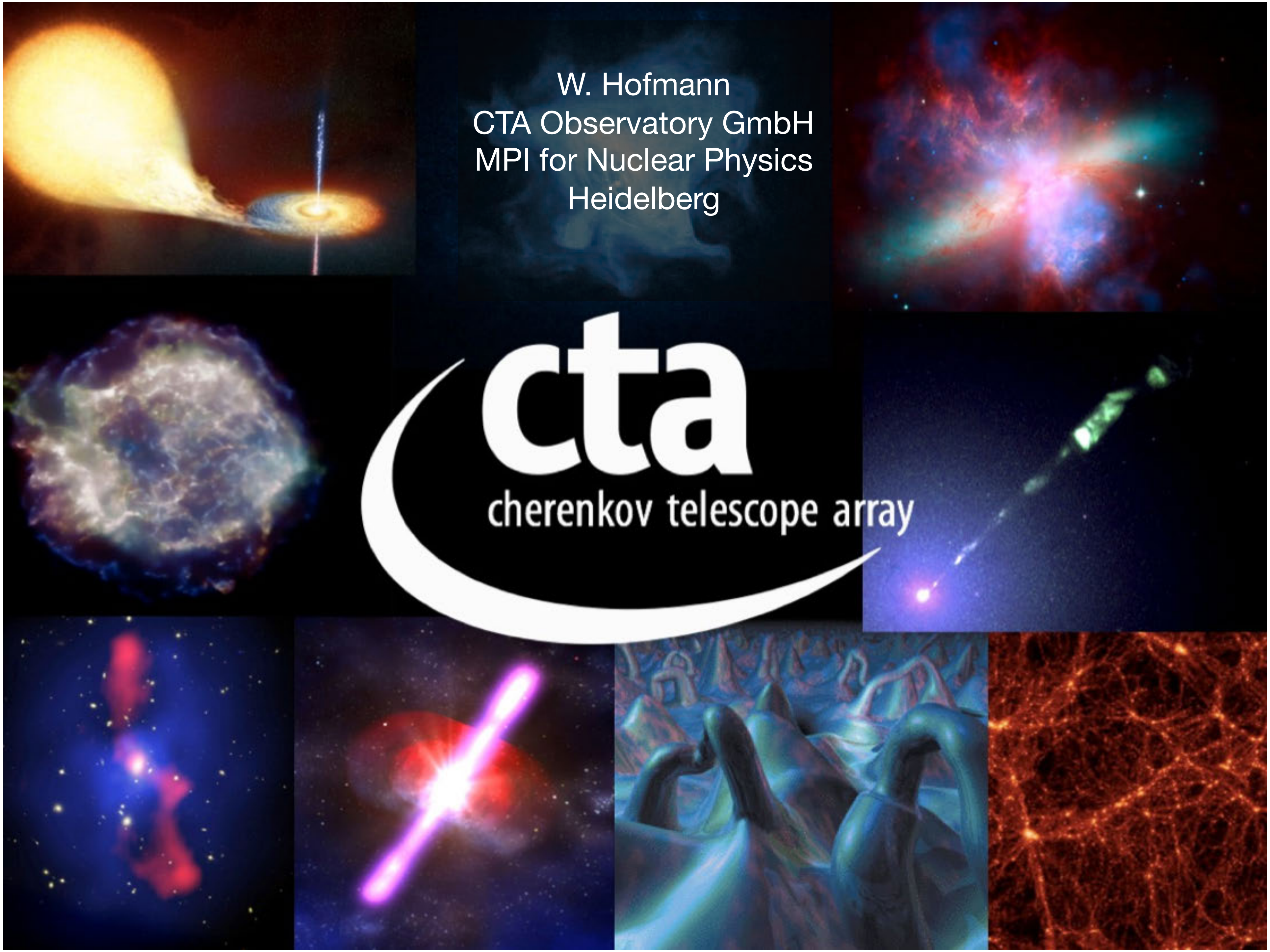
W. Hofmann
CTA Observatory GmbH
MPI for Nuclear Physics
Heidelberg

cta
cherenkov telescope array

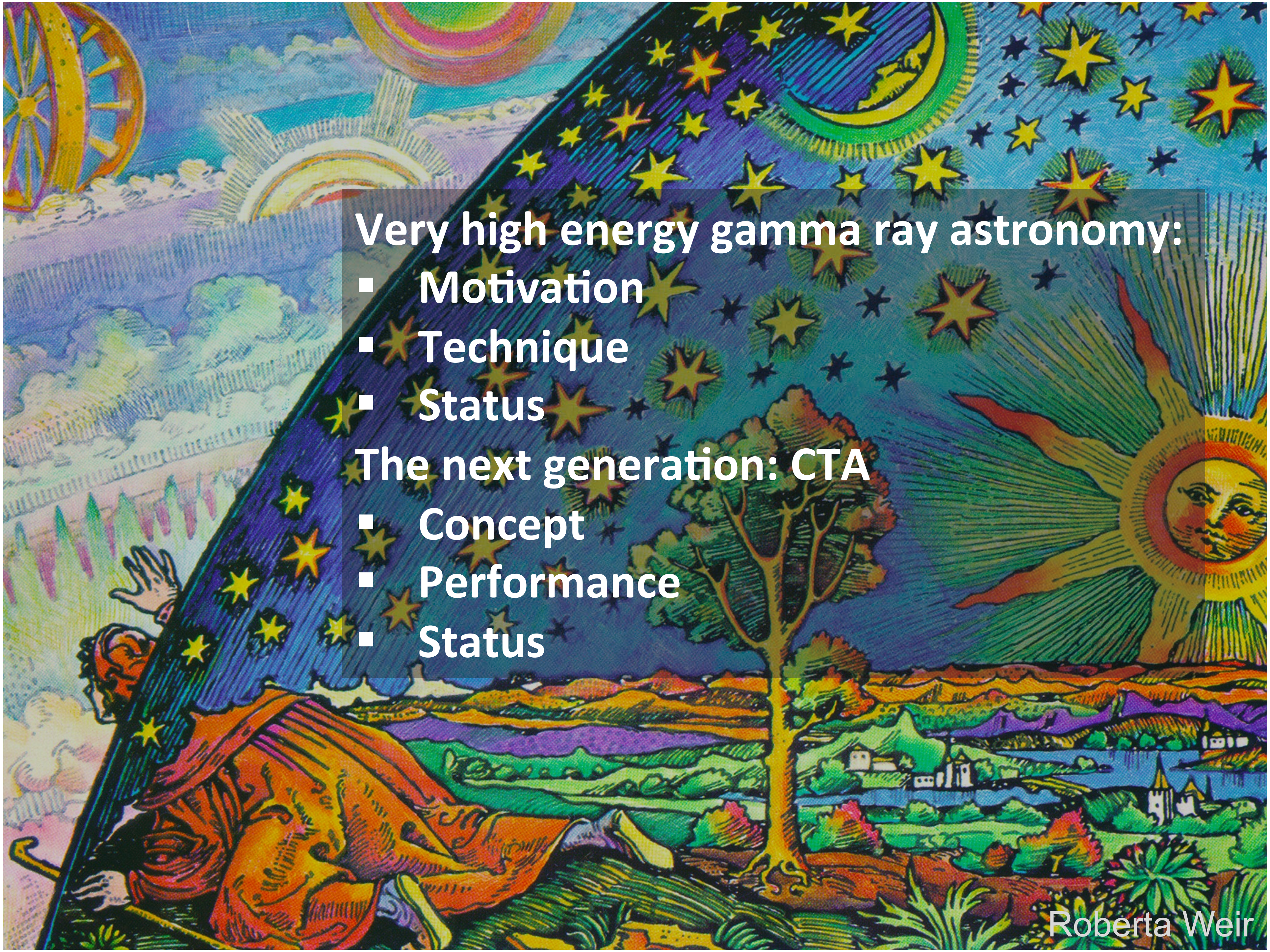


Very high energy gamma ray astronomy:

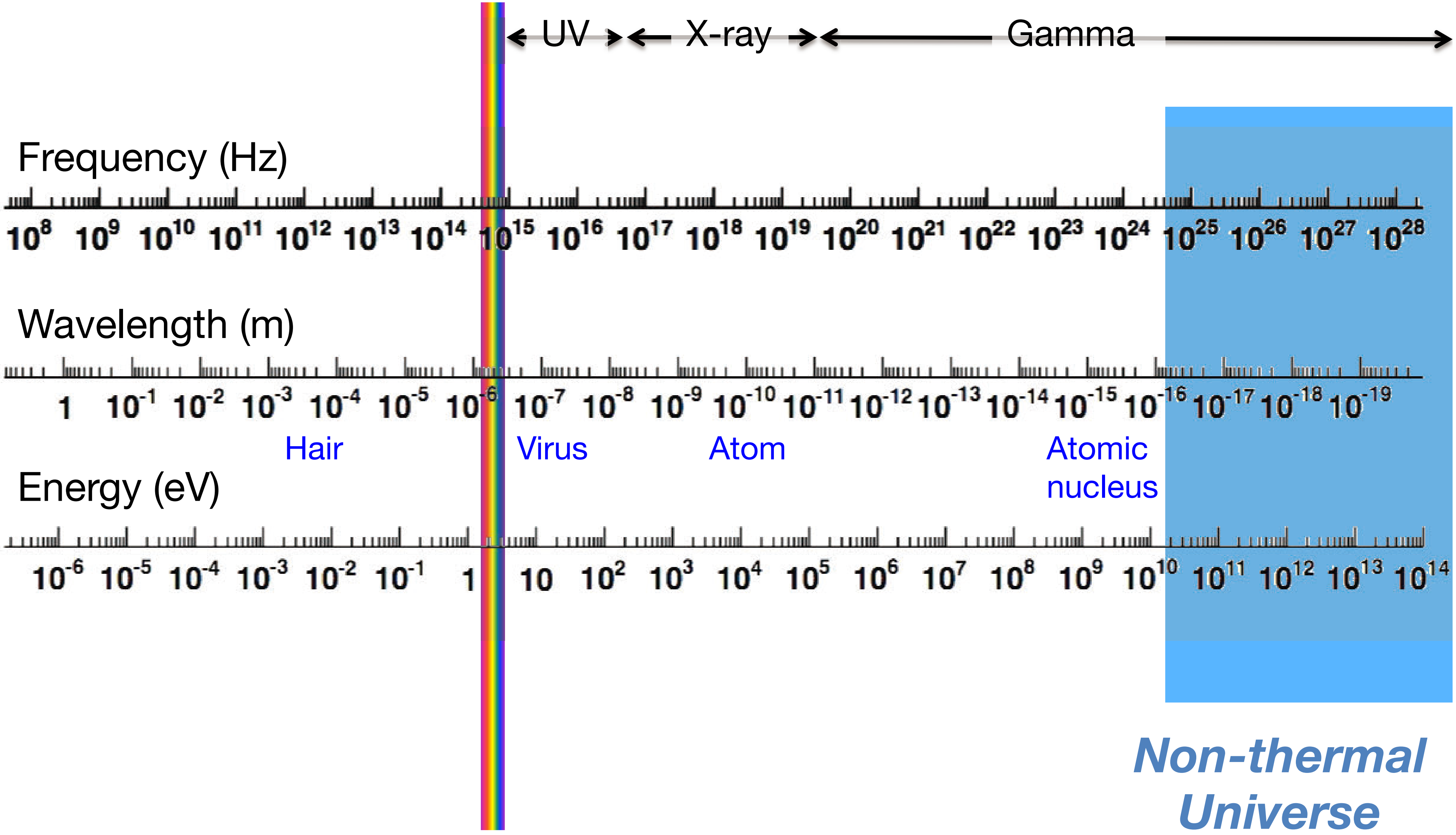
- Motivation
- Technique
- Status

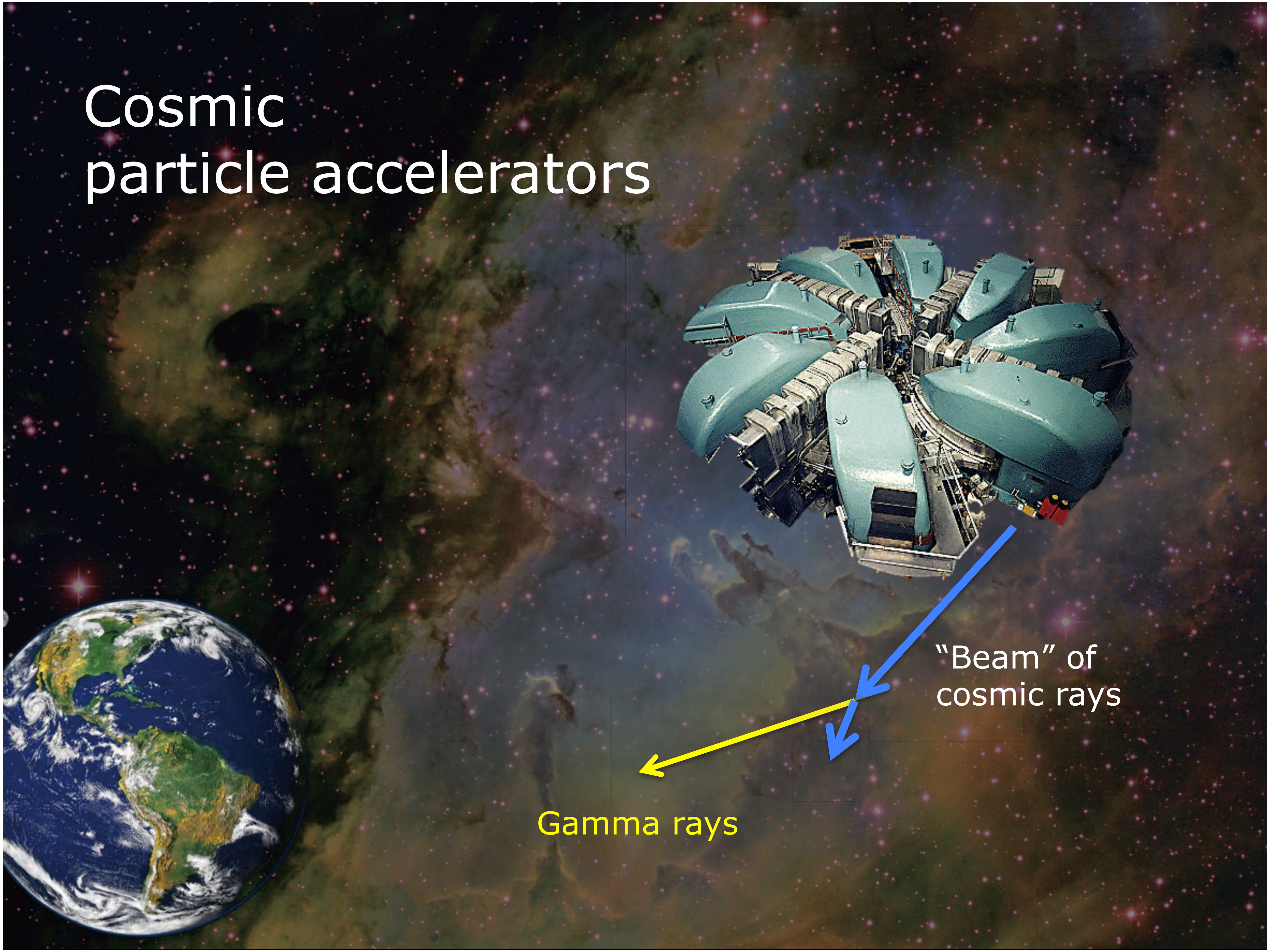
The next generation: CTA

- Concept
- Performance
- Status



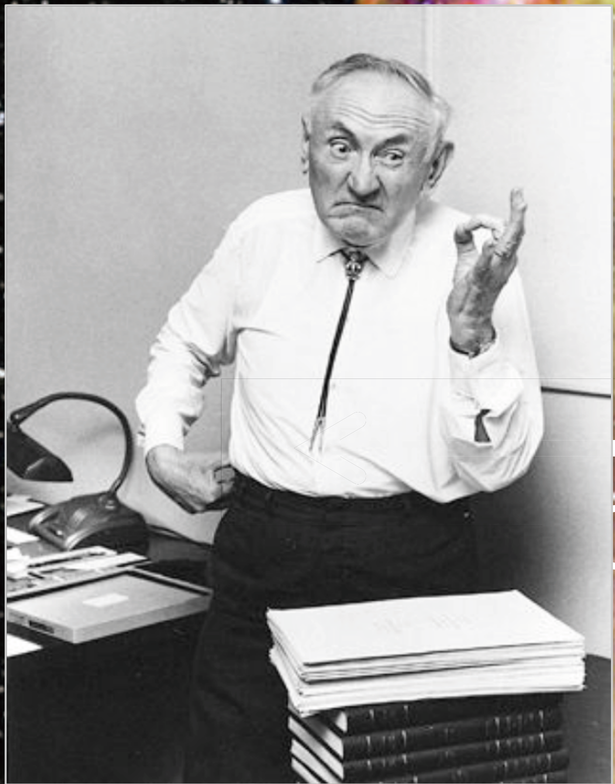
FREQUENCY, WAVELENGTH, ENERGY



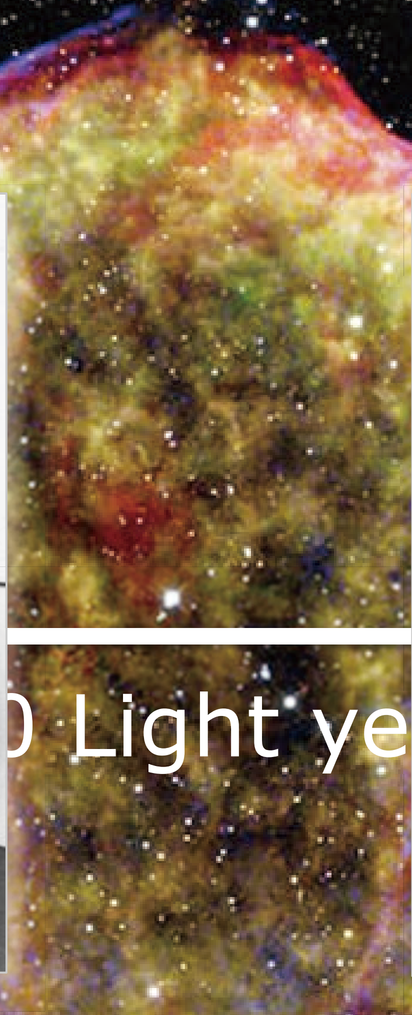

Cosmic
particle accelerators
"Beam" of
cosmic rays
Gamma rays

Supernovae as cosmic accelerators

Zwicky 1933

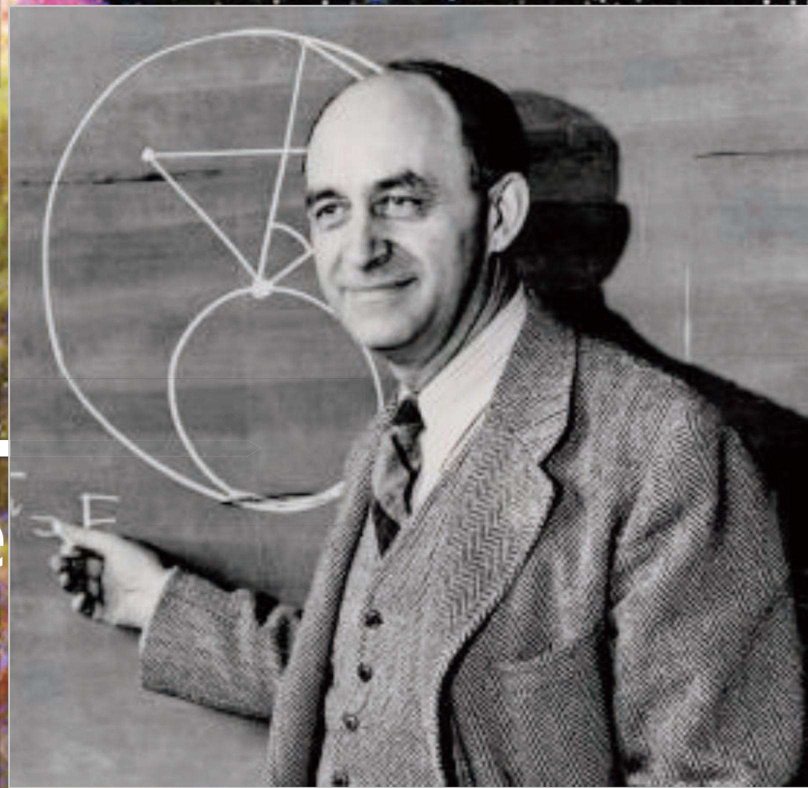


Sufficient power source



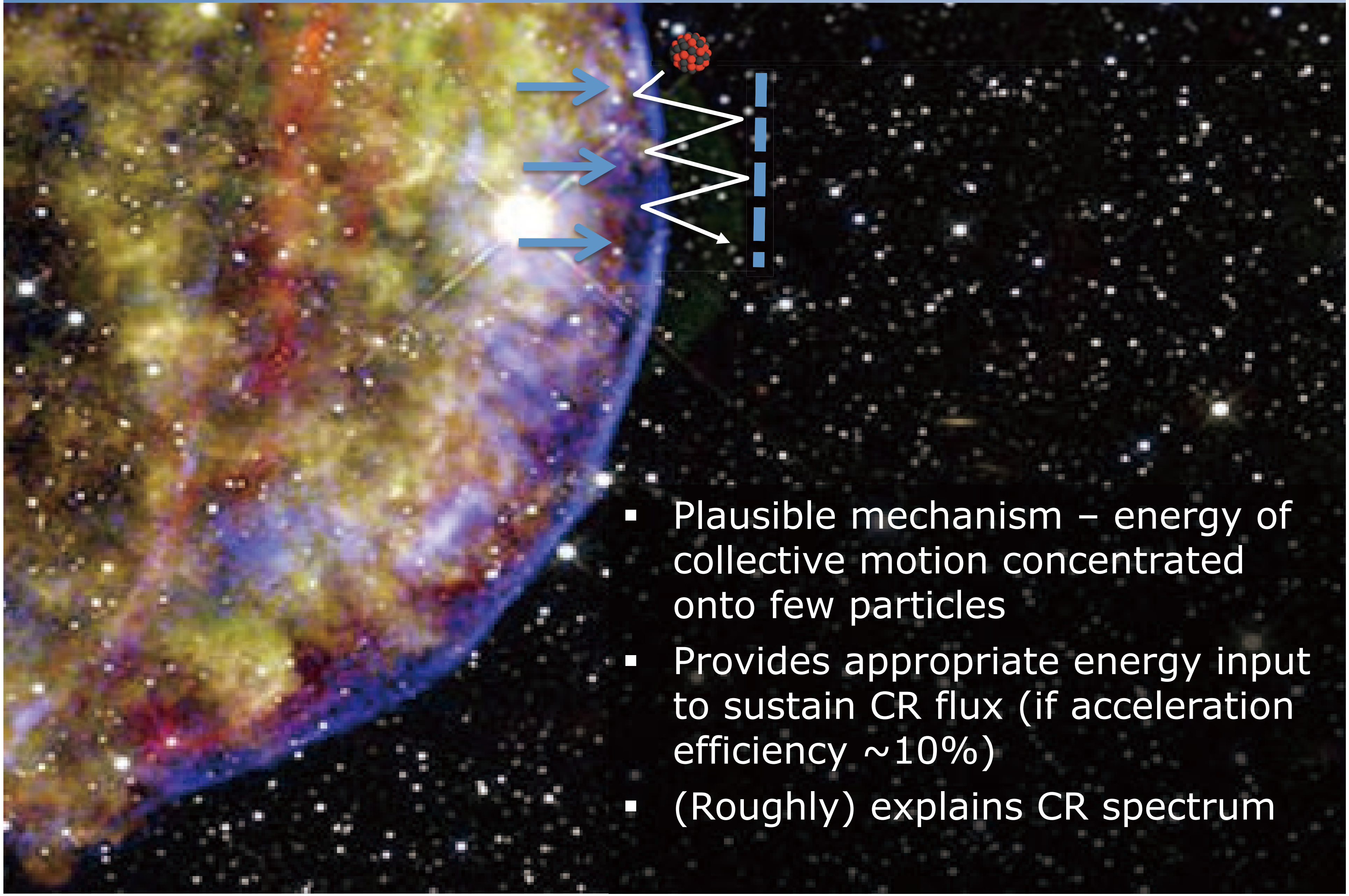
Tychos Supernova of 1572

Fermi 1949

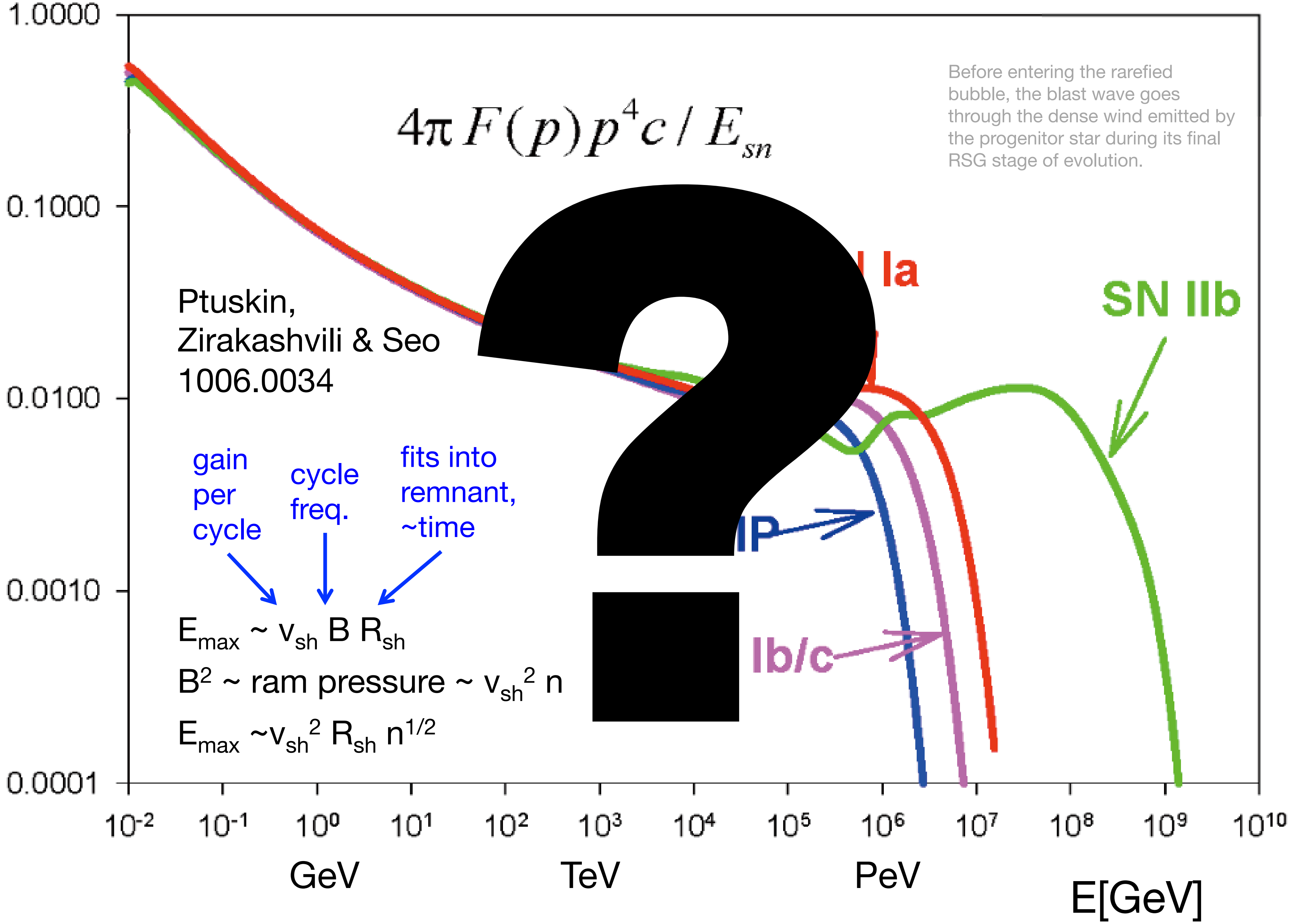


Acceleration mechanism

FERMI ACCELERATION IN SNR



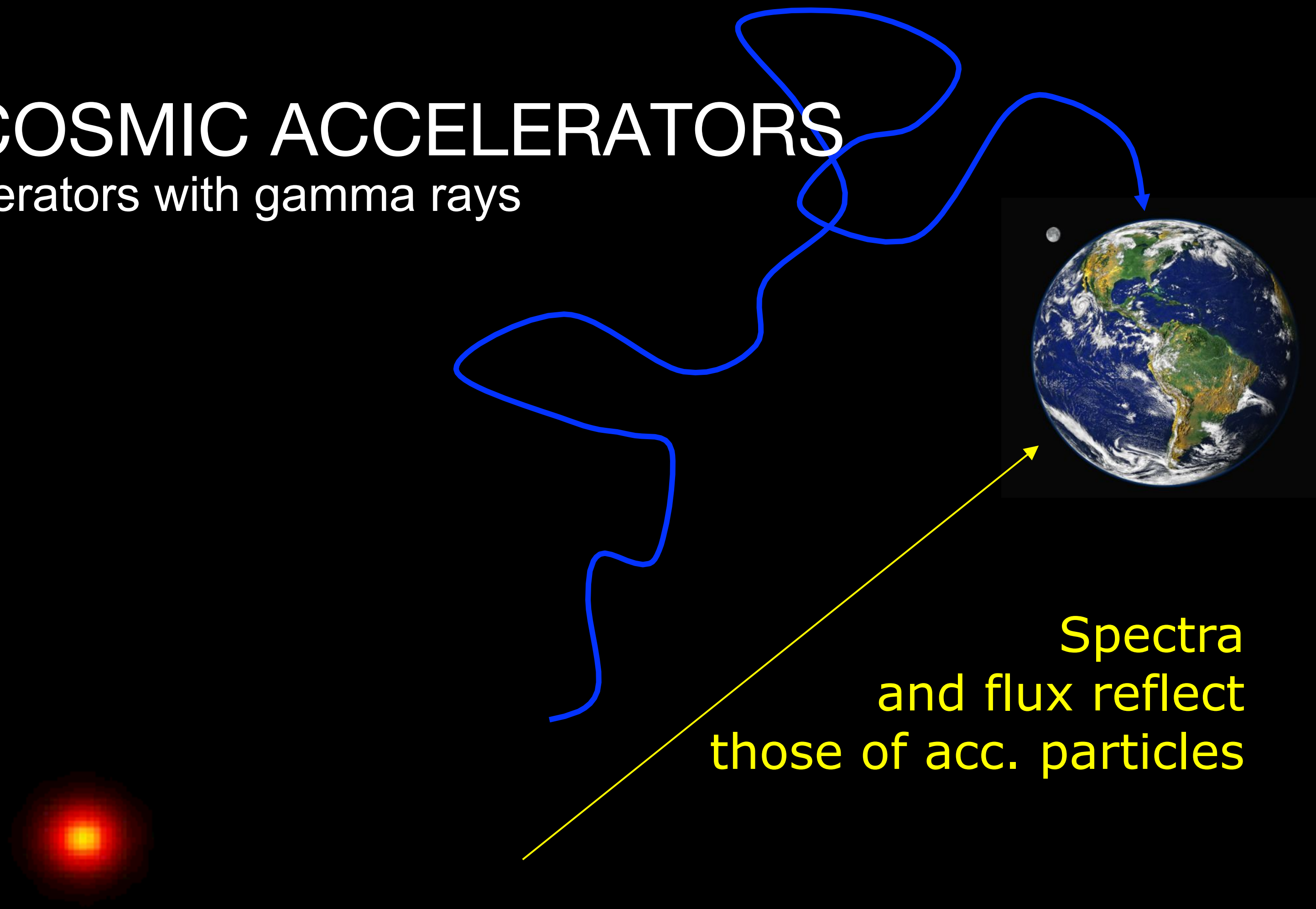
- Plausible mechanism – energy of collective motion concentrated onto few particles
- Provides appropriate energy input to sustain CR flux (if acceleration efficiency ~10%)
- (Roughly) explains CR spectrum



1.0000
0.1000
0.0100
0.0010
0.0001
$4\pi F(p) p^4 c / E_{sn}$
Before entering the rarefied bubble, the blast wave goes through the dense wind emitted by the progenitor star during its final RSG stage of evolution.
Ia
SN IIb
Ptuskin,
Zirakashvili & Seo
1006.0034
gain per cycle
cycle freq.
fits into remnant, ~time
$E_{max} \sim v_{sh}\ B\ R_{sh}$
$B^2 \sim$ ram pressure $\sim v_{sh}^2\ n$
$E_{max} \sim v_{sh}^2\ R_{sh}\ n^{1/2}$
IP
Ib/c
10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10}
GeV
TeV
PeV
E[GeV]

SEEING COSMIC ACCELERATORS

➔ Image accelerators with gamma rays

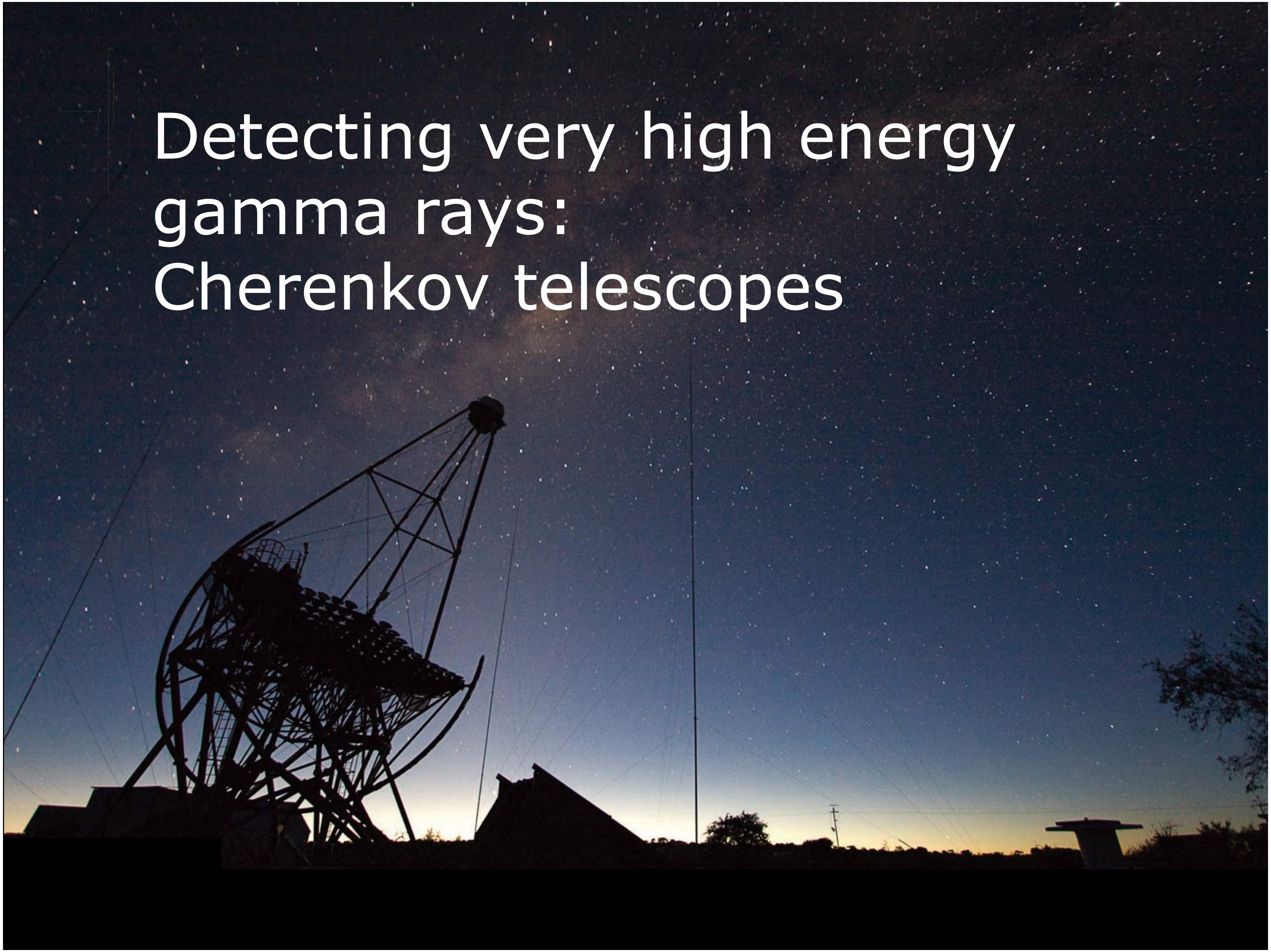


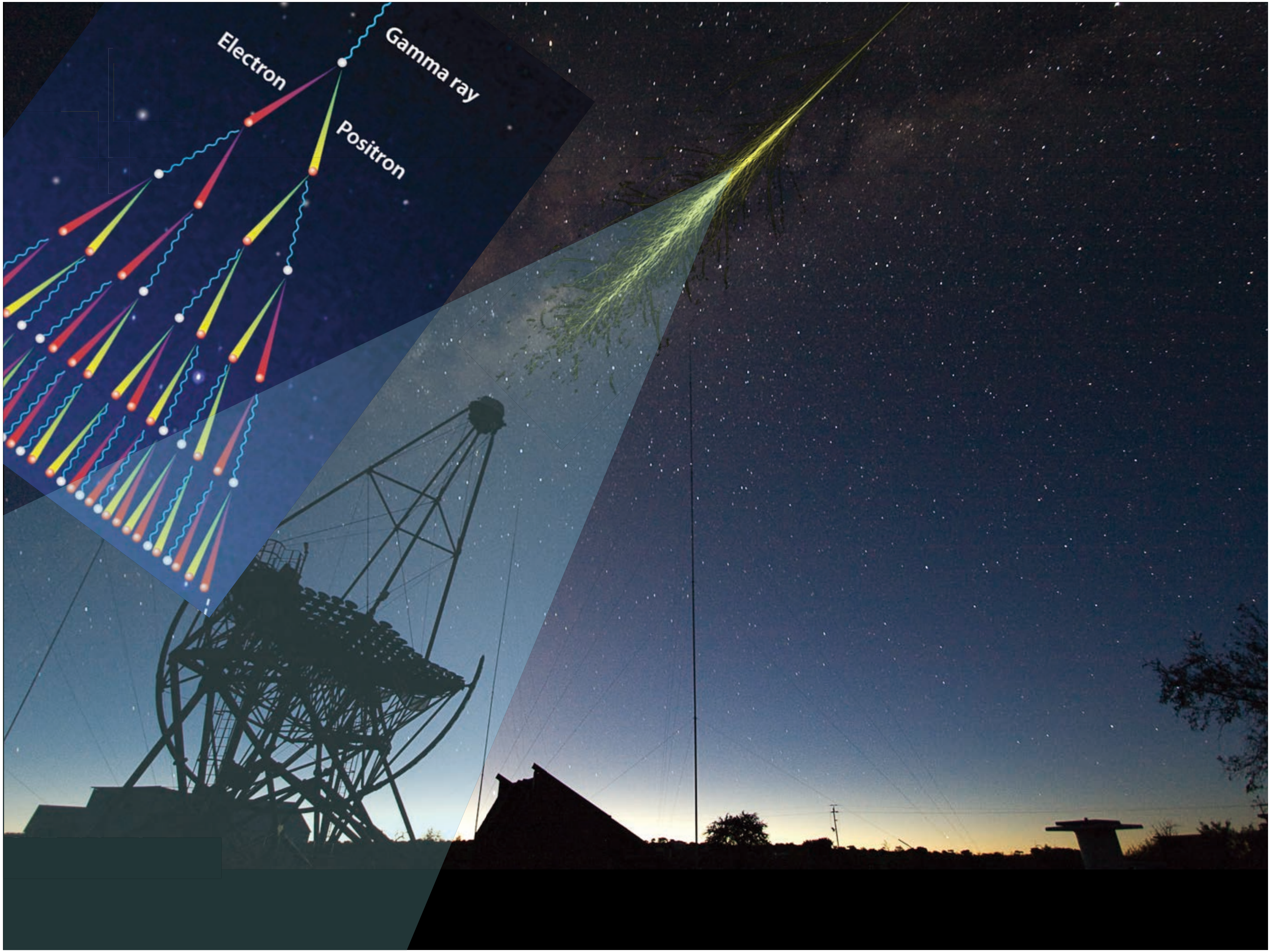
$p + \text{nucleus} \rightarrow \pi + X$

