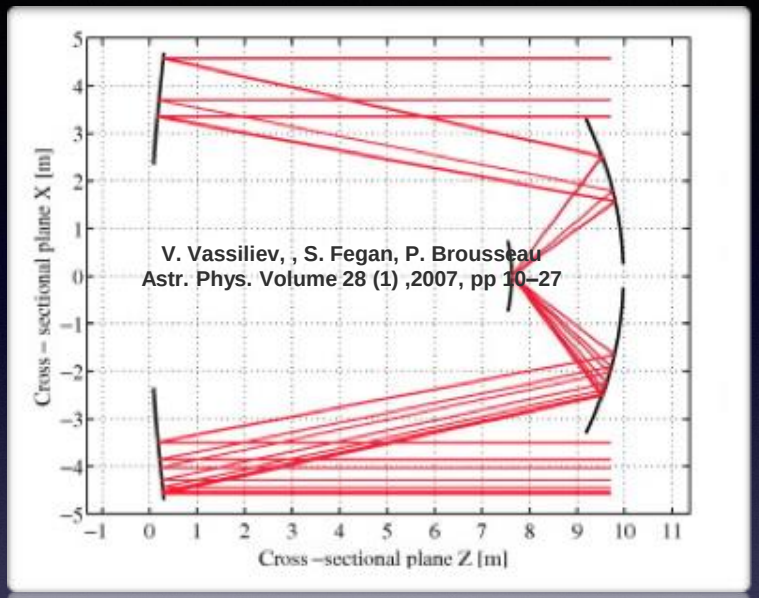
70 SST: WITH A SPACING BY 200-300 M

- Davies-Cotton Design
- 4m diameter single mirror
- f/D = 1.4
- SiPM camera with new hexago sensor



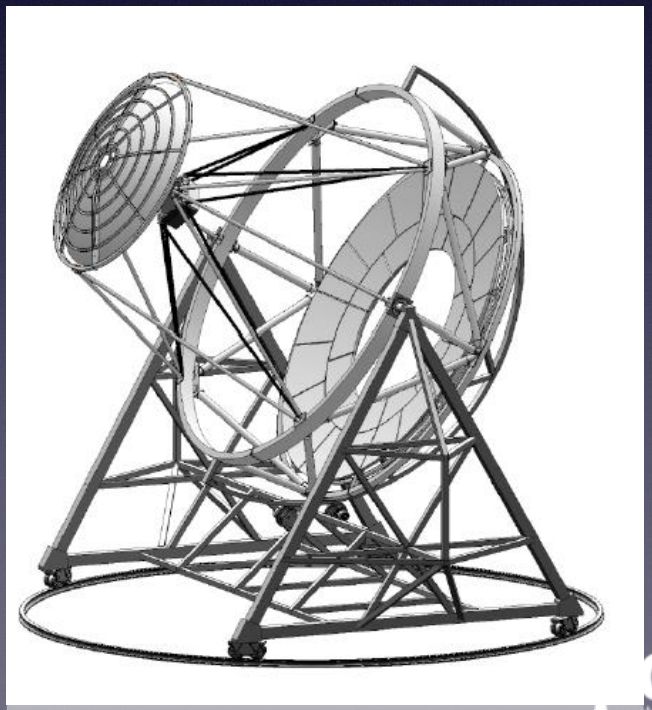
SST-1M Prototype in Krakow

Dual-Mirror Telescope



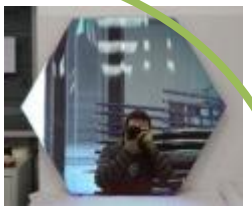
- Cost-Effective small telescope with compact camera (SST-2M)
- Higher-performance telescope with small pixels (SCT)

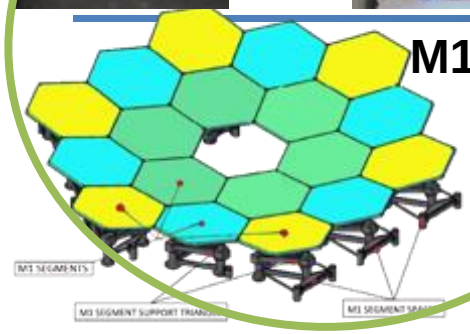
- **Reduce plate size**
- **Reduce PSF**
- **Uniform PSF across FoV**



ASTRI - Dual Mirror SST

- 4m diameter dual mirror
  - Segmented primary
  - Monolithic Secondary
- Effective area: 6 m^2
- Focal length: 2.2m
- FoV: 9.6°
- Pixel angular size 0.17°



