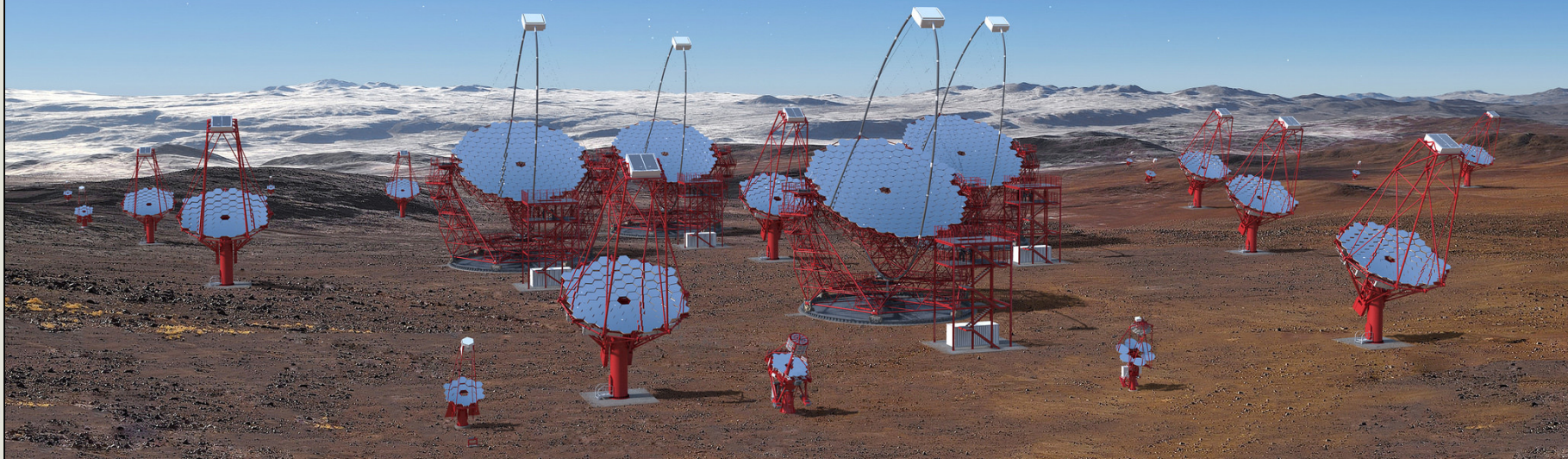
SubirFest2023

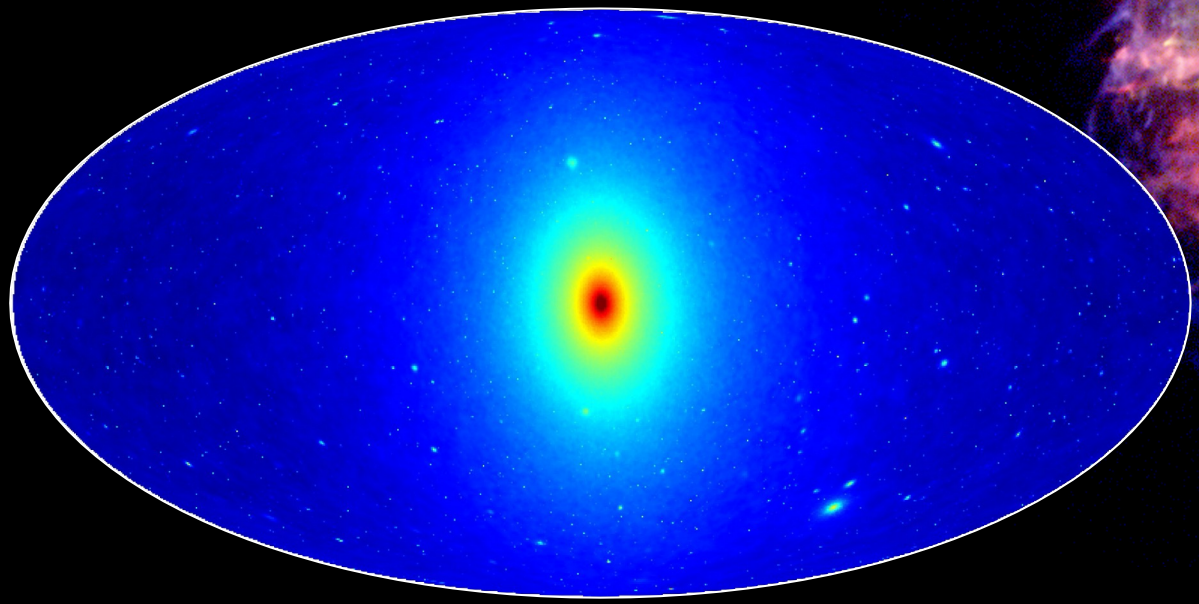
Very High Energy Gamma Rays

Jim Hinton, MPIK, Heidelberg



> 10^{11} eV Photons

- Probes of cosmic particle acceleration
  - And propagation, impact/feedback …
- Probes of fundamental physics
  - Dark matter, LIV, …



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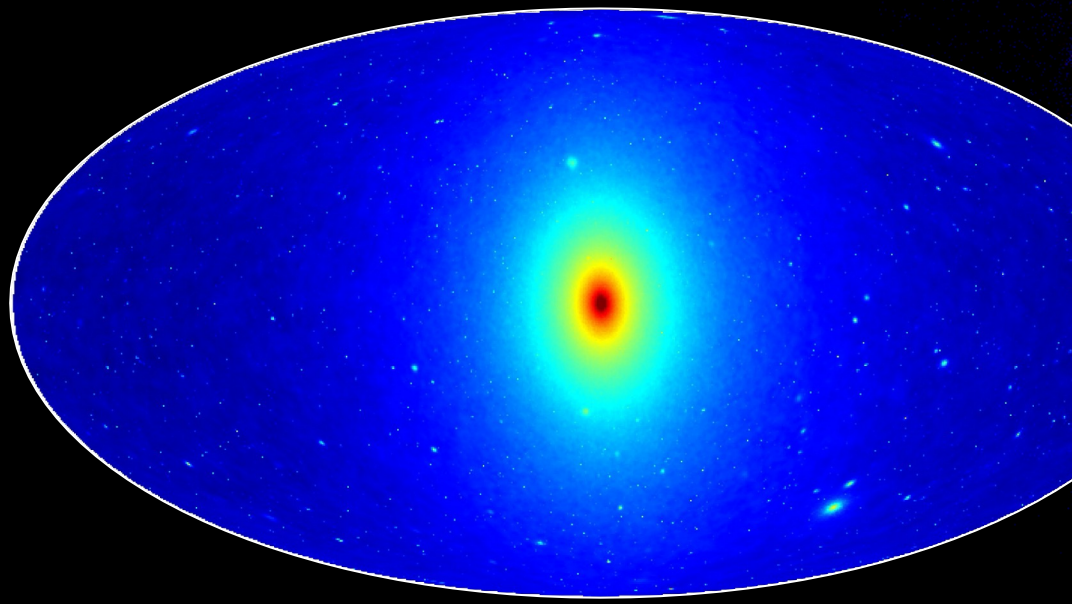


Mon. Not. R. astr. Soc. (1980) **191**, 855–861

A lower limit to the magnetic field in Cassiopeia-A

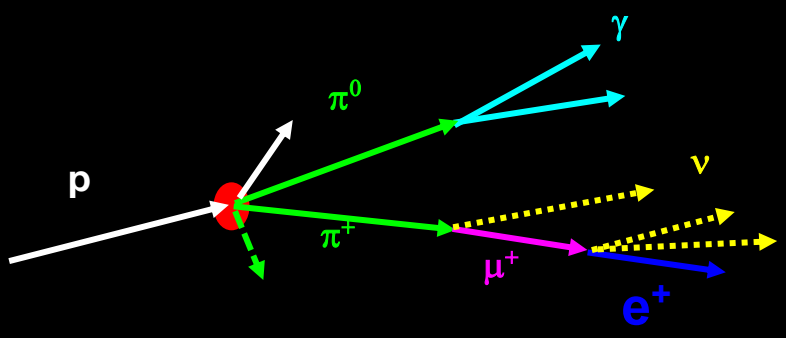
Ramanath Cowsik and Subir Sarkar *Tata Institute of Fundamental Research, Bombay 400005, India*

Received 1979 November 8; in original form 1979 March 8

Summary. The magnetic field strength in the radio-emitting shell of the supernova remnant Cassiopeia-A should be greater than 8×10^{-5}G if the bremsstrahlung by the electrons responsible for the non-thermal radio emission is not to exceed the upper limits to the gamma-ray emissivity set by the recent observations. This field strength is shown to be too large to be generated by a mere compression of the interstellar field by the supernova shock but must arise due to magnetohydrodynamic instabilities in the expanding shell. Gamma-ray generation through inverse-Compton scattering of photons in the surrounding H II region is also briefly discussed.