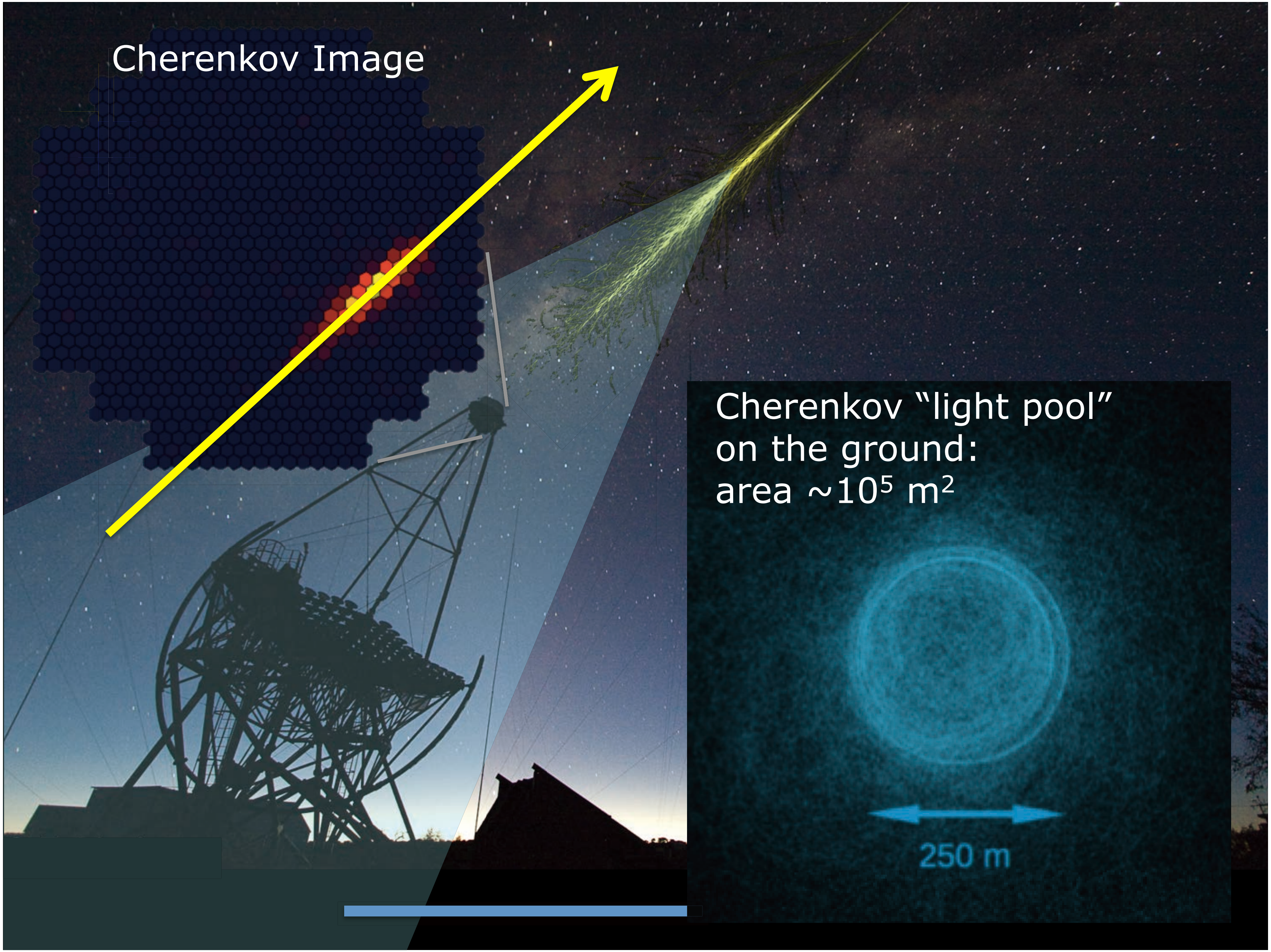
$\pi^{o} \rightarrow \gamma\gamma$

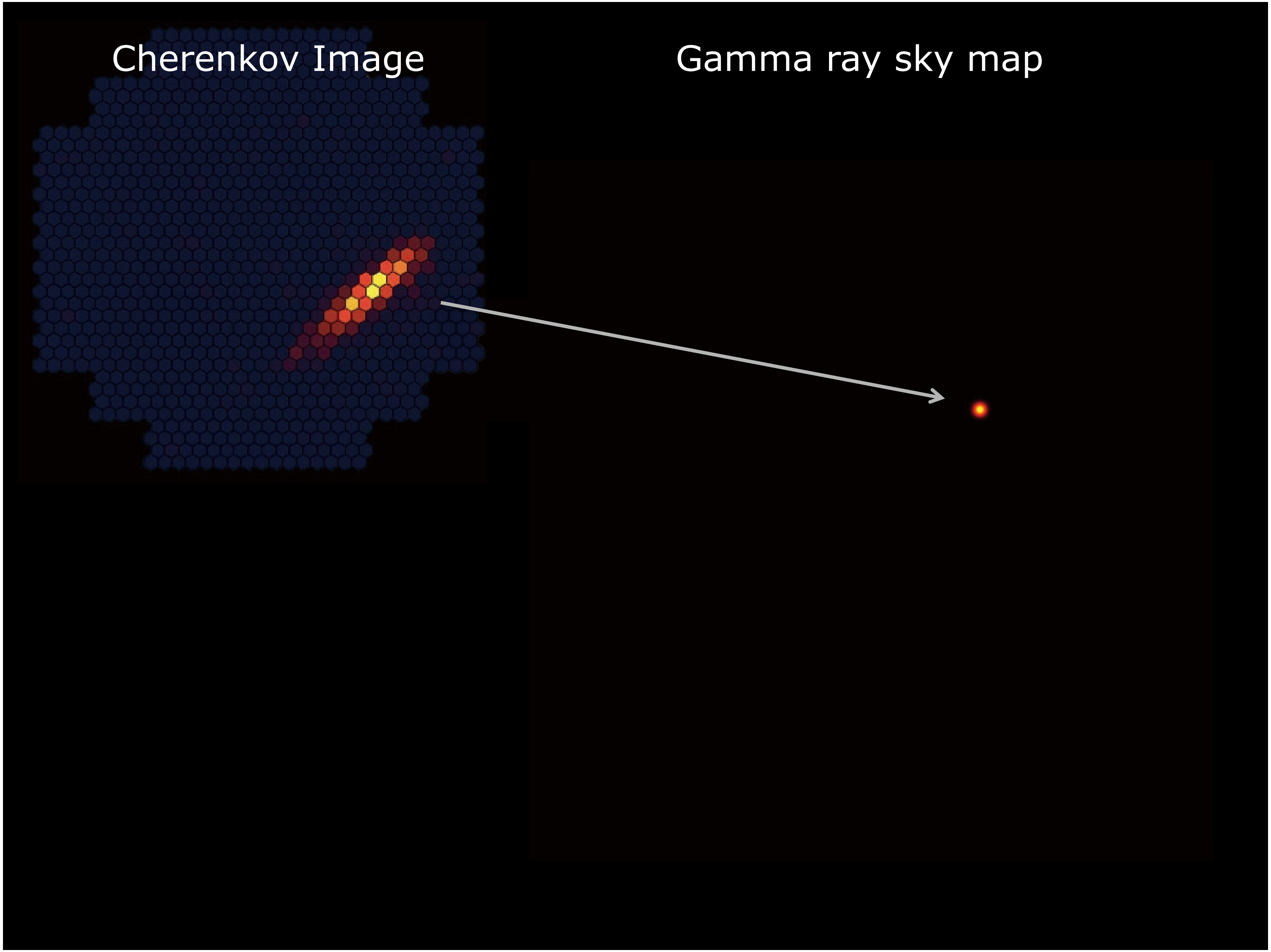
$\pi^{\pm} \rightarrow \mu^{\pm}\,\nu$


"Gamma ray astronomy traces the
energy skeleton of the Universe"


Detecting very high energy
gamma rays:
Cherenkov telescopes


Electron
Gamma ray
Positron


Cherenkov Image
Cherenkov "light pool"
on the ground:
area ~10⁵ m²
250 m

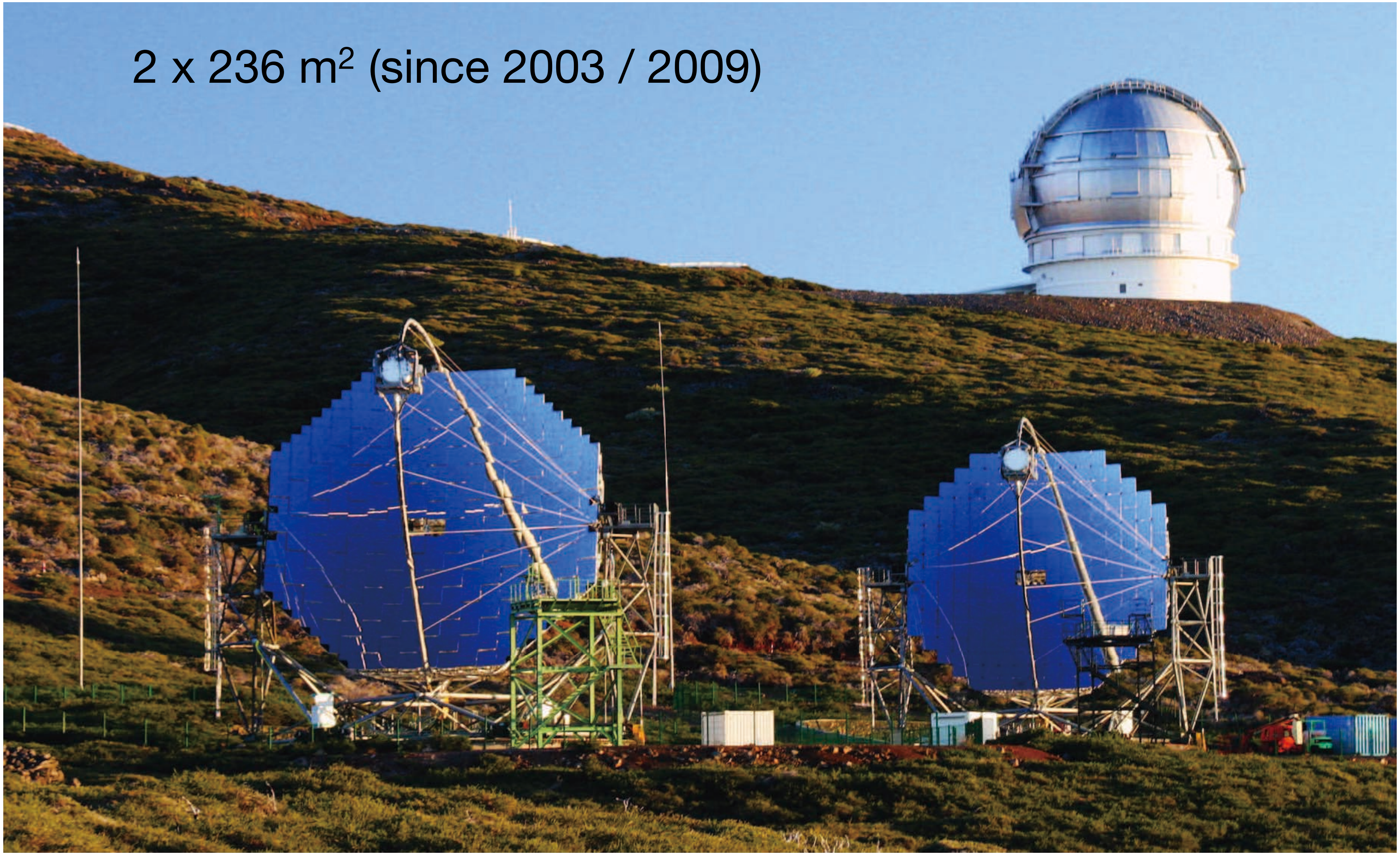

Cherenkov Image
Gamma ray sky map

H.E.S.S TELESCOPES (NAMIBIA)

4 x 108 m^2 (since 2003)
1 x 614 m^2 (since 2012)

MAGIC TELESCOPES (LA PALMA)

2 x 236 m^2 (since 2003 / 2009)



VERITAS TELESCOPES (ARIZONA)

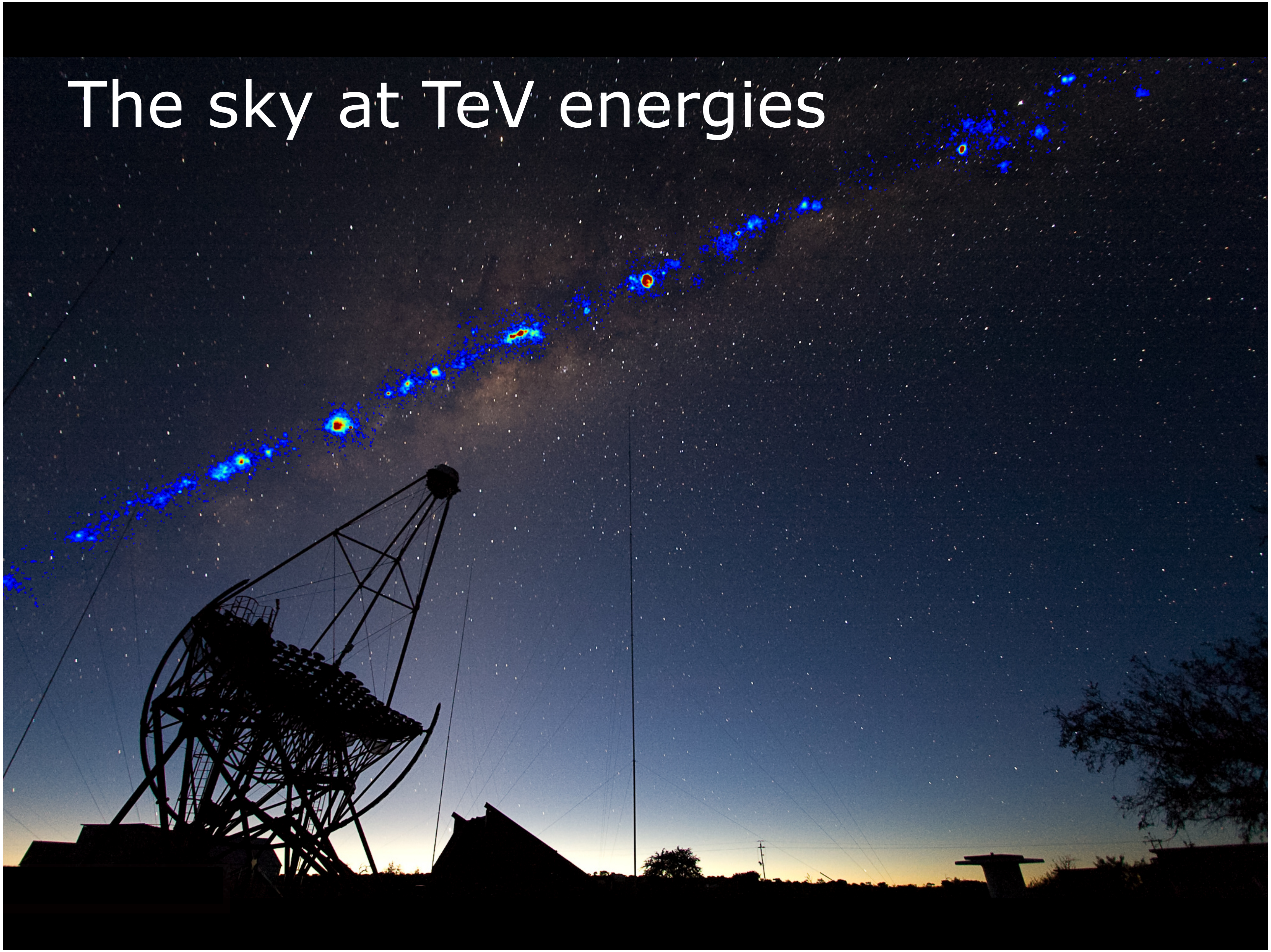
4 x 110 m^2 (since 2007)

"REAL ASTRONOMY" IN A NEW ENERGY BAND

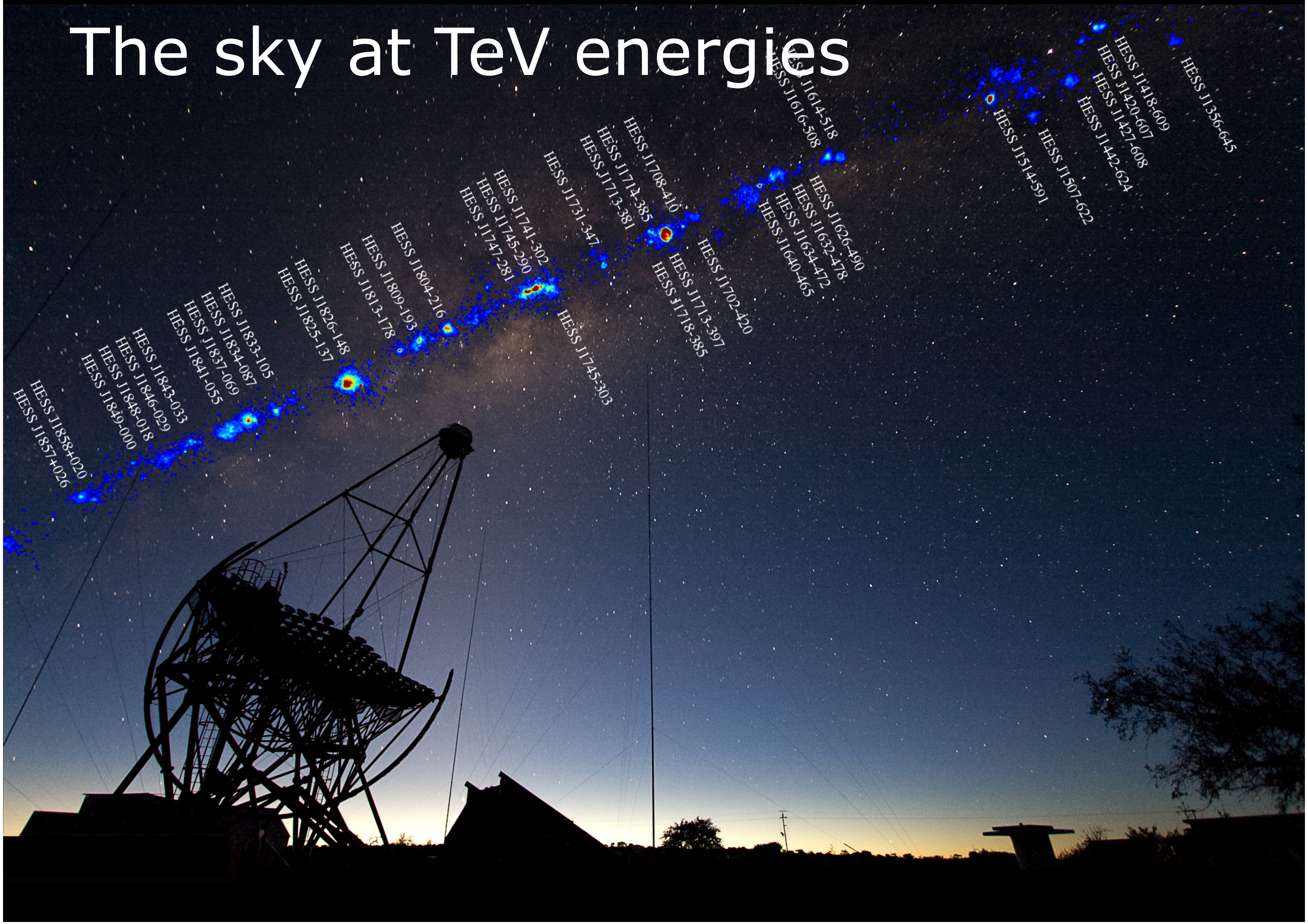
- High sensitivity
  - 3 orders of magnitude dynamic range in flux, down to 0.01 "Crab"
- Wide spectral range
  - >2 orders of magnitude coverage in energy, up to 10s of TeV
  - 10-15% energy resolution
- Resolved source morphology
  - ~5′ angular resolution
  - 10-20″ source localization
- Survey capability
  - H.E.S.S. Galactic Plane Survey:
  - better than 2% Crab sensitivity
- Well-resolved light curves
  - Minute-scale variability of AGN

