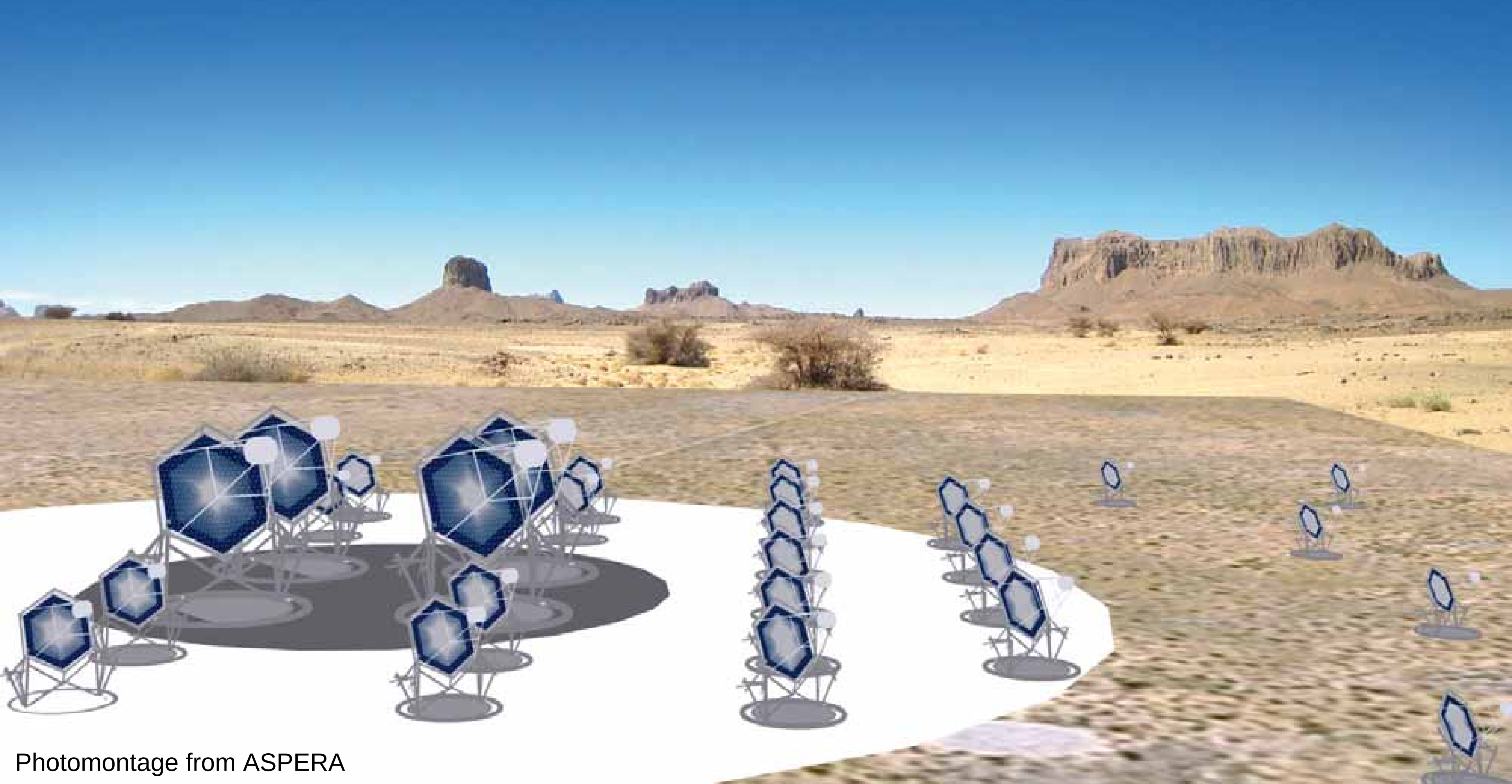
Ground-based Gamma-Ray Astronomy

G.Hermann
MPIK, Heidelberg

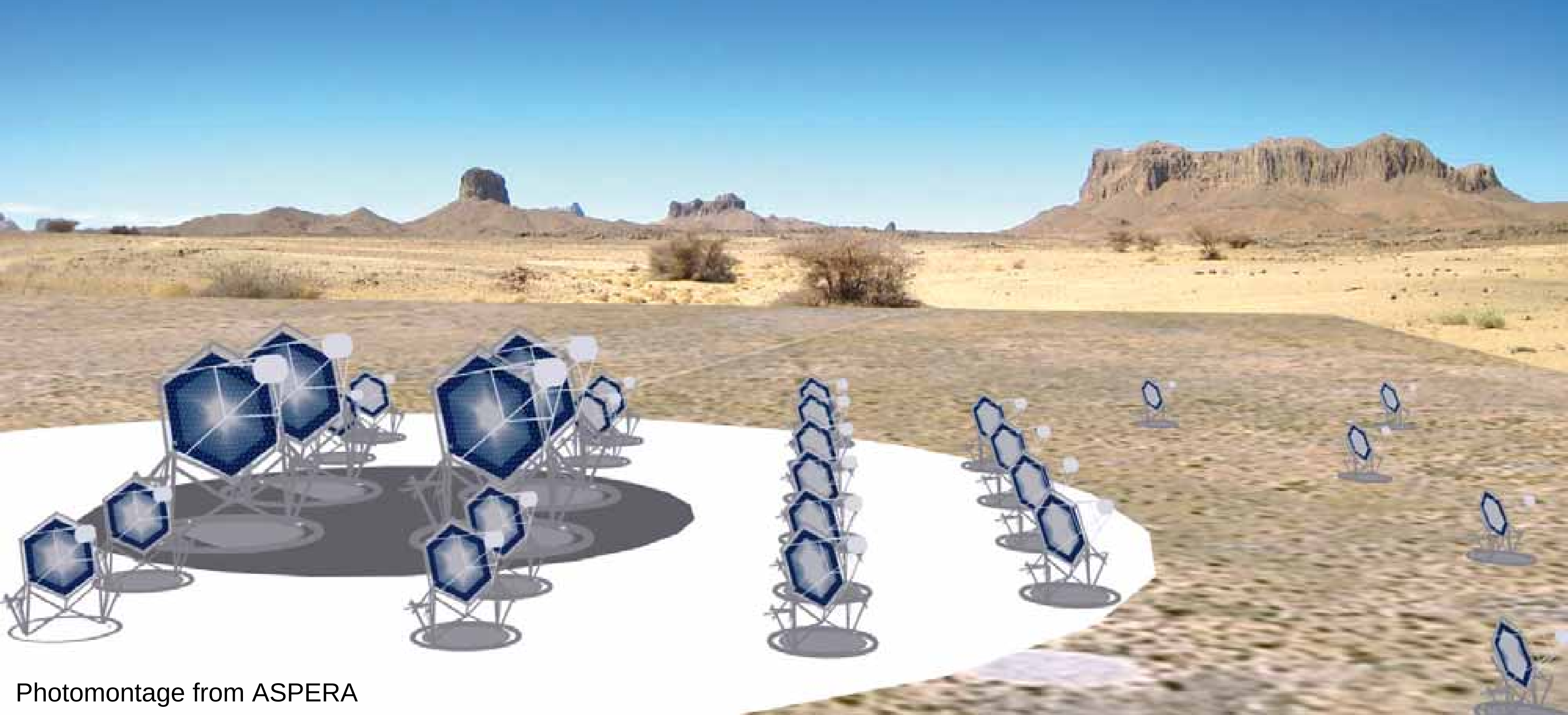


Photomontage from ASPERA

Towards the Future Cherenkov Telescope Array *CTA*

- Imaging Atmospheric Cherenkov Telescopes
- The Cherenkov Telescope Array
- Technical Developments
- Timeline

G.Hermann
MPIK, Heidelberg



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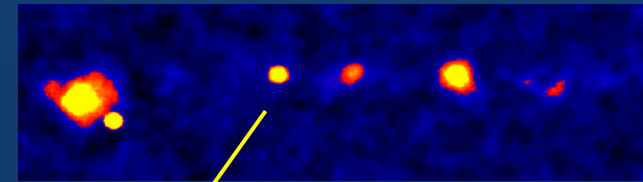
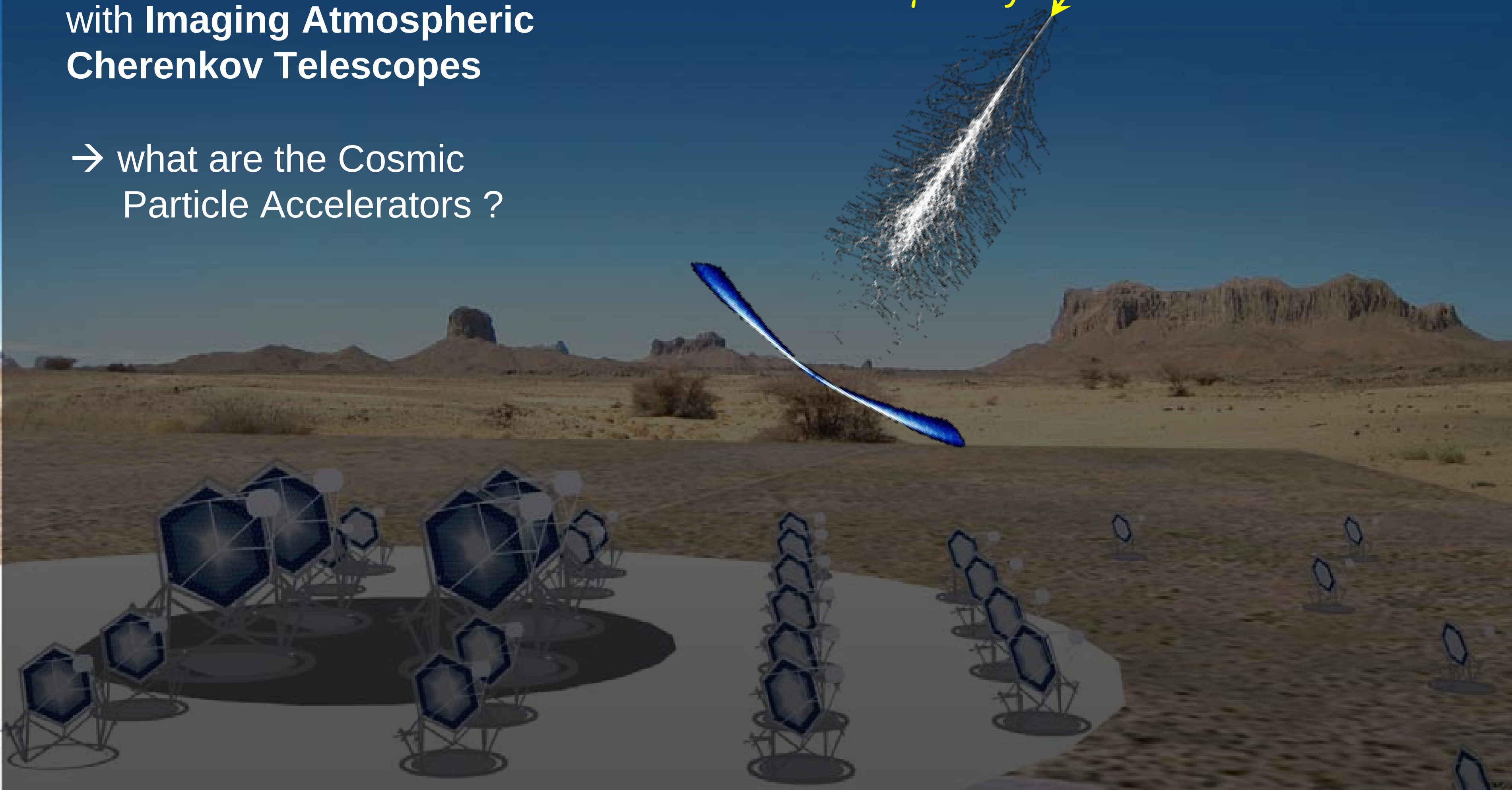
Imaging Atmospheric Cherenkov Technique



VHE gamma-ray astronomy with **Imaging Atmospheric Cherenkov Telescopes**

→ what are the Cosmic Particle Accelerators ?