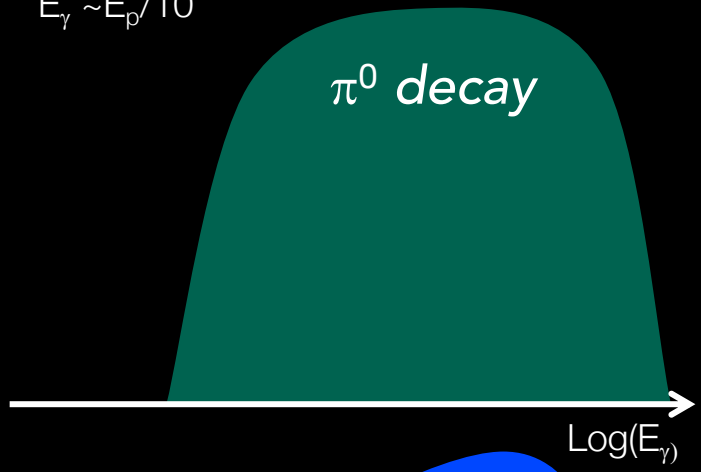
Dominant Emission Mechanisms

$F_\pi \sim n_H$

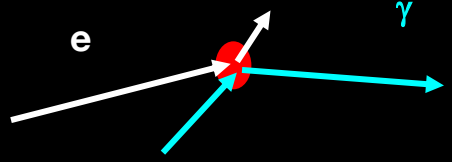


Typical photon spectra

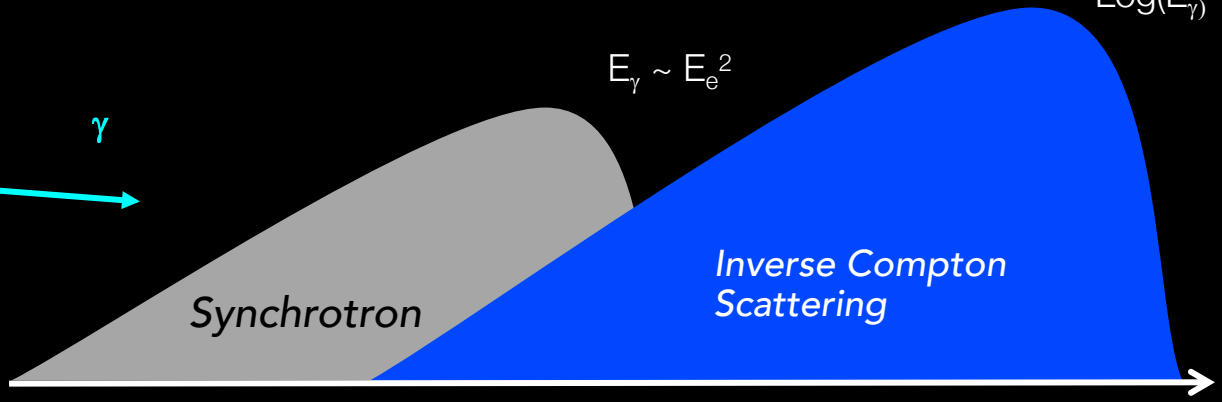
$E_\gamma \sim E_p/10$



$F_{IC}/F_{Sync} \sim U_{Rad}/U_B$

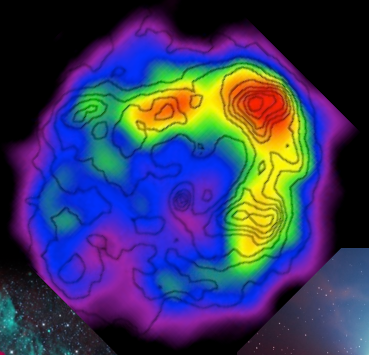


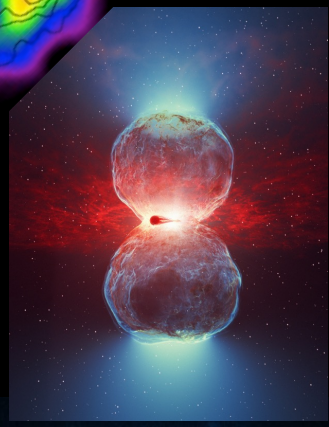
$E_\gamma \sim E_e^2$

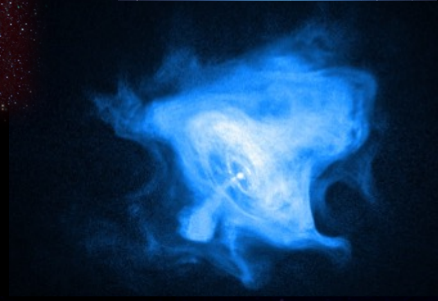


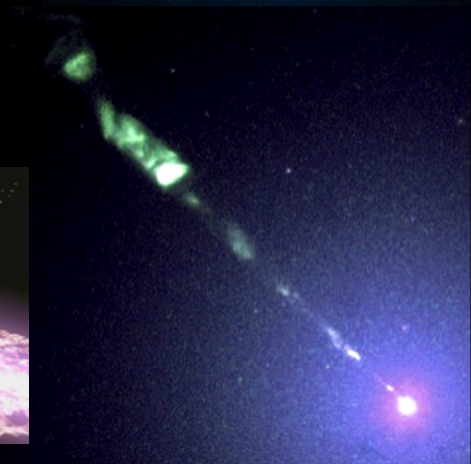
VHE Photon Astronomy

- Astonishing variety of VHE emitters
  - Within the Milky Way:
    - Supernova remnants
    - Novae
    - Bombarded molecular clouds
    - Colliding wind binaries
