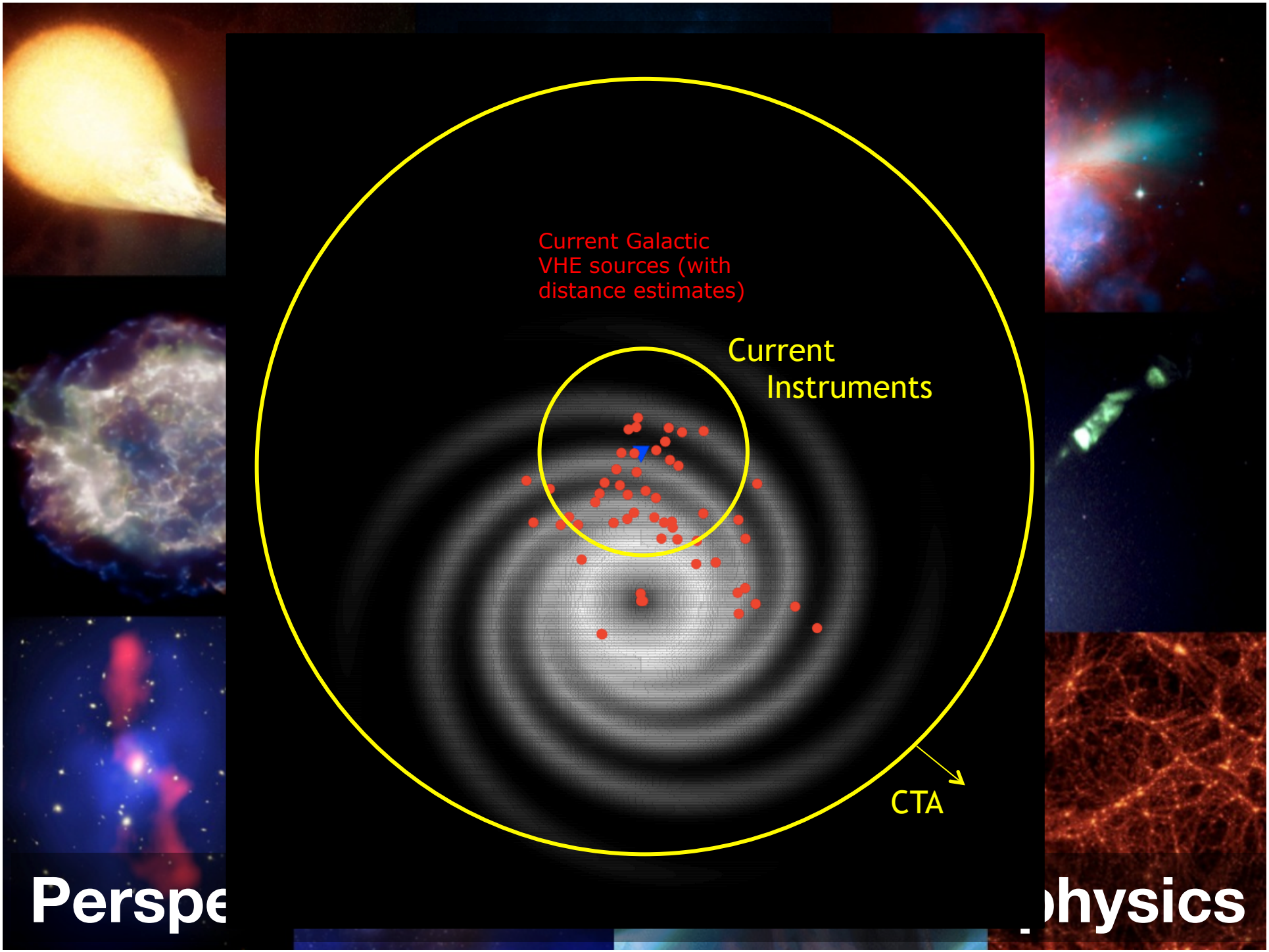
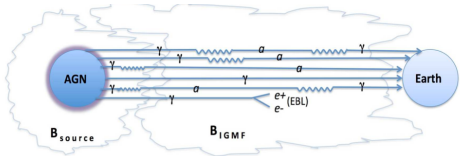
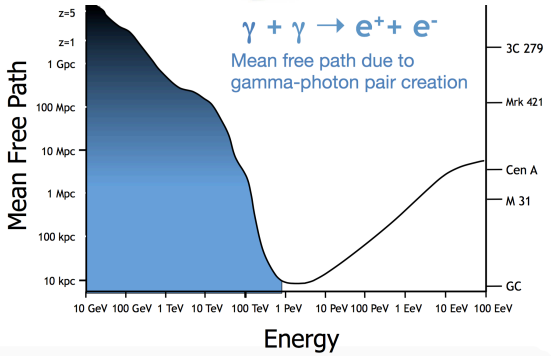
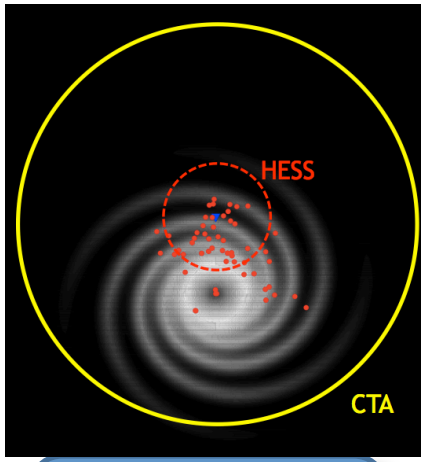
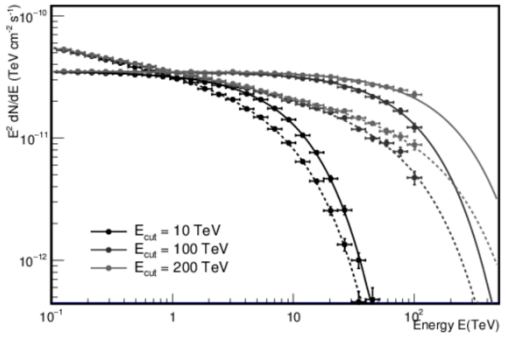

W. Hofmann
MPI for Nuclear Physics
CTA Observatory GmbH
Heidelberg
for the CTA Consortium
cta
cherenkov telescope array
Perspectives in Relativistic Astrophysics

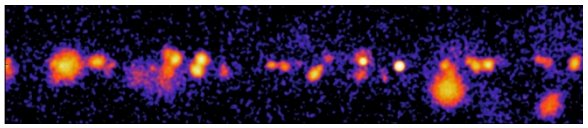

Current Galactic
VHE sources (with
distance estimates)
Current
Instruments
CTA
Perspe
hysics

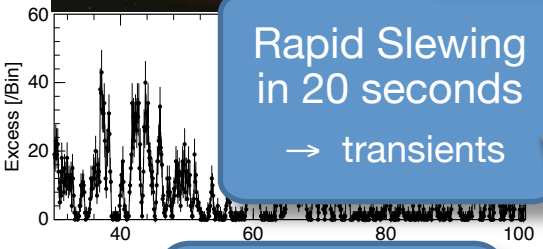


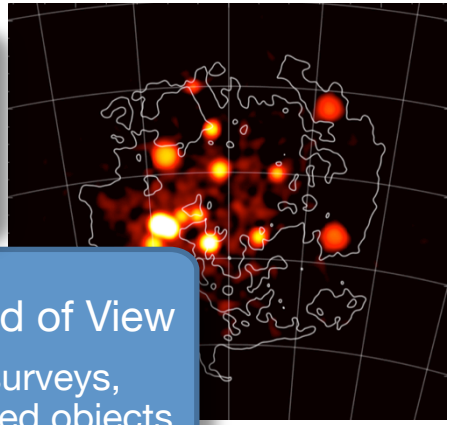



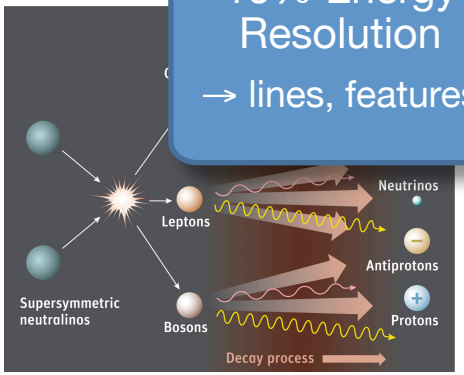



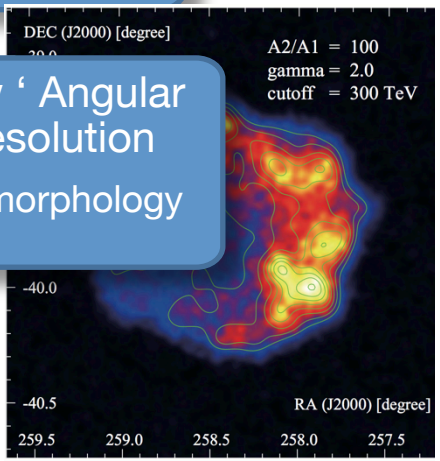








10 x Sensitivity, Large Collection Area → all topics

Energies down to 20 GeV → Cosmology++

Energies up to 300 TeV → Pevatrons

Rapid Slewing in 20 seconds → transients

8° Field of View → surveys, extended objects

10% Energy Resolution → lines, features

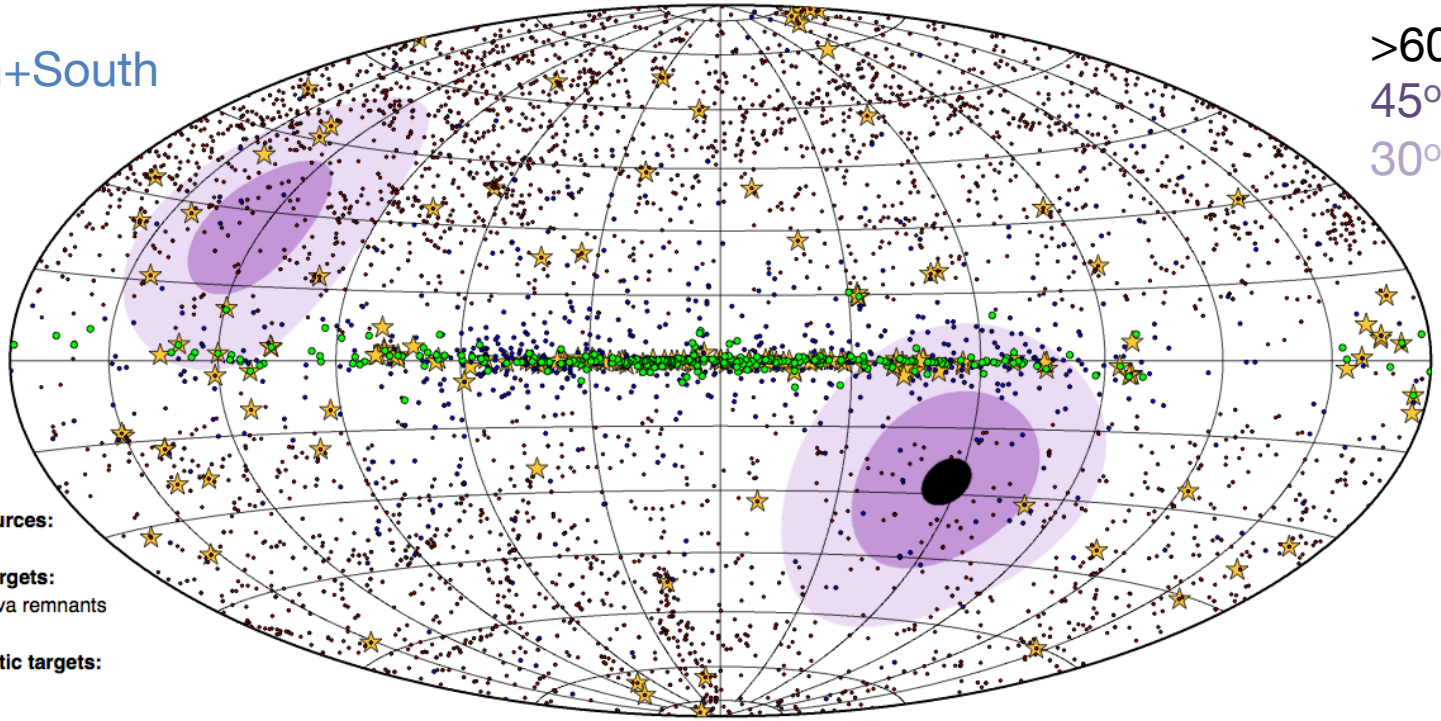
Few ' Angular Resolution → morphology

cta
cherenkov telescope array

# PLUS: ALL-SKY COVERAGE

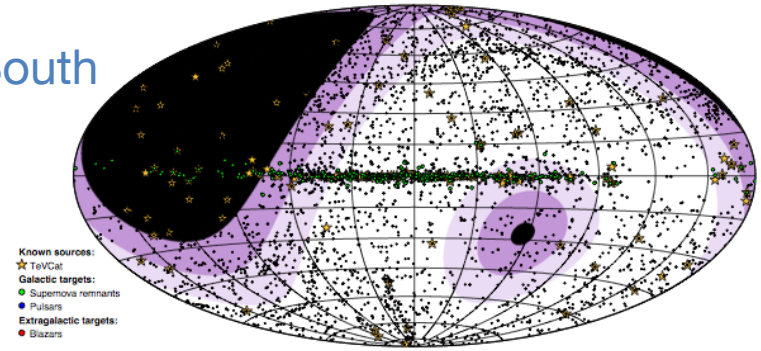
## WITH A NORTHERN AND A SOUTHERN SITE

North+South

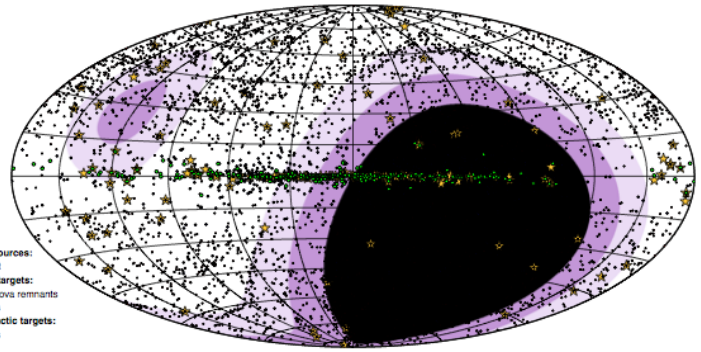



>60° zenith
45°-60°
30°-45°

South




North



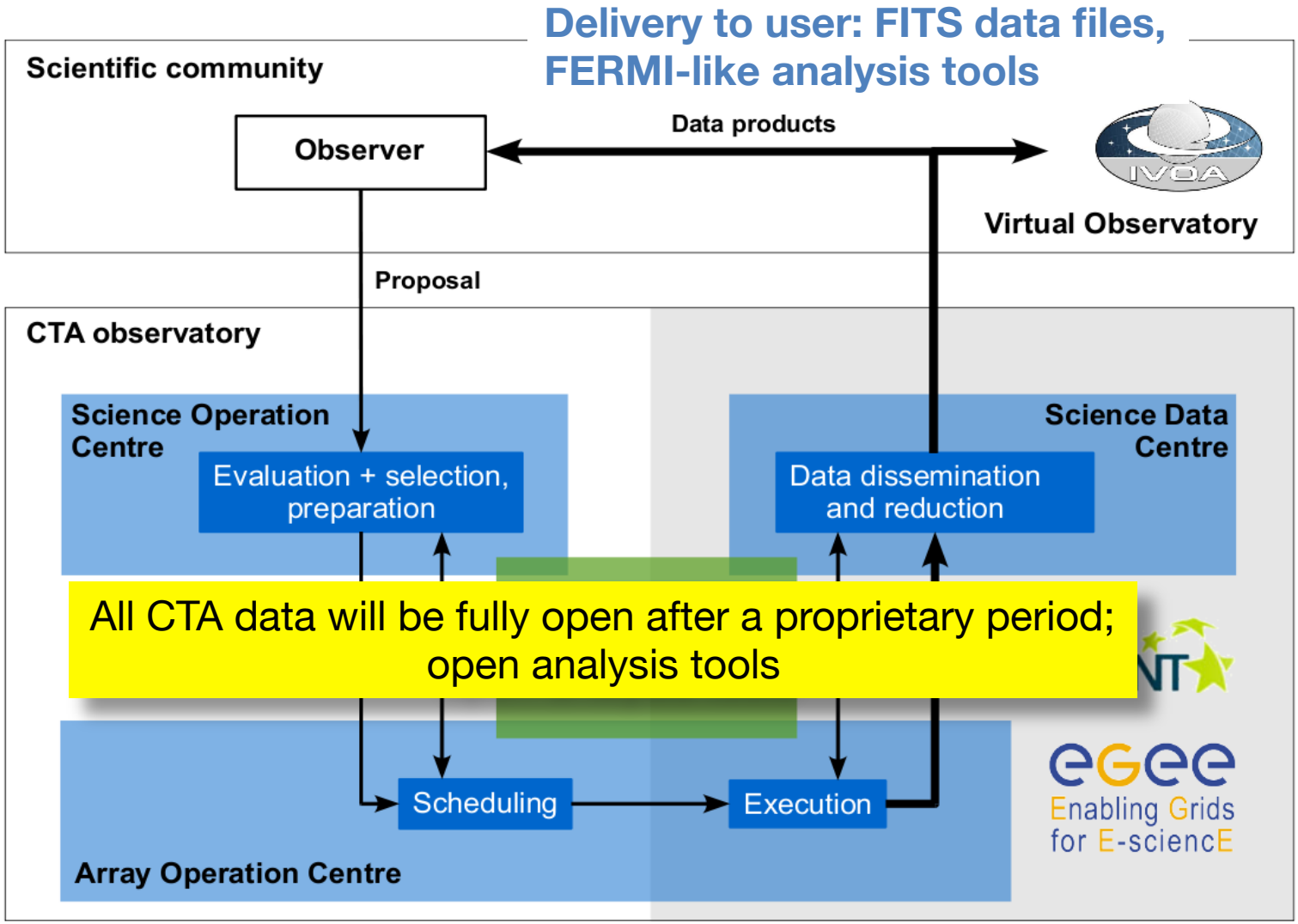
# NEWS RELEASE

**FOR IMMEDIATE RELEASE**
**16 July 2015**

## Paranal and La Palma Sites Chosen for Final Negotiations to Host World's Largest Array of Gamma-Ray Telescopes

**Zeuthen, Germany** – On 15 and 16 July 2015, the Cherenkov Telescope Array (CTA)

# PLUS: OPERATION AS OBSERVATORY




The CTA Telescope Arrays
CTA Performance
The Big Science Themes
The Basis: Surveys
Particle Acceleration
Active Galaxies
Fundamental Physics
& Dark Matter
cta
cherenkov telescope array