TeV
γ- Ray



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The Pioneering Single Dish Instrument

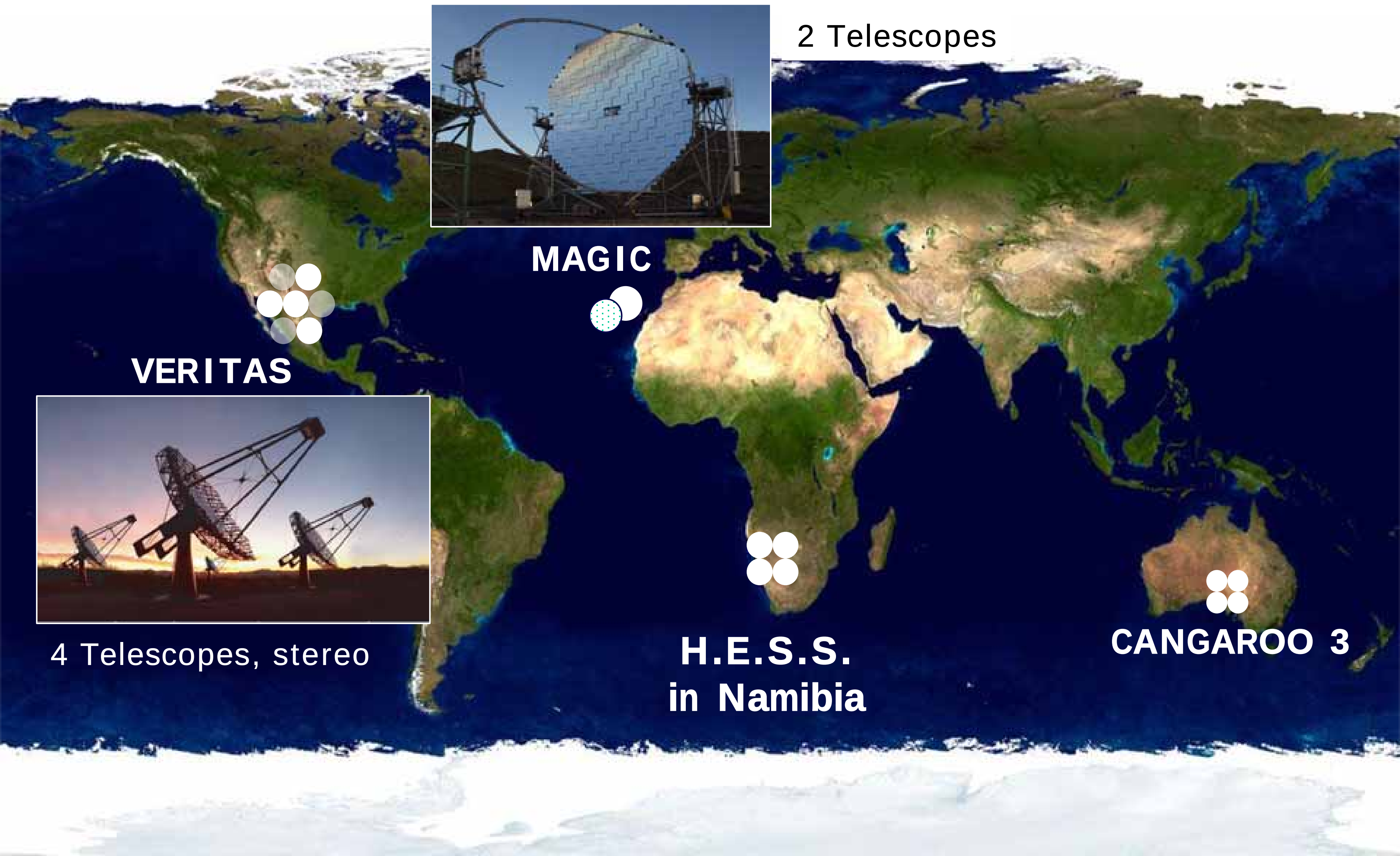
The Pioneers:

WHIPPLE

10 m dish, 60s
Arizona, USA

first TeV source:
Crab Nebula (1989)
(just 22 years ago)