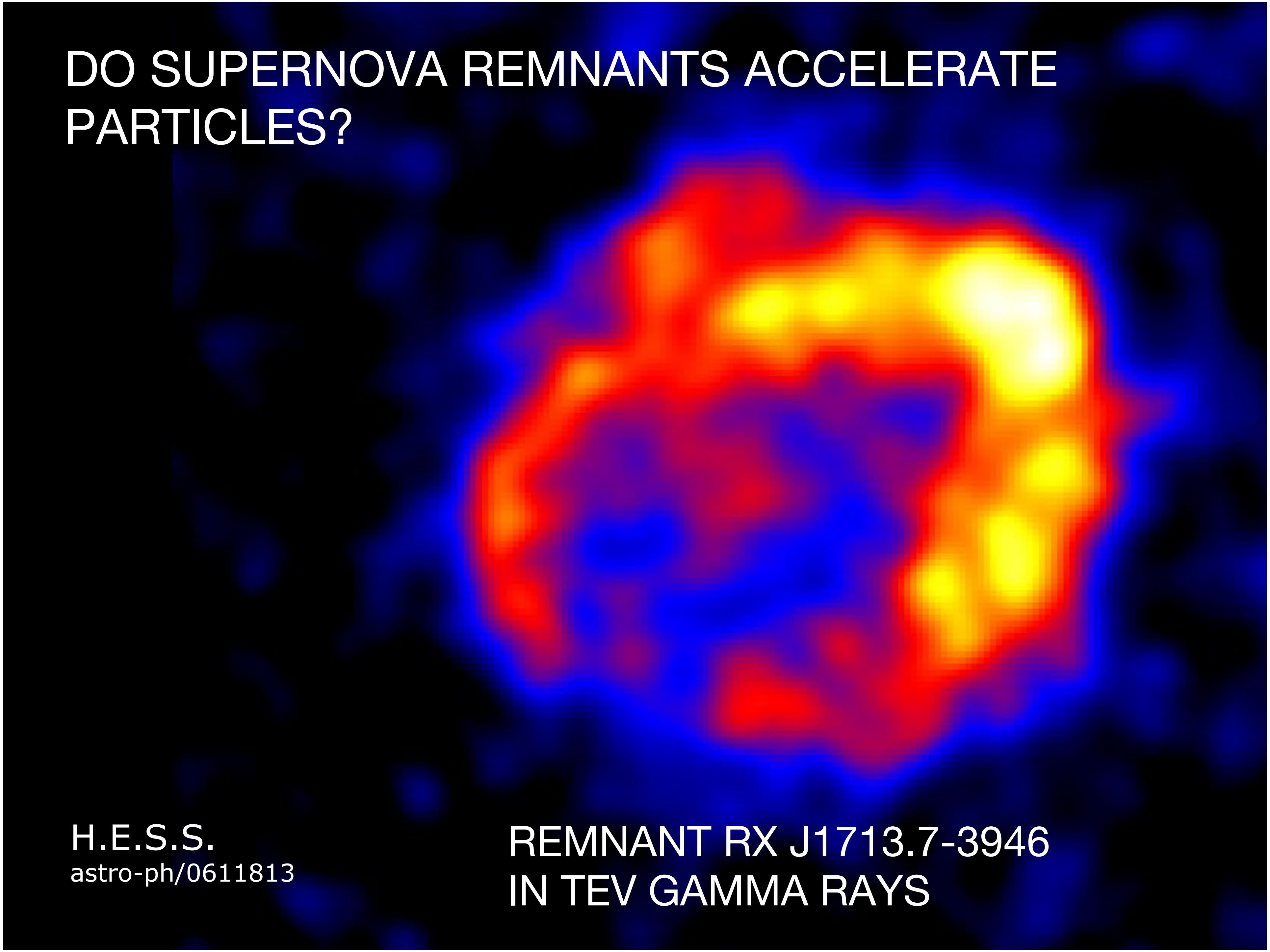
The sky at TeV energies

The sky at TeV energies

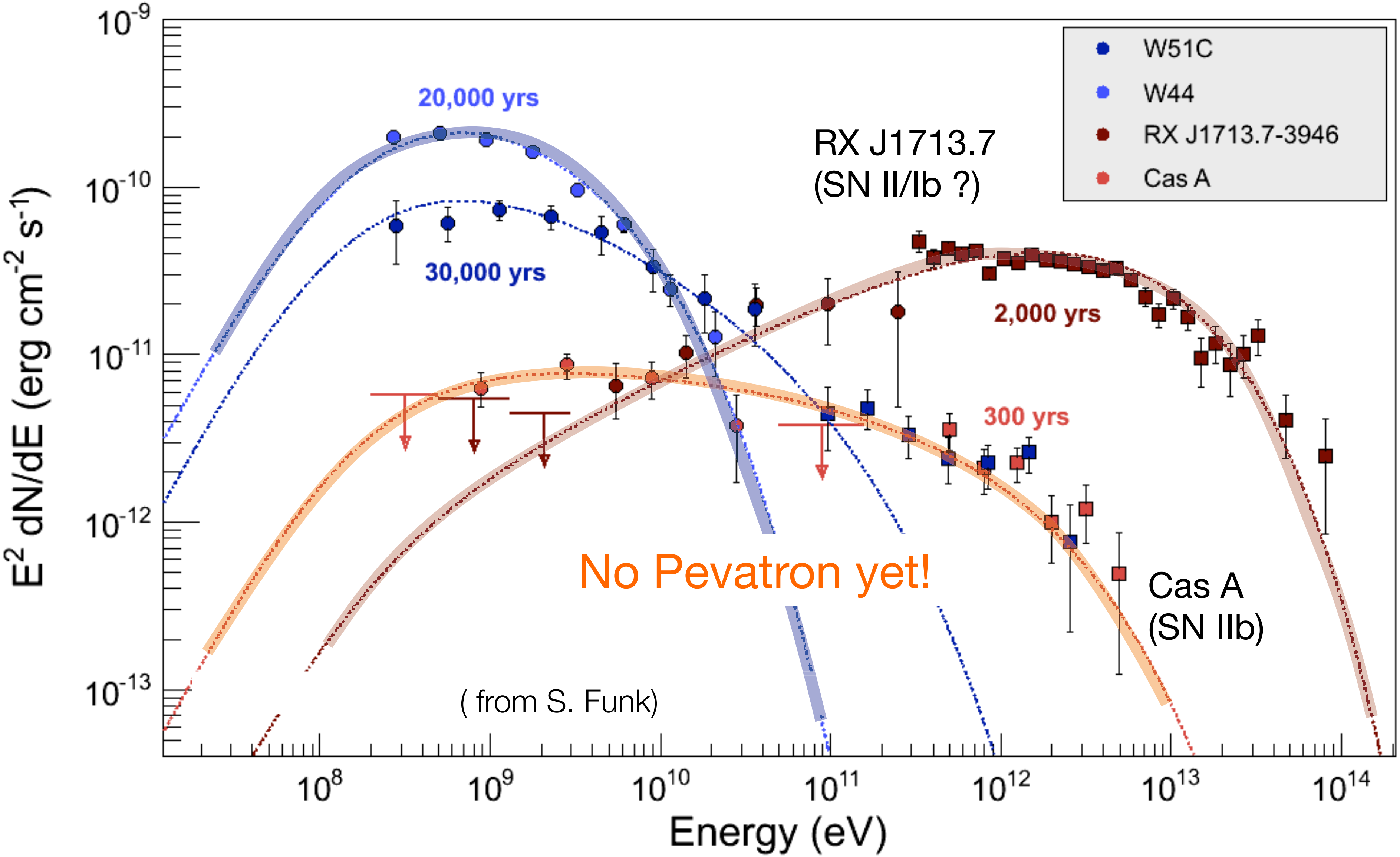


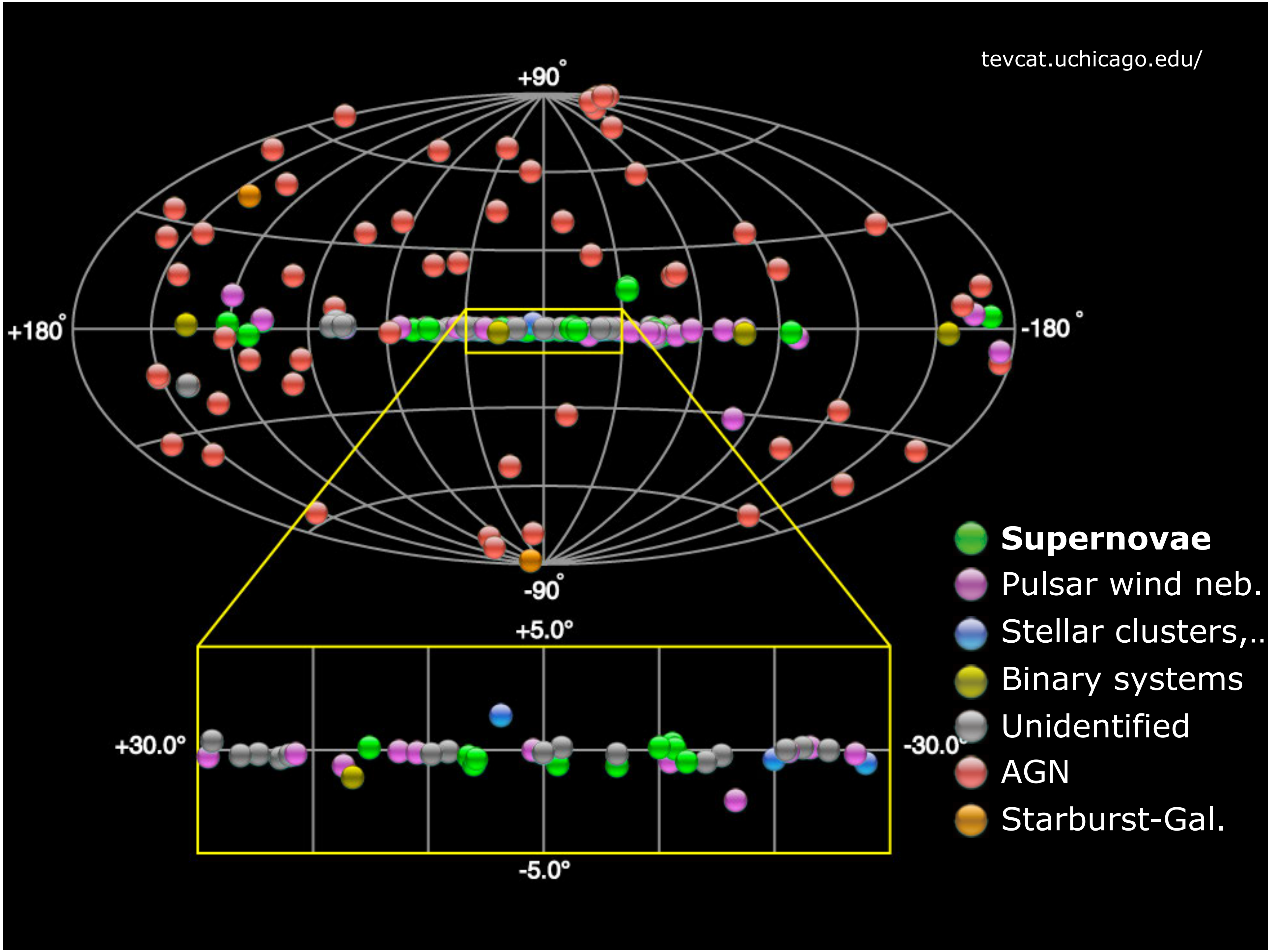
The sky at TeV energies




DO SUPERNOVA REMNANTS ACCELERATE PARTICLES?
H.E.S.S.
astro-ph/0611813
REMNANT RX J1713.7-3946
IN TEV GAMMA RAYS

SPECTRA OF SUPERNOVA REMNANTS

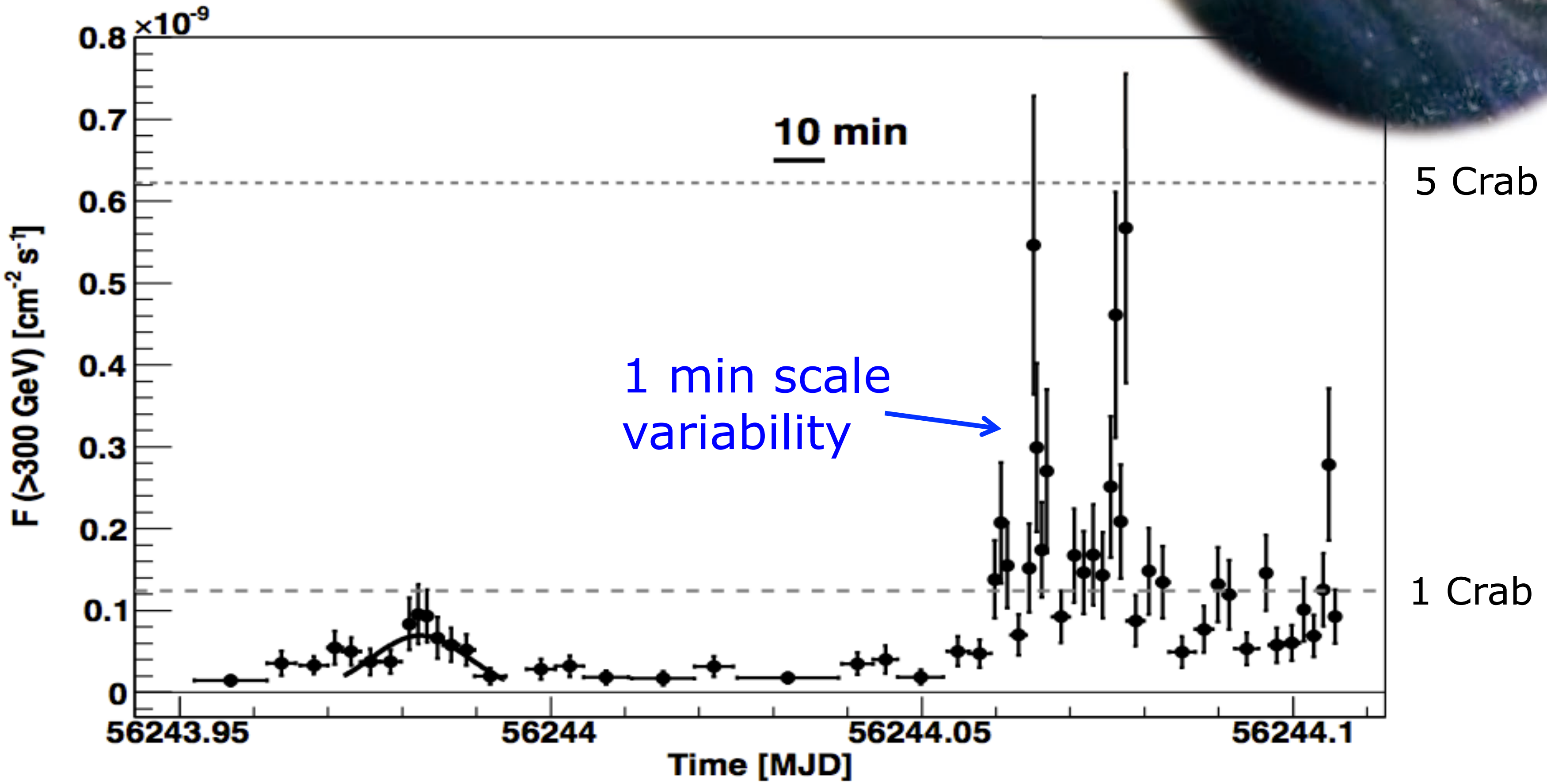



tevcat.uchicago.edu/
+90°
+180°
-180°
-90°
+5.0°
+30.0°
-30.0°
-5.0°
Supernovae
Pulsar wind neb.
Stellar clusters,..
Binary systems
Unidentified
AGN
Starburst-Gal.

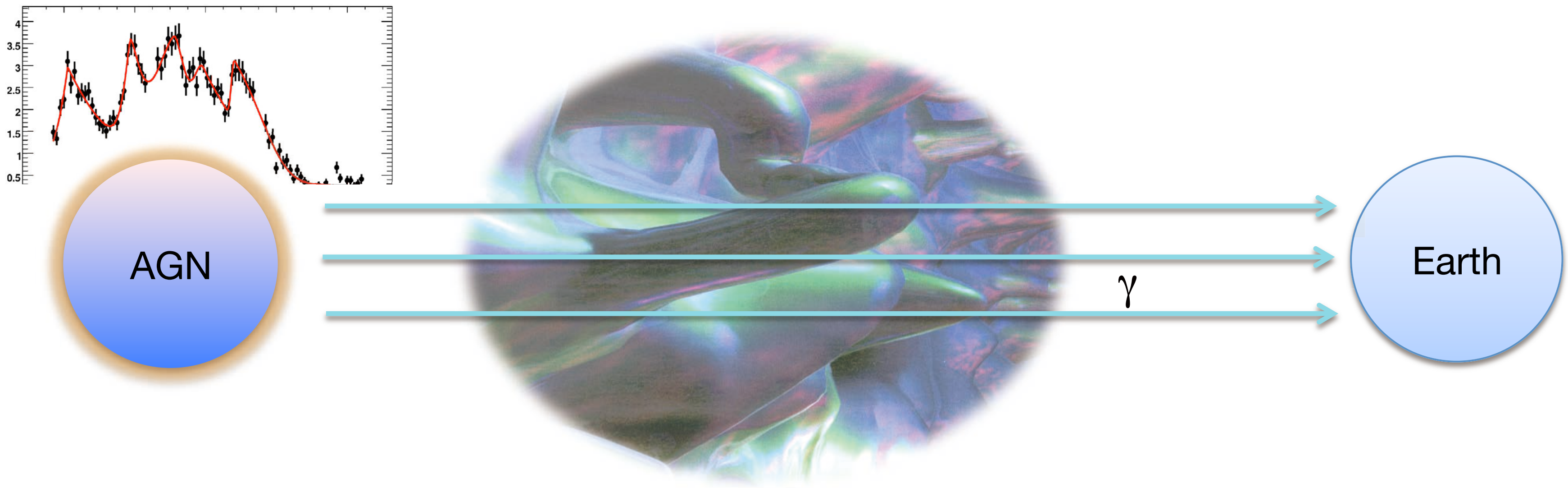
AMAZING TEV FLARES: IC 310

MAGIC Coll.
Science 346 (2014) 1080

Radio galaxy, jets inclined to line of sight



FUNDAMENTAL PHYSICS: LI VIOLATION



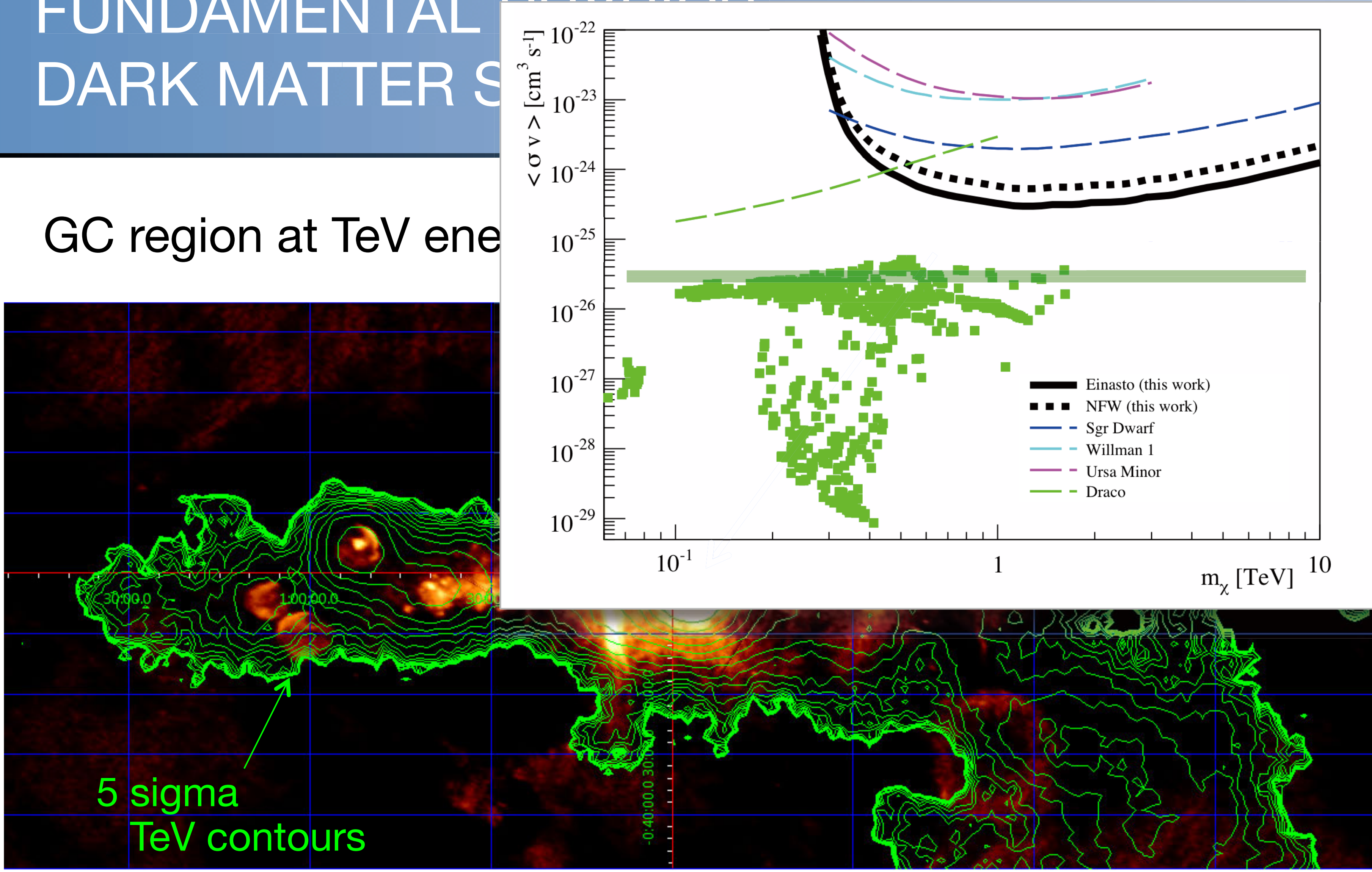
Velocity dispersion across TeV energy range less than ~20 s for ~10^9 y travel ≃ 10^{-15}