# The CTA Telescope Arrays

CTA Performance

The Big Science Themes

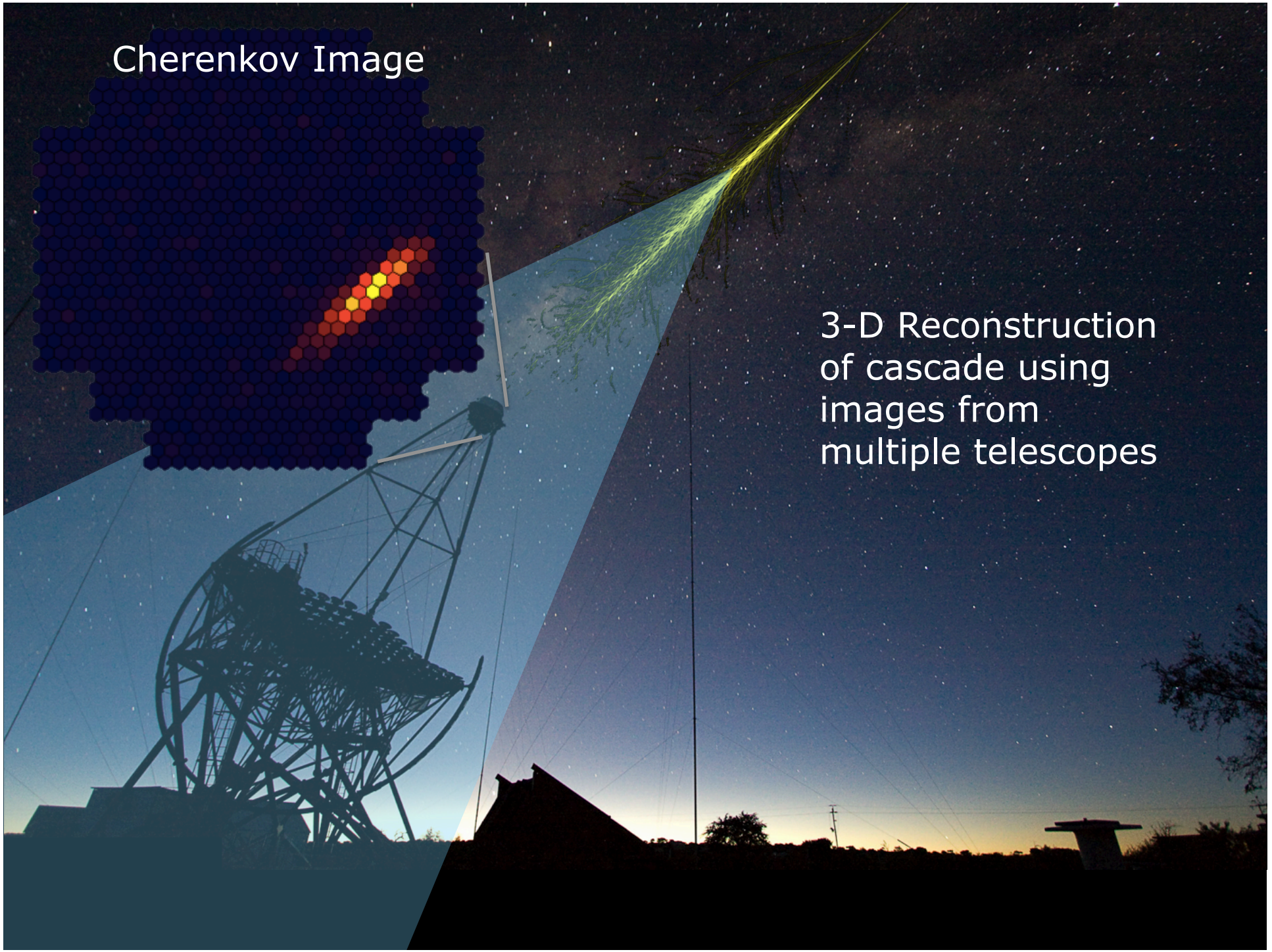
The Basis: Surveys

Particle Acceleration

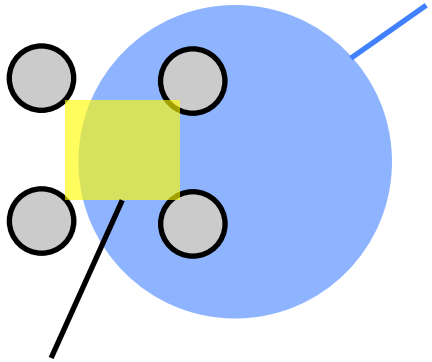
Active Galaxies

Fundamental Physics

& Dark Matter

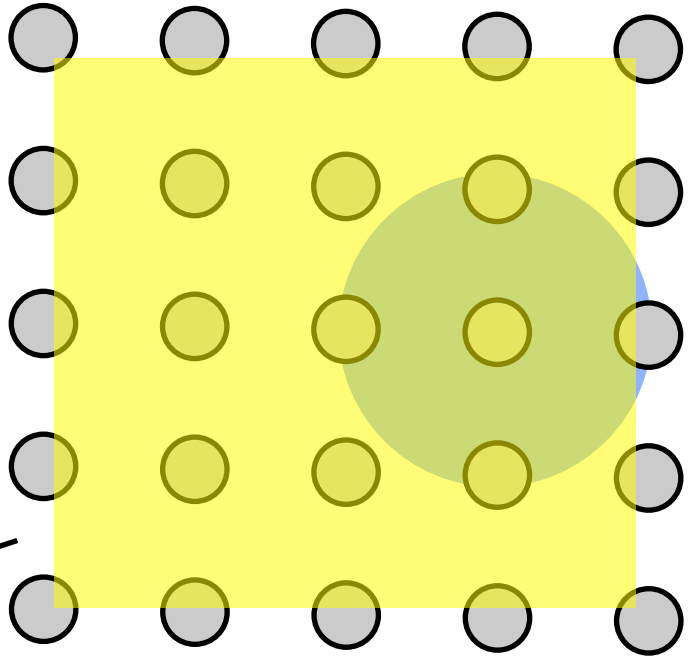

Cherenkov Image
3-D Reconstruction of cascade using images from multiple telescopes

# FROM CURRENT ARRAYS TO CTA

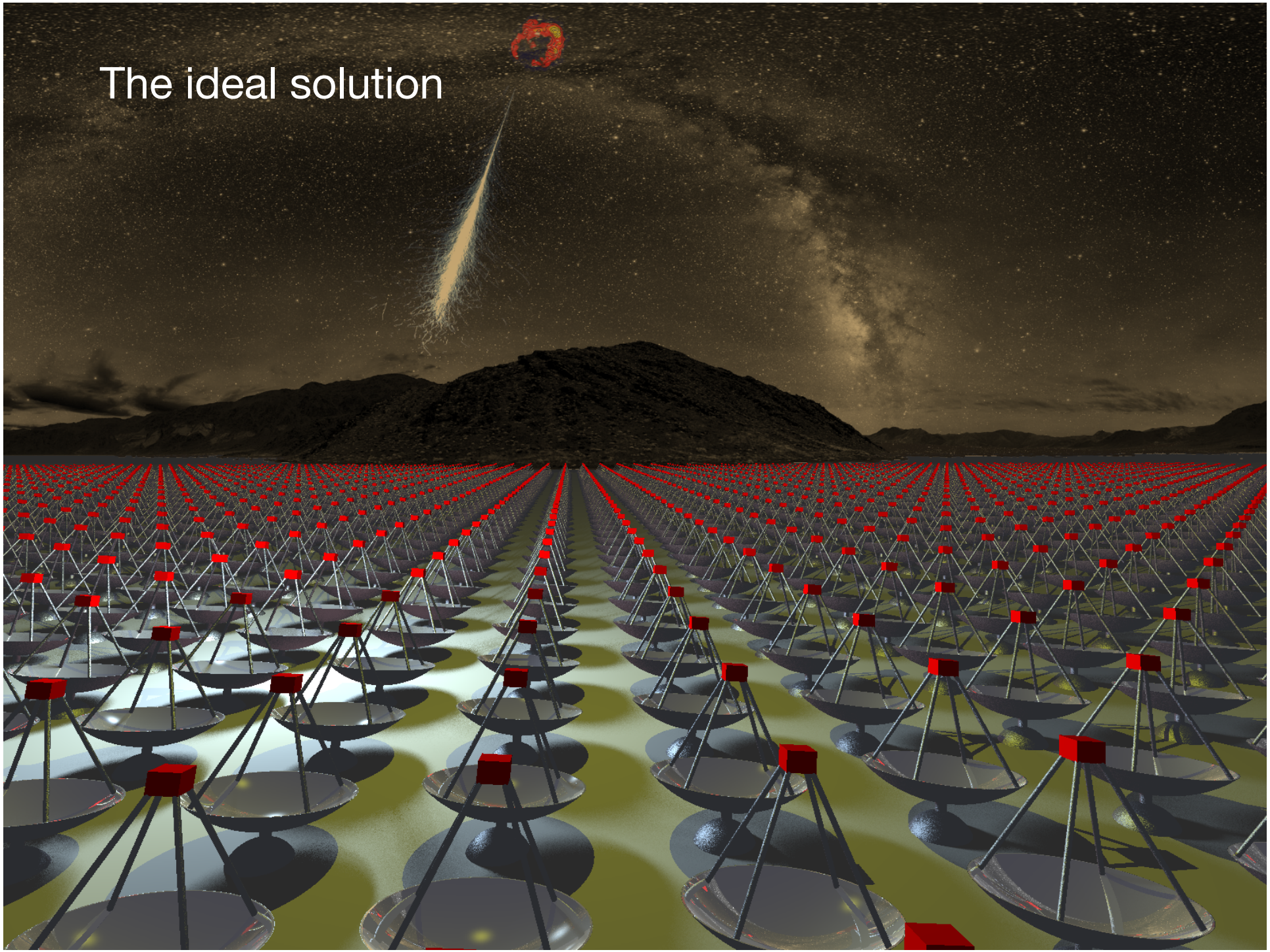


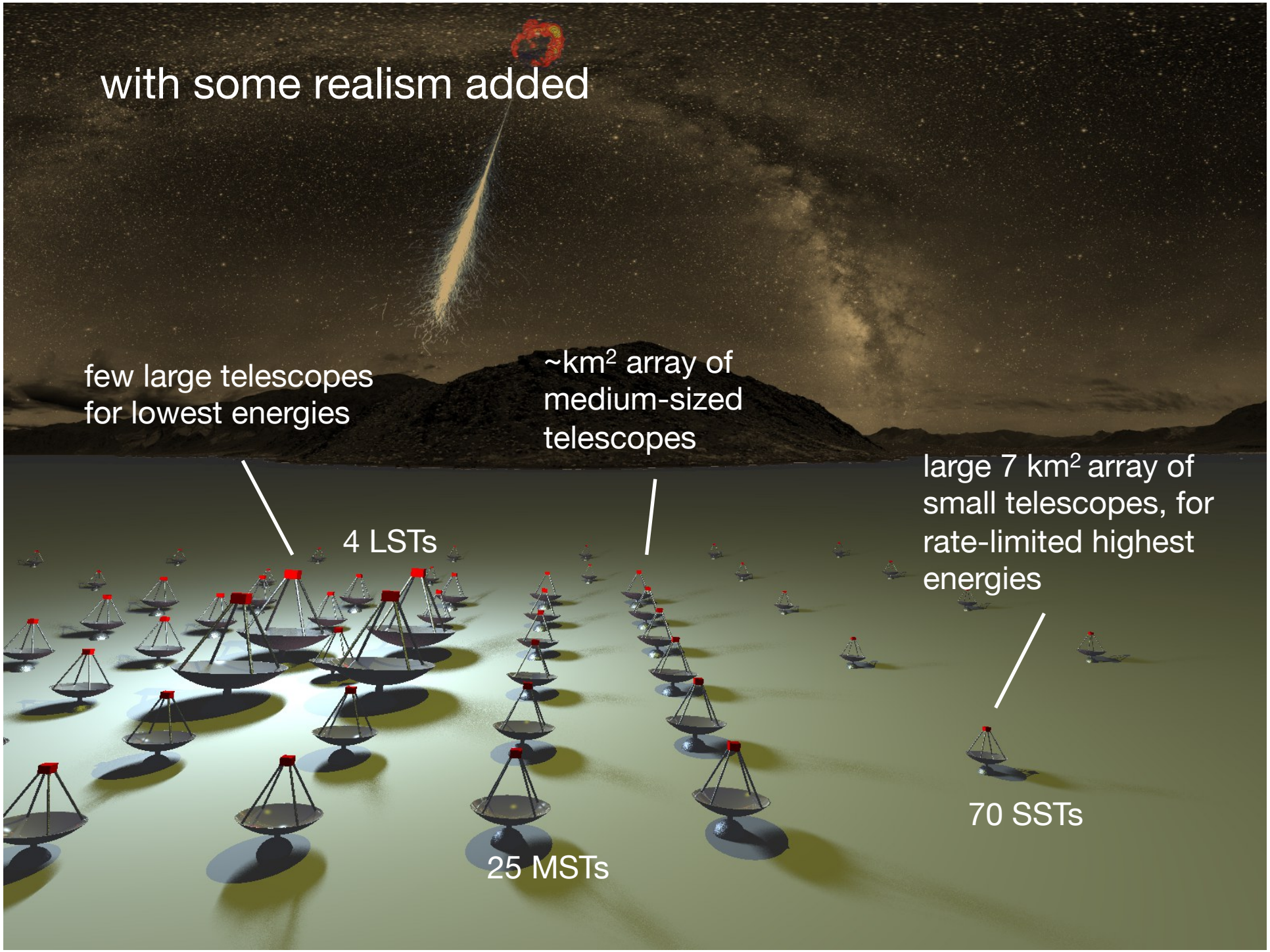
light pool radius
R ≈100-150 m
≈ typical telescope spacing

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

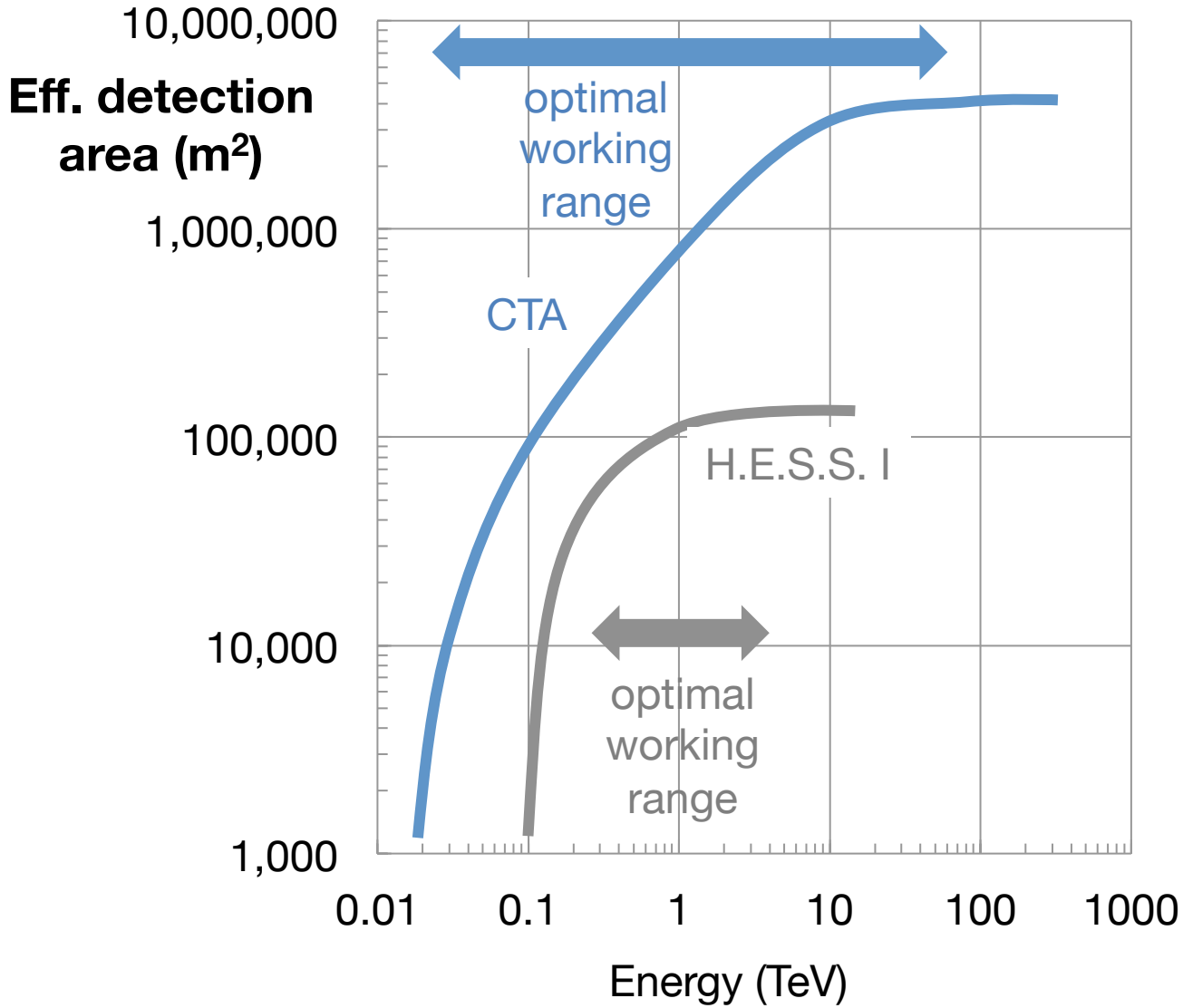


large detection area
more images per shower
lower trigger threshold


The ideal solution

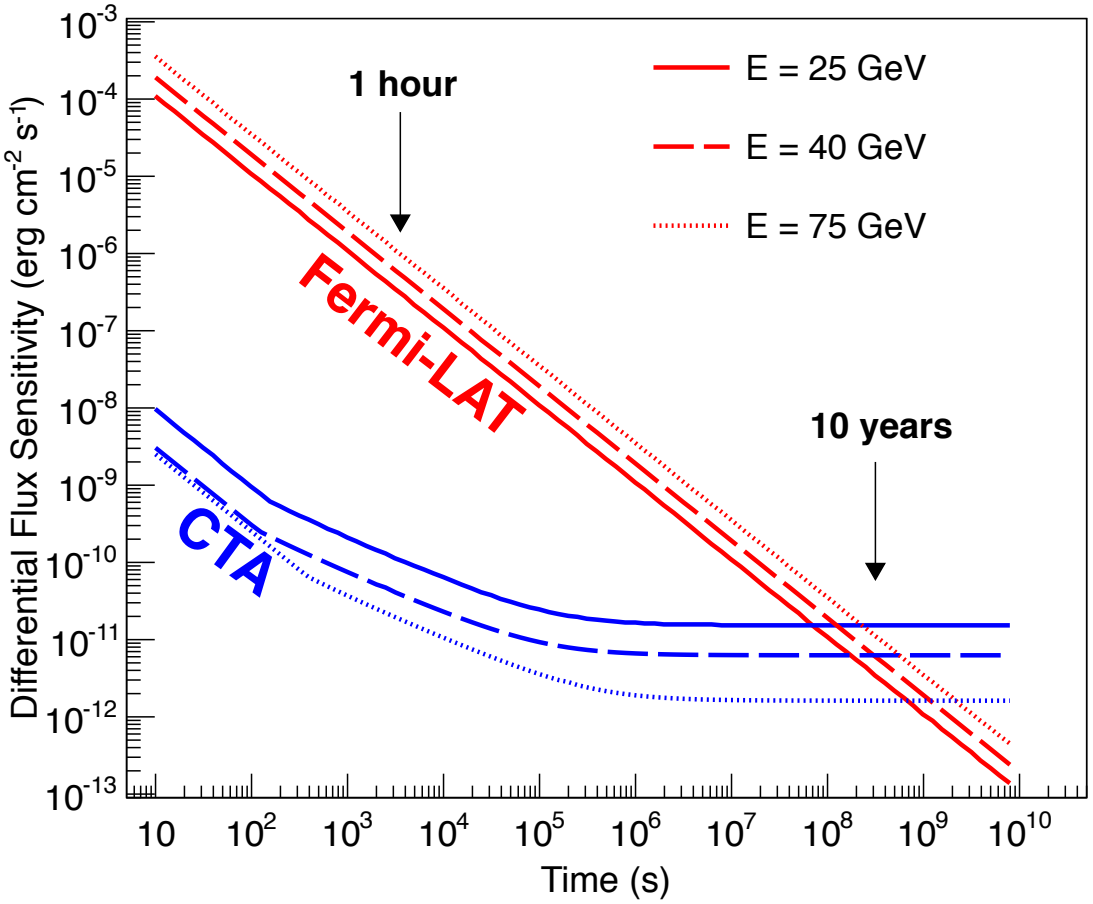

with some realism added
few large telescopes
for lowest energies
~km² array of
medium-sized
telescopes
large 7 km² array of
small telescopes, for
rate-limited highest
energies
4 LSTs
25 MSTs
70 SSTs