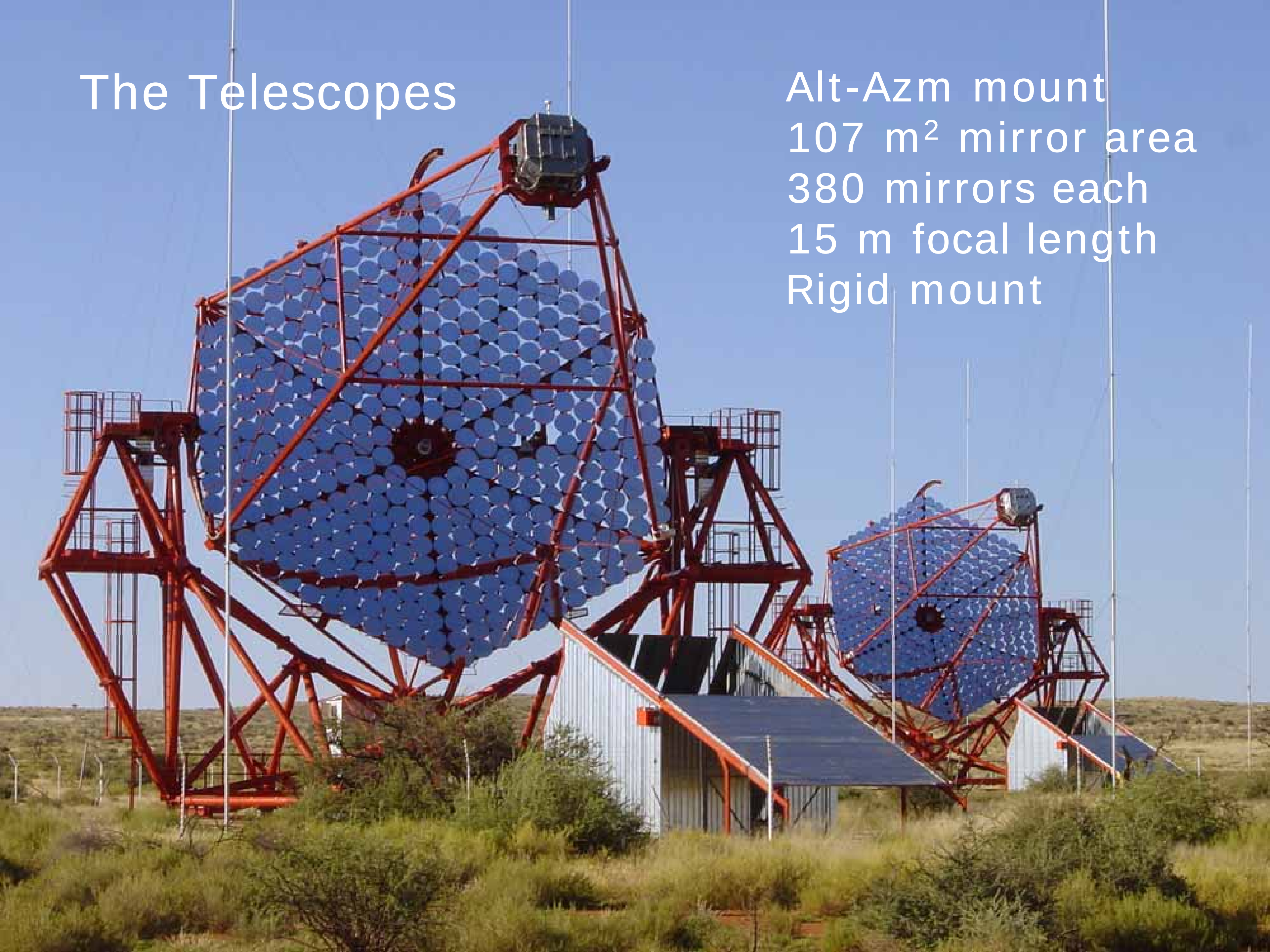
Major Ground-Based γ-Ray Installations

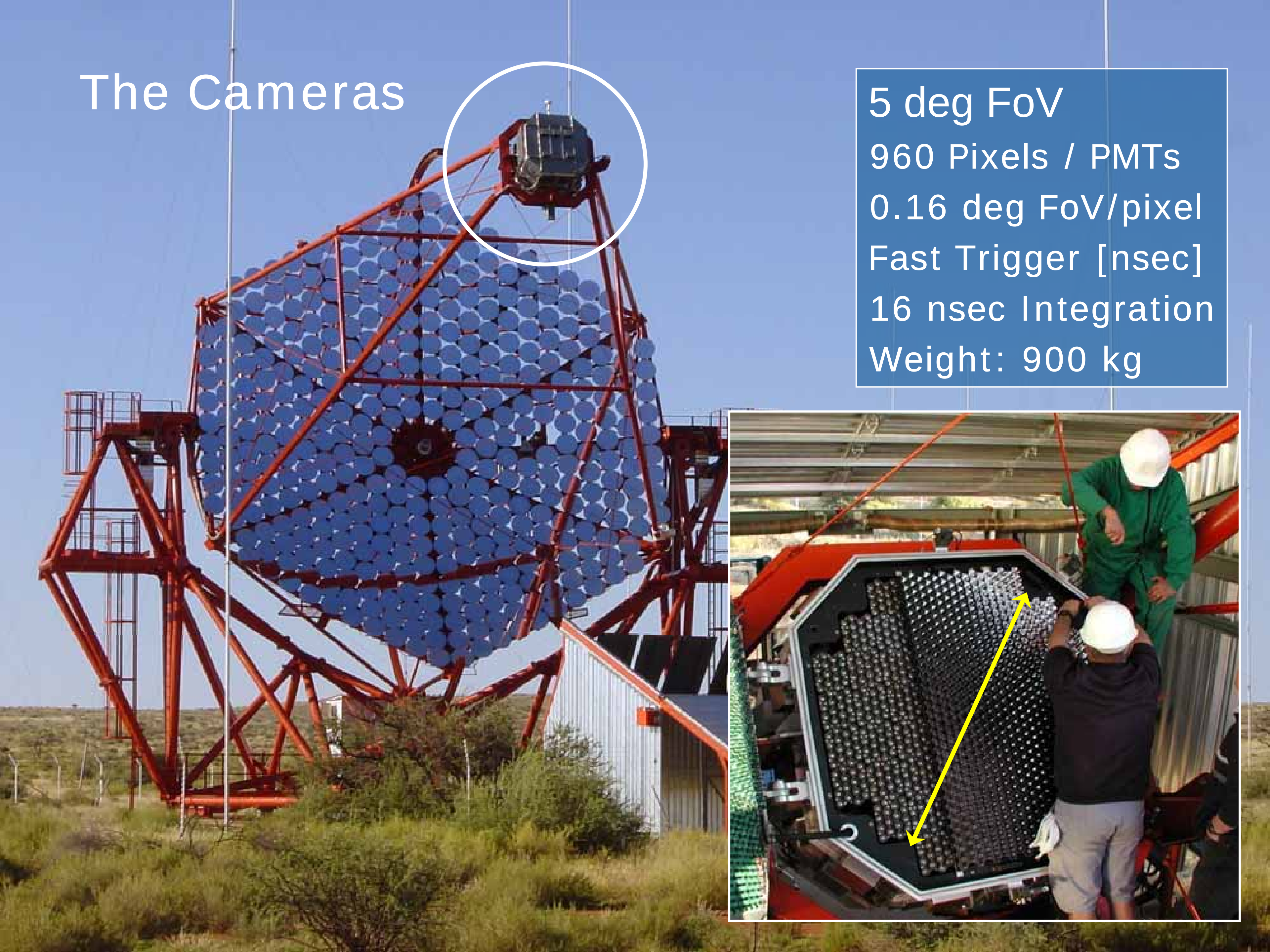


High Energy Stereoscopic System H.E.S.S.

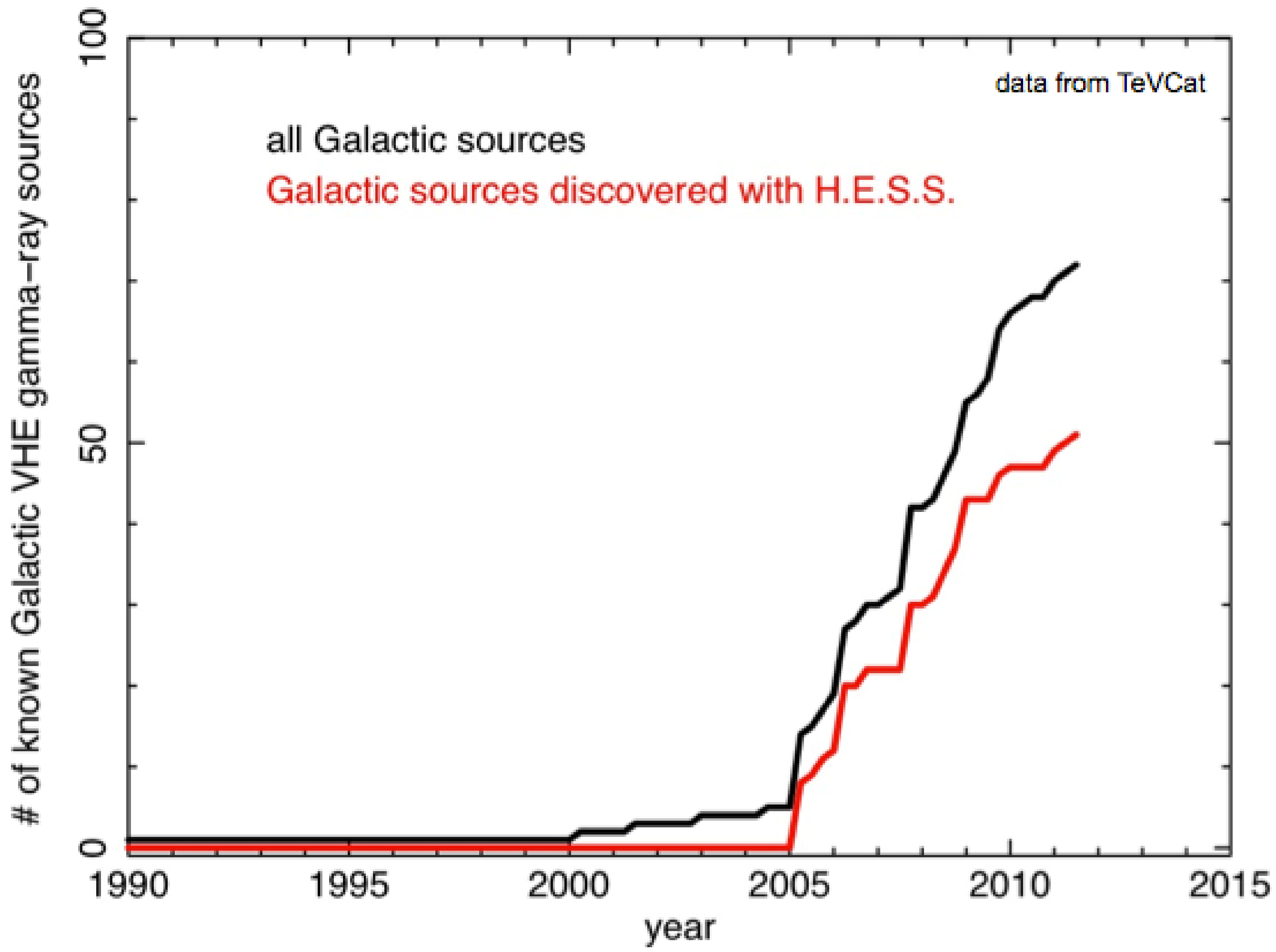
The Telescopes

Alt-Azm mount
$107\ m^2$ mirror area
380 mirrors each
15 m focal length
Rigid mount



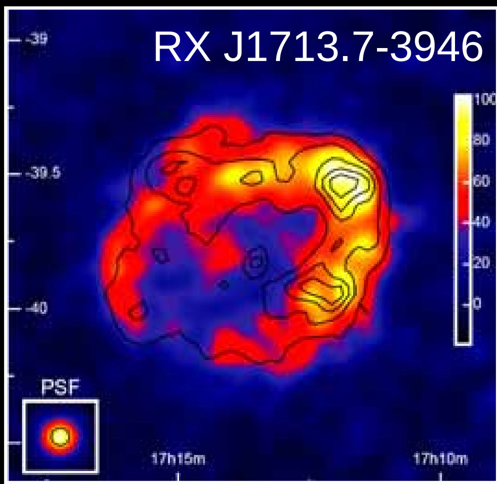

The Cameras
5 deg FoV
960 Pixels / PMTs
0.16 deg FoV/pixel
Fast Trigger [nsec]
16 nsec Integration
Weight: 900 kg

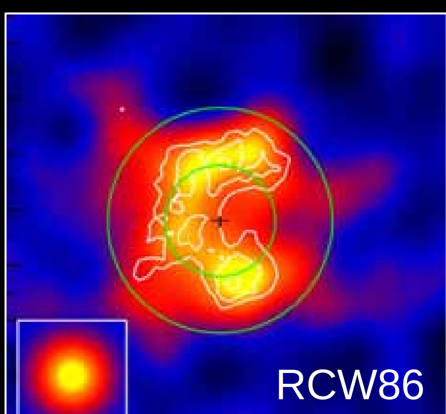
> 100 sources detected during last ~10 yrs

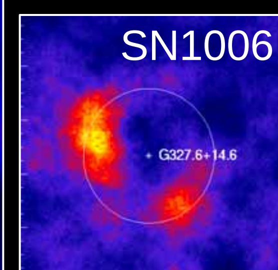


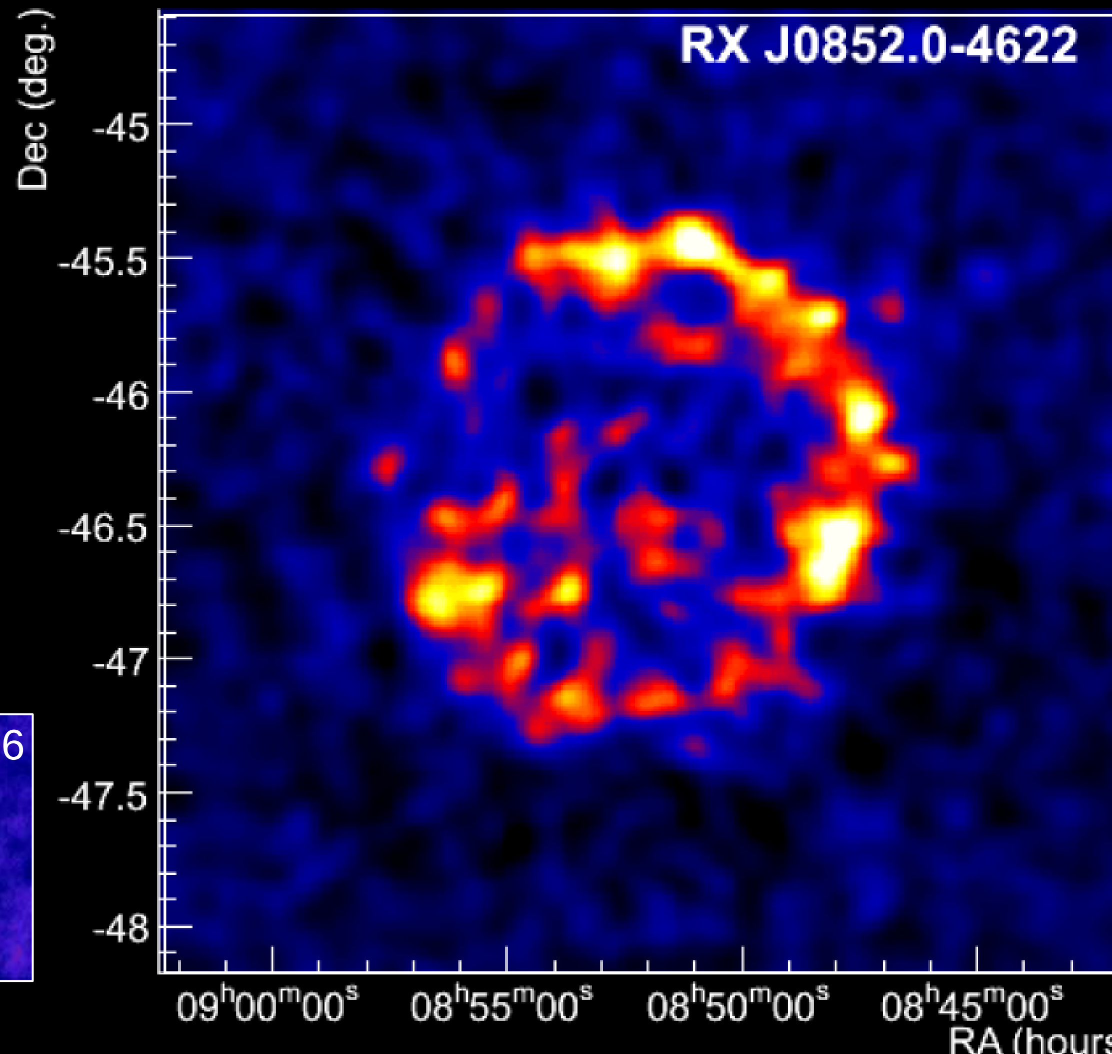
HESS: shell type SNRs as CR accelerators