    - Massive stellar clusters
    - Pulsars and pulsar wind nebulae
    - Microquasar jets
    - Supermassive black hole Sgr A*
  - Extragalactic:
    - Starburst galaxies
    - MW satellites
    - Radio galaxies
    - Flat-spectrum radio quasars
    - ‘BL Lac’ objects
    - Gamma-ray bursts
- Acceleration to TeV+ energies is common, gamma-rays are an effective probe









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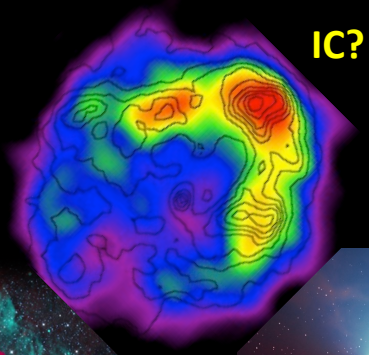
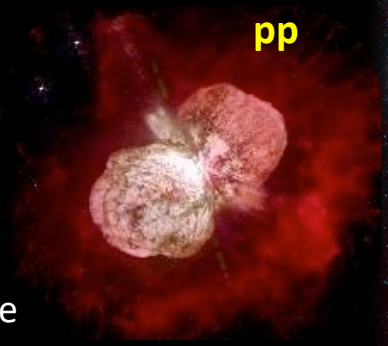
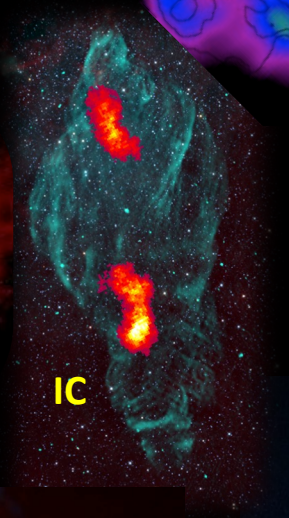
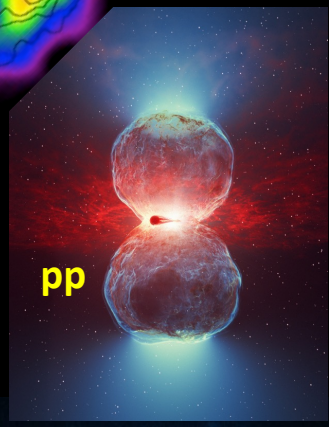
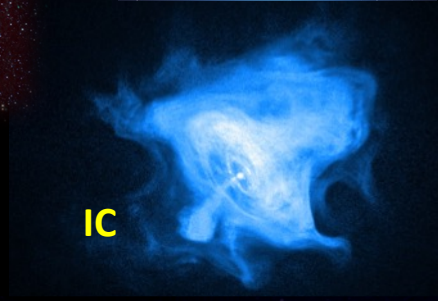