but: Expect effects of order E_γ/M_{Planck} ~ 10^{-16}

HESS, arXiv:1101.3650
arXiv:0810.3475

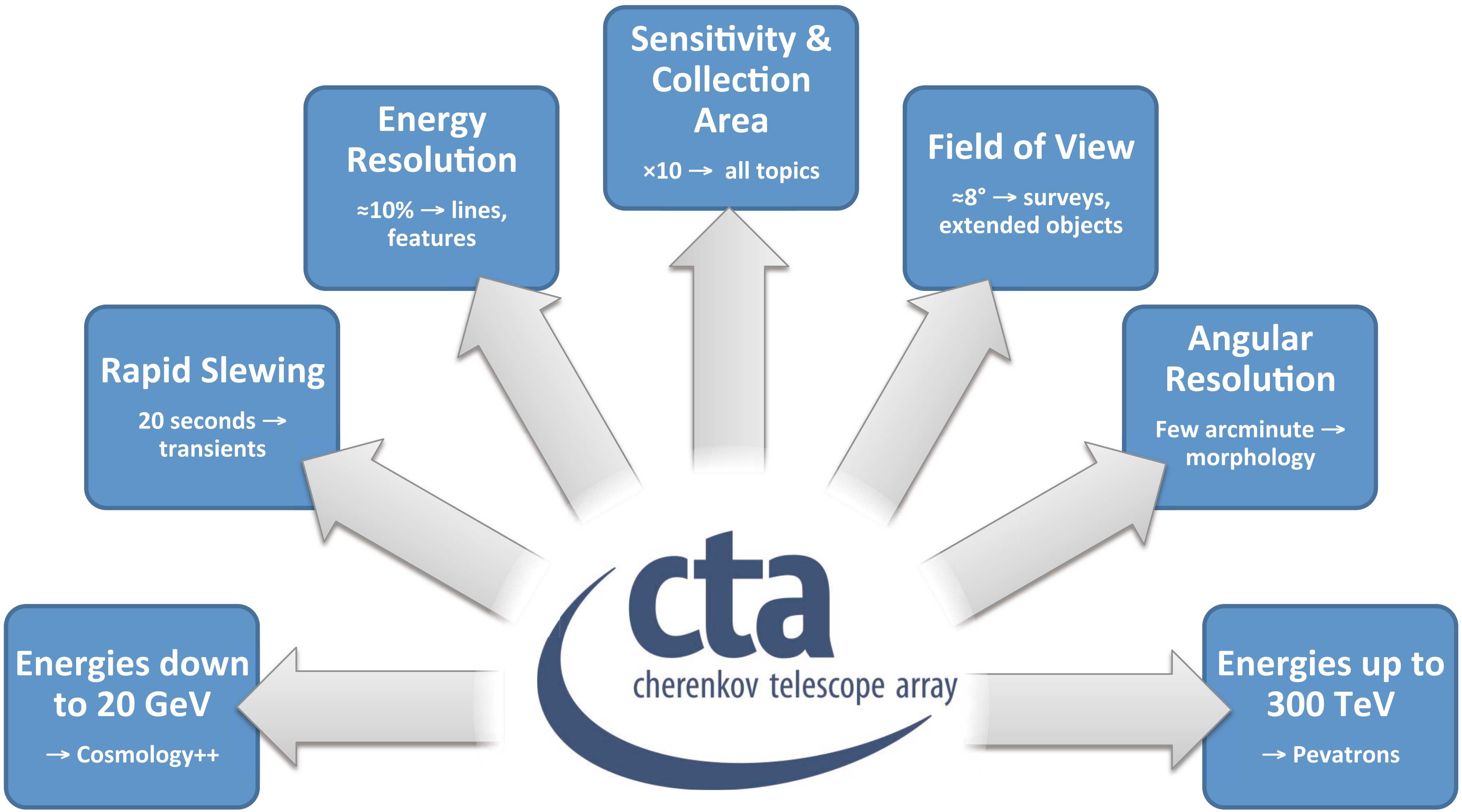
FUNDAMENTAL
DARK MATTER S

GC region at TeV ene

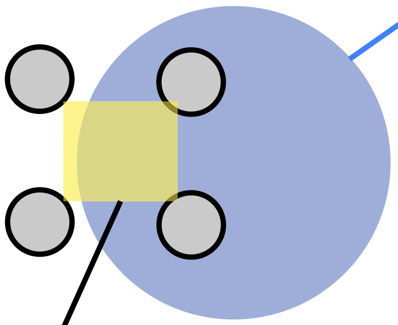


2°
300 pc

CTA: REQUIREMENTS & DRIVERS

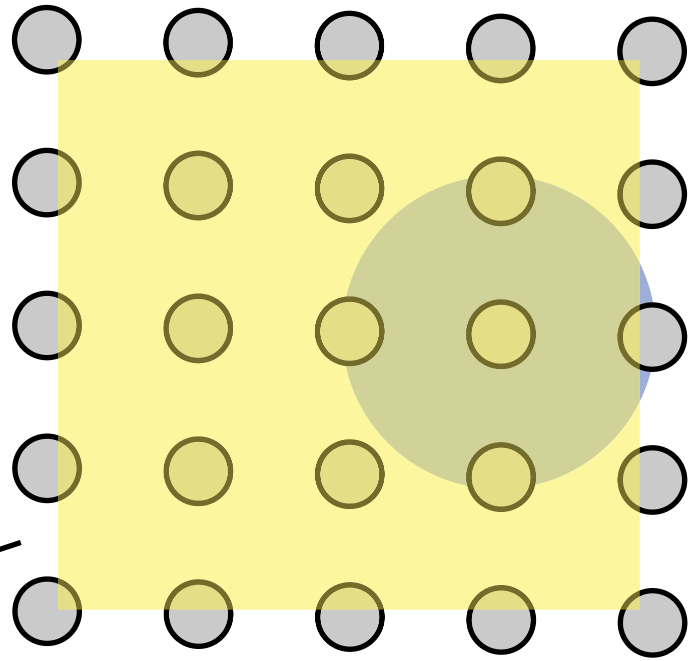


FROM CURRENT ARRAYS TO CTA

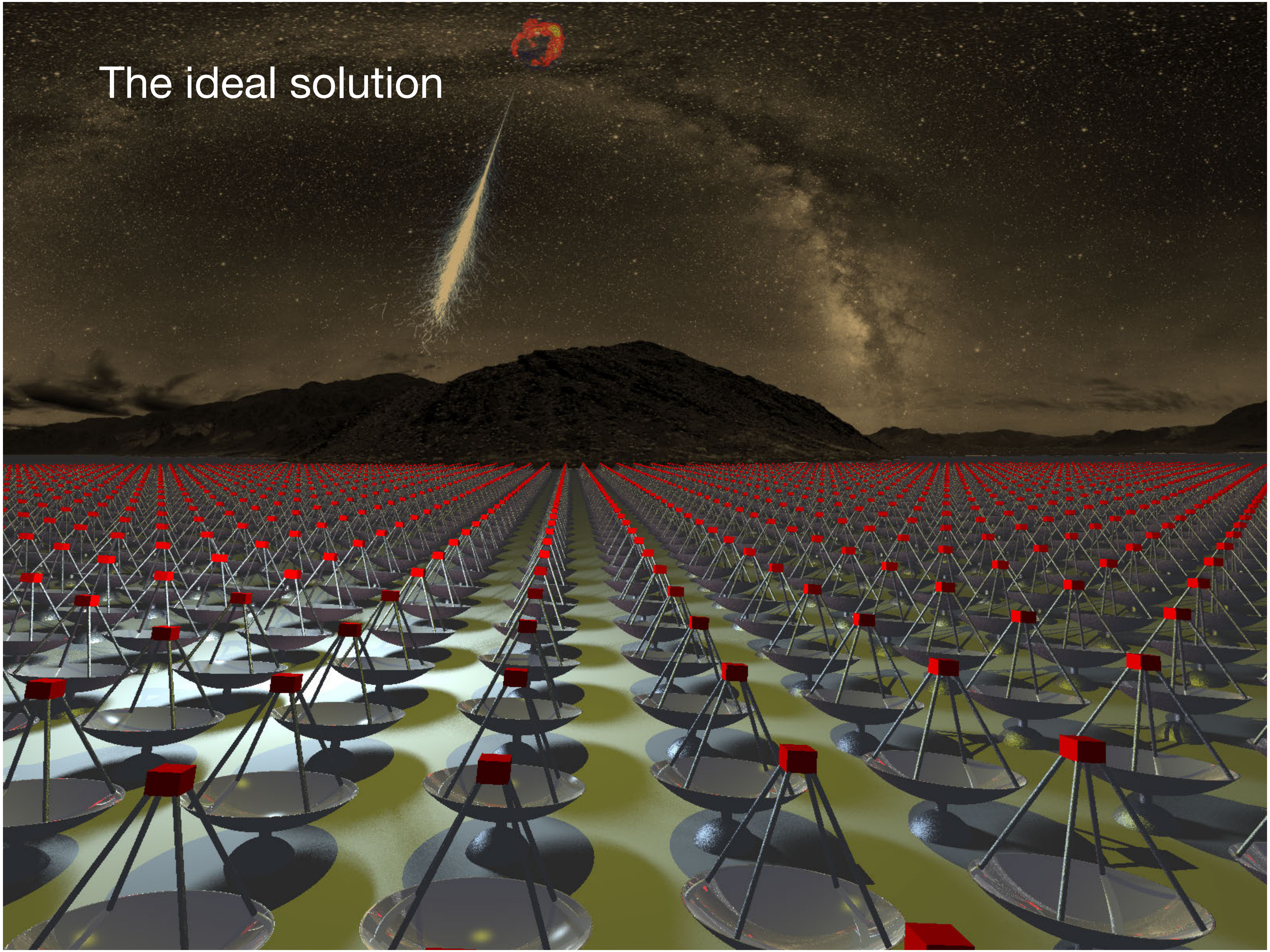


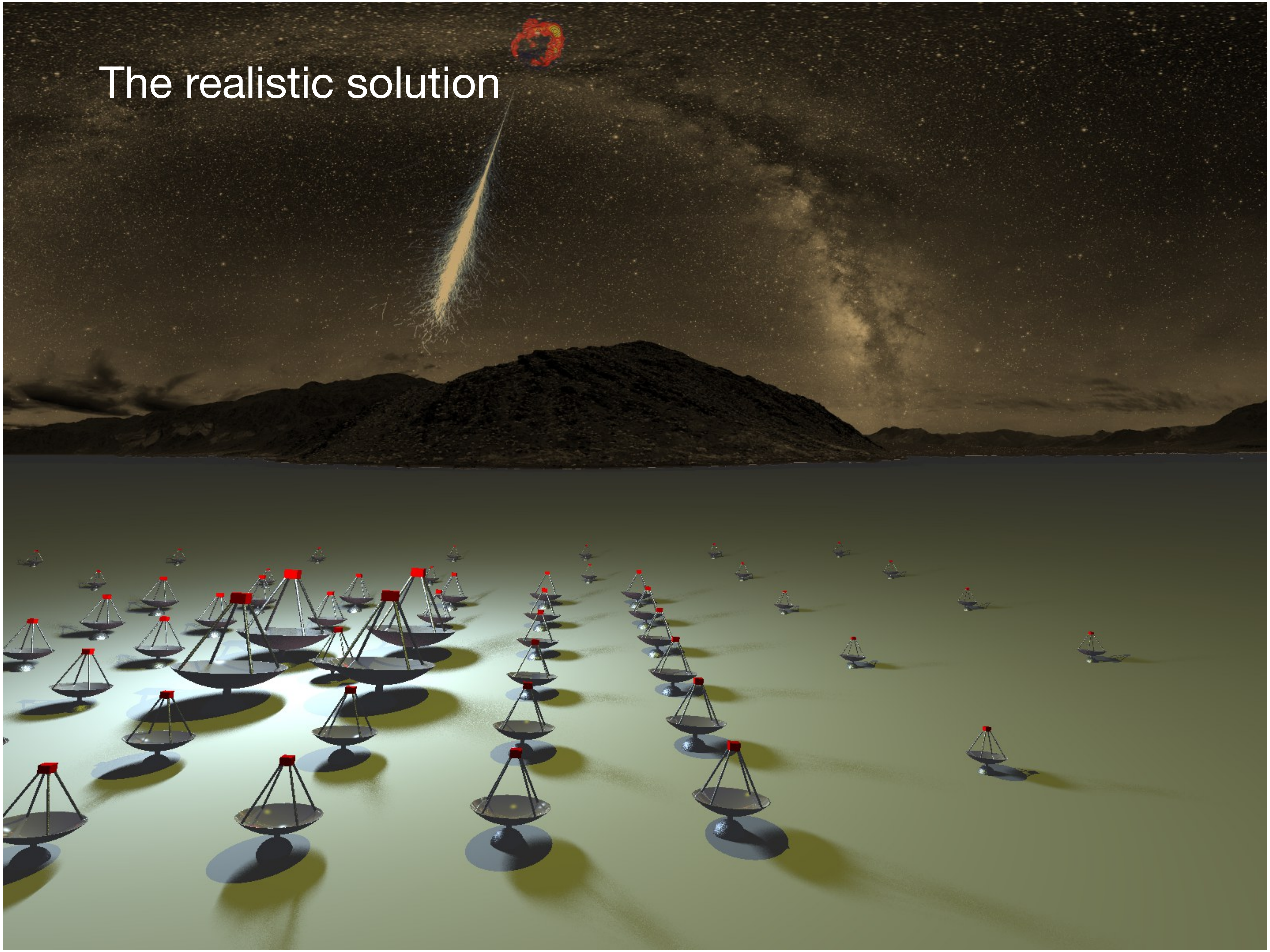
light pool radius
R ≈100-150 m
≈ typical telescope spacing

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

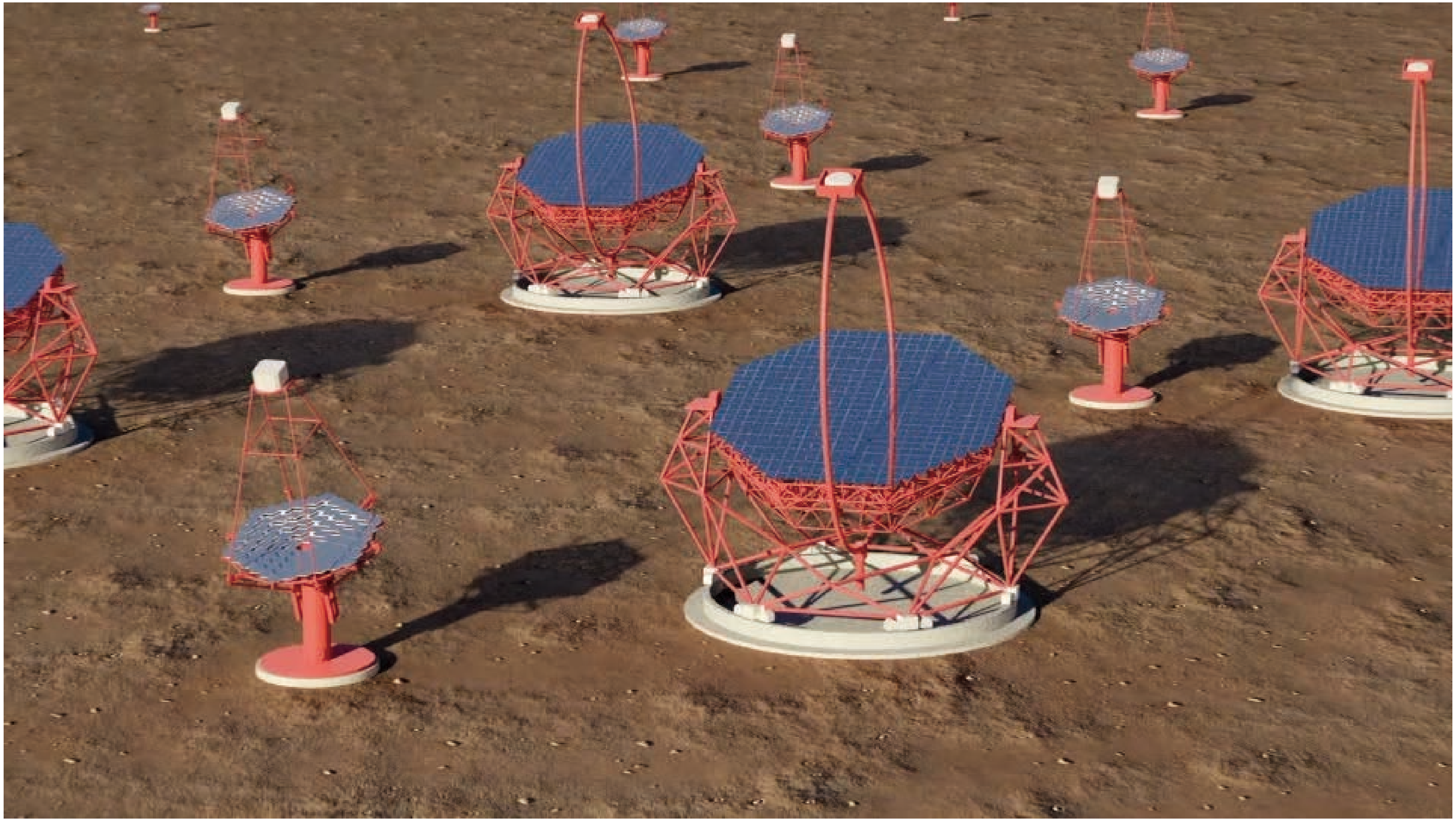


large detection area
more images per shower
lower trigger threshold

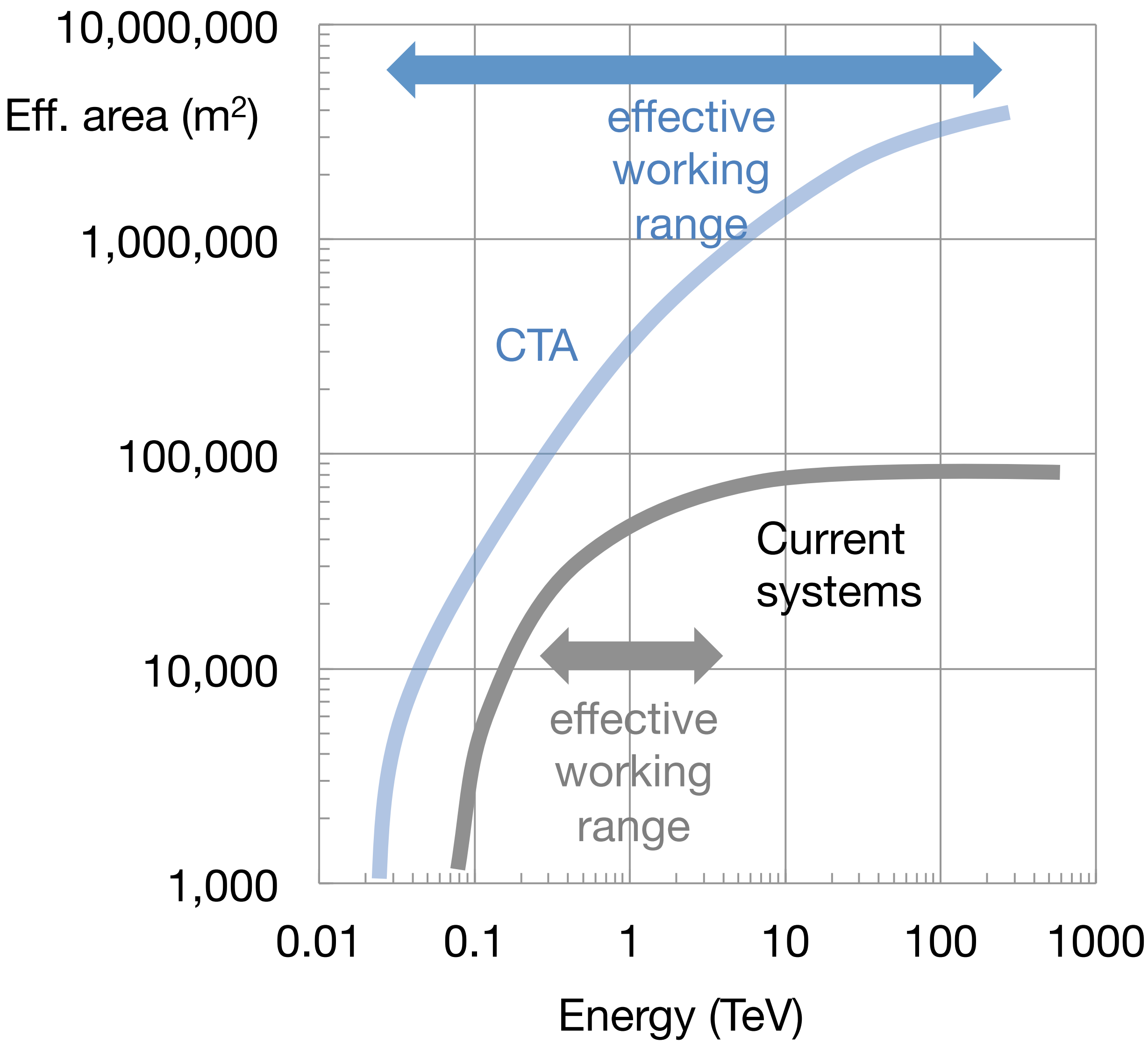

The ideal solution


The realistic solution

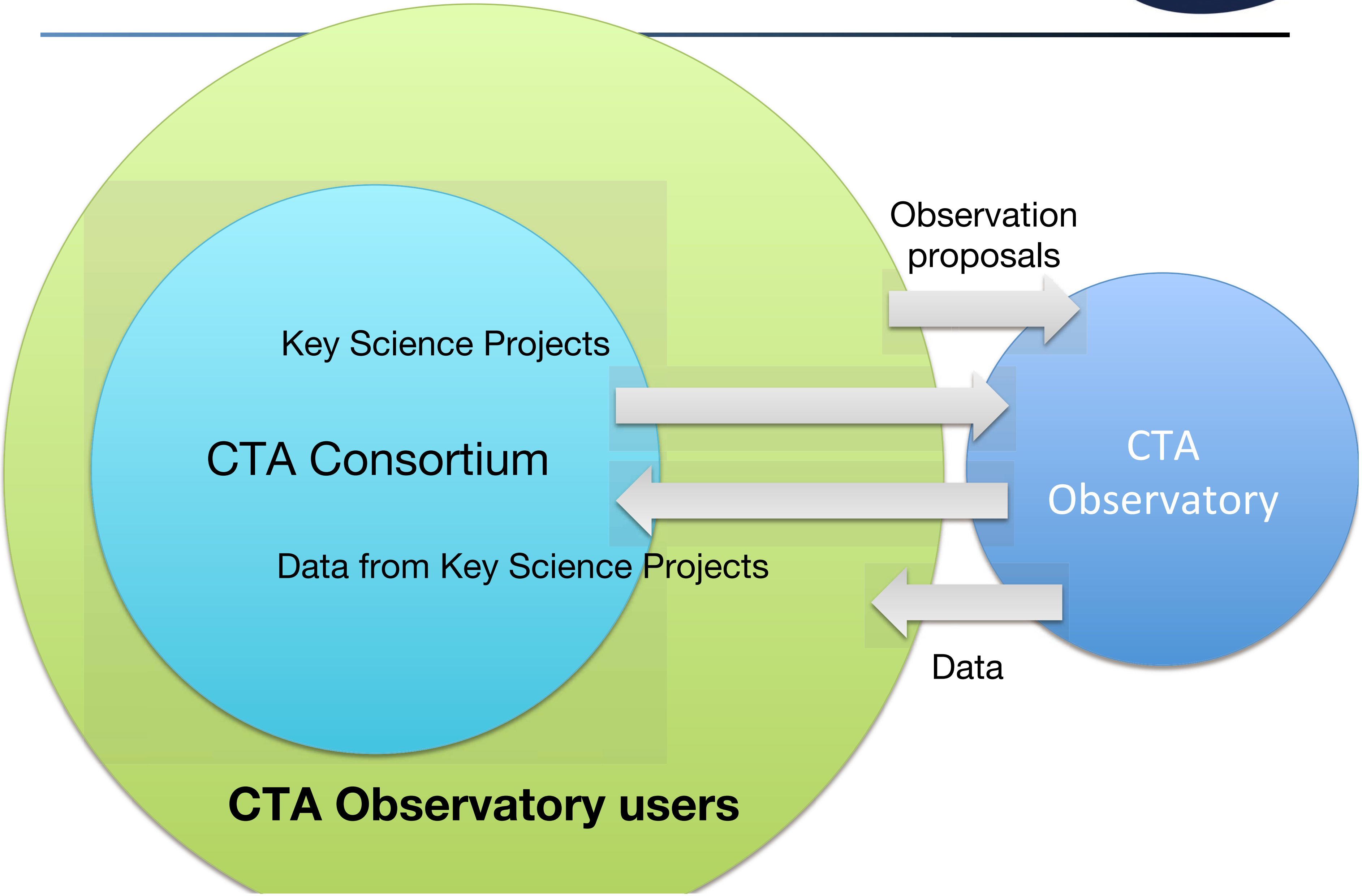
Credit:
Multimedia Service,
Institute of Astrophysics of Canary Islands