Maps ~ to scale

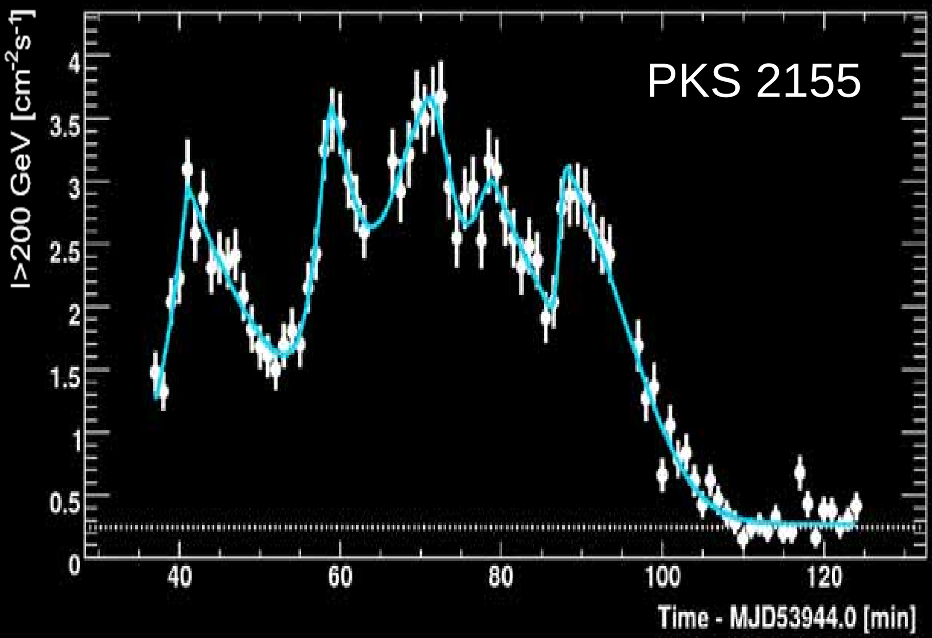






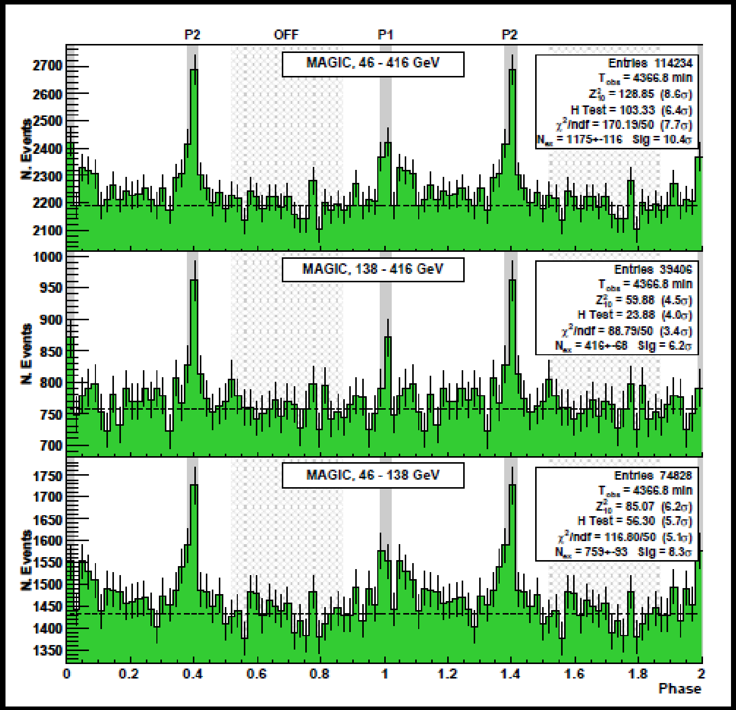


VERITAS, MAGIC, HESS: compact objects

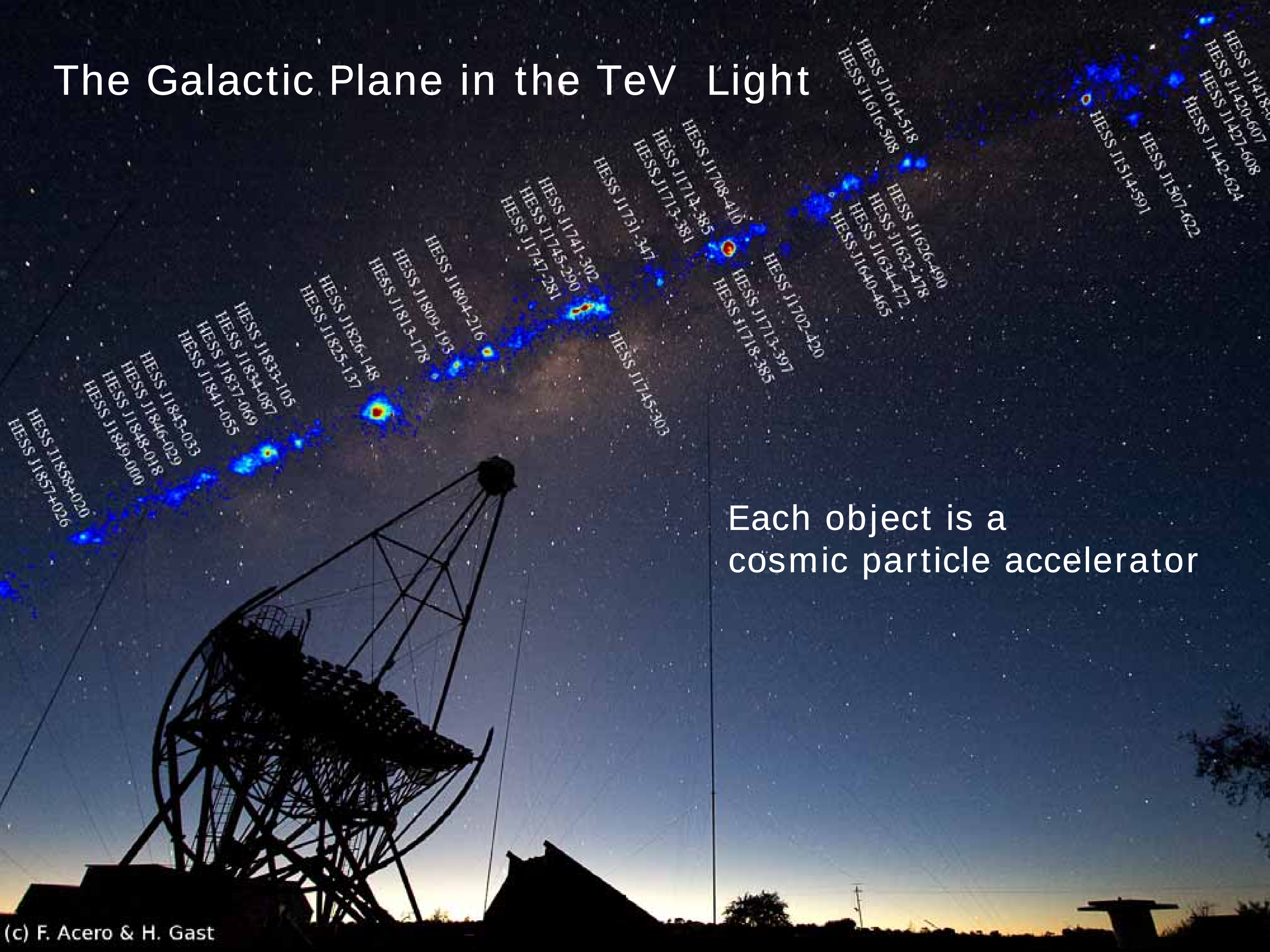


→ Variability on minute timescale from surroundings of SMBH

→ Periodic (33 msec) emission from Crab pulsar up to 400 GeV



The Galactic Plane in the TeV Light



Each object is a
cosmic particle accelerator

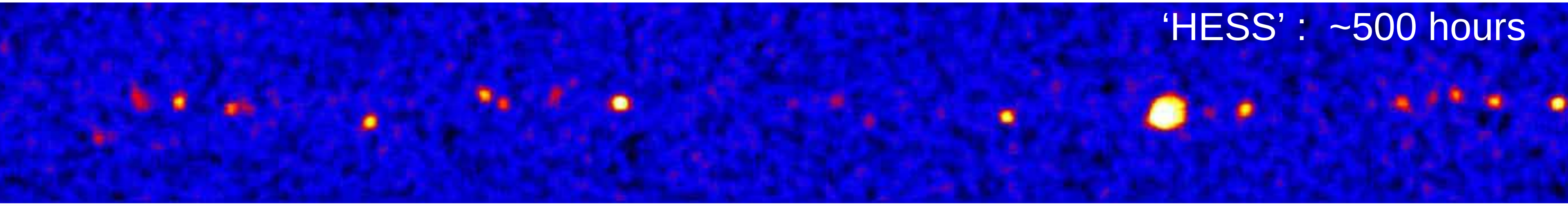
What instrument do we need
to get (much) better ?