# CTA ENERGY COVERAGE



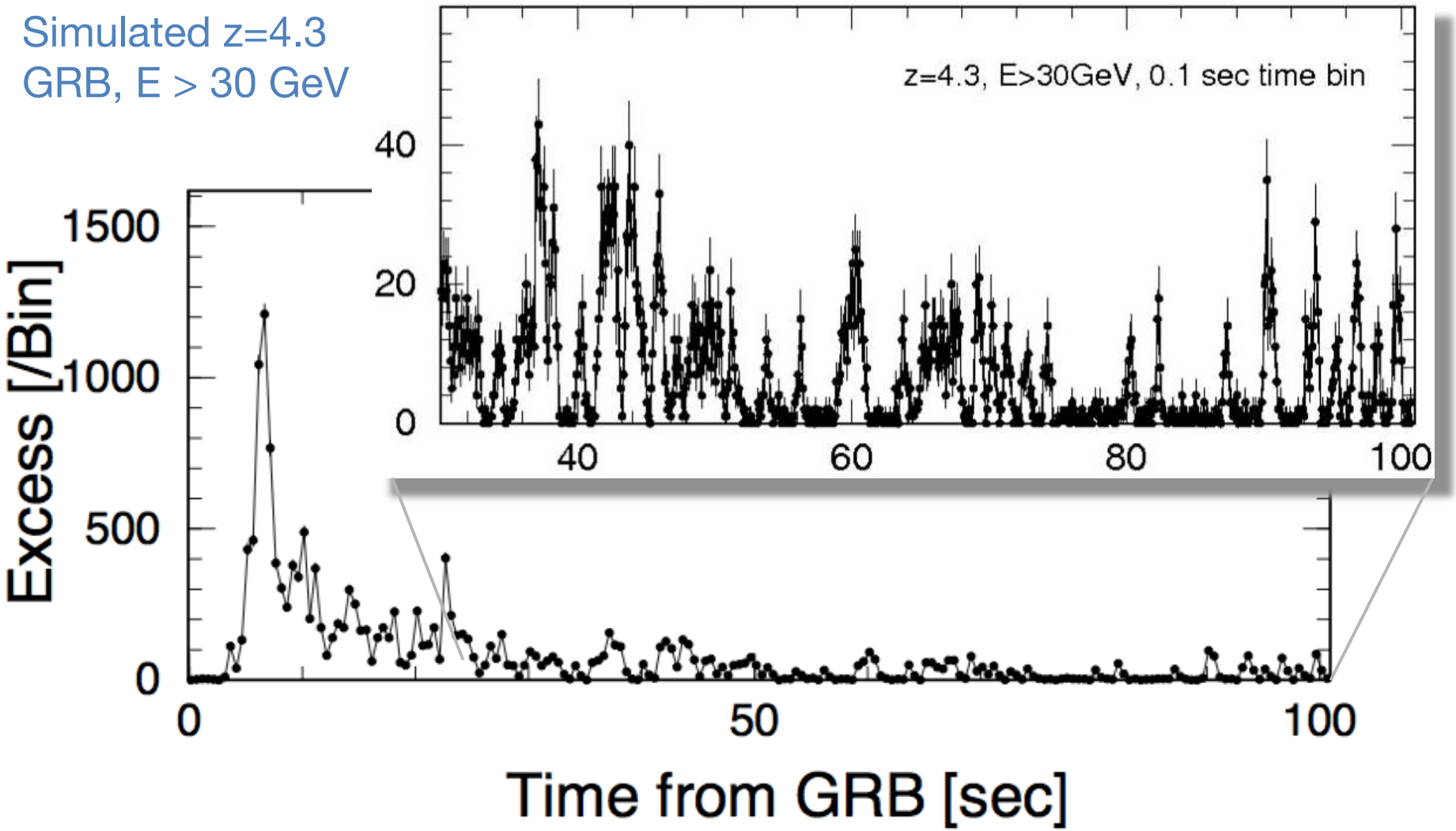
# CTA AS A TRANSIENT FACTORY

- Huge advantage over Fermi in energy range of overlap for ~minute to ~week timescale phenomena
  - Explosive transients, AGN flares, binary systems
- Disadvantage
  - Slewing time ~20 s and limited (cf Fermi) Field of View
  - External triggers critical

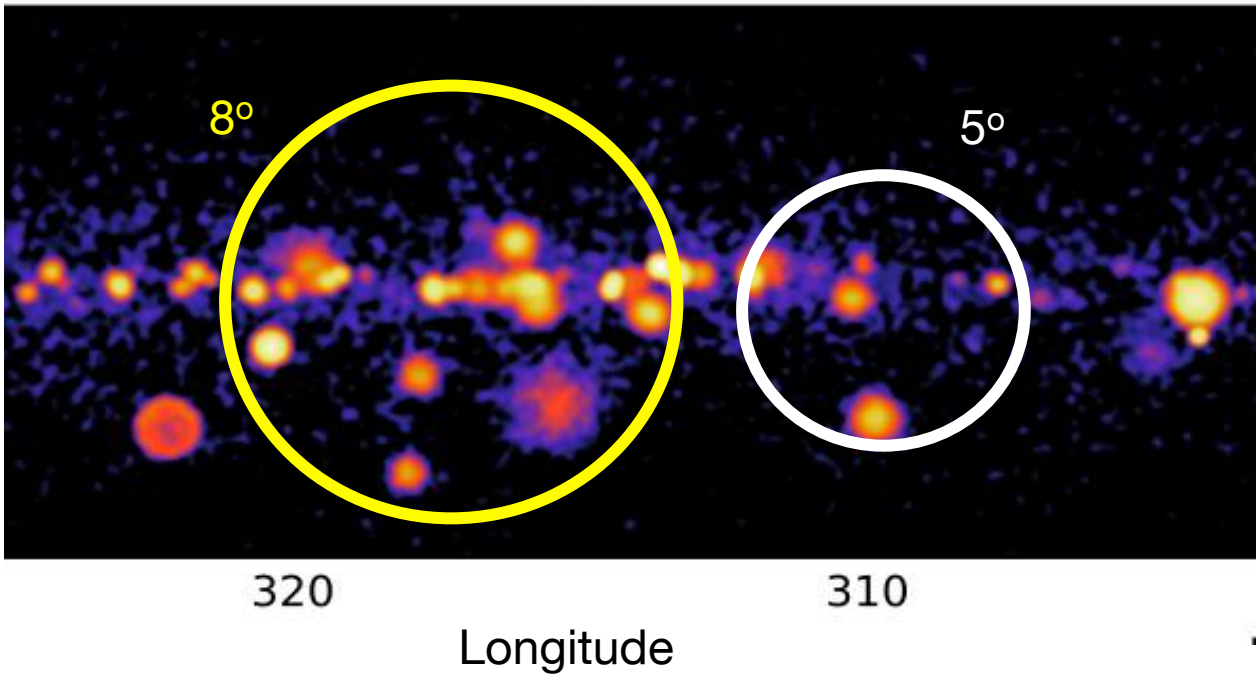


# CTA AS A TRANSIENT FACTORY

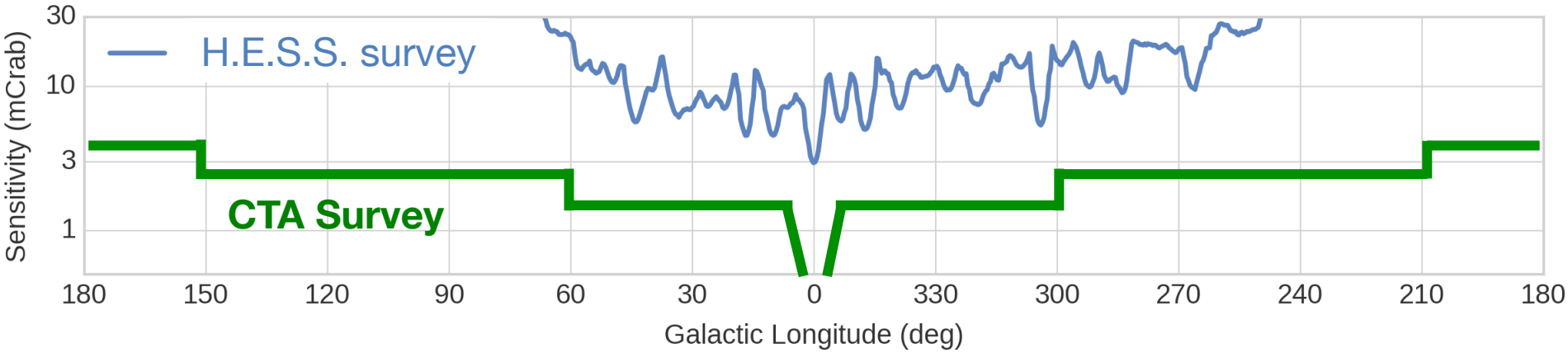
Simulated z=4.3
GRB, E > 30 GeV



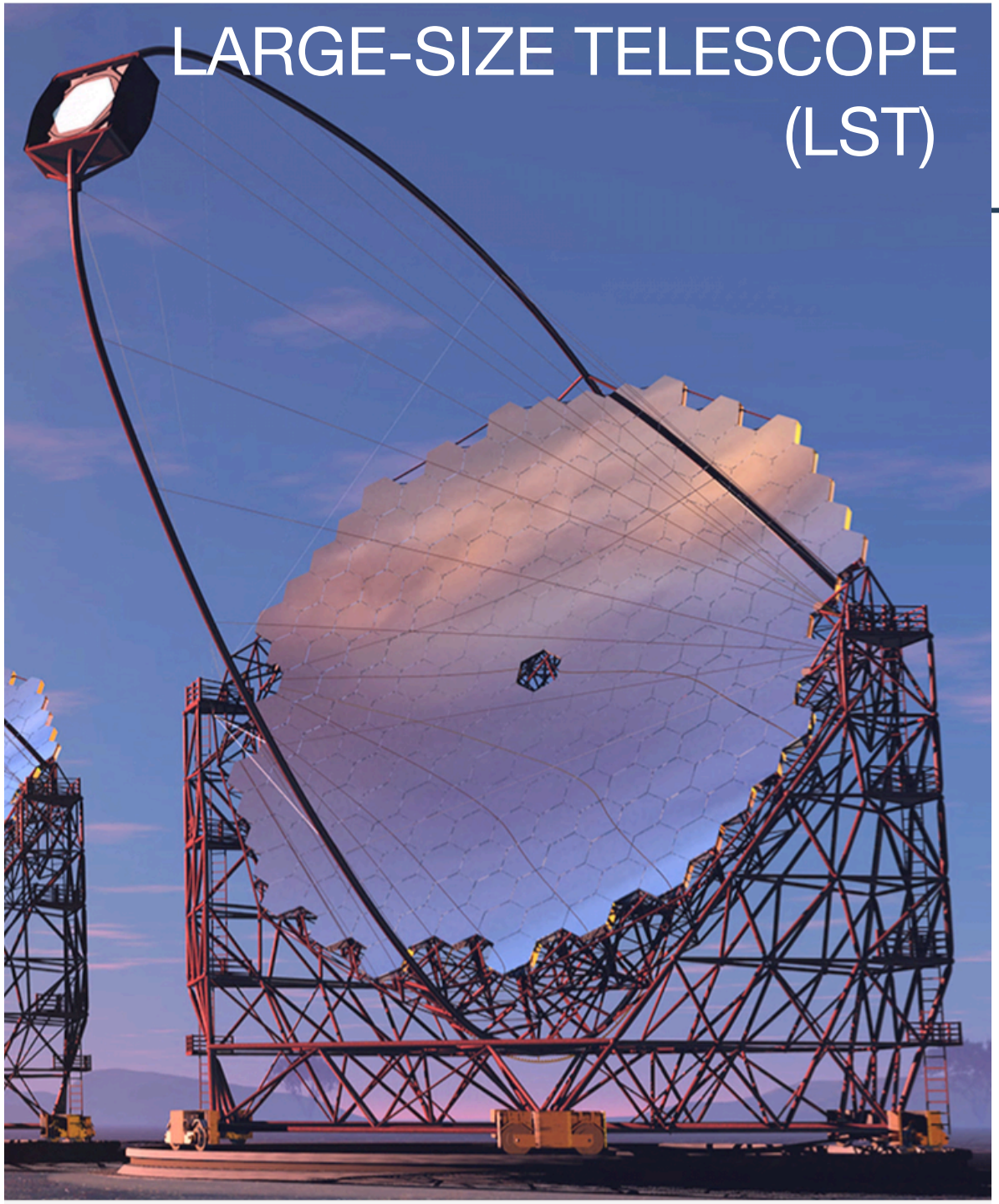
# CTA AS A SURVEY MACHINE




Simulated
CTA Galactic Survey



# LARGE-SIZE TELESCOPE (LST)



cta
cherenkov telescope array

23 m diameter, f= 28 m
368 $m^2$ eff. mirror area
1.5 m mirror facets
Active mirror control