NOVEL:
CTA ENERGY COVERAGE



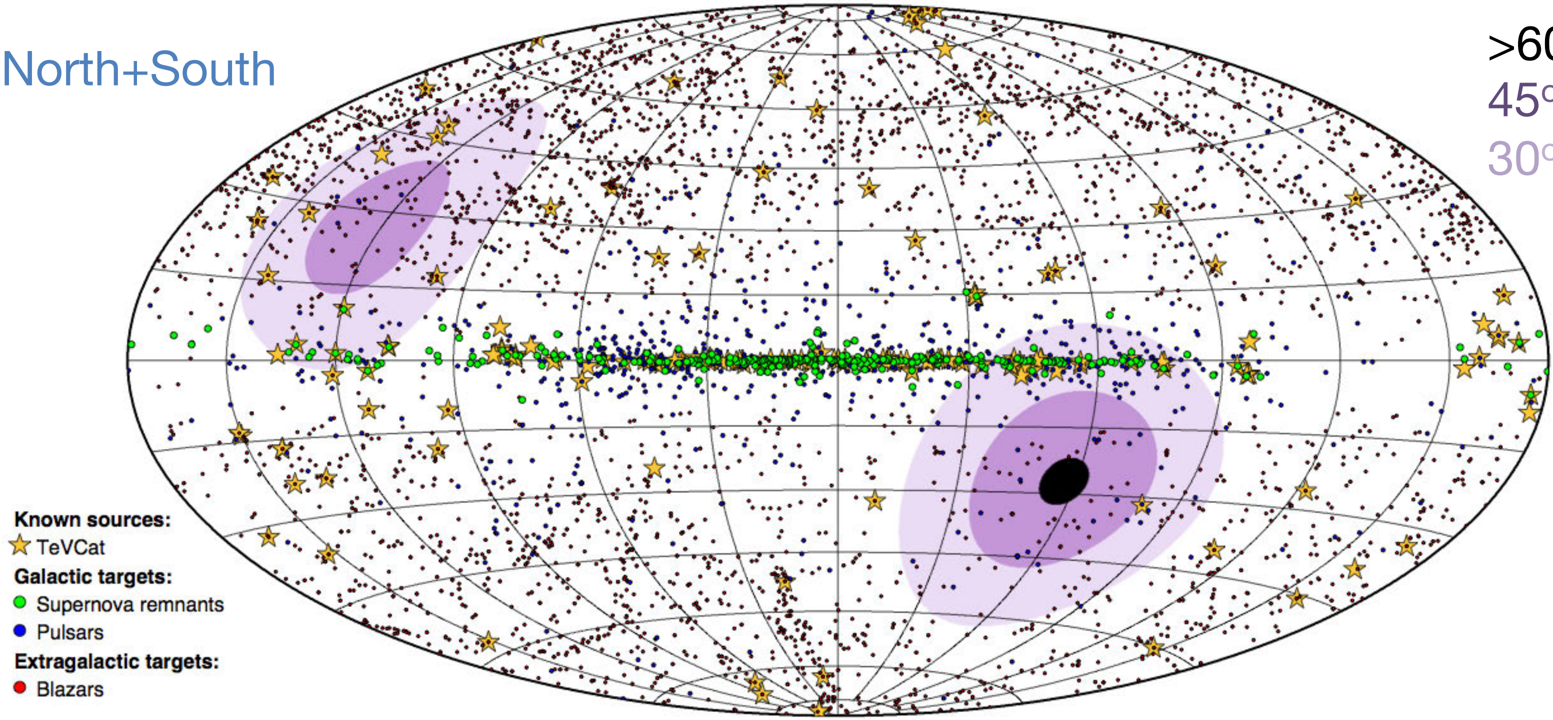
NOVEL: OBSERVATORY



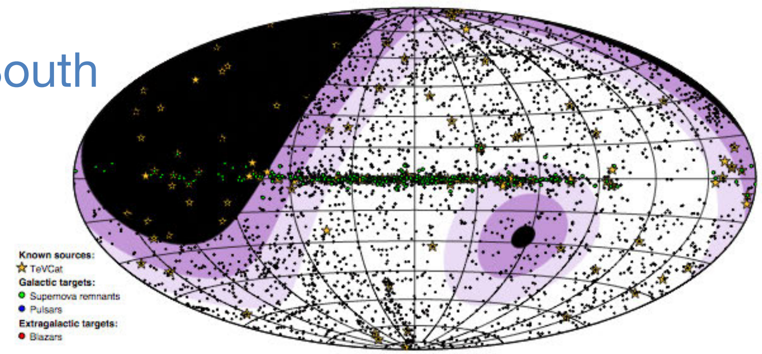
NOVEL:
ALL-SKY COVERAGE

>60° zenith
45°-60°
30°-45°

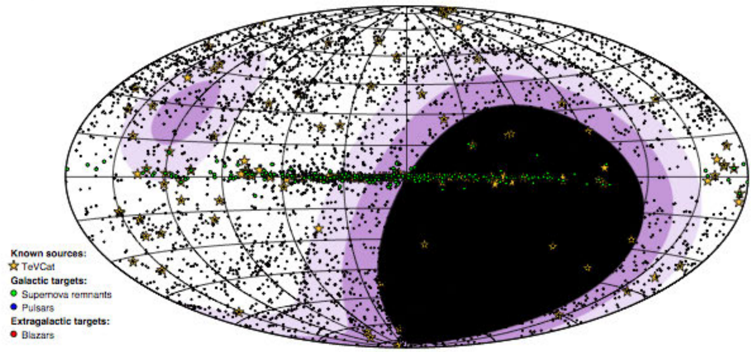
North+South



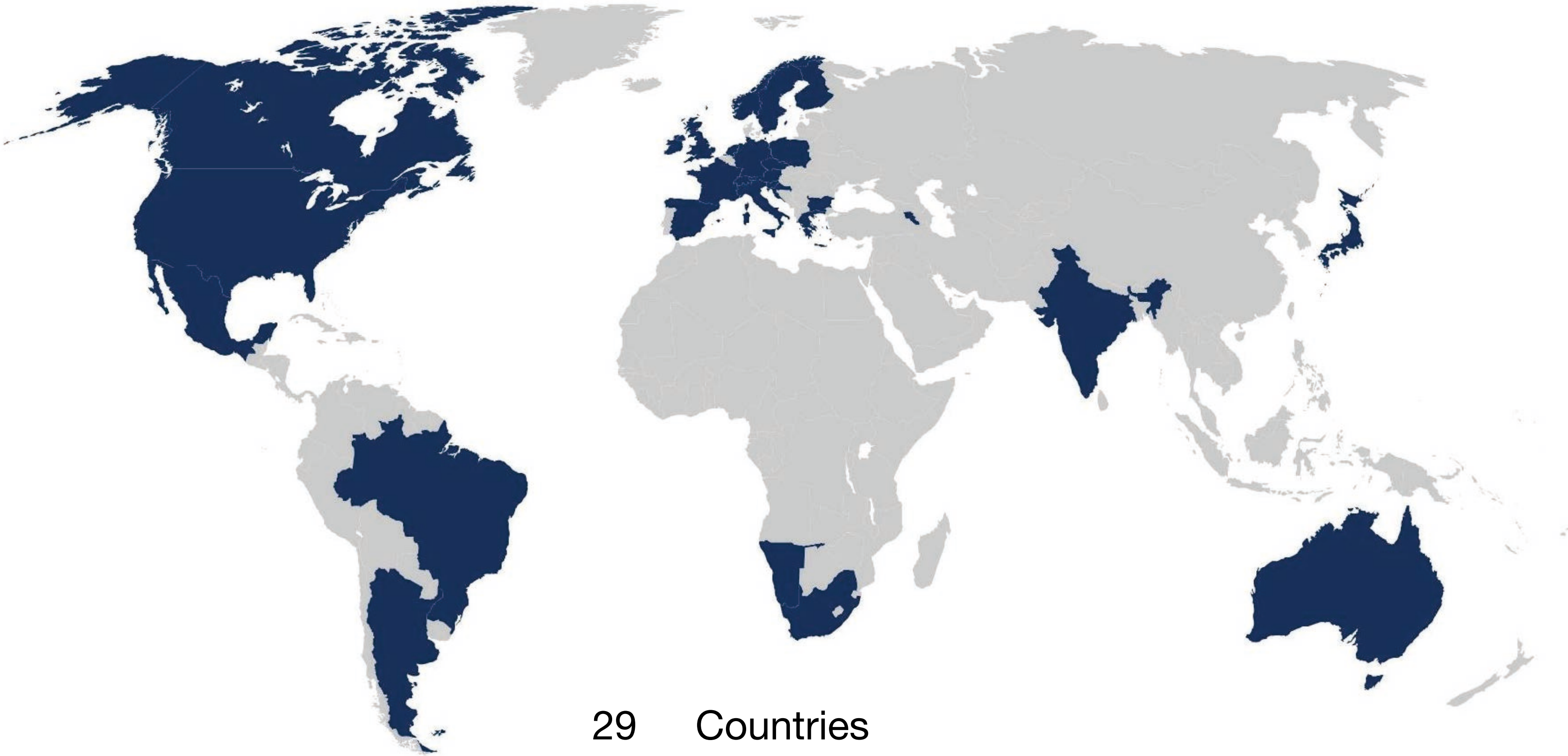
South



North

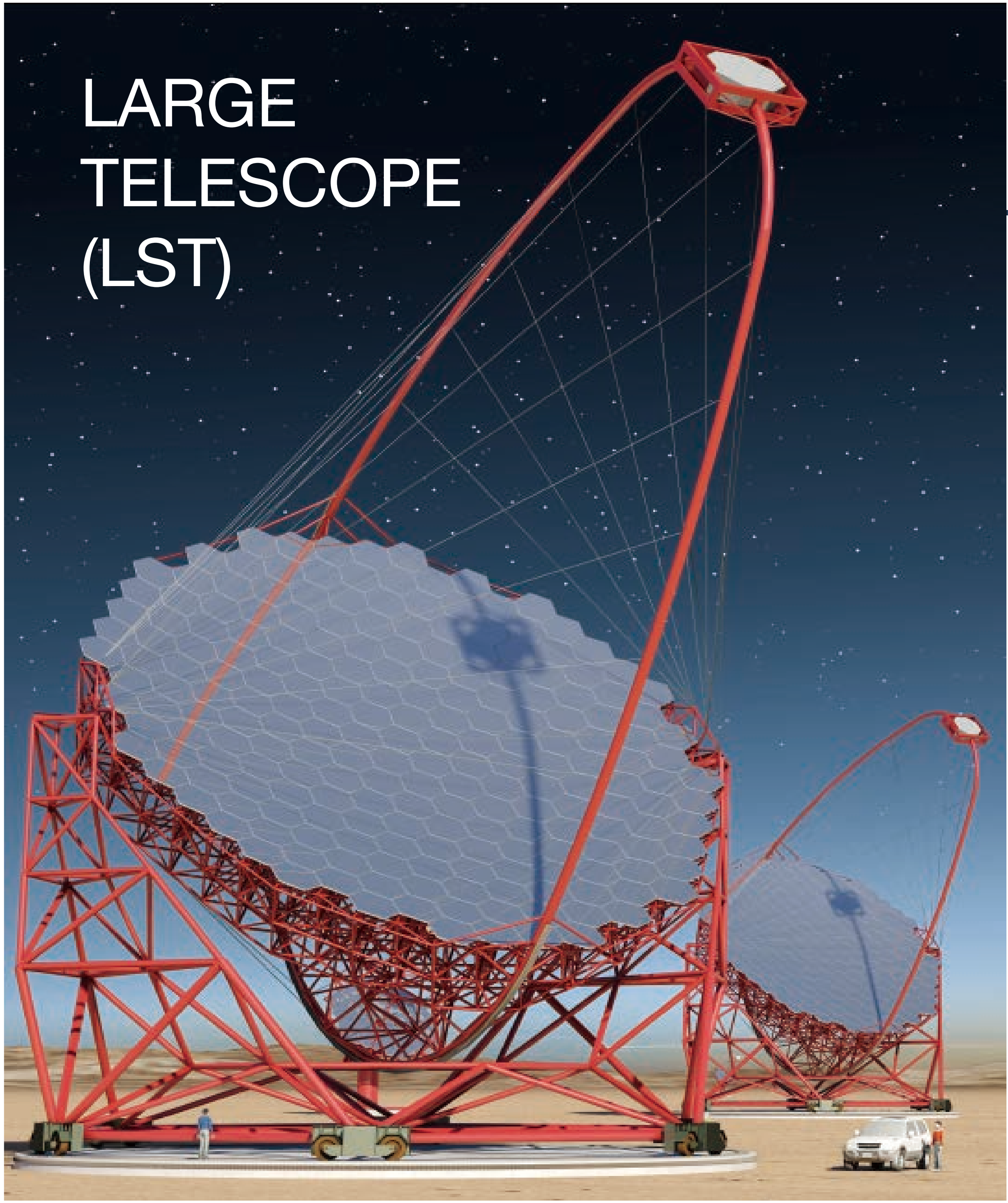


NOVEL:
WORLD-WIDE COOPERATION



29 Countries
179 Institutes
1207 Members

CTA TELESCOPES



23 m diameter
389 m² dish area
28 m focal length
1.5 m mirror facets

4.5° field of view
0.1° pixels
Camera ∅ over 2 m

Carbon-fibre structure
for 20 s positioning

Active mirror control

4 LSTs on South site
4 LSTs on North site
Prototype = 1st telescope

MEDIUM-SIZED 12 M TELESCOPE

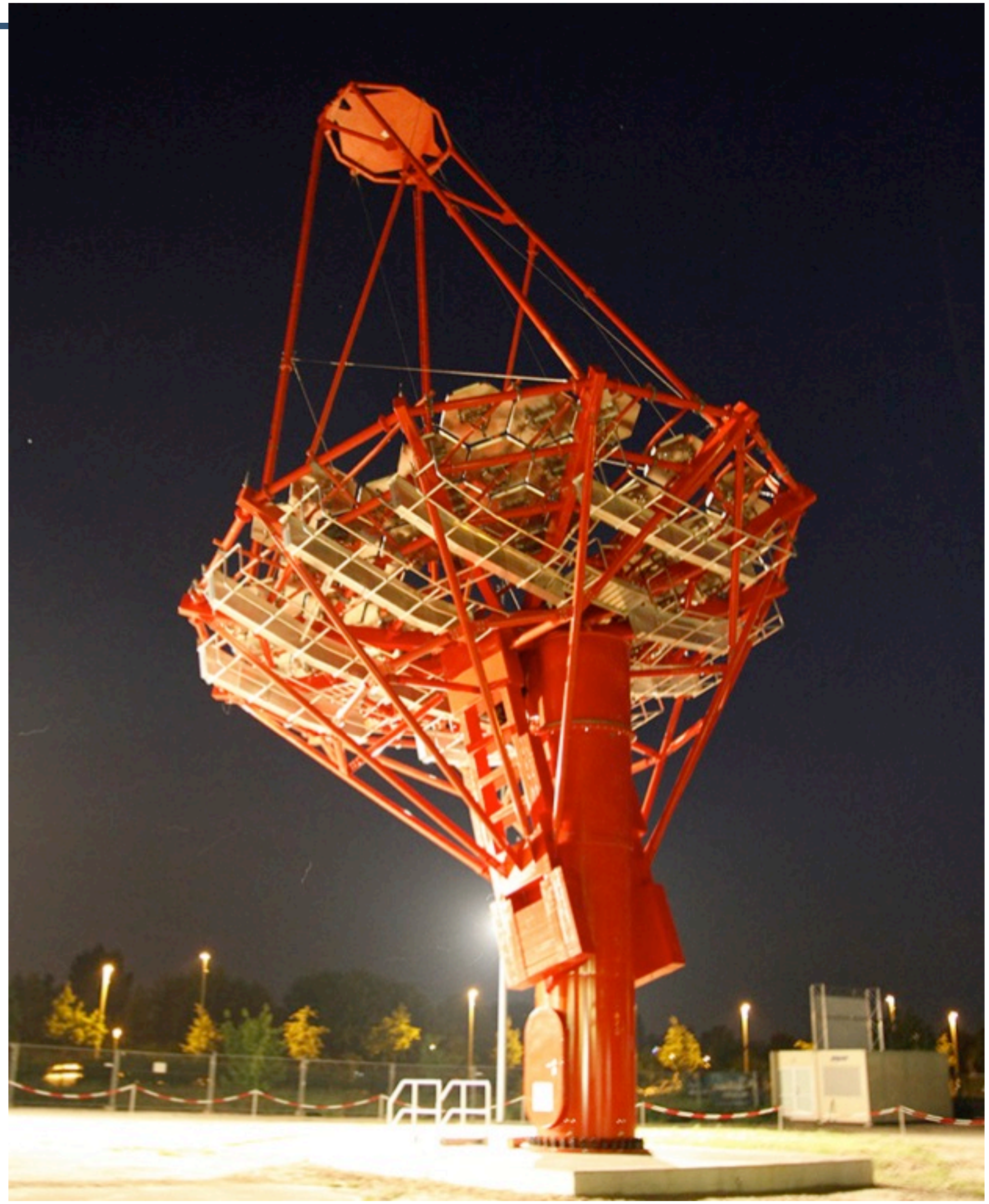
OPTIMIZED FOR THE 100 GEV TO ~10 TEV RANGE

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

8° field of view
~2000 x 0.18° pixels

25 MSTs on South site
15 MSTs on North site

Berlin
MST prototype
operational



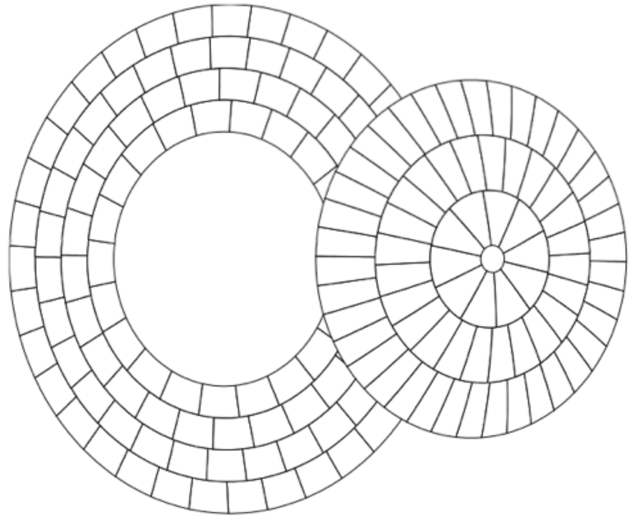
SST - OPTIMIZED FOR THE RANGE ABOVE 10 TEV