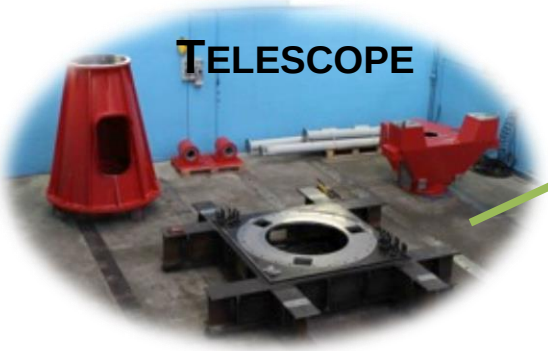


M1 MIRROR

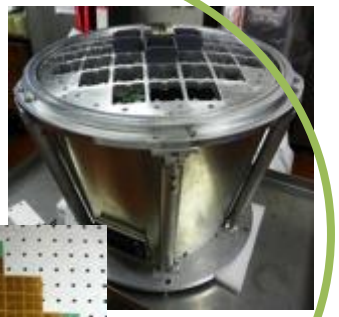
M2 MIRROR

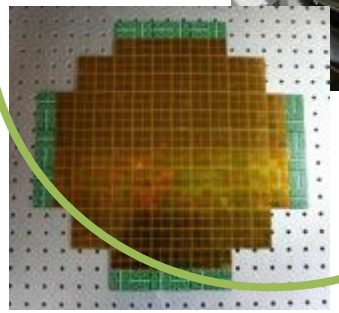
AUX

END TO END APPROACH



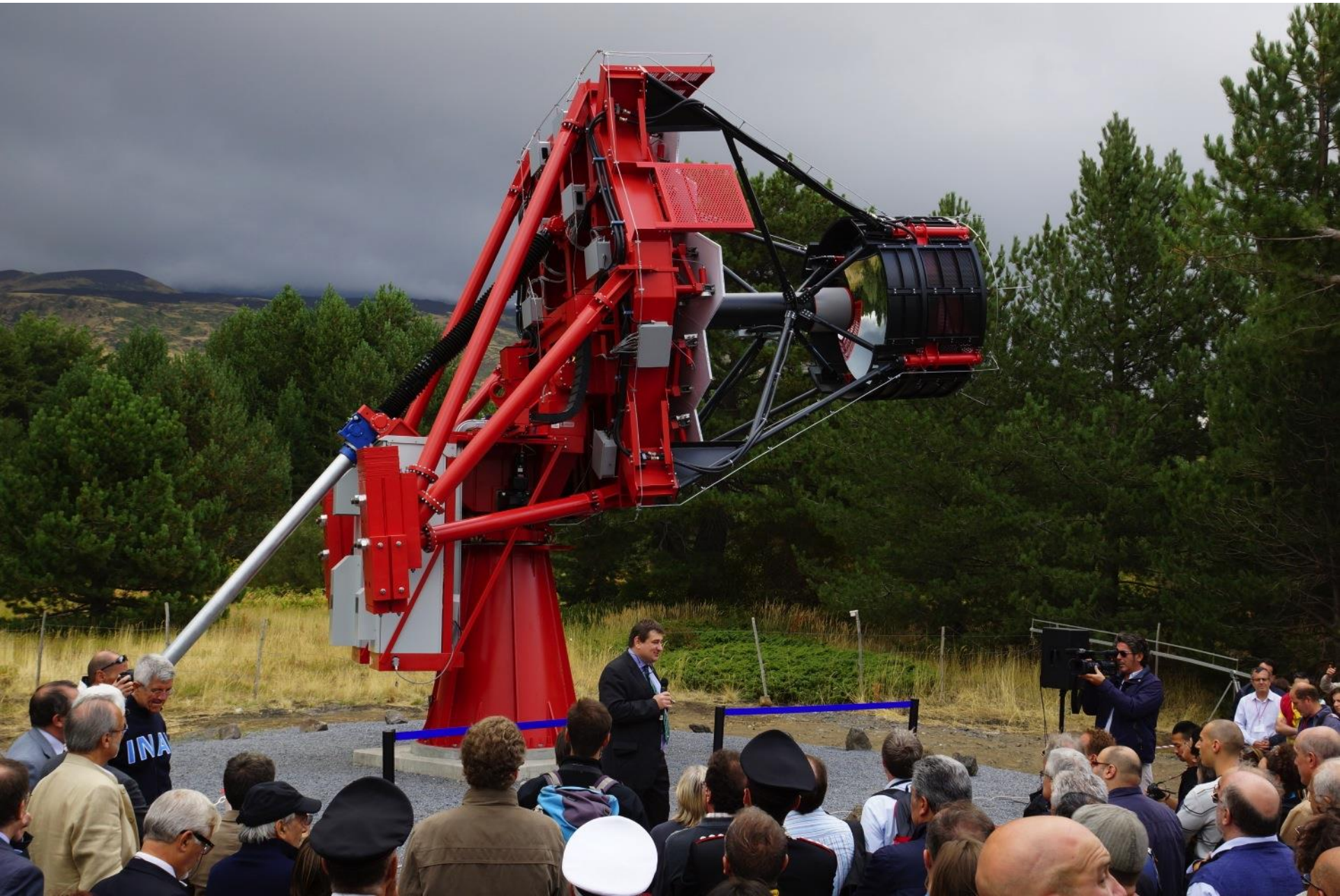
TELESCOPE





CAMERA

https://www.youtube.com/watch?v=lDfWUdxFQjo



FEB,1, 2015

Next task: building a mini-array