4.5° field of view
0.1° PMT pixels
QE-enhanced PMTs

Carbon-fibre structure
for 20 s positioning

**4 LSTs on southern site**
**4 LSTs on northern site**

# MEDIUM-SIZED 13.8 M TELESCOPE

## OPTIMIZED FOR THE 100 GEV TO ~10 TEV RANGE

88 $m^2$ eff. mirror area
16 m focal length
1.2 m mirror facets

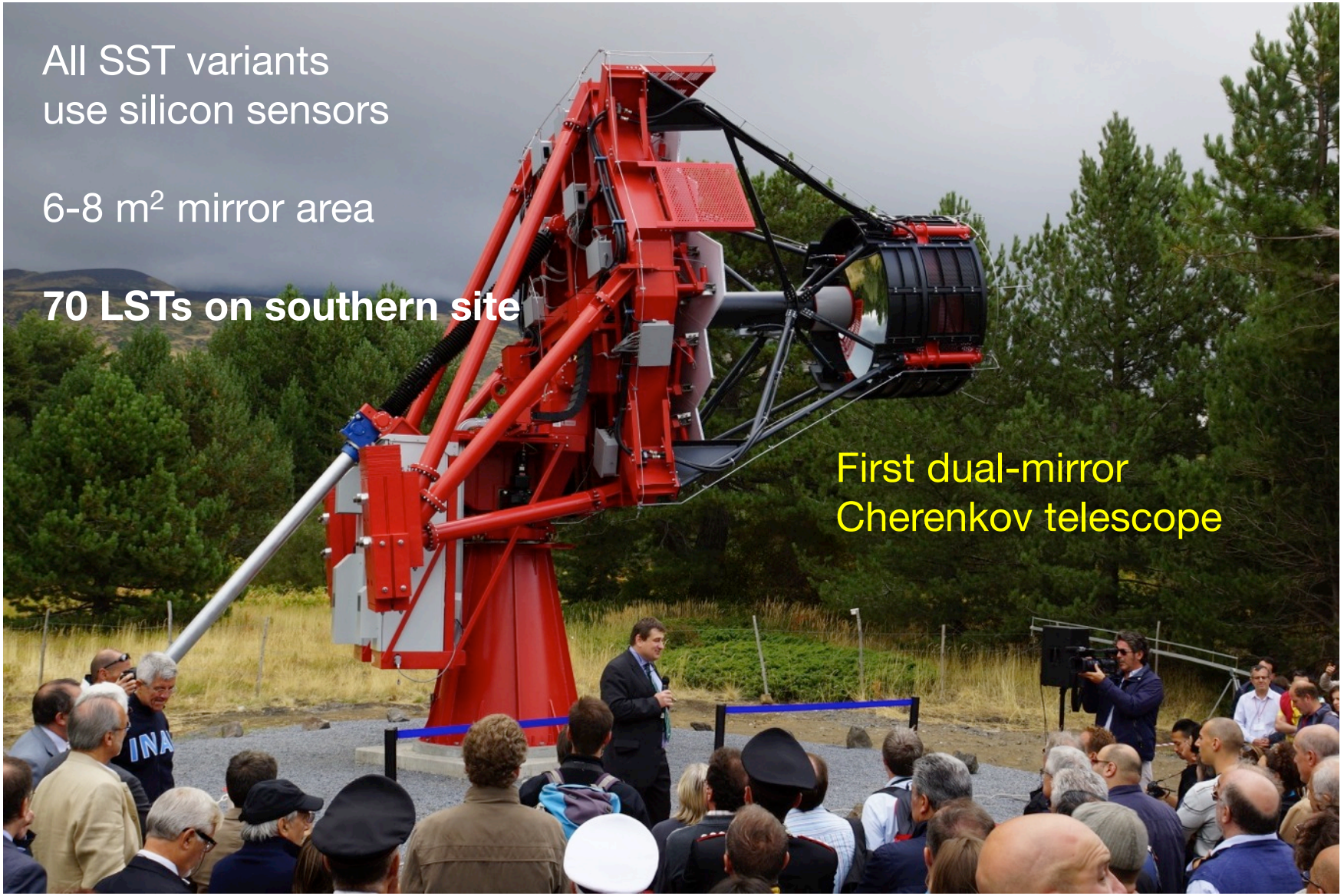
8° field of view
~1800 x 0.18° pixels

**25 MSTs on southern site**
**15 MSTs on northern site**


Prototype at
Berlin-Adlershof

# SMALL SIZE TELESCOPE (SST)

## THREE VARIANTS; SHOWN HERE: ASTRI PROTOTYPE



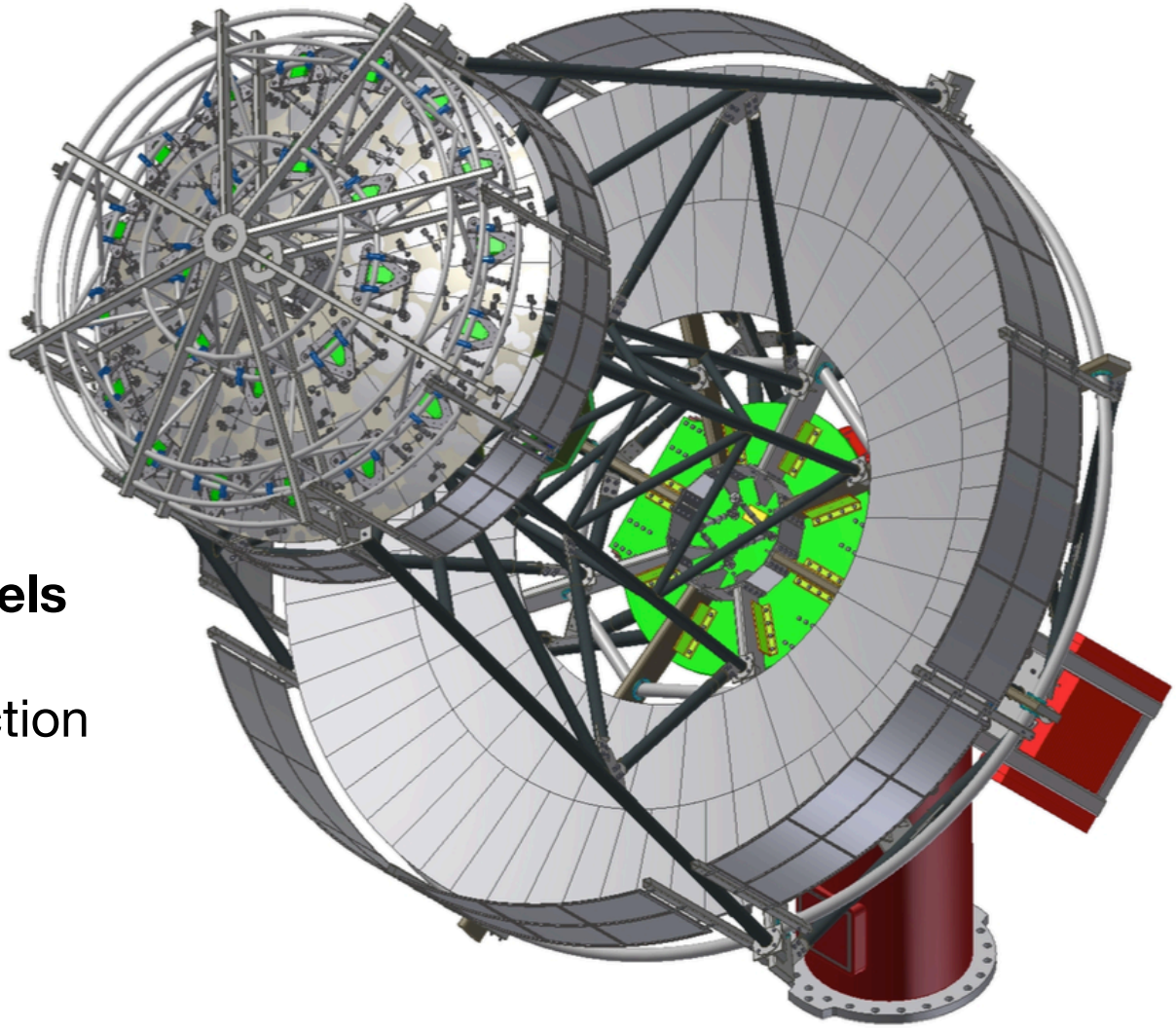
# MEDIUM-SIZED DUAL MIRROR TEL.

## EXTENDING THE MST ARRAY

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

8° field of view
**11328 x 0.07° SiPMT pixels**

Prototype under construction
(VERITAS sites)




The CTA Telescope Arrays
More on CTA Performance
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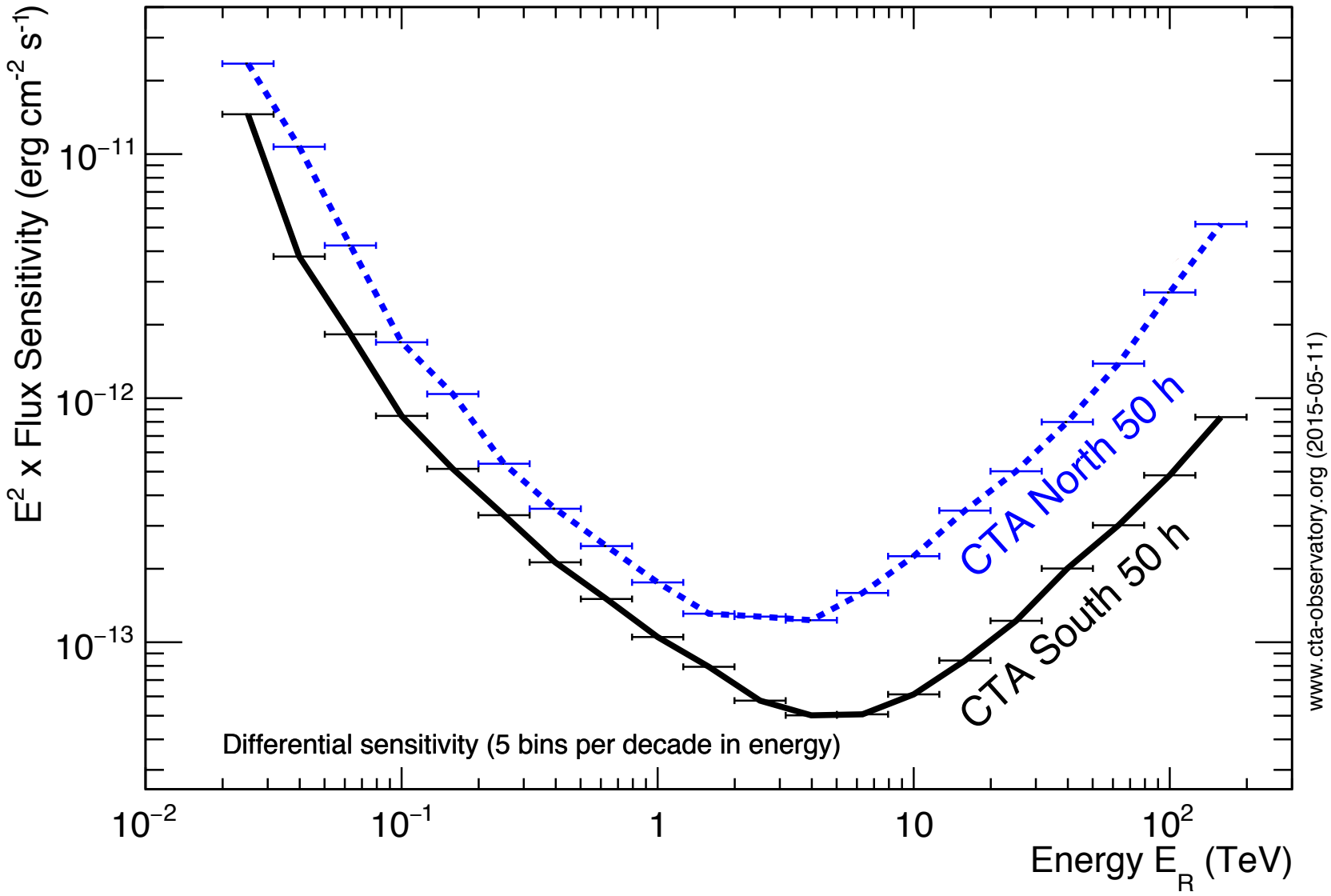
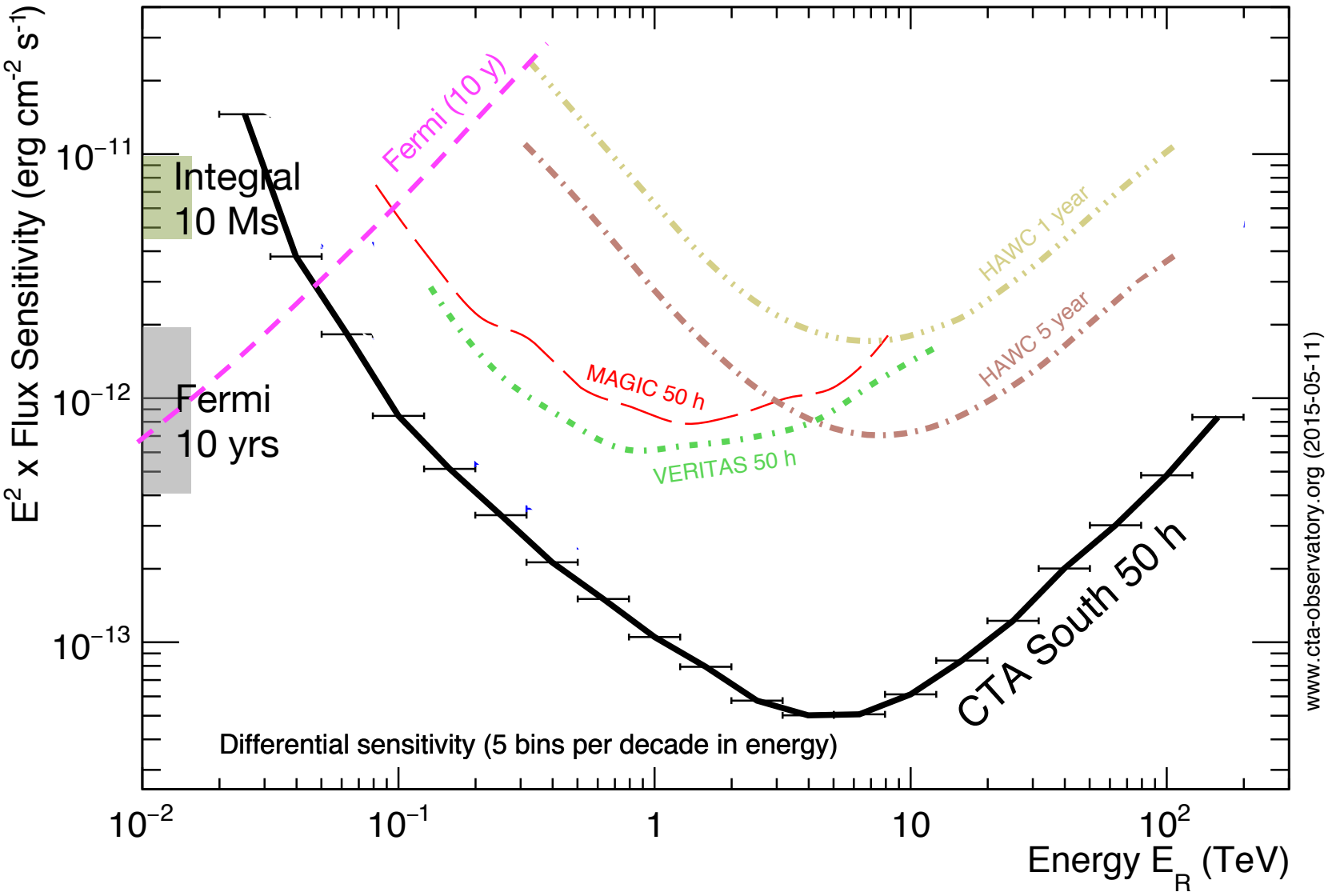
# (DIFFERENTIAL) SENSITIVITY



# (DIFFERENTIAL) SENSITIVITY




THE CTA TELESCOPE ARRAYS
CTA PERFORMANCE
**THE BIG THEMES**
THE BASIS: SURVEYS
PARTICLE ACCELERATION
ACTIVE GALAXIES
FUNDAMENTAL PHYSICS
& DARK MATTER

## 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

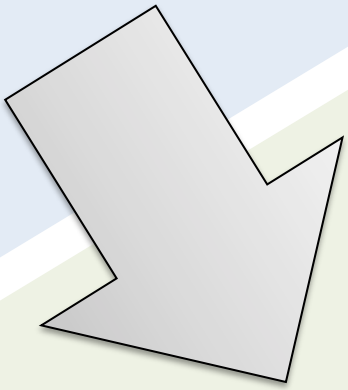
## Theme 3: Physics Frontiers – beyond the SM

- 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?

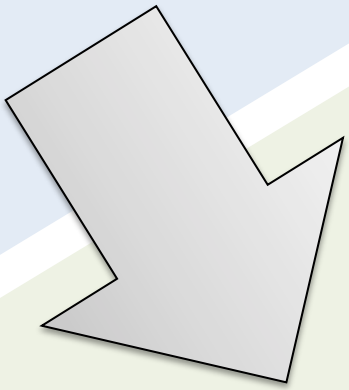
# CTA SCIENCE PROGRAMME

## Key Science Programmes

- Ensure that important science questions for CTA are addressed in a coherent fashion and with a well-defined strategy,
- Conceived to provide legacy data sets for the entire community



**Example: galactic and extragalactic surveys**



- Deep investigation of known sources
- Follow-up of KSP discovered sources
- Multiwavelength campaigns
- Follow-up of ToOs from other wavebands / messengers
- Search for new sources
- …

**Proposal-Driven User Programme**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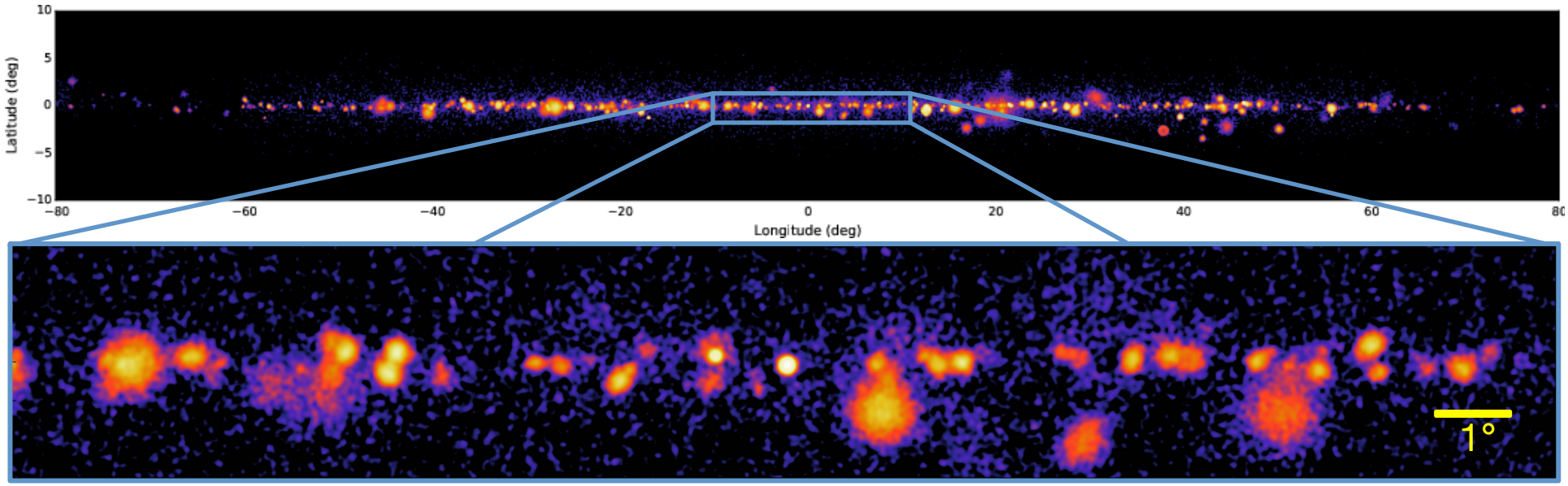
# SURVEYS

Planned surveys: a deep view of the high energy universe

- Full Galactic Plane (~1000 h)
- Deep image of Galactic Centre region (~300 h on 10° x 10° region, ~500 h on GC )
- The Large Magellanic Cloud (~340 h)
- ¼ of the sky down to 6 mCrab (~1000 h)