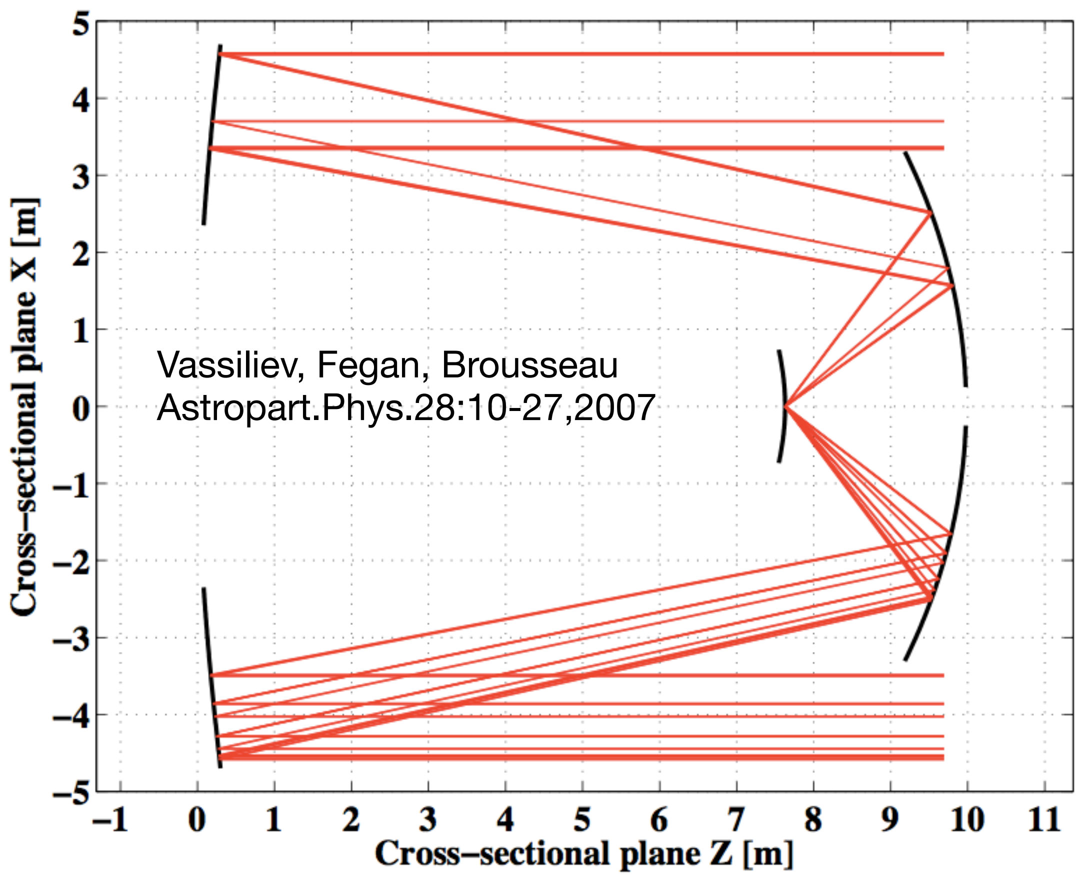
DUAL MIRROR ASTRI SST

PROTOTYPE INAUGURATION SEPT 24

cta
cherenkov telescope array

DUAL-MIRROR TELESCOPES



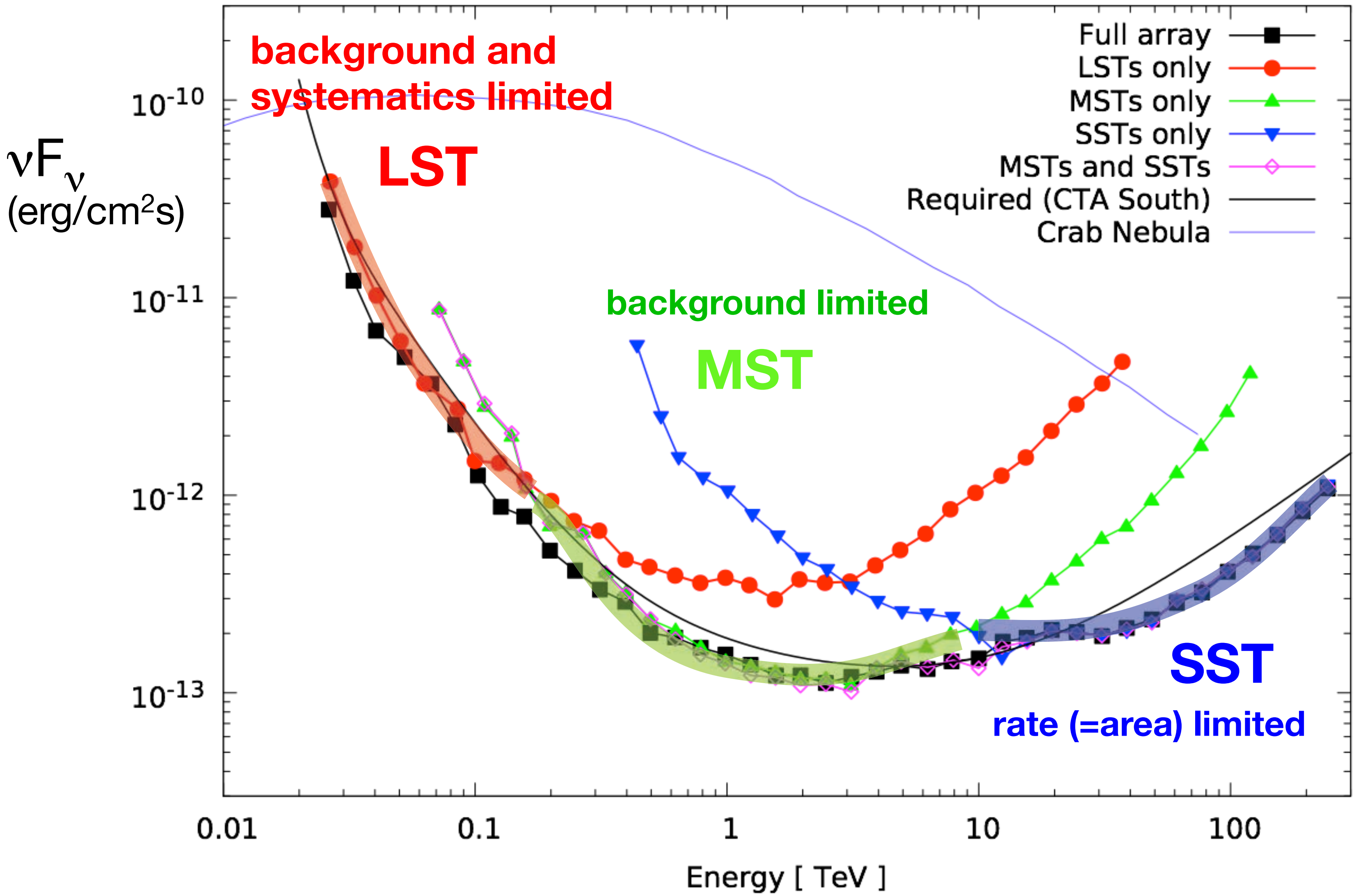


- Reduced plate scale
- Reduced psf
- Uniform psf across f.o.v.

➜ Cost-effective small telescopes with compact camera using silicon sensors

PERFORMANCE

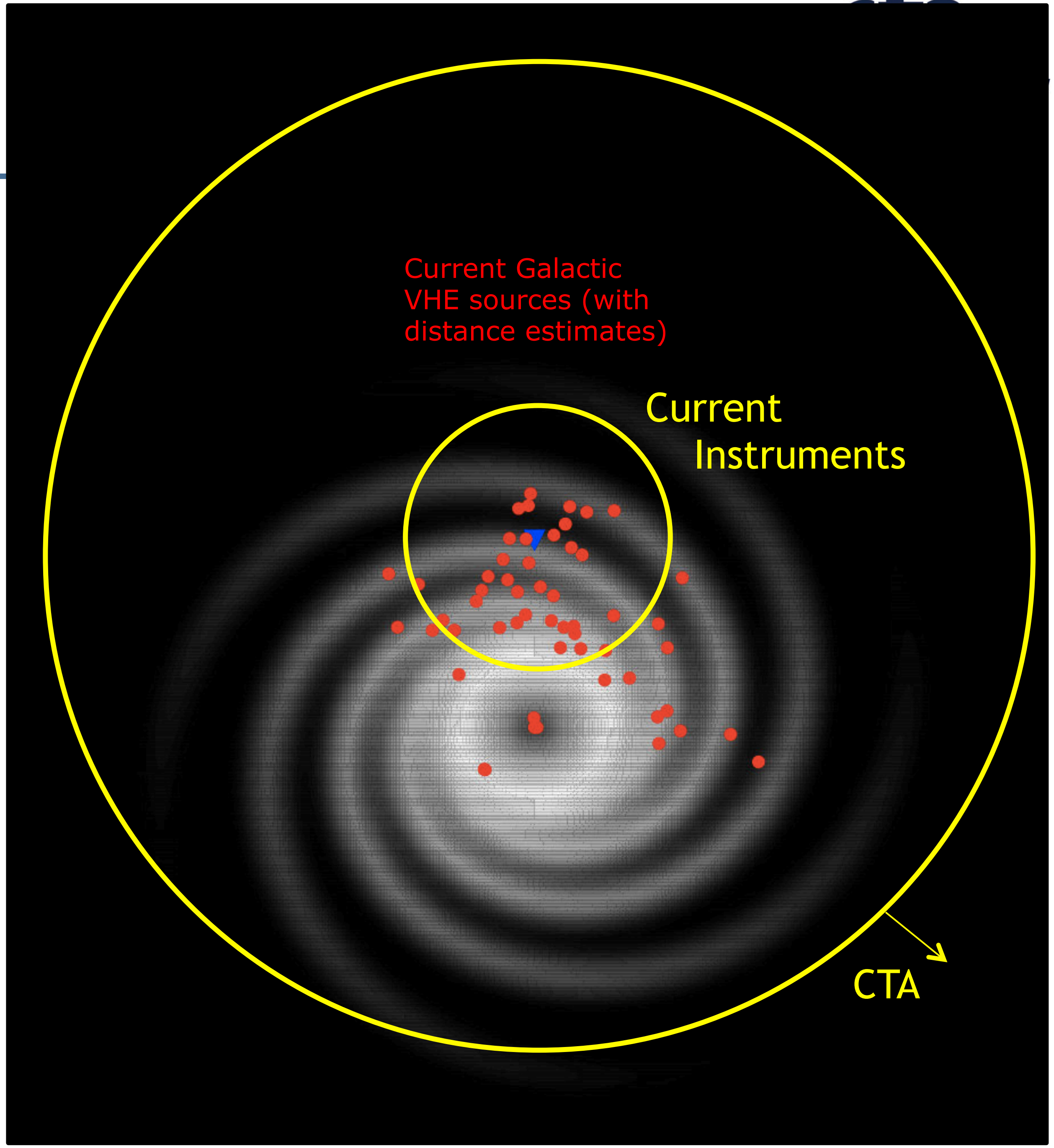
SENSITIVITY



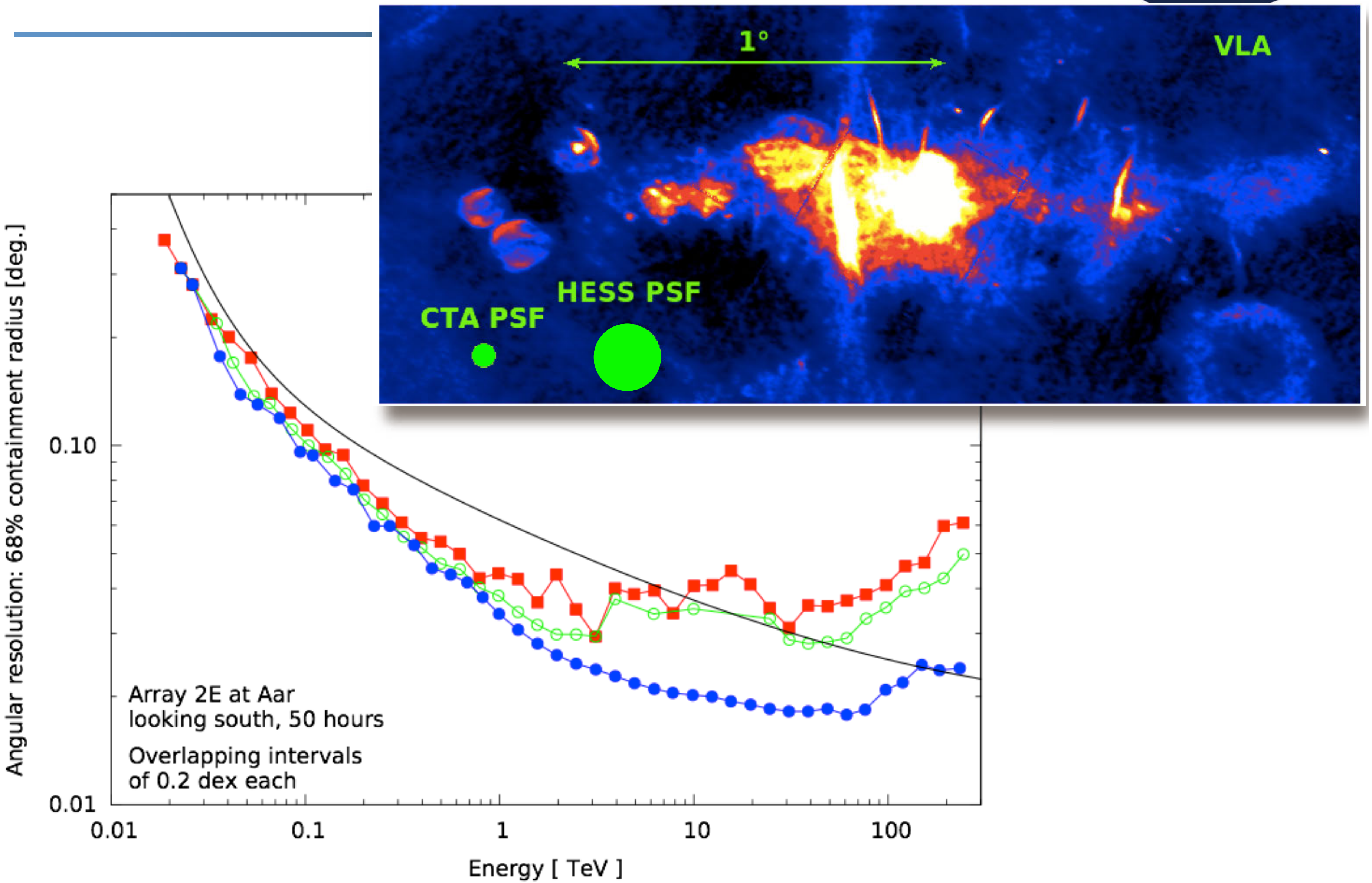
SENSITIVITY

Galactic Plane Survey with mCrab sensitivity

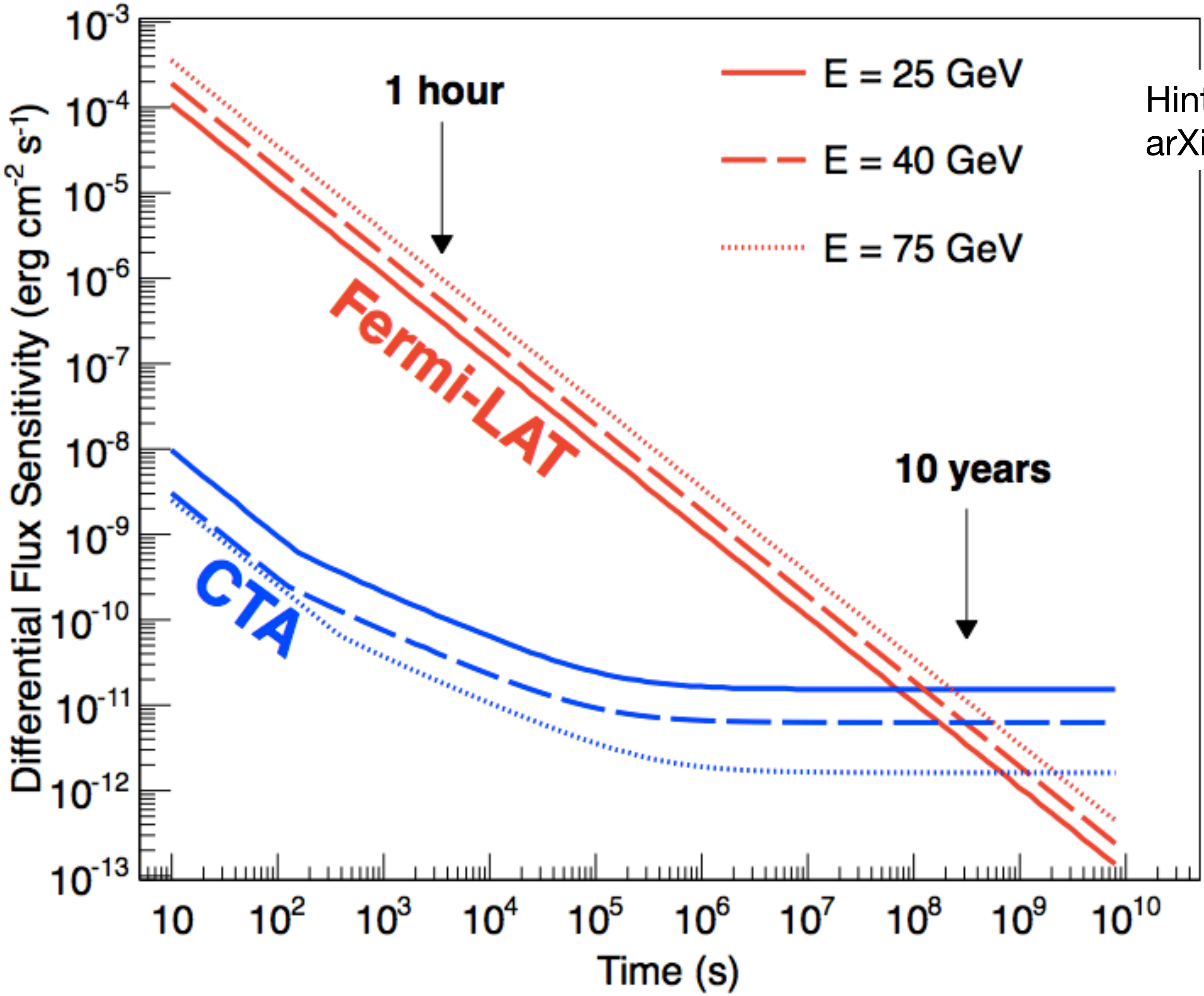
(HESS: 2% Crab)