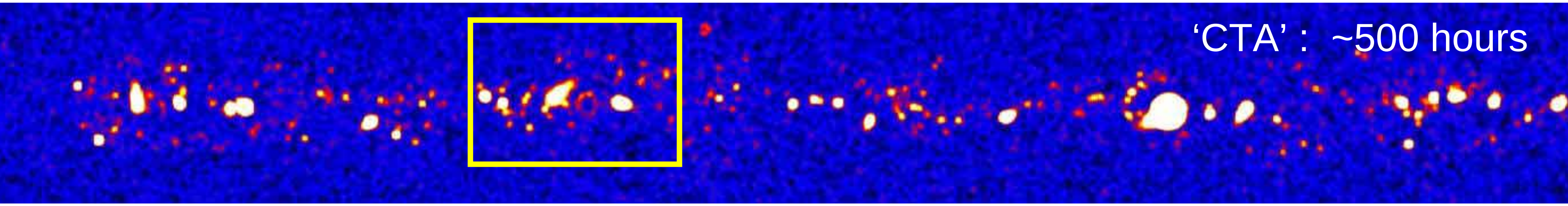
Wish list: x 10 improved sensitivity

Factor 10 improvement in sensitivity in core (TeV) energy regime:

→ Expecting (hoping) for O(1000) sources (galactic + extragalactic)

→ In depth/precision study of individual objects



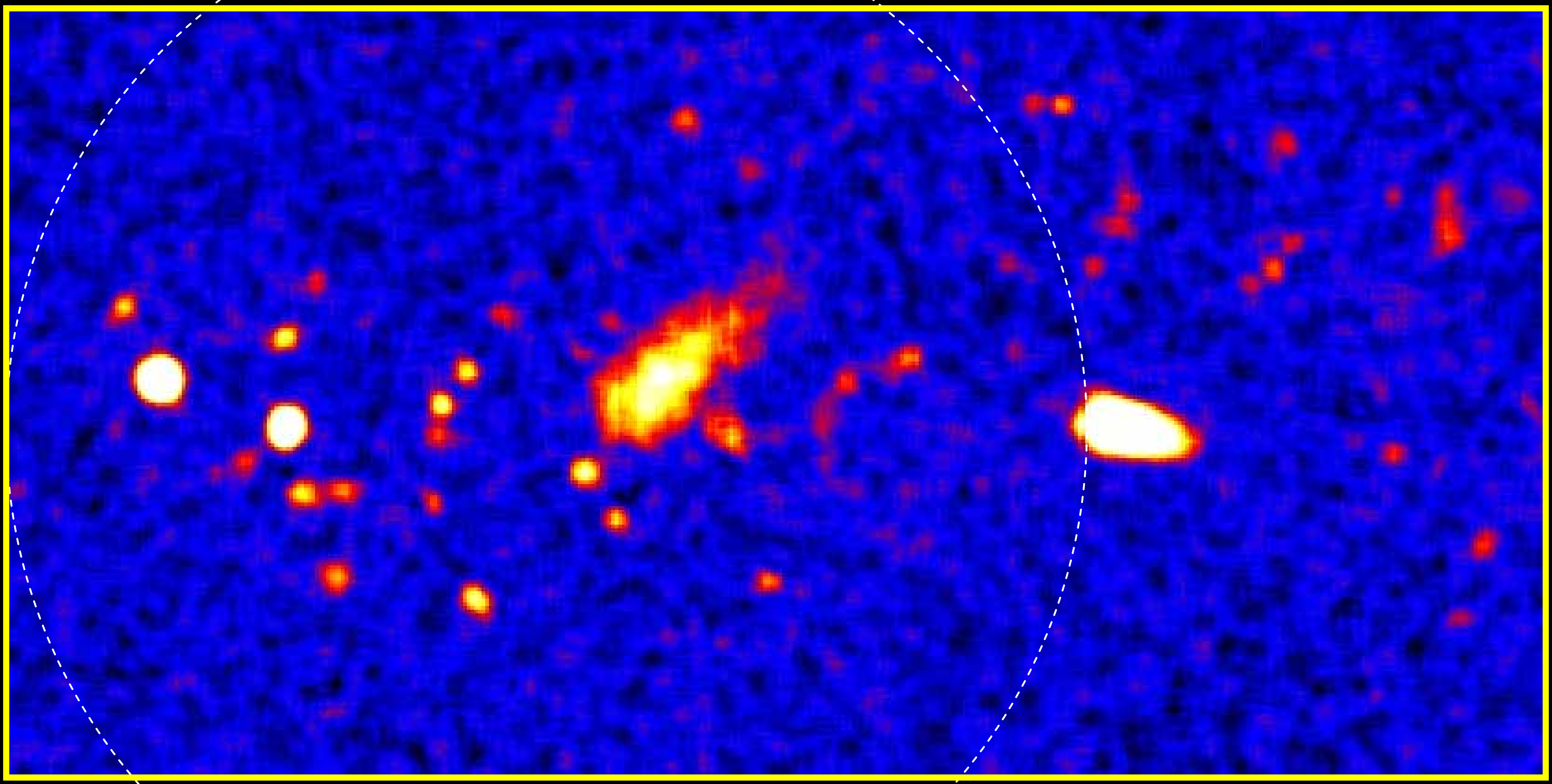


Images of a simulated ‘galactic plane’ with uniform exposure

(GH 2008)

Wish list: x 10 improved sensitivity and better angular resolution

Expecting / hoping for : O(1000) sources (galactic + extragalactic)

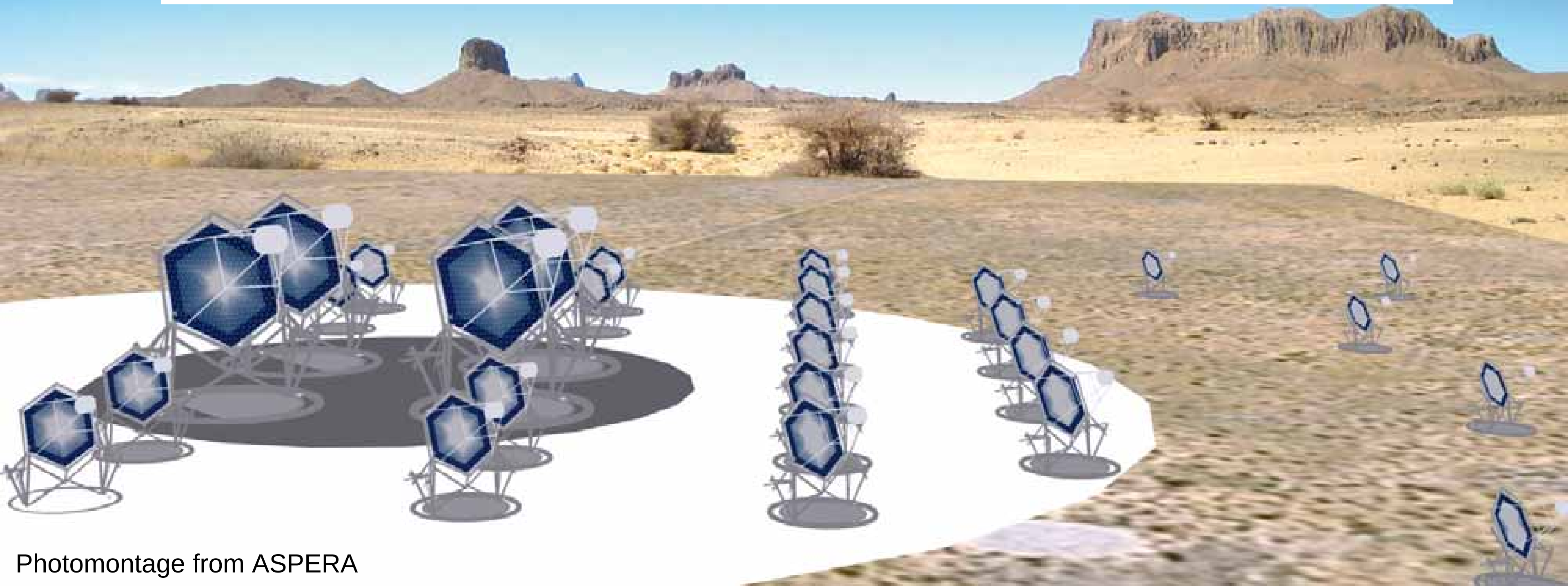


6 deg FoV

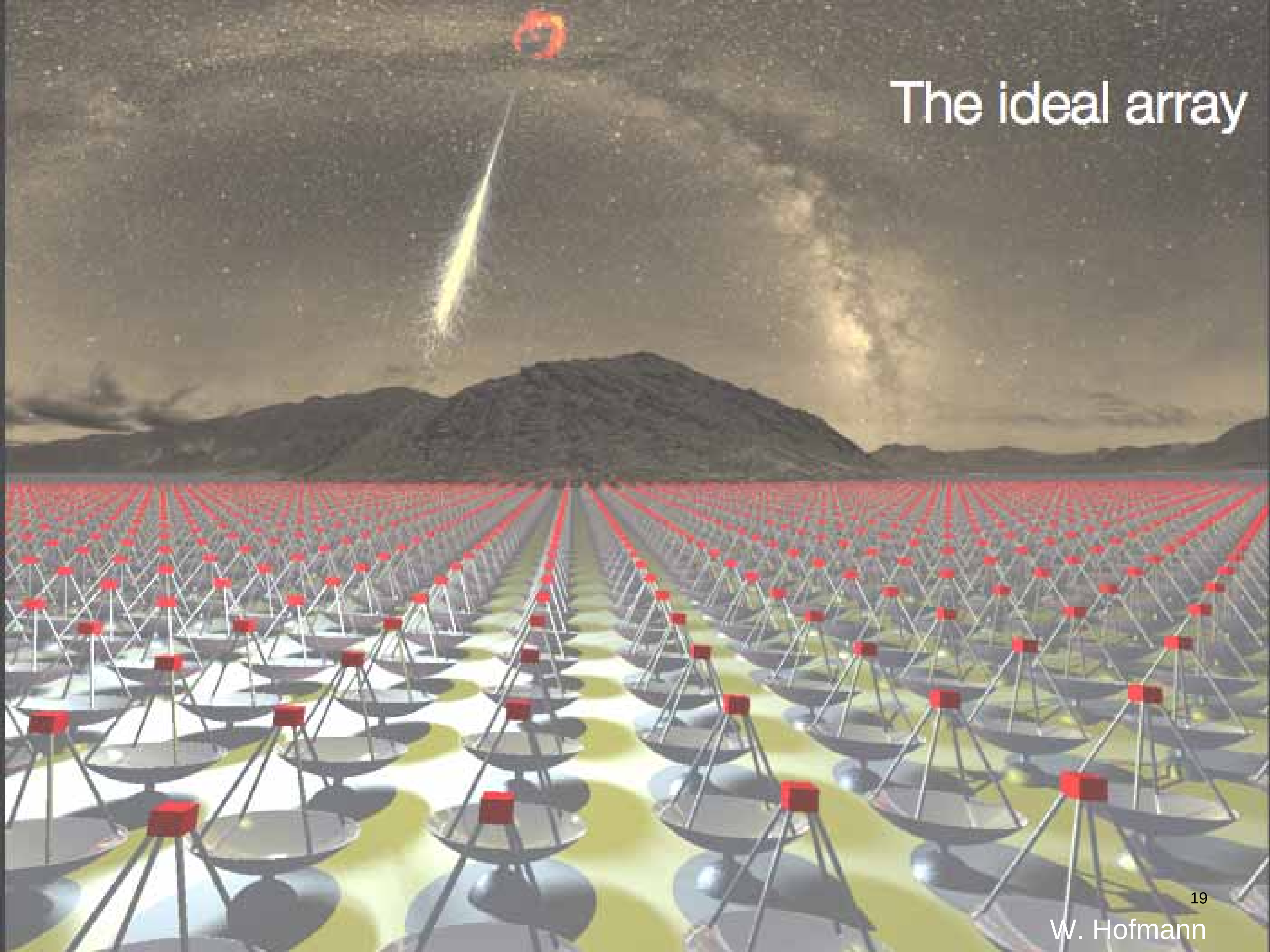
angular resolution: 0.05 deg (> 1TeV)