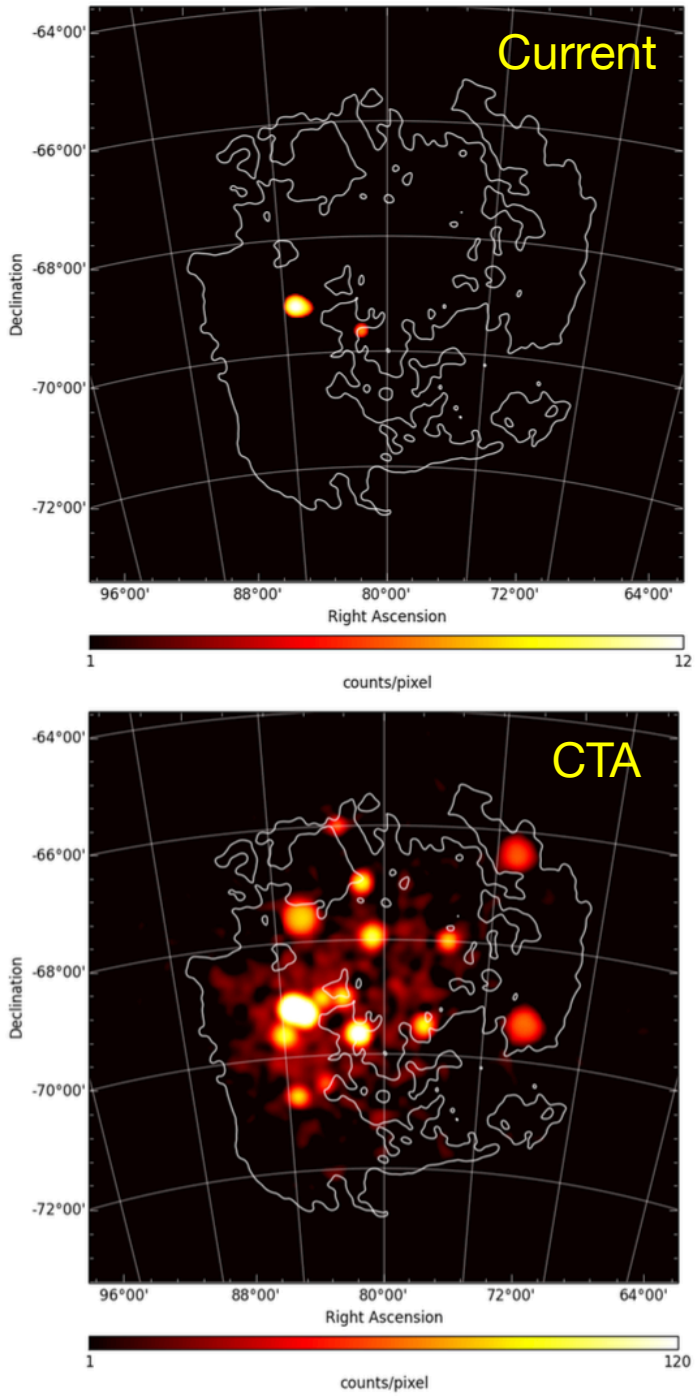
# LMC SURVEY

The Large Magellanic Cloud

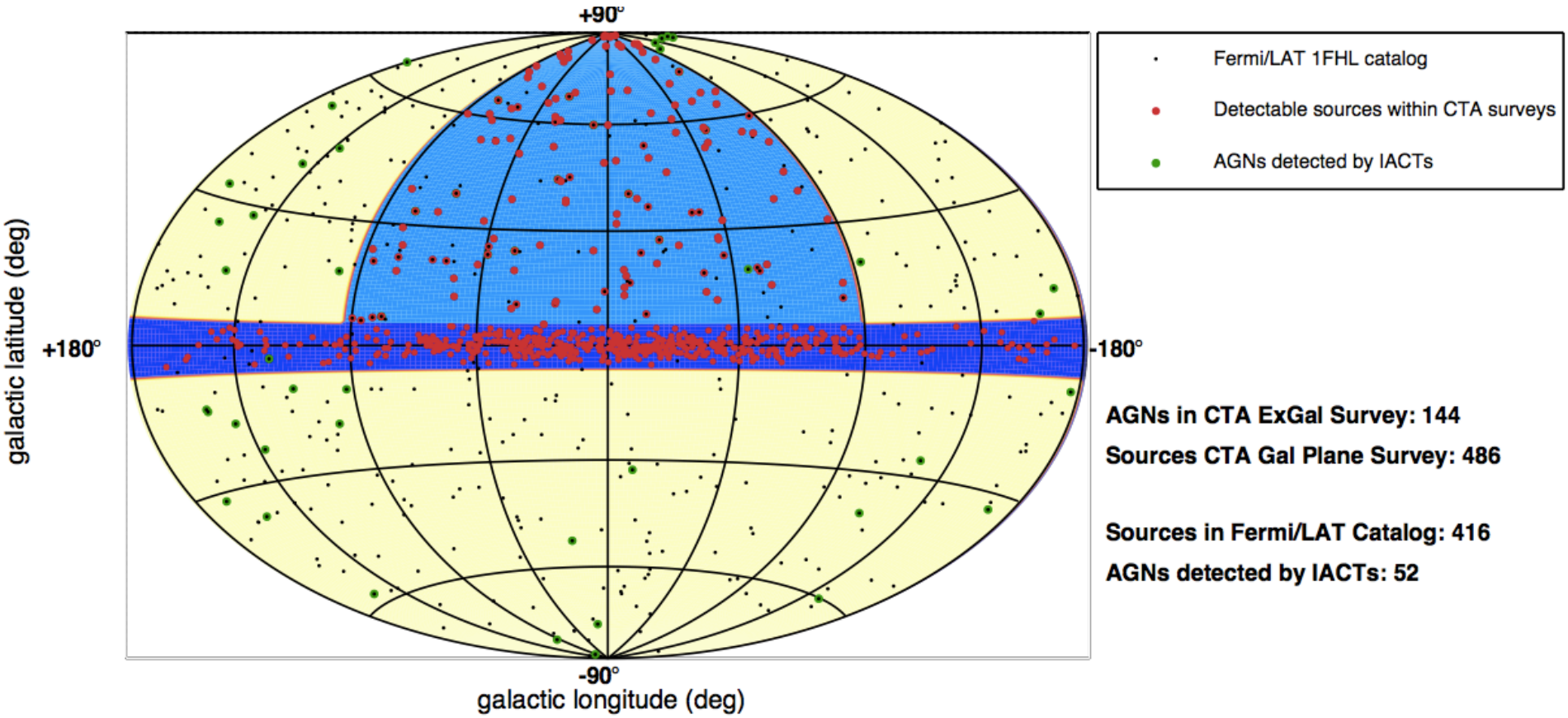
- 10% of MW star formation (2% vol.)
- Hosts extreme accelerators (HESS Coll. 2015, Science 347, 406)
- Approximately face on
- Well known distance – 50 kpc

Deep CTA observation will reveal source populations and diffuse emission

- Probing particle acceleration and propagation
- Highly complementary to GPS
- Link of star formation to CRs?



# UNBIASED SURVEY OF ¼ SKY




- Expect ~150 AGN detections
- Complementary to FERMI survey – hard-spectrum sources

# QUANTITY & QUALITY: THERE'S MORE THAN NUMBERS

Surveys allow

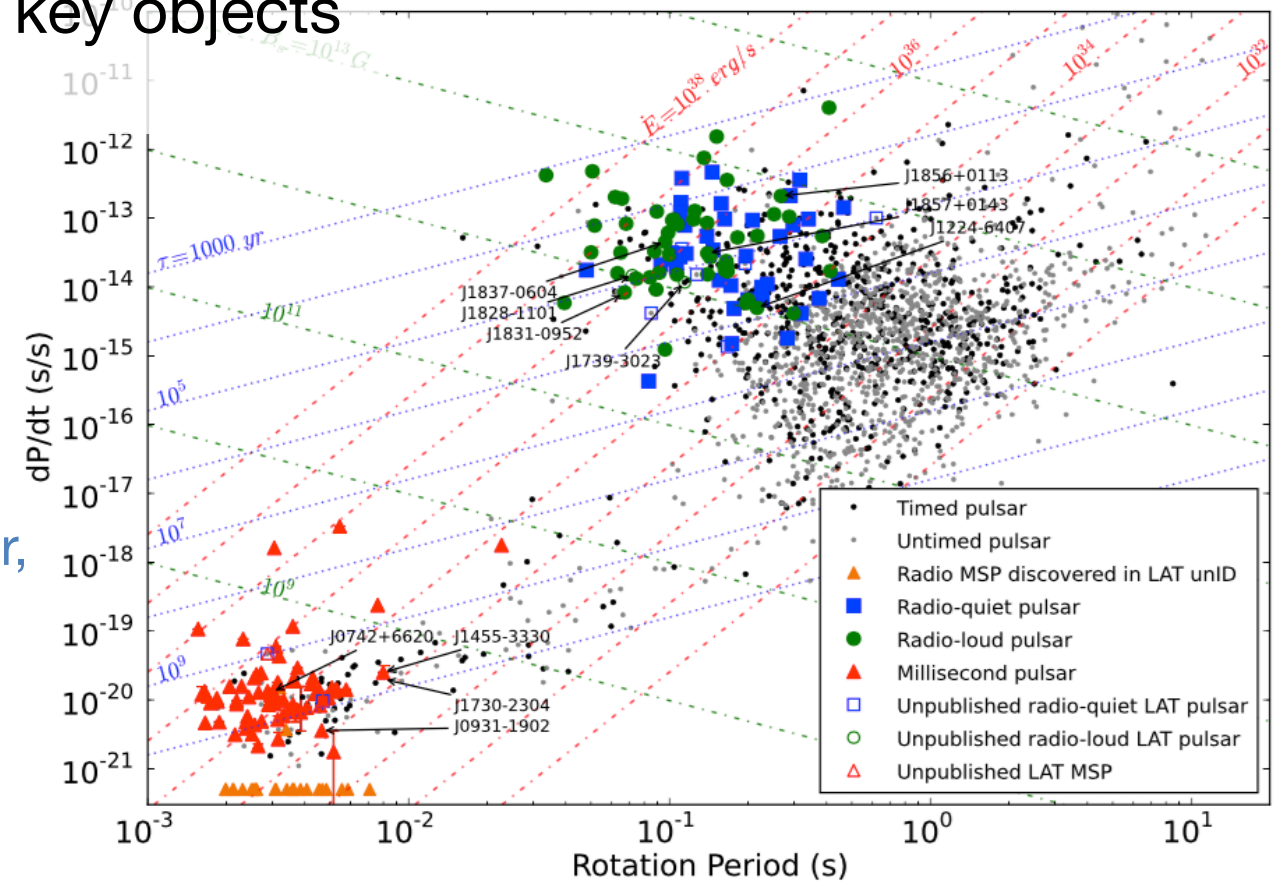
- population synthesis
- finding the few key objects

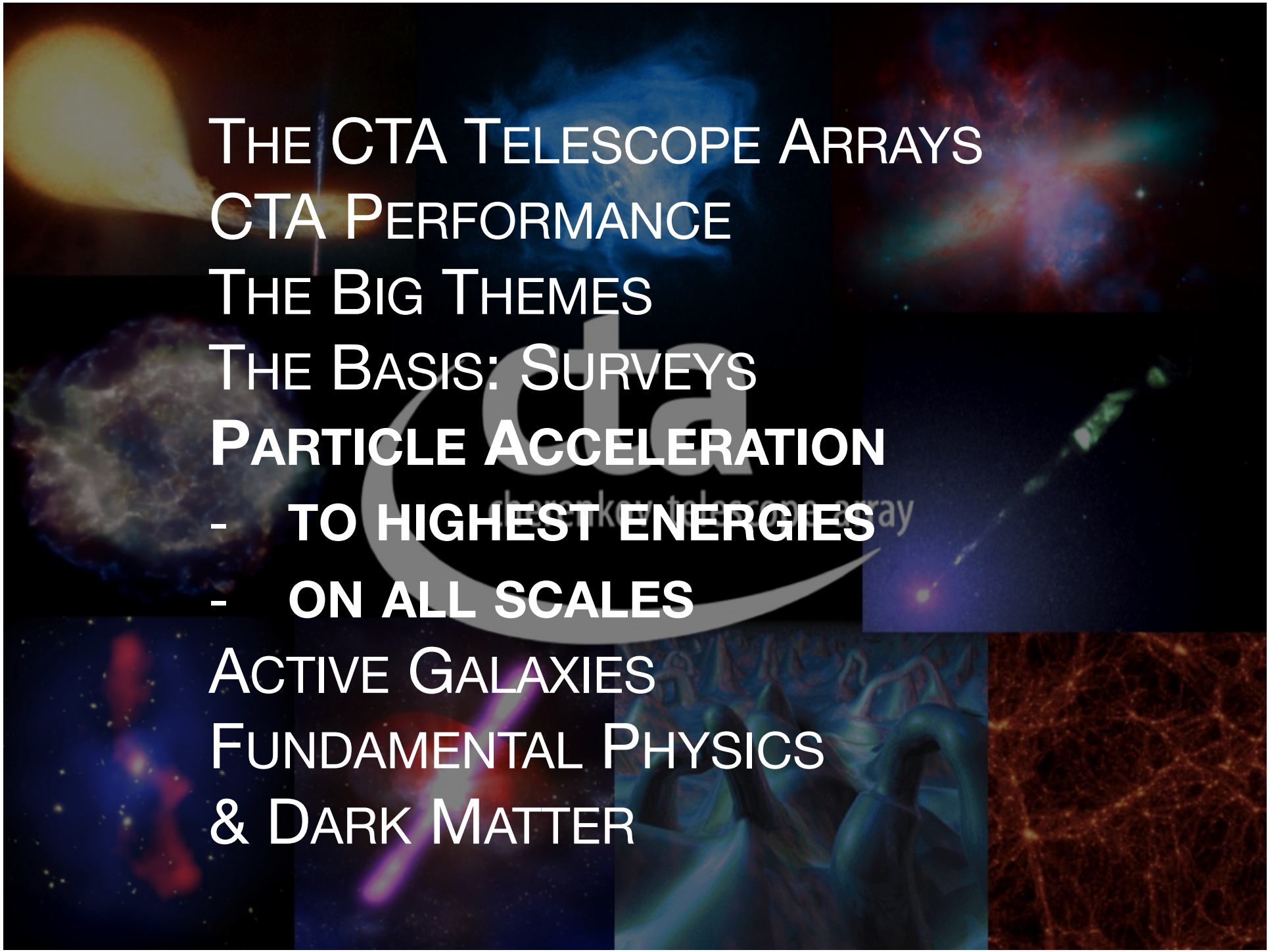
"Historical" example:
Pulsar population

&

the Hulse-Taylor pulsar,
the Double Pulsar

Laffon et al.
arXiv:1502.03251




The CTA Telescope Arrays
CTA Performance
The Big Themes
The Basis: Surveys
Particle Acceleration
- to highest energies
- on all scales
Active Galaxies
Fundamental Physics
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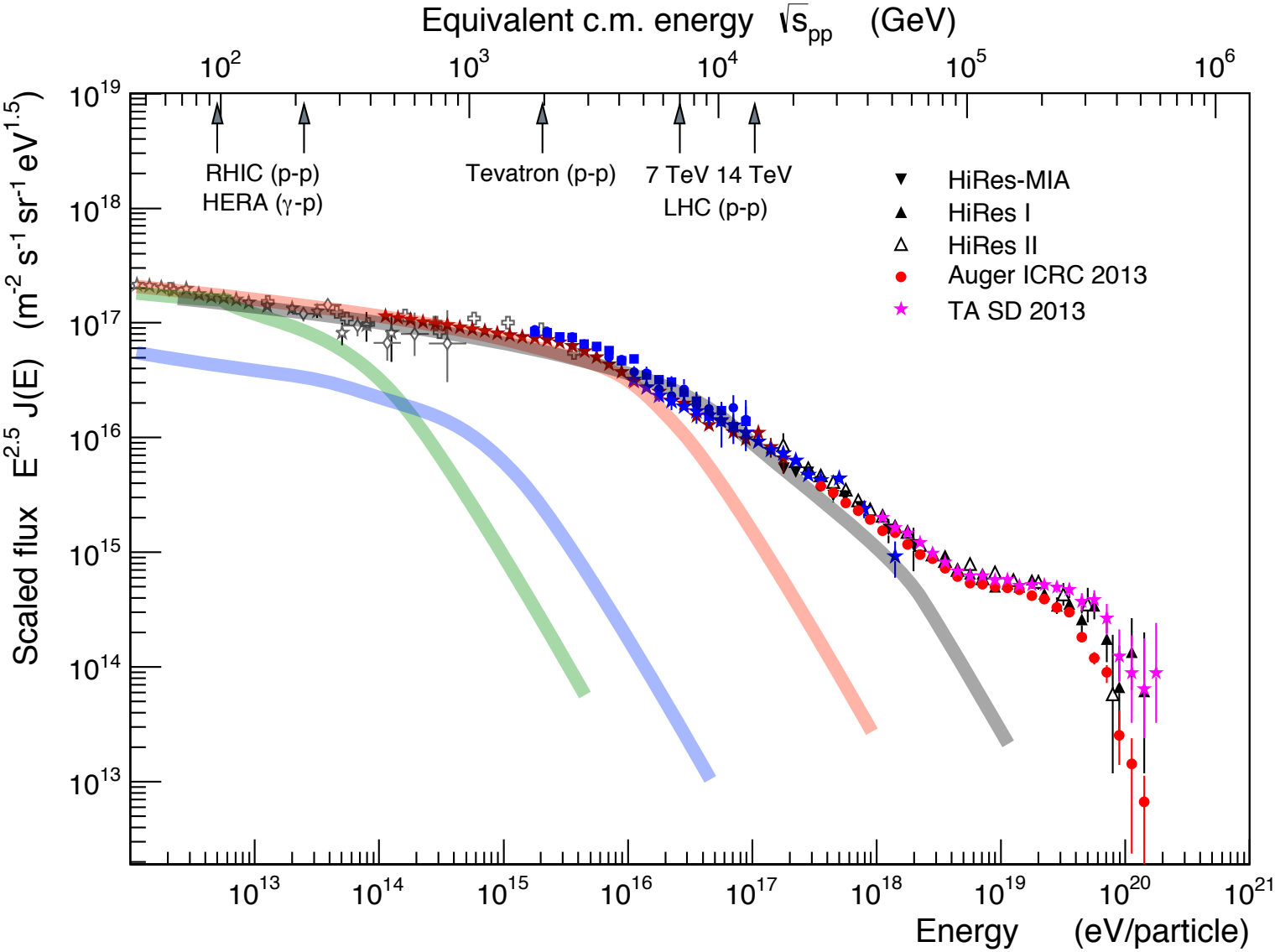
# COSMIC RAY SPECTRUM & SUPERNOVA REMNANTS