ANGULAR RESOLUTION

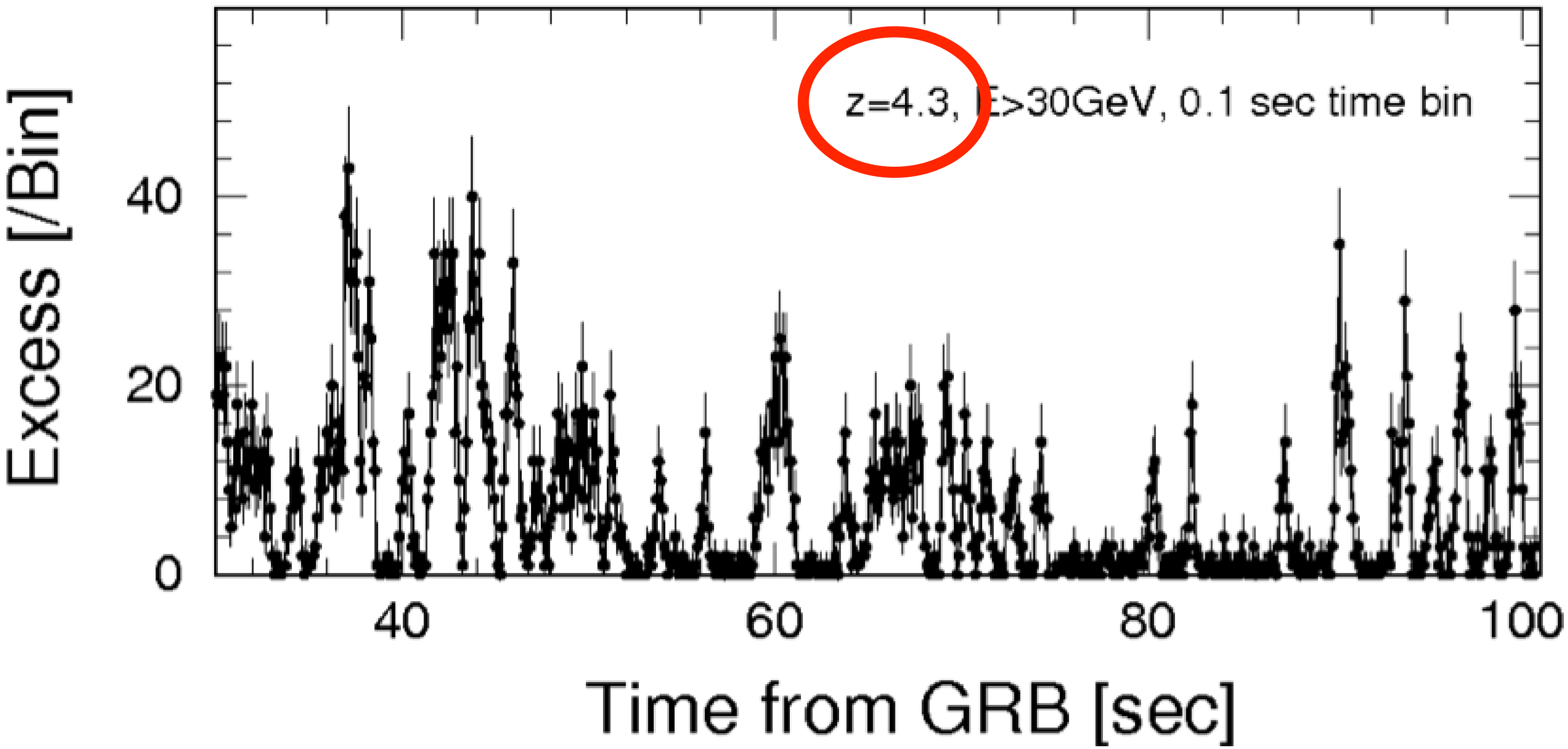


TRANSIENTS WITH CTA



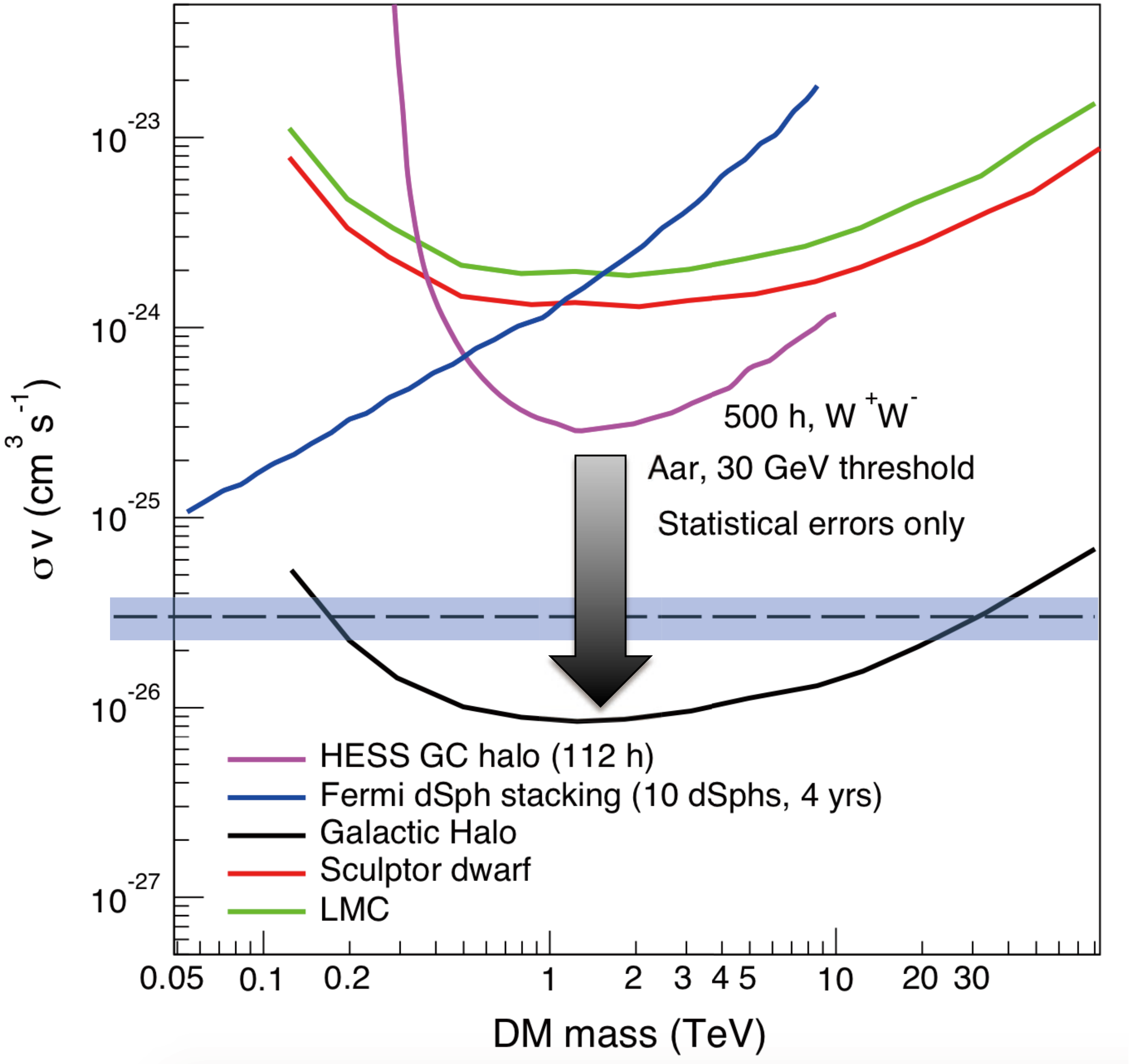
Hinton & Funk
arXiv:1205.0832

GAMMA RAY BURSTS (E > 30 GEV)



from
Gamma-Ray Burst Science in the Era of Cherenkov Telescope Array
(Astroparticle Physics special issue article)
Susumu Inoue et al., arXiv:1301.3014

DARK MATTER ANNIHILATION

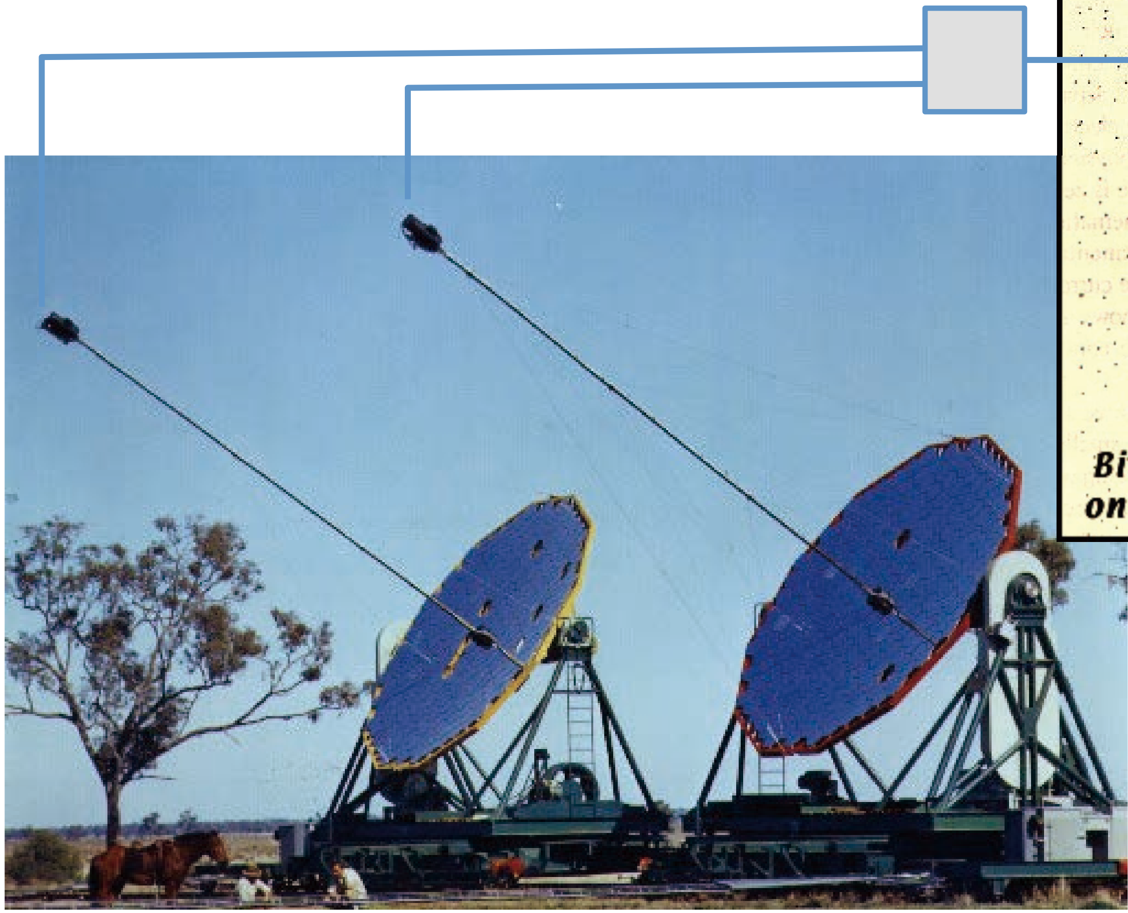


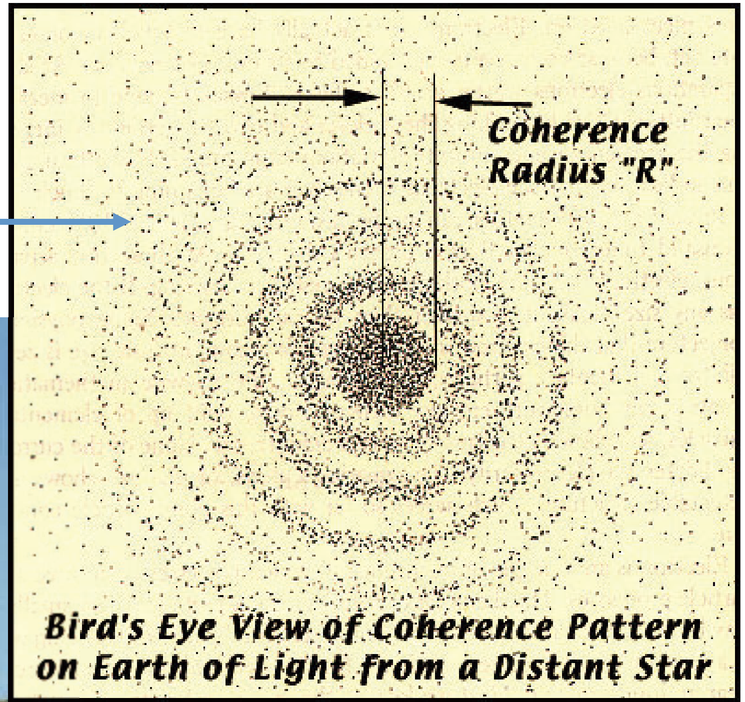
Canonical cross section

INTENSITY INTERFEROMETRY

Hanbury Brown and Twiss
Narrabri, Australia

Correlator



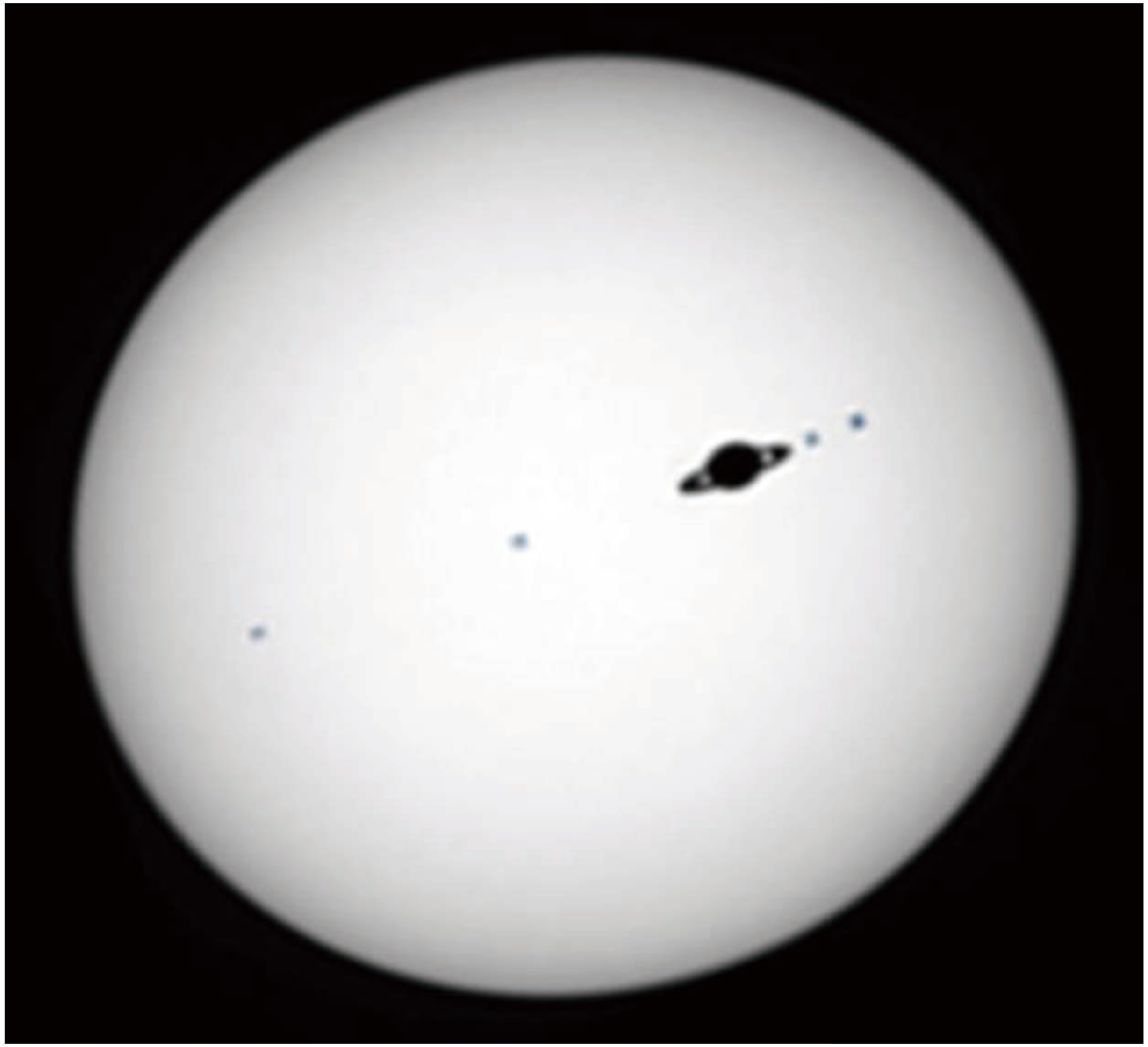


Measurement of
stellar diameters

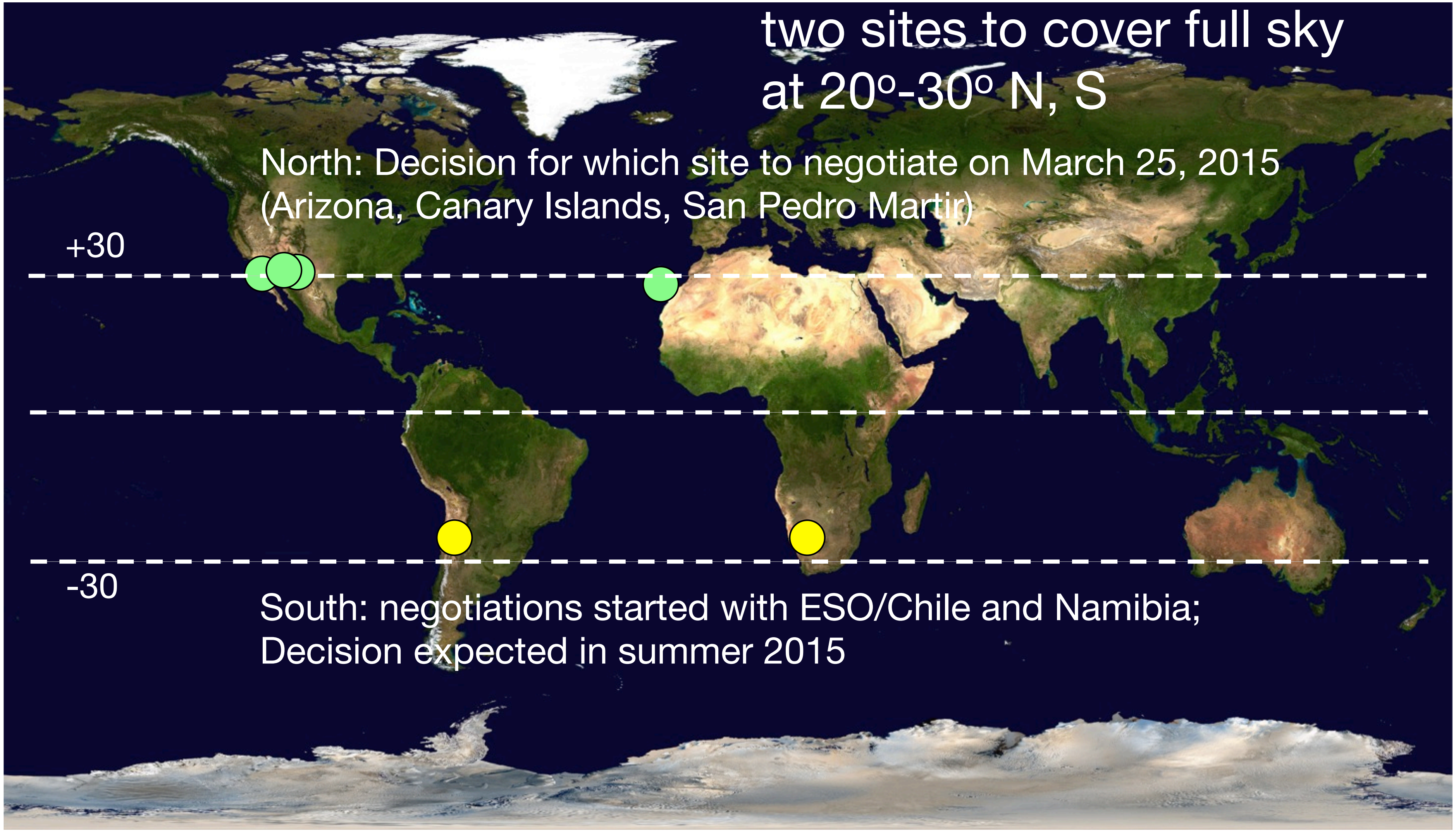
INTENSITY INTERFEROMETRY

Dravins & Lagadec 2014

Saturn rings in the Sirius system



SITE SELECTION



SCHEDULE

Deploy ~10% of tels. | Mass deployment

Pre-Construction Phase 2014-2015

Pre-Production Phase 2016-2017

Production Phase 2018-2020

7/2016
First telescopes
on site (earliest)

Pre-Construction Phase 2014-2015

4/2014
Site
narrowing
South

7/2014
Interim LE
founded:
CTAO GmbH

3/2015
Site
narrowing
South

6/2015
Critical
Design
Review

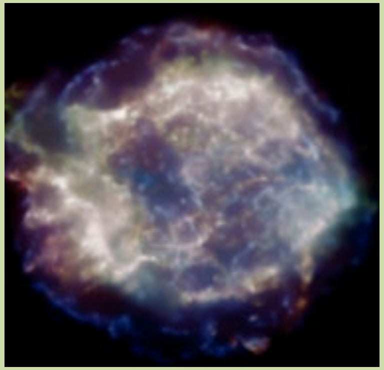
7/2017
Site
decision
South

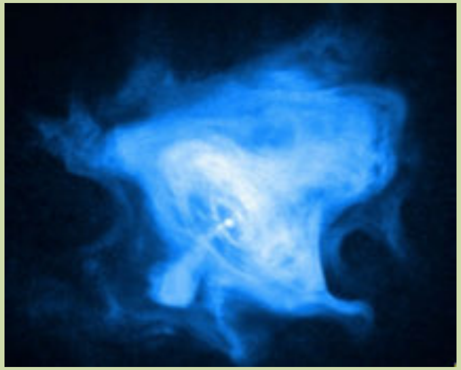
Site
decision
North

Founding
Agree-
ment

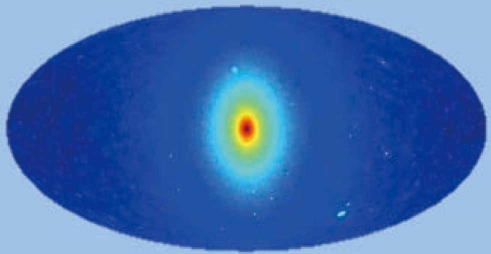
CTA SCIENCE

In-depth understanding of known objects and their mechanisms





Expected discoveries of new object classes



The fun part:
Things we haven't thought of

?