The Cherenkov Telescope Array *CTA*
→ *Goals*

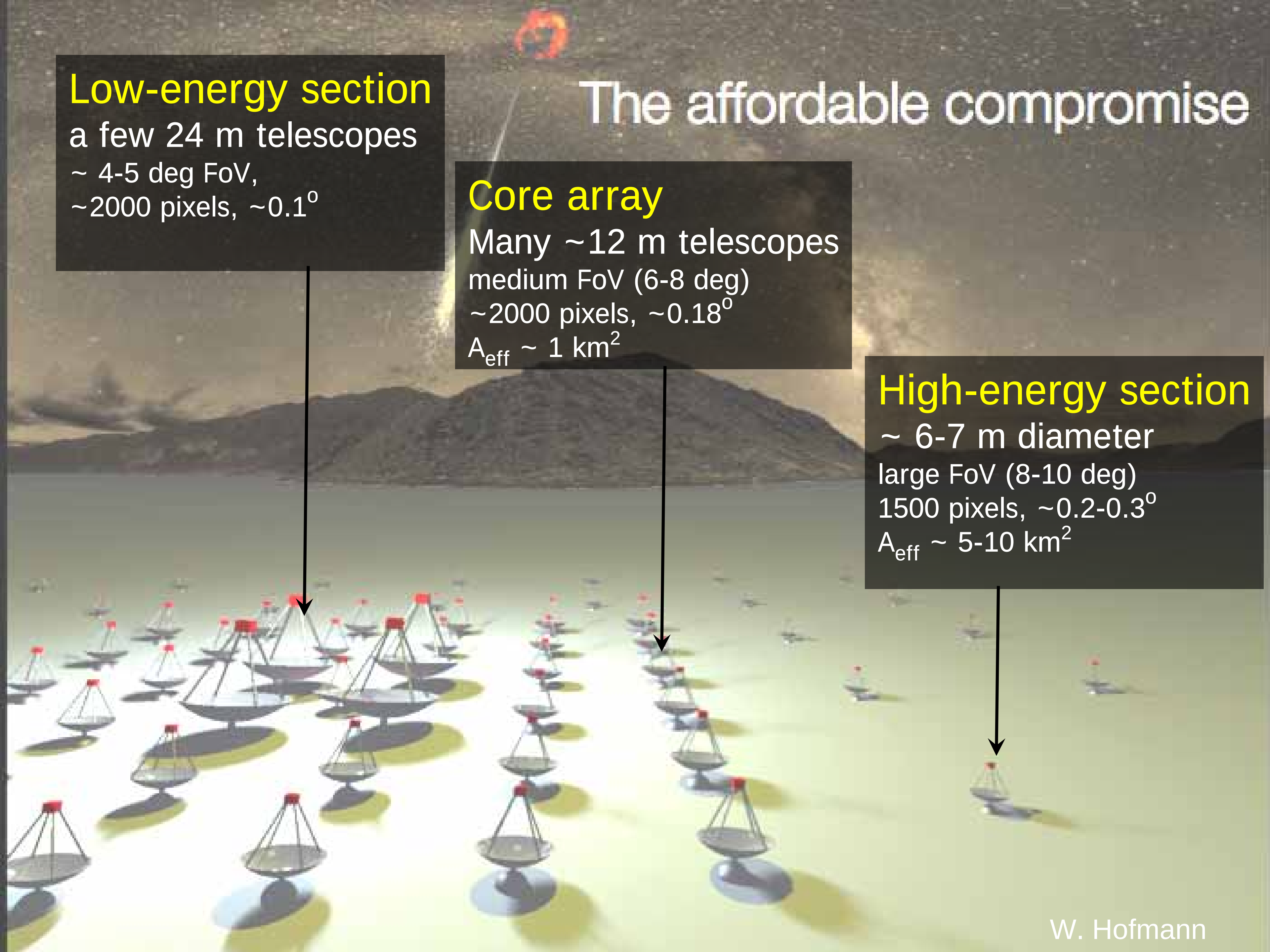
- x10 in sensitivity in the core energy range (about 100 GeV to 10 TeV
- some 10 GeV to several 100 TeV energy range
- Gamma-hadron discrimination
- Angular resolution
- Energy resolution
- Field of view for gamma-rays
- Full sky coverage, through sites on both hemispheres



Photomontage from ASPERA


The ideal array
W. Hofmann

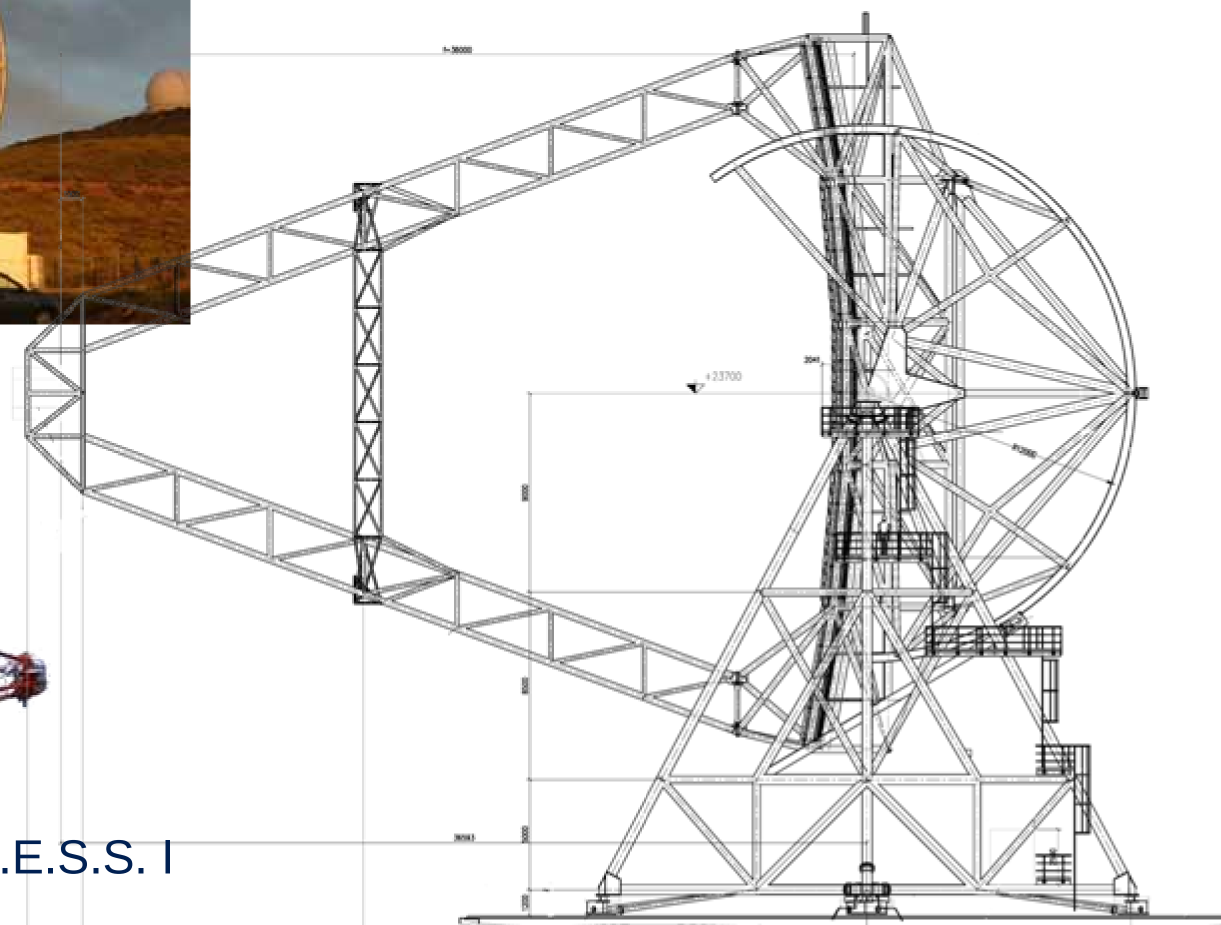

The affordable compromise
W. Hofmann


The affordable compromise
Low-energy section
a few 24 m telescopes
~ 4-5 deg FoV,
~2000 pixels, ~0.1°
Core array
Many ~12 m telescopes
medium FoV (6-8 deg)
~2000 pixels, ~0.18°
A_eff ~ 1 km²
High-energy section
~ 6-7 m diameter
large FoV (8-10 deg)
1500 pixels, ~0.2-0.3°
A_eff ~ 5-10 km²
W. Hofmann

We (believe to) know, how to build telescopes …

MAGIC

H.E.S.S. II (under construction)



H.E.S.S. I

… but …

- **Current telescopes not optimized for large-scale production**
  - Cost would exceed target cost (150 M€ as of 2006) by factor 1.5 to 2
  - Instrument reliability needs to be improved / built-in
- We believe **we can built even better / more efficient telescopes**
  - wider field of view
  - improved photo sensors
  - improved electronics signal recording
  - overall optimized array layout
- Need to develop tools to **operate a user facility** and to provide effective data access
  - Observation scheduling and system control
  - Science data center and data access tools

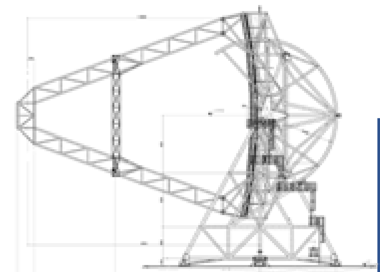
... and there are ‘a few’ challenges ...