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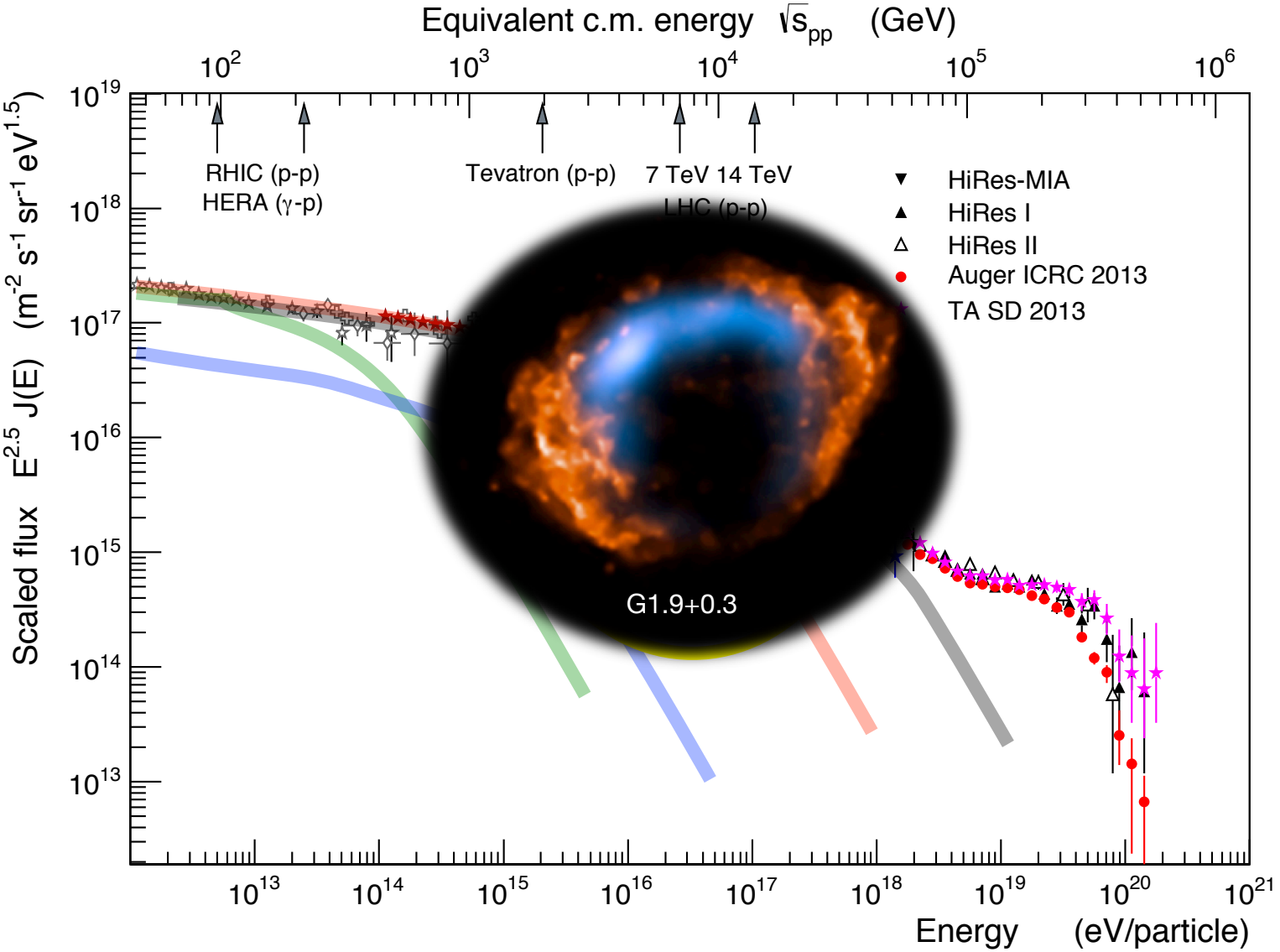
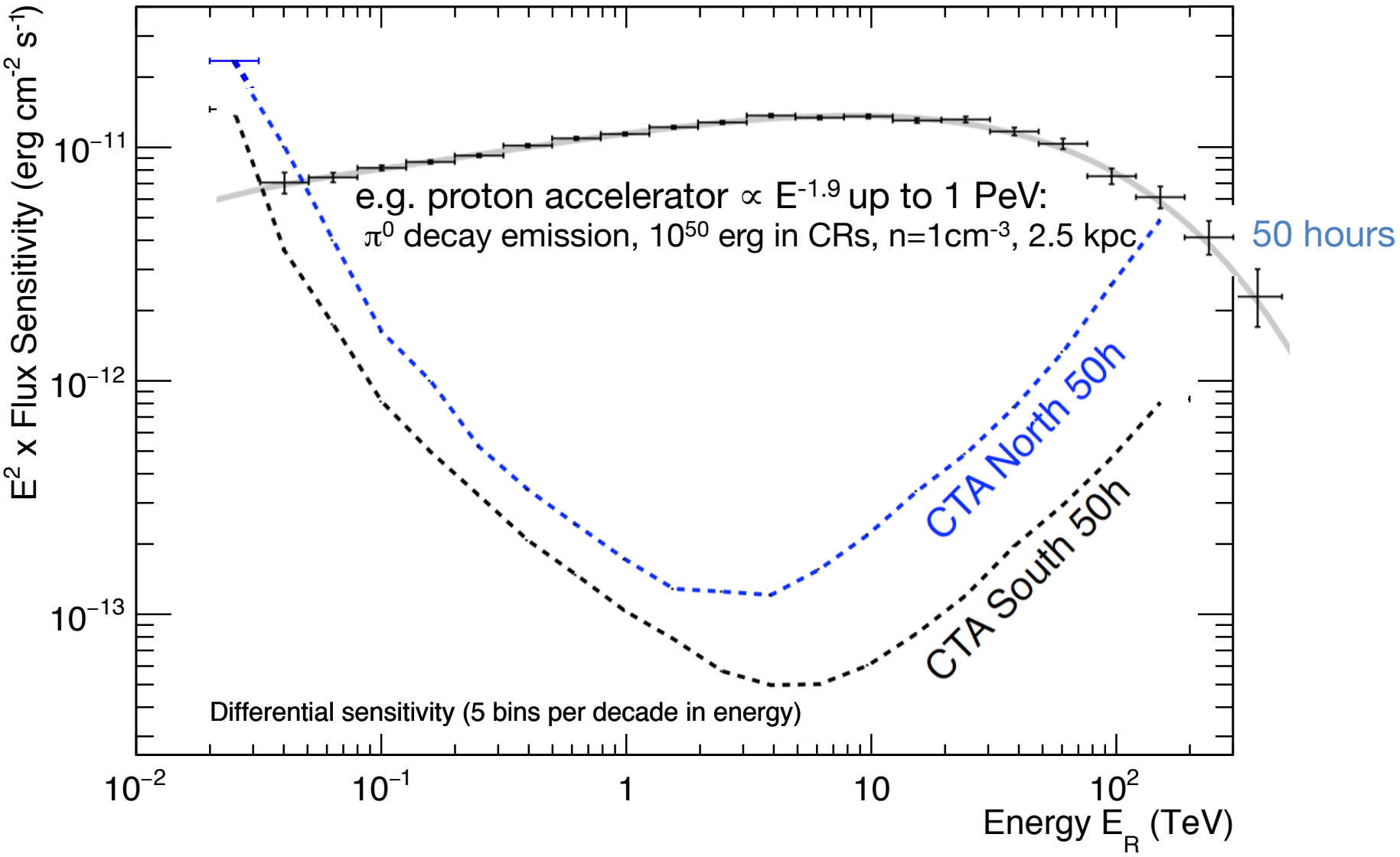
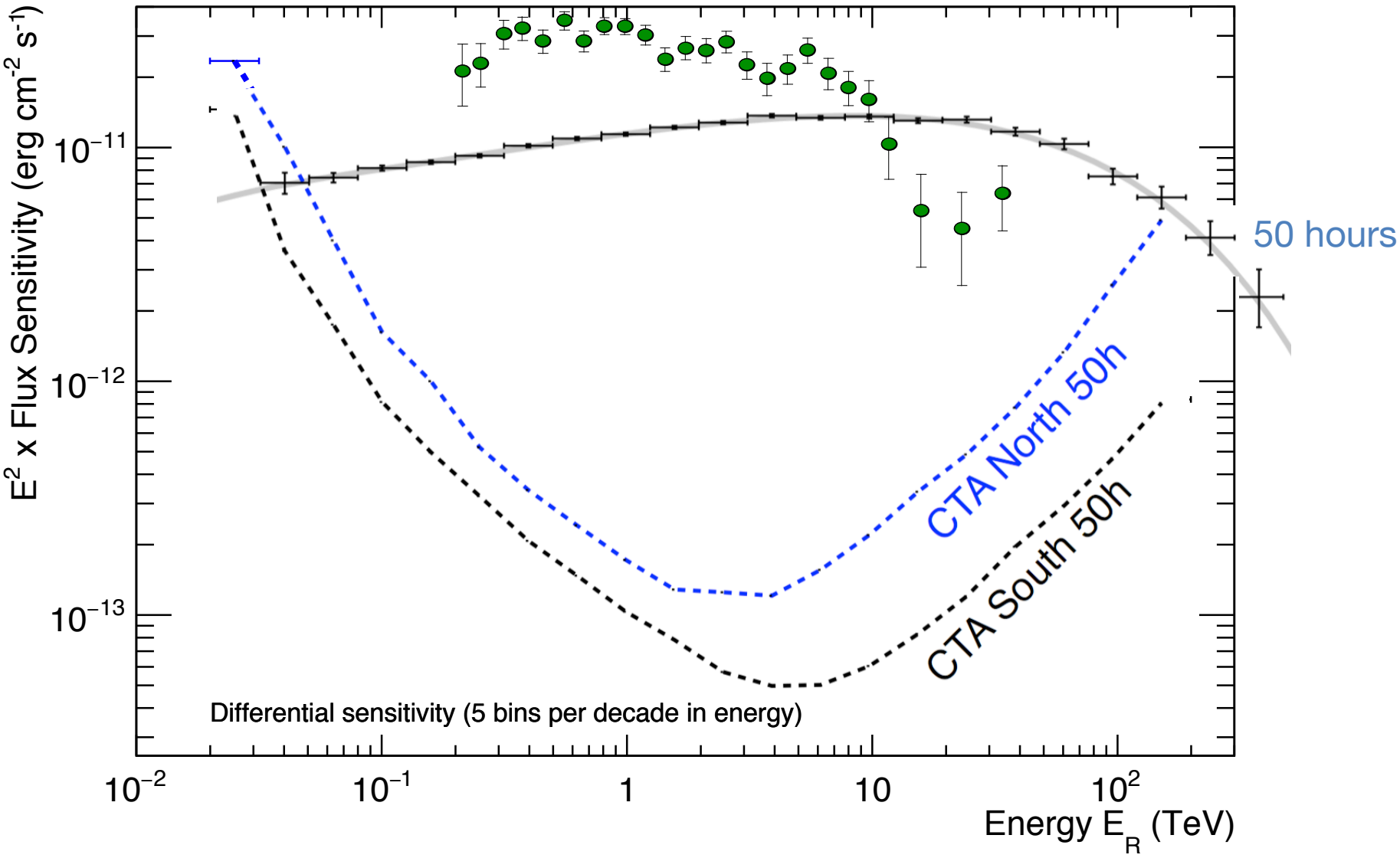


# GALACTIC PEVATRONS

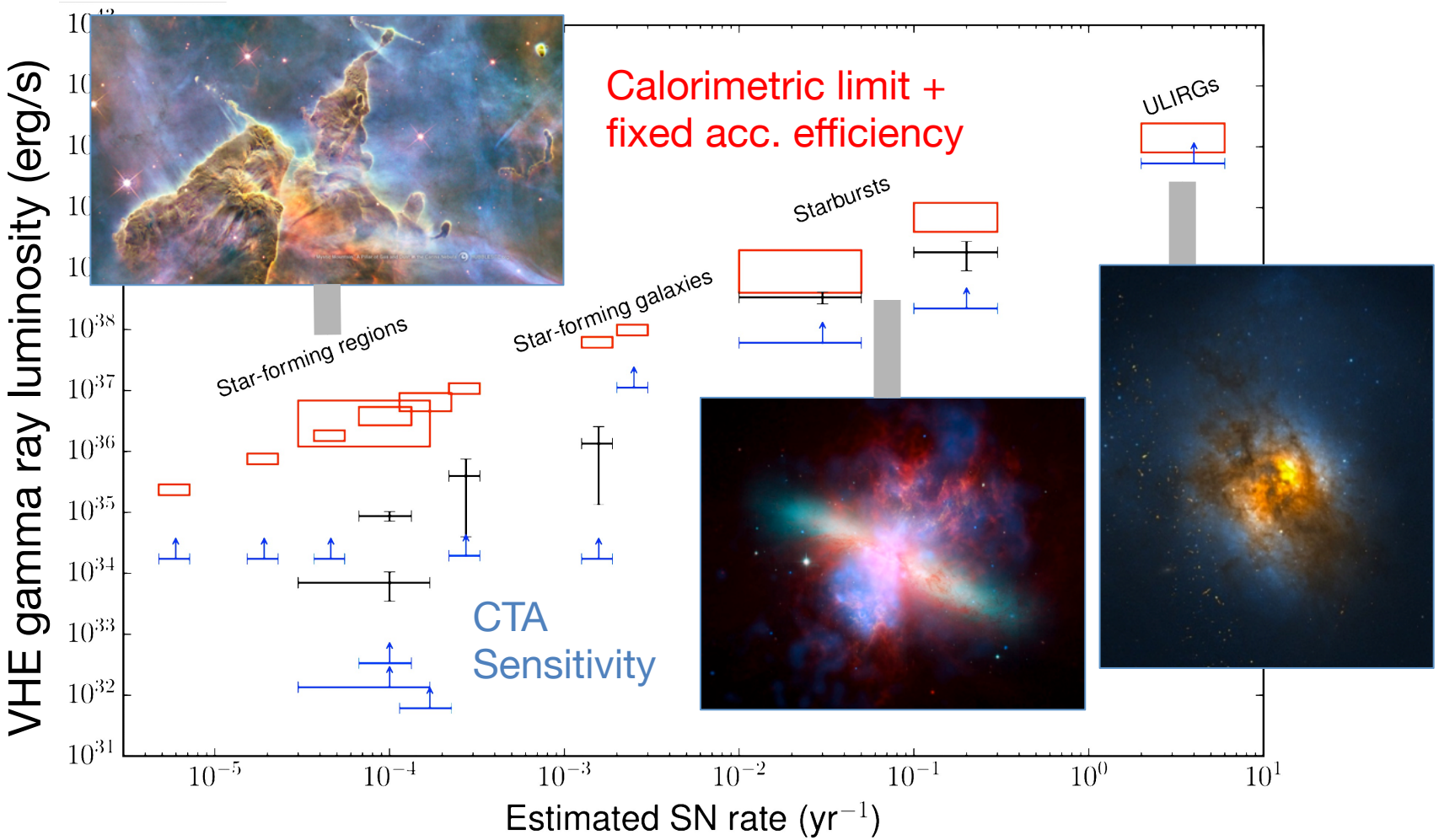


# GALACTIC PEVATRONS

cf HESS RX J1713-3946



# ACCELERATION @ ALL SCALES: STAR-FORMING SYSTEMS




- What role do accelerated particles play in star forming systems?
- How do the conditions in SFRs affect acceleration and transport?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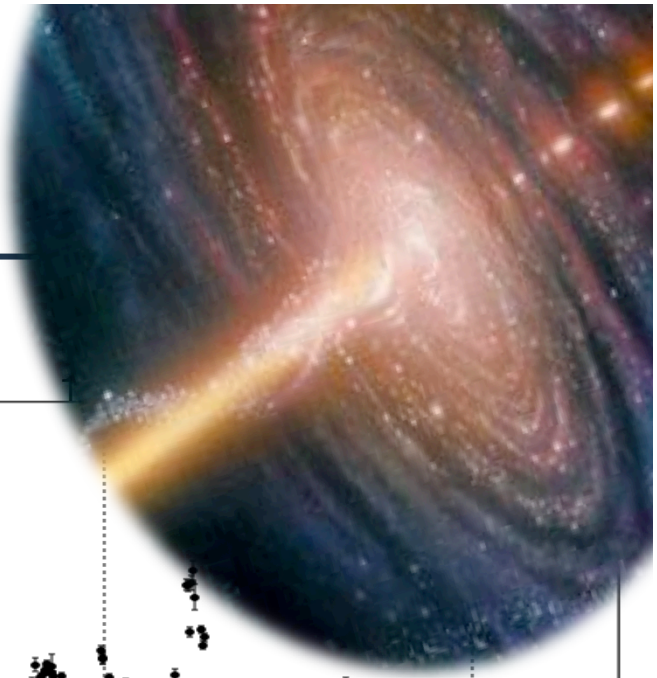
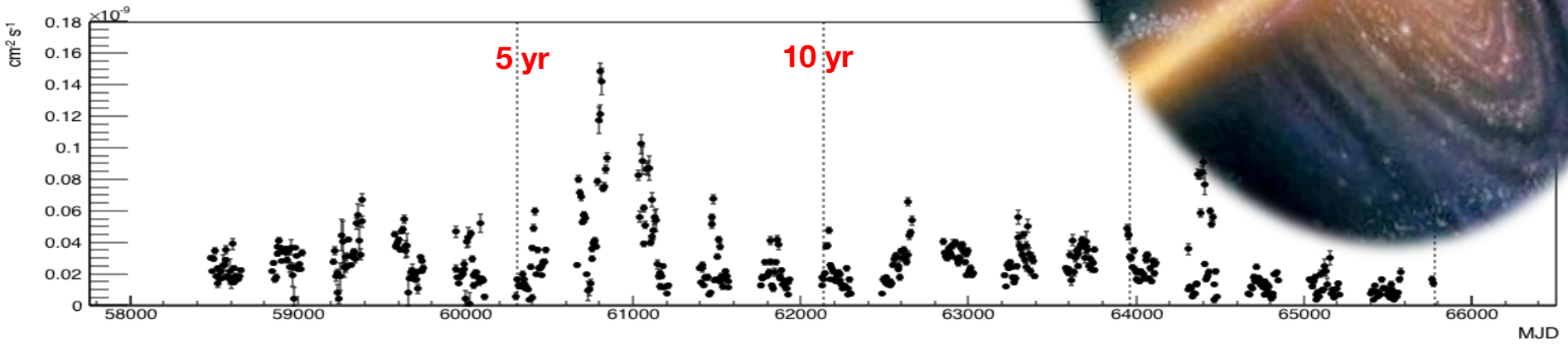
# FOCUS ON AGN VARIABILITY



from the longest variations ...

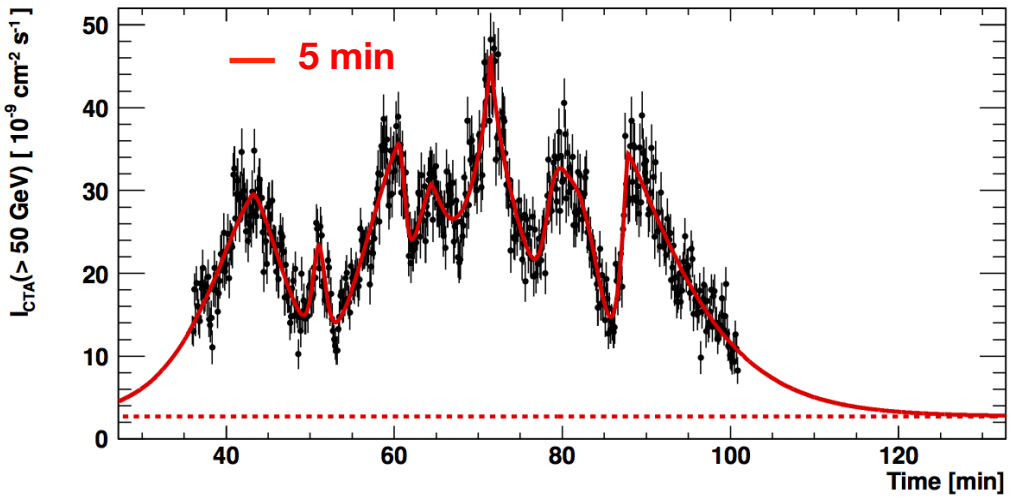



- duty cycle ?
- (quasi) periodicities ?
- breaks in the power spectra ?