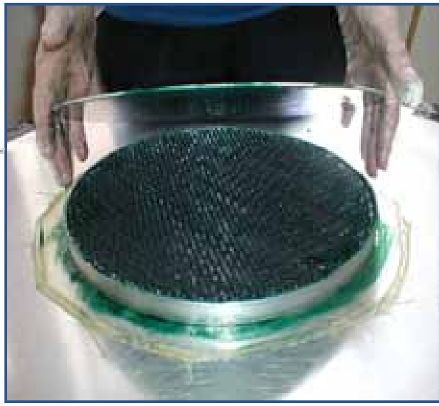
Will need
- O(50-100) telescopes, core array
- O(10000) m^2 mirror area
- O(70) m^2 photo sensitive area
- O(100k) electronics channels

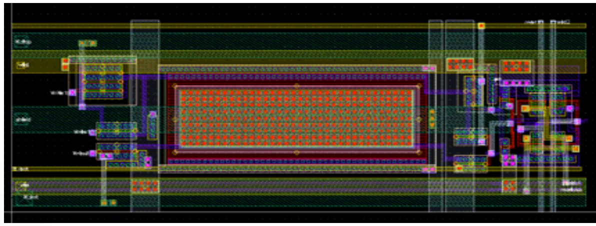
→ Factor of 10 in sensitivity
with only factor of 10 in M€

Find an optimized array layout
that has the required performance

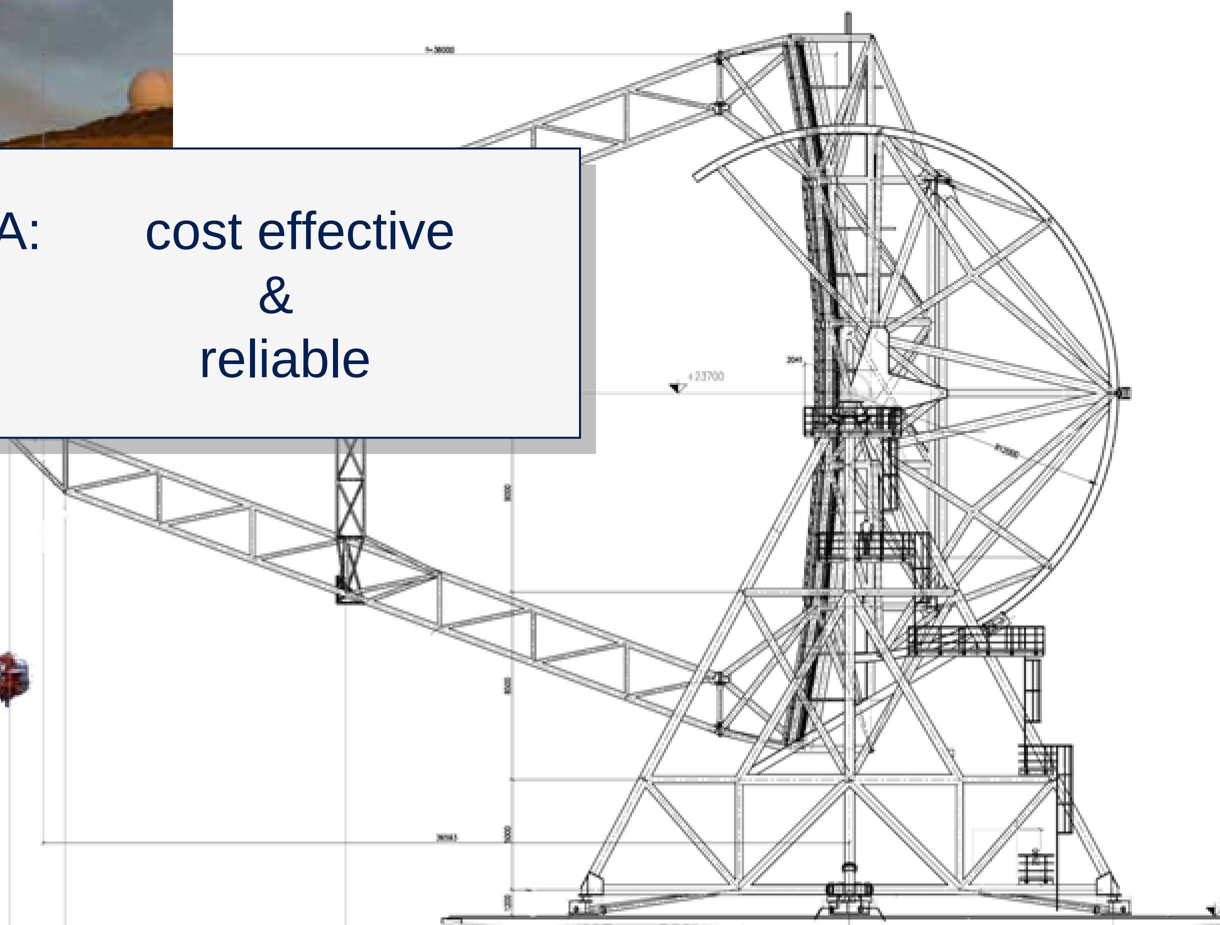
Optimize design for effective production /
commissioning, and for
stability and high reliability





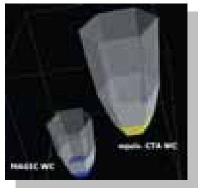


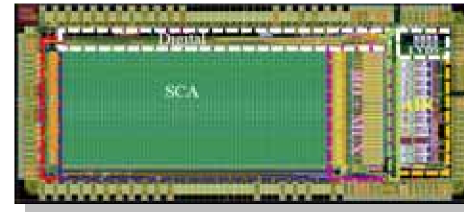
... and there are ‘a few’ challenges ...

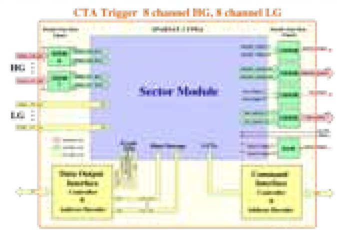


CTA: cost effective
&
reliable

CTA Design Study: 2007 – 2010
many R&D projects







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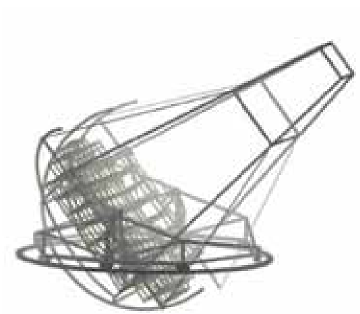
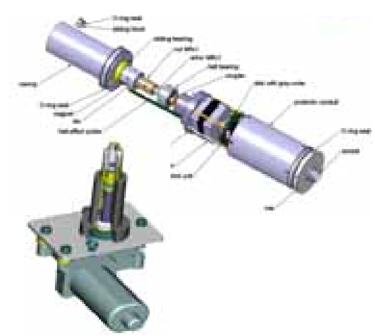
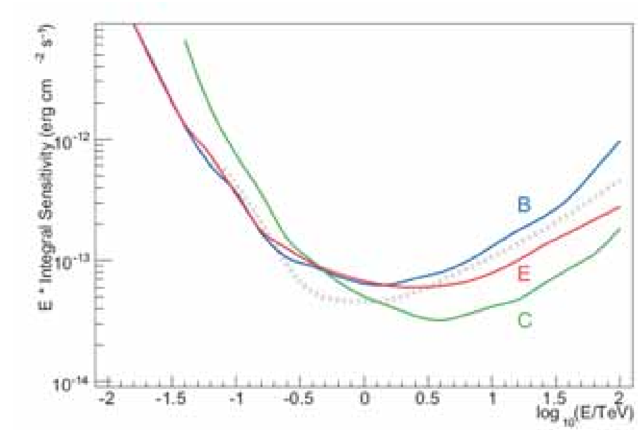
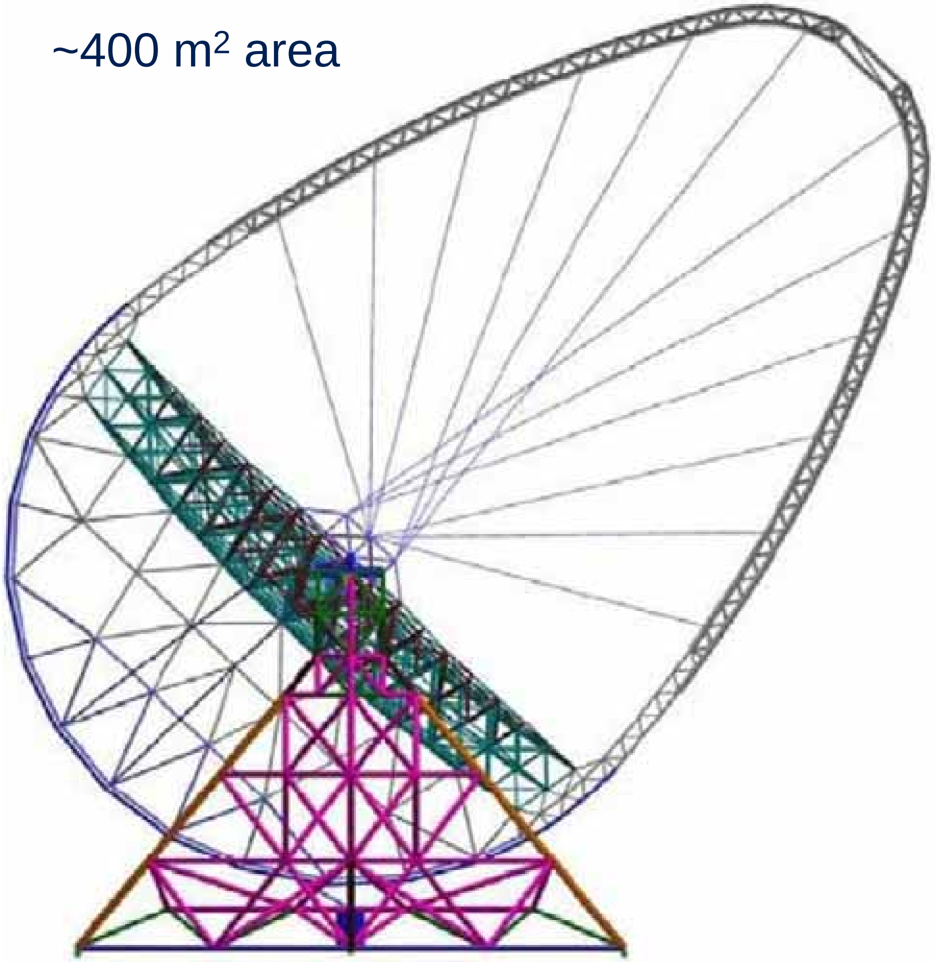