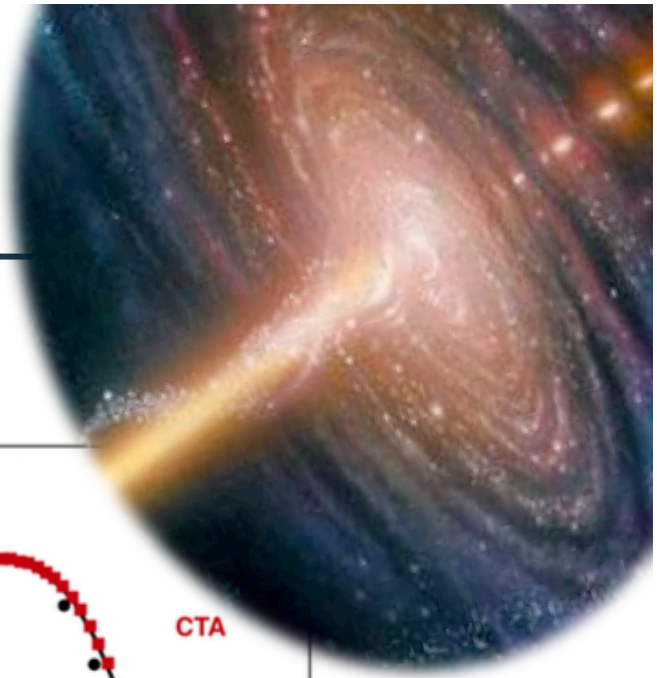
- size ( location, nature) of the emission region ?

- acceleration and cooling mechanisms ?

... to the shortest flares

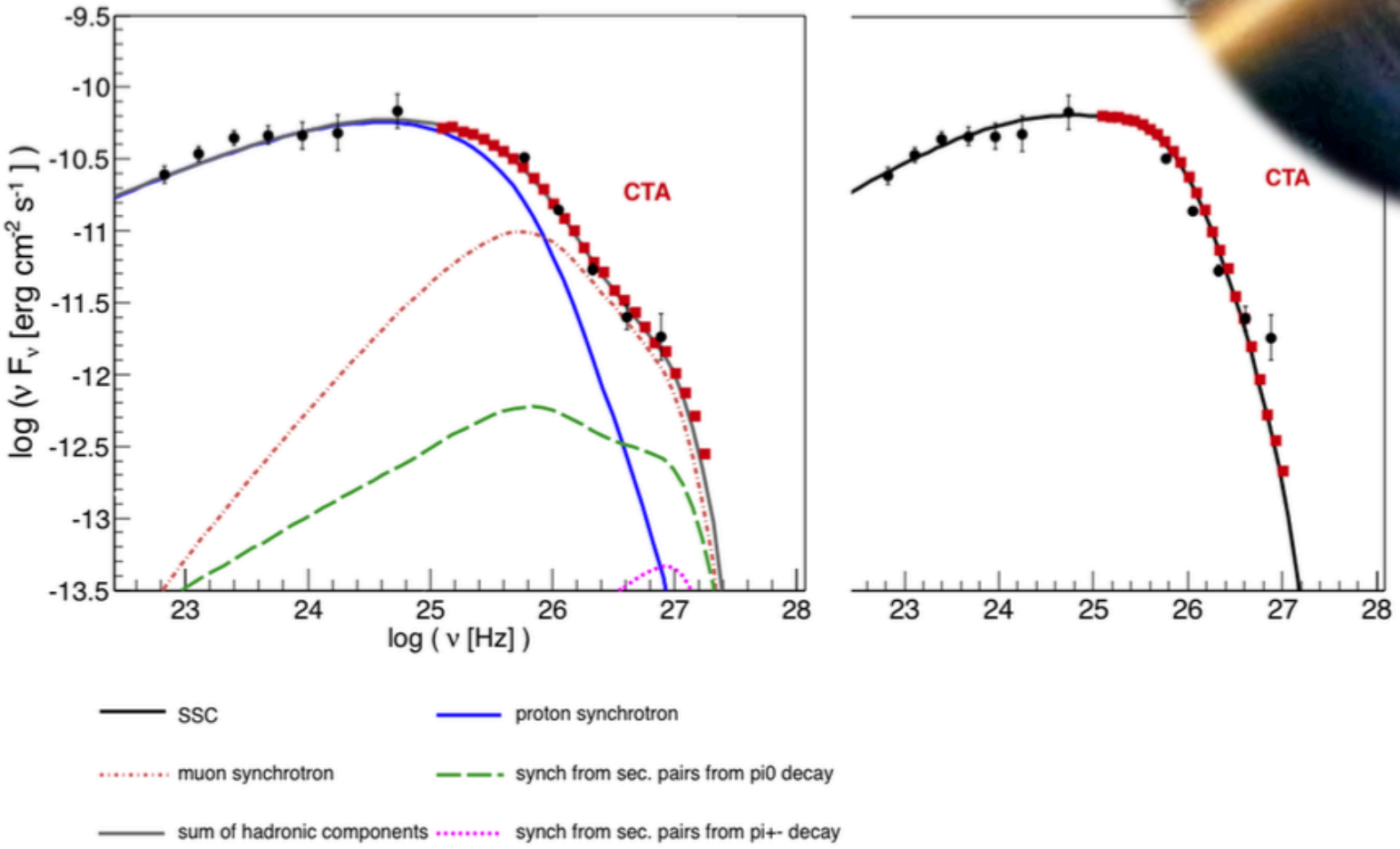


# ACCELERATION MECHANISM

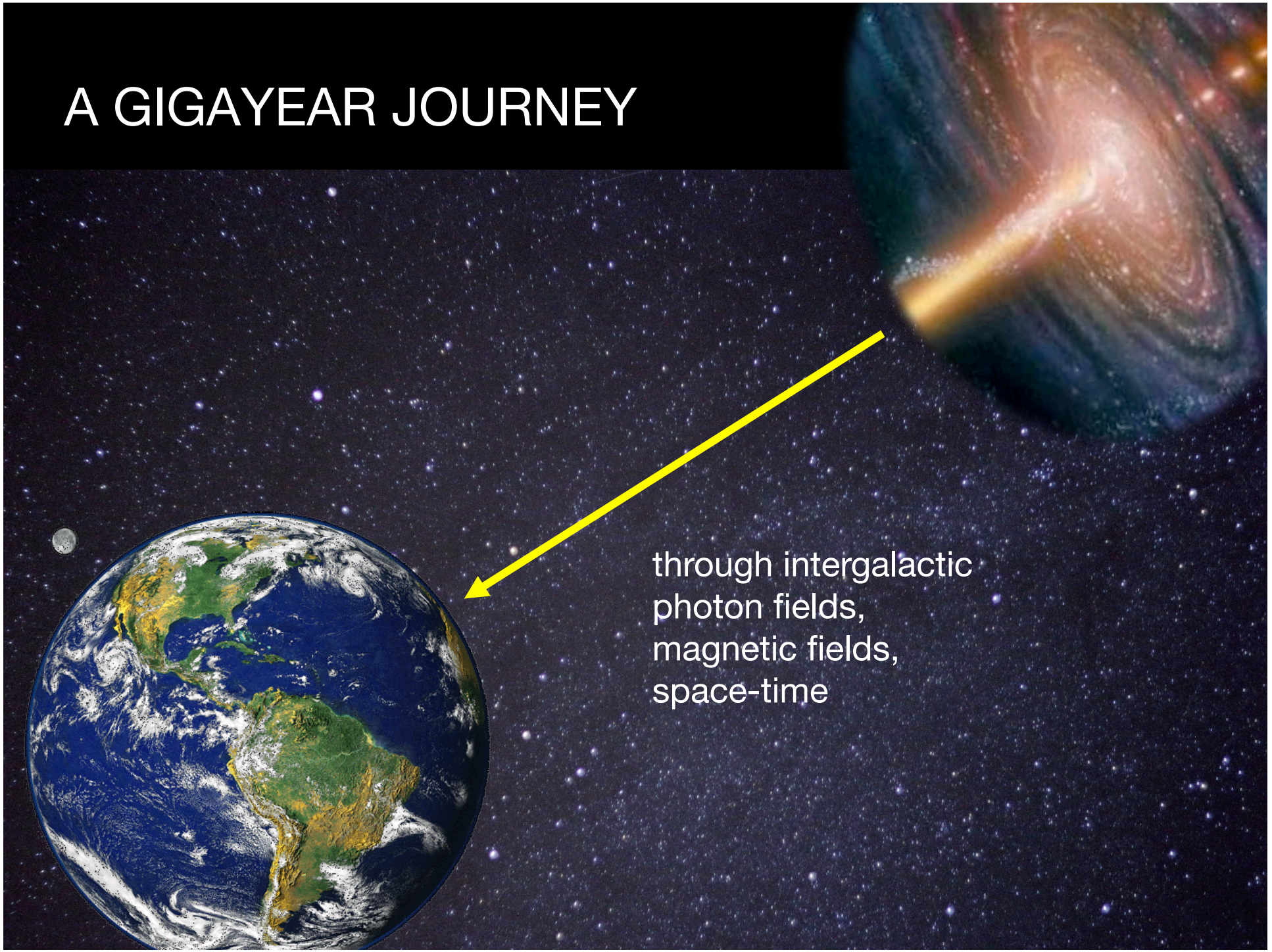


Hadronic Scenario

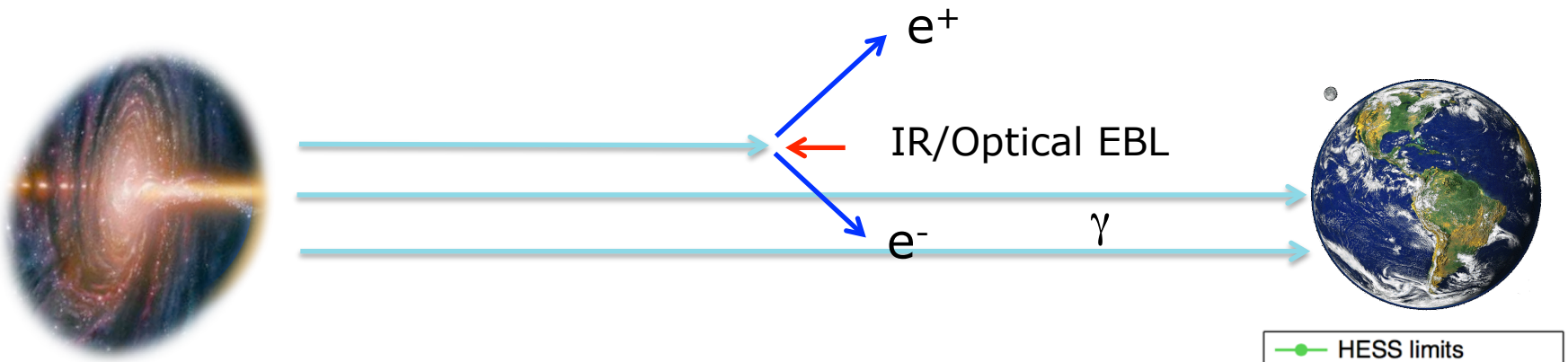
Leptonic Scenario



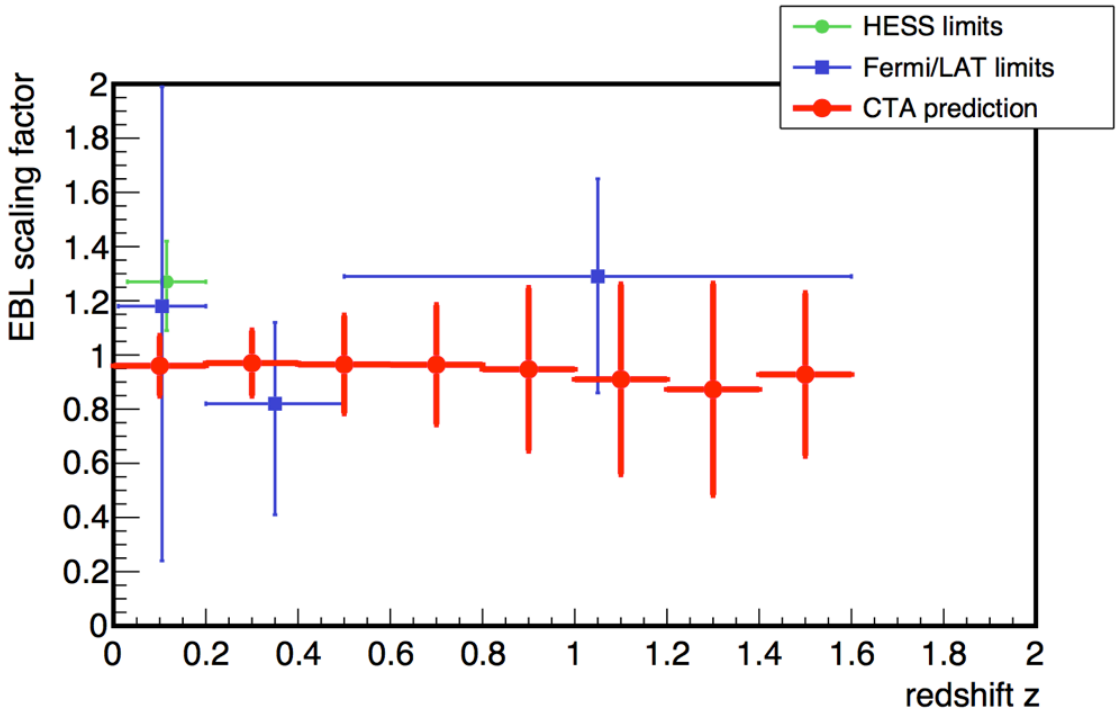
# A GIGAYEAR JOURNEY



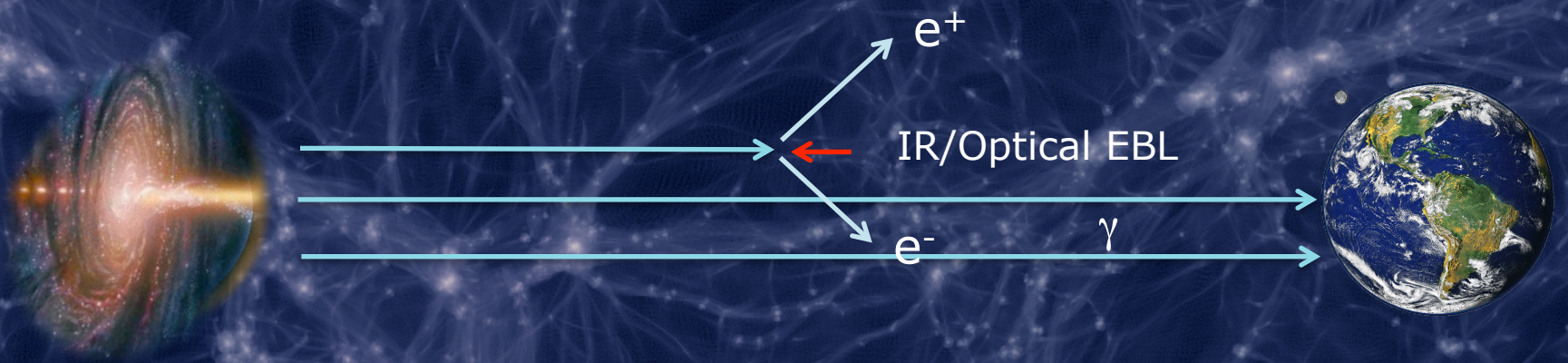
# GAMMA-RAY PROPAGATION: OPTICAL DEPTH




Unique absorption spectral signatures allow measuring **EBL(z)** using a large sample of AGN at different z

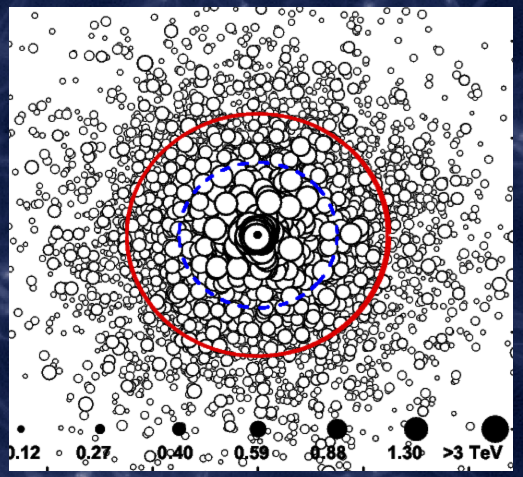


# WHAT HAPPENS WITH THE ENERGY DEPOSITED IN EXTRAGALACTIC SPACE?




- Scondary electron/gamma cascades
  ➜ determination of cosmic magnetic fields

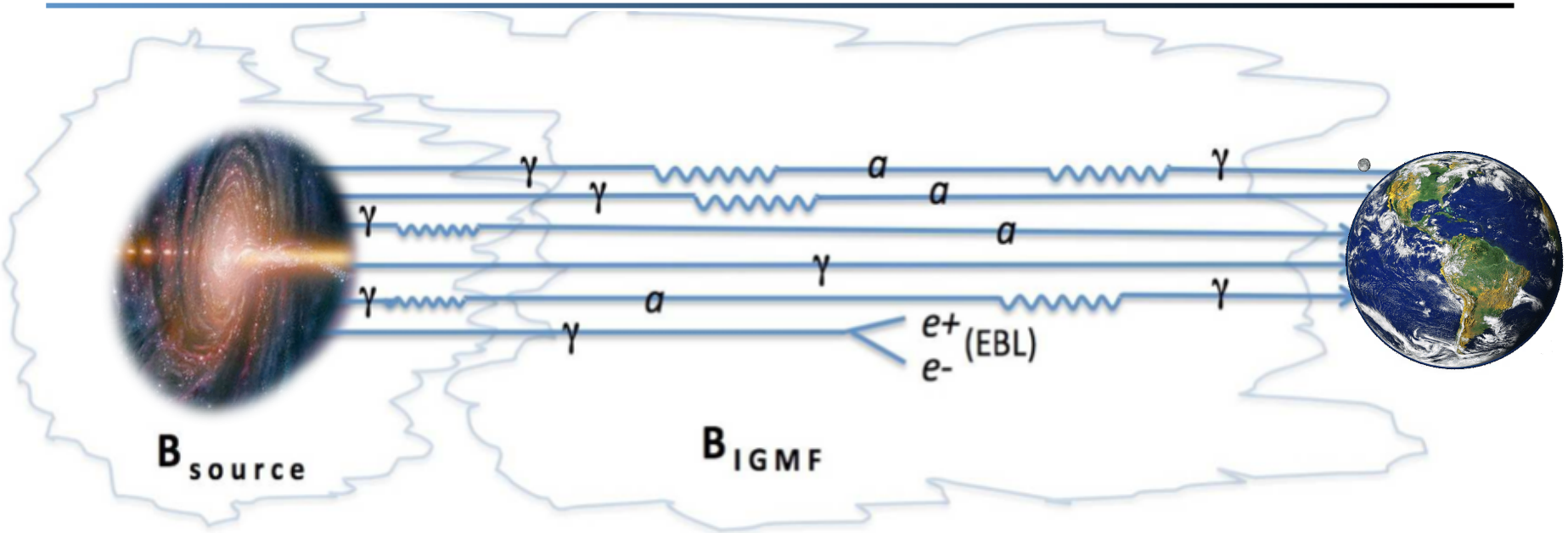
- Heating of intergalactic medium
  ➜ impact on structure formation
  $10^4$ K ➜ $10^5$ K @ z = 2
  Broderick, Chang, Pfrommer
  arXiv 1106.5494,1106.5504,1106.5505