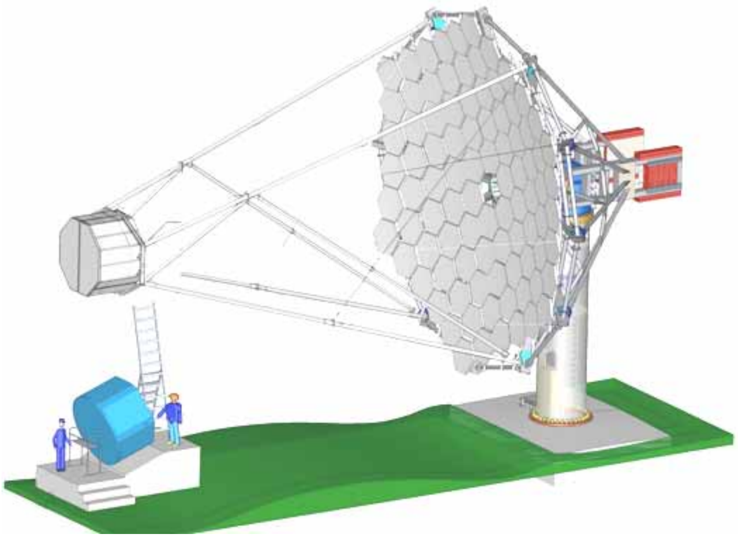


CTA Preparatory Phase: 2010 – 2013 prototyping

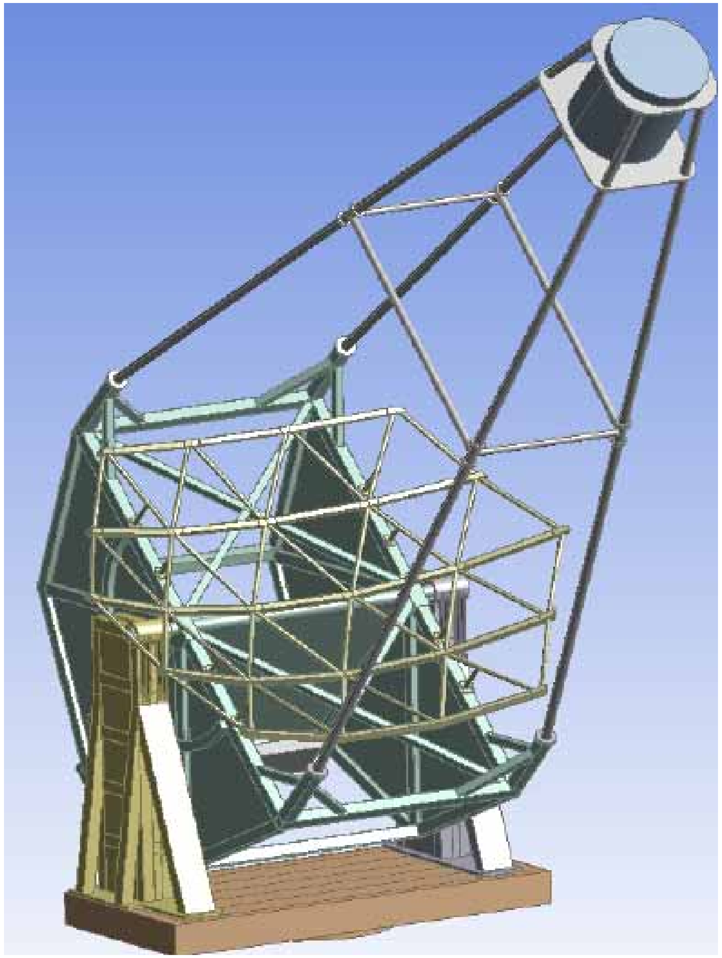
~400 m² area



~100 m² area



CTA Preparatory Phase: 2010 – 2013 prototyping



~30 m^2 area

~10 m^2 area

Mirrors for CTA

Mirrors for CTA: ‘requirements’

- CTA will have O(10000) m^2 mirror area
- Mirrors will be exposed to rough environment
- Lifetime of > 10 (>20) years required; < 1 % refl. loss/yr (wish) ; ideally no recoating

+ Optical quality : these are not astronomical mirrors !
  The total reflectance shall exceed 85% with respect to the amount of light incident onto the mirror surface for 300–600 nm
+ Optical PSF:
  80 % containment in 0.5 …. 1 mrad

→ cheapest possible technology

Mirrors for CTA: technologies

Slumping technologies (cold and hot):

glass on substrate (Al honeycomb, ‘foam’, tubes …)

All aluminum mirrors:

diamond milling

Glass mirrors

SMC: “sheet moulding compound” technology

carbon fibre/epoxy compound

→ see presentations

Coating for CTA mirrors

wavelength range: 300 – 600 nm

Al natural choice as reflective material

but: mirrors exposed to environment all the time

→ protective coatings needed!

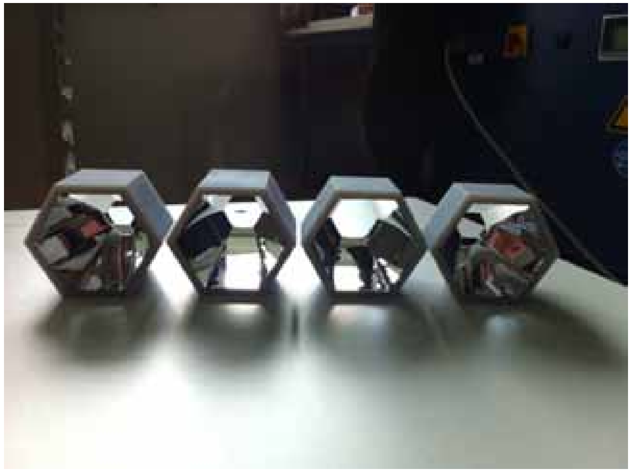
standard: SiO_2 (H.E.S.S.) or Al_2O_3 (Veritas)

Alternative coatings under development / test

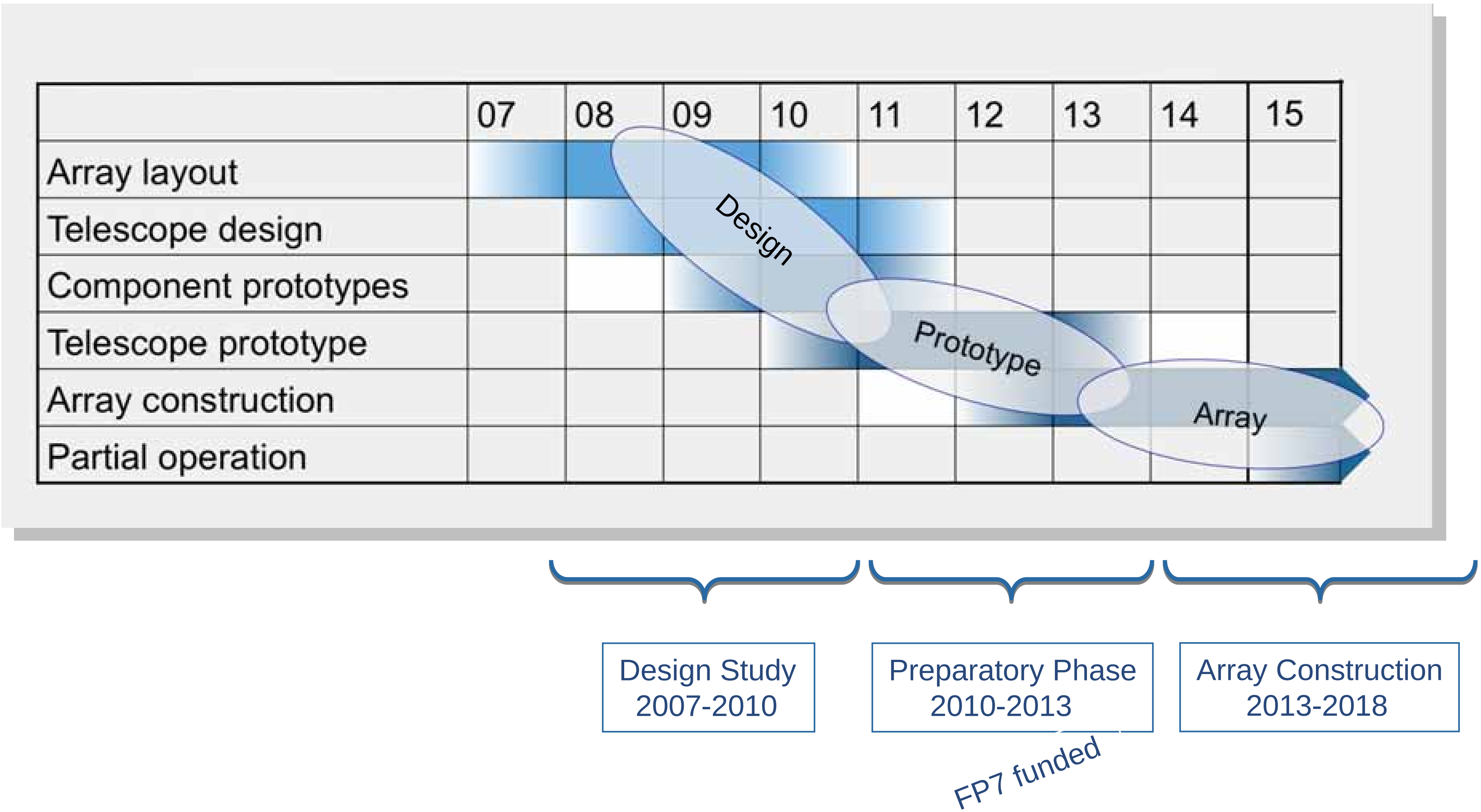
→ see presentations

Reflective light guides for cameras

CTA will need up to ~ 100 000 light guides from hexagonal entrance window to PMT cathode window

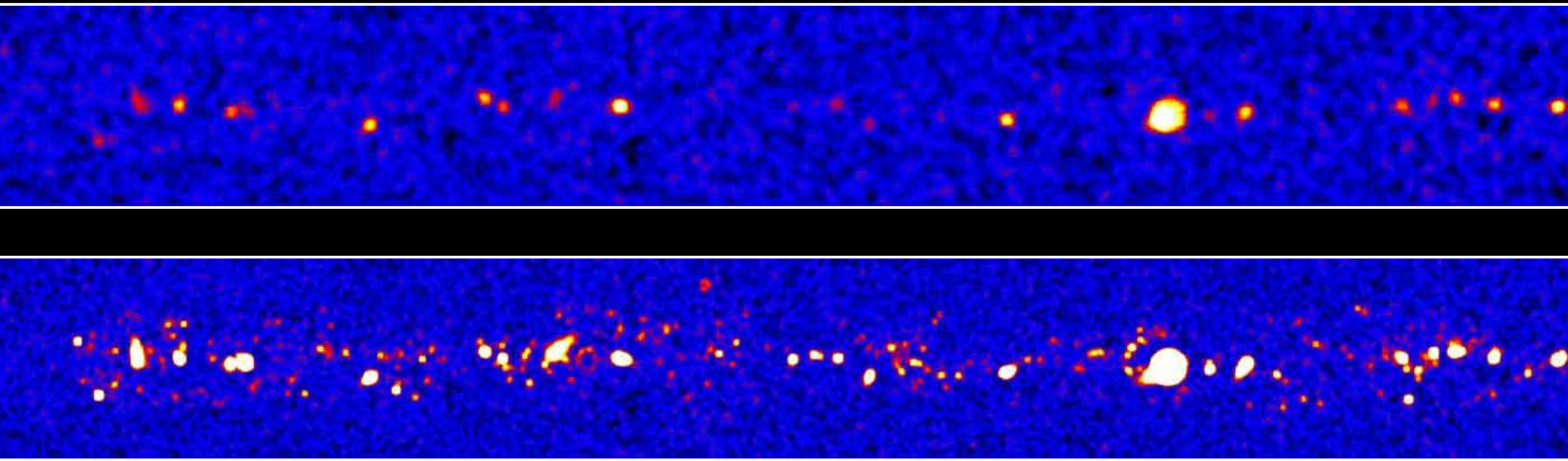


Tentative Timeline for development & production



Ground-based gamma-ray astronomy now and in 2020

2007



2020