Halo around source
Elyiv et a. 2009

(Image: Brant Robertson)

# UNIVERSE TOO TRANSPARENT FOR GAMMA RAYS? AXIONS!




De Angelis et al.
arXiv:0707.2695,0707.4312

Sanchez-Conde et al.,
arXiv:0905.3270

- Increased transparency of Universe
- Modulation of spectra

In neV Axion mass range
more sensitive than
dedicated experiments

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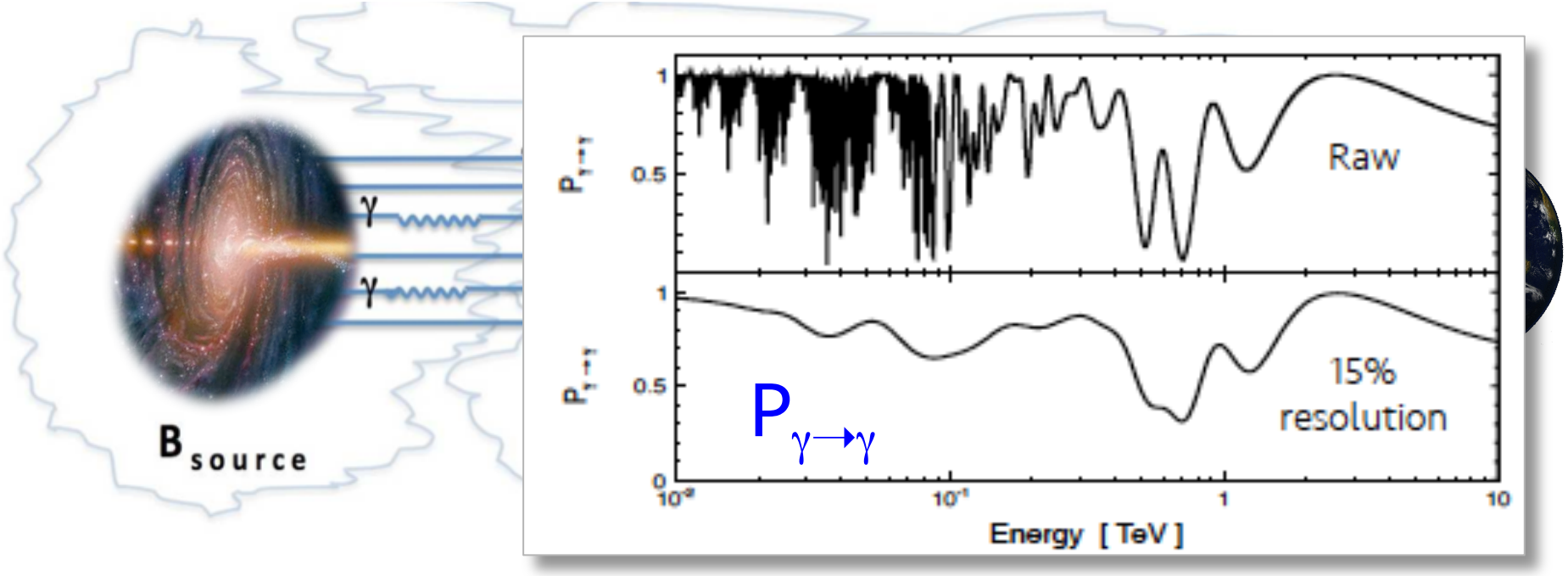


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- Increased transparency of Universe
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In neV Axion mass range
more sensitive than
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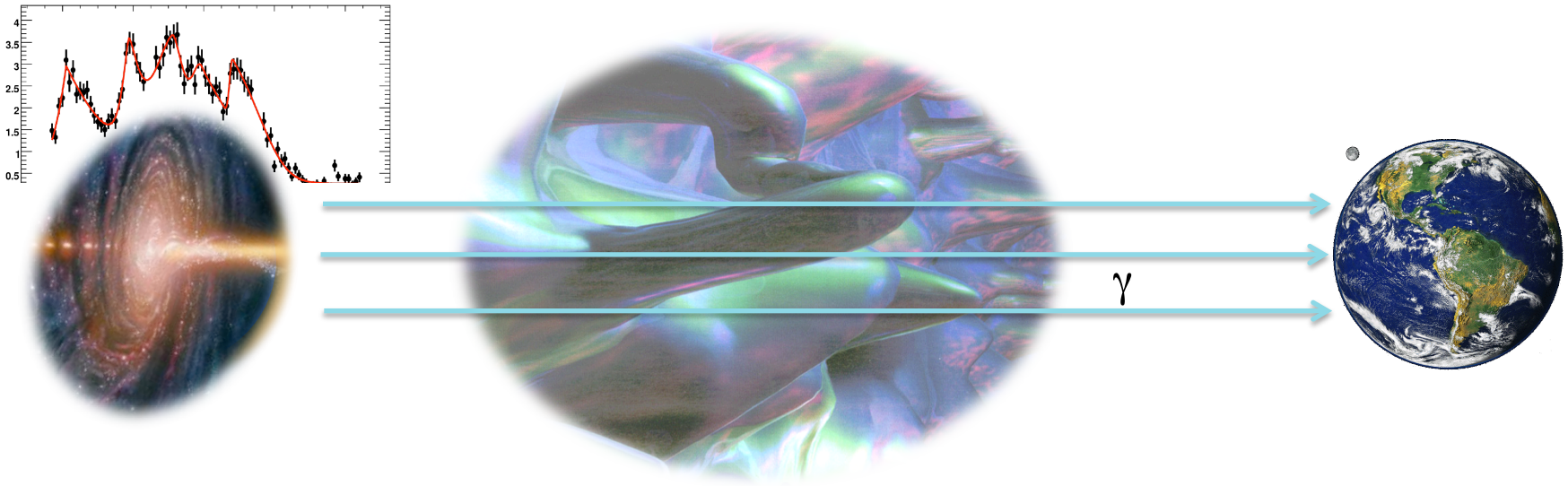
# GAMMA RAY PROPAGATION: LI VIOLATION

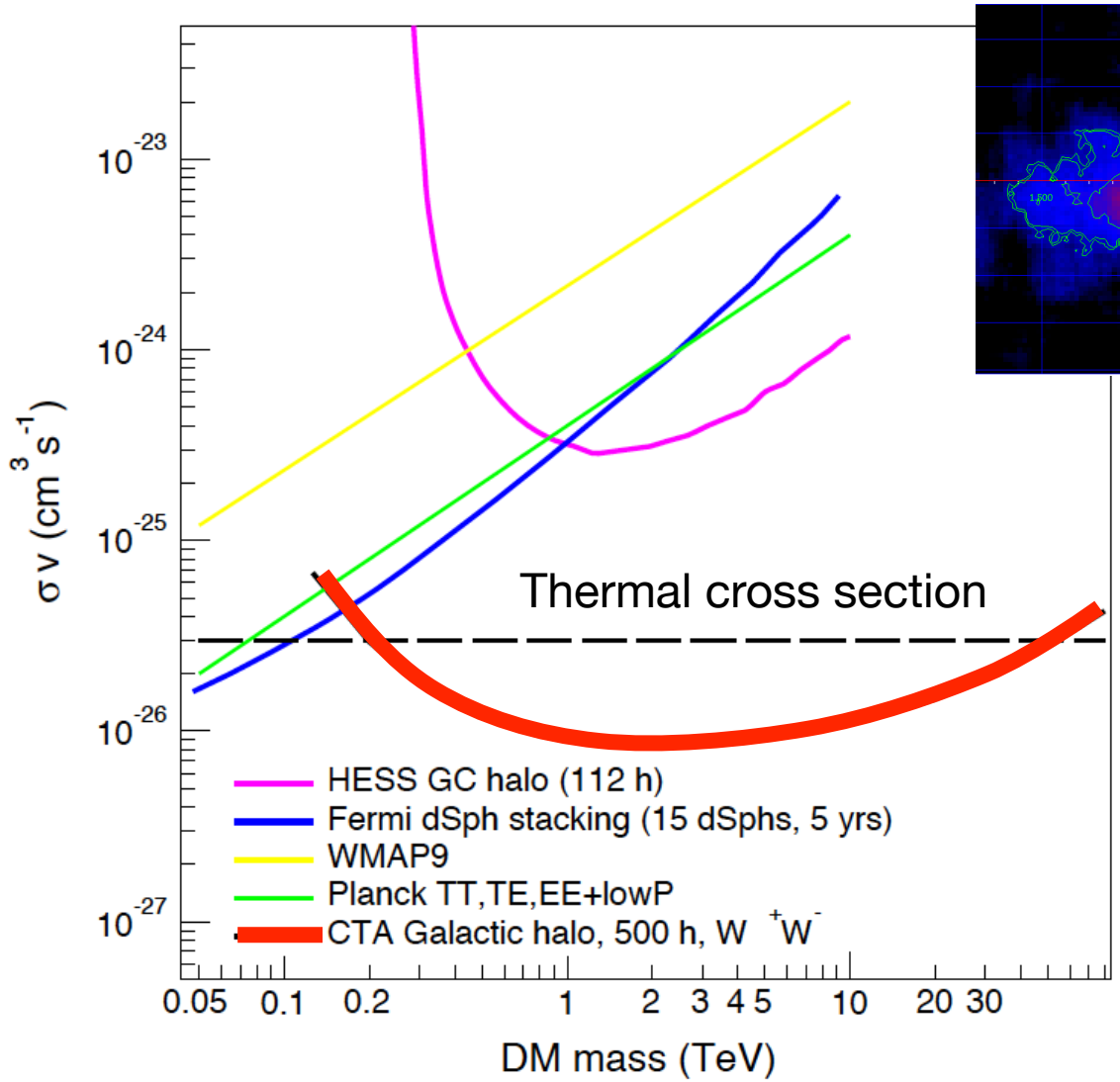


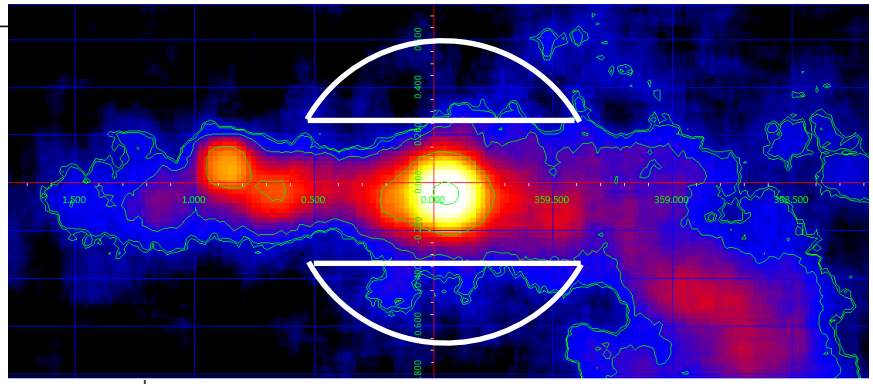

Planck-scale effect linear in $E_\gamma$:
Velocity dispersion across TeV energy range
O(1 s) for ~$10^9$ y travel

In reach with the right AGN or GRB


The CTA Telescope Arrays
CTA Performance
The Big Themes
The Basis: Surveys
Particle Acceleration
Active Galaxies
Fundamental Physics
& Dark Matter
cta
cherenkov telescope array

# DARK MATTER IN GC HALO



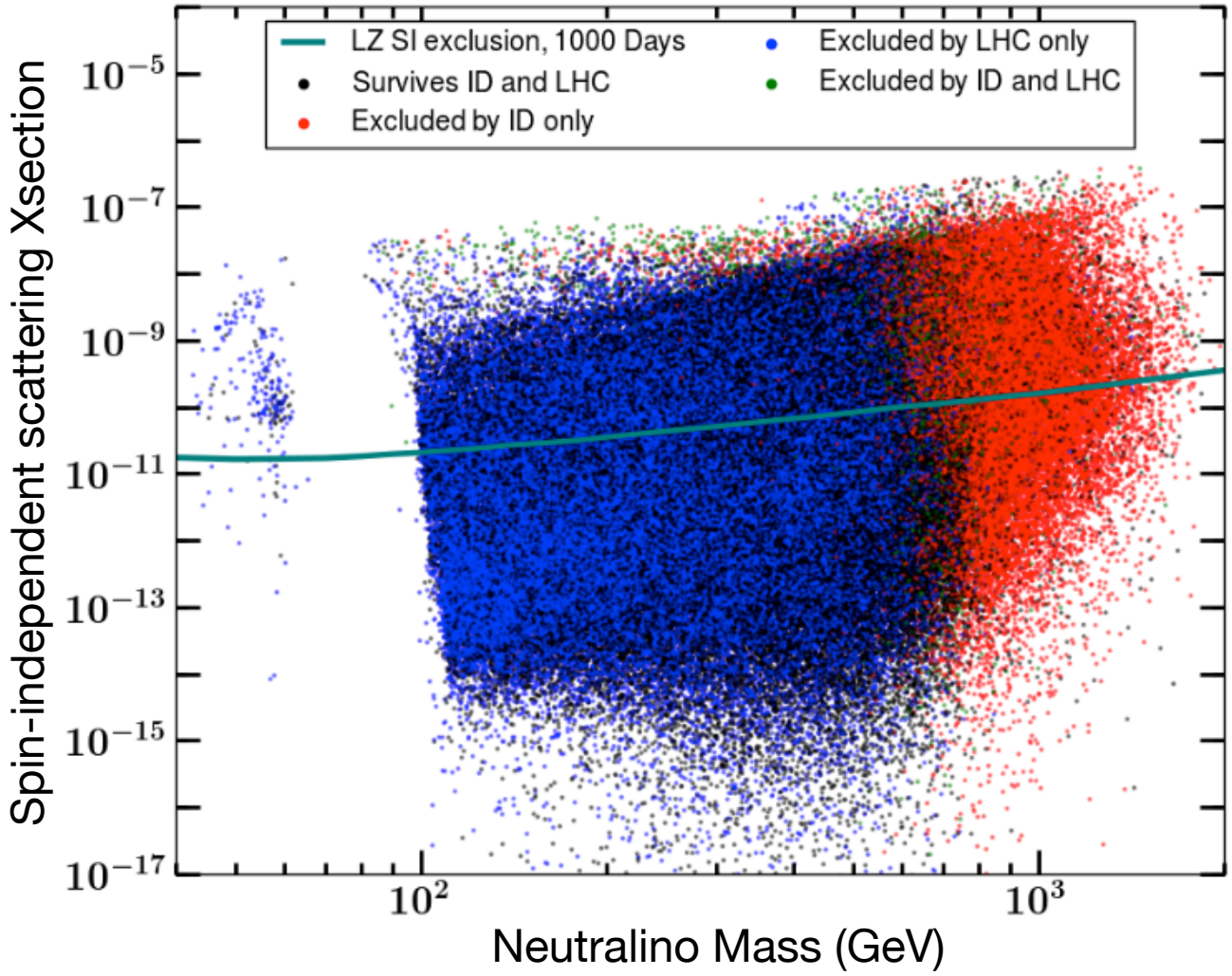



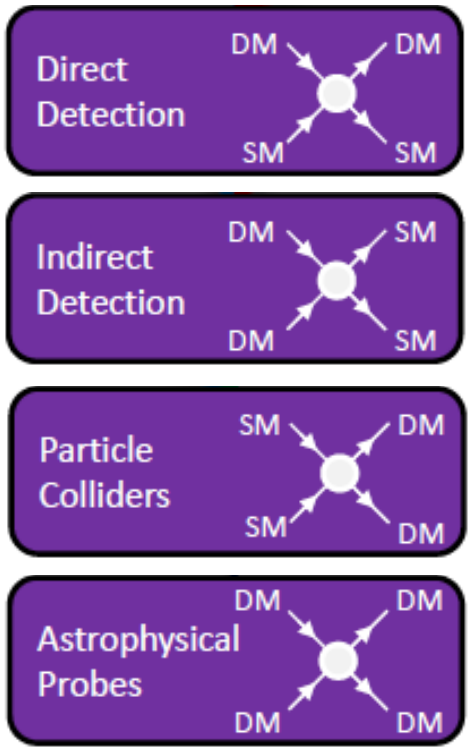
Avoiding inner region with its

- "normal" sources
- highly uncertain DM profile

Deep 500 h exposure

# COMPLEMENTARITY

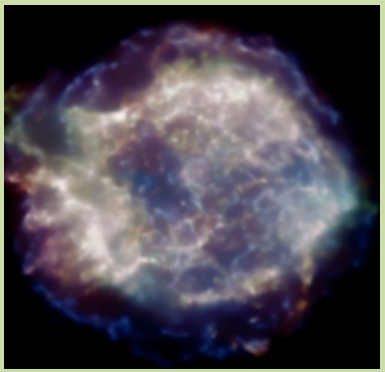


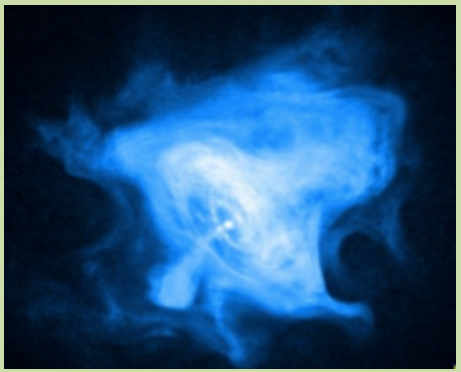




Cahill-Rowley et al.
arXiv:1405.6716

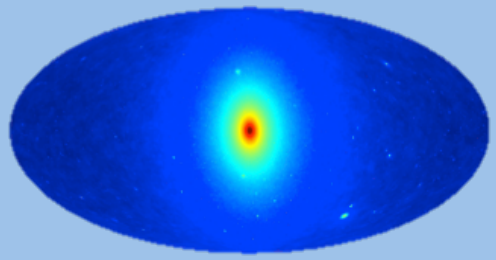
# CTA PERSPECTIVES

In-depth understanding of known objects and their mechanisms





Expected discoveries of new object classes



The fun part:
Things we haven't thought of

?

# CTA CONSORTIUM

**Largest national share:**
**Italy with ~21% of total**
**CTA manpower**

31 Countries
194 Institutes
>1200 Members

Credit:
Multimedia Service,
Institute of Astrophysics of Canary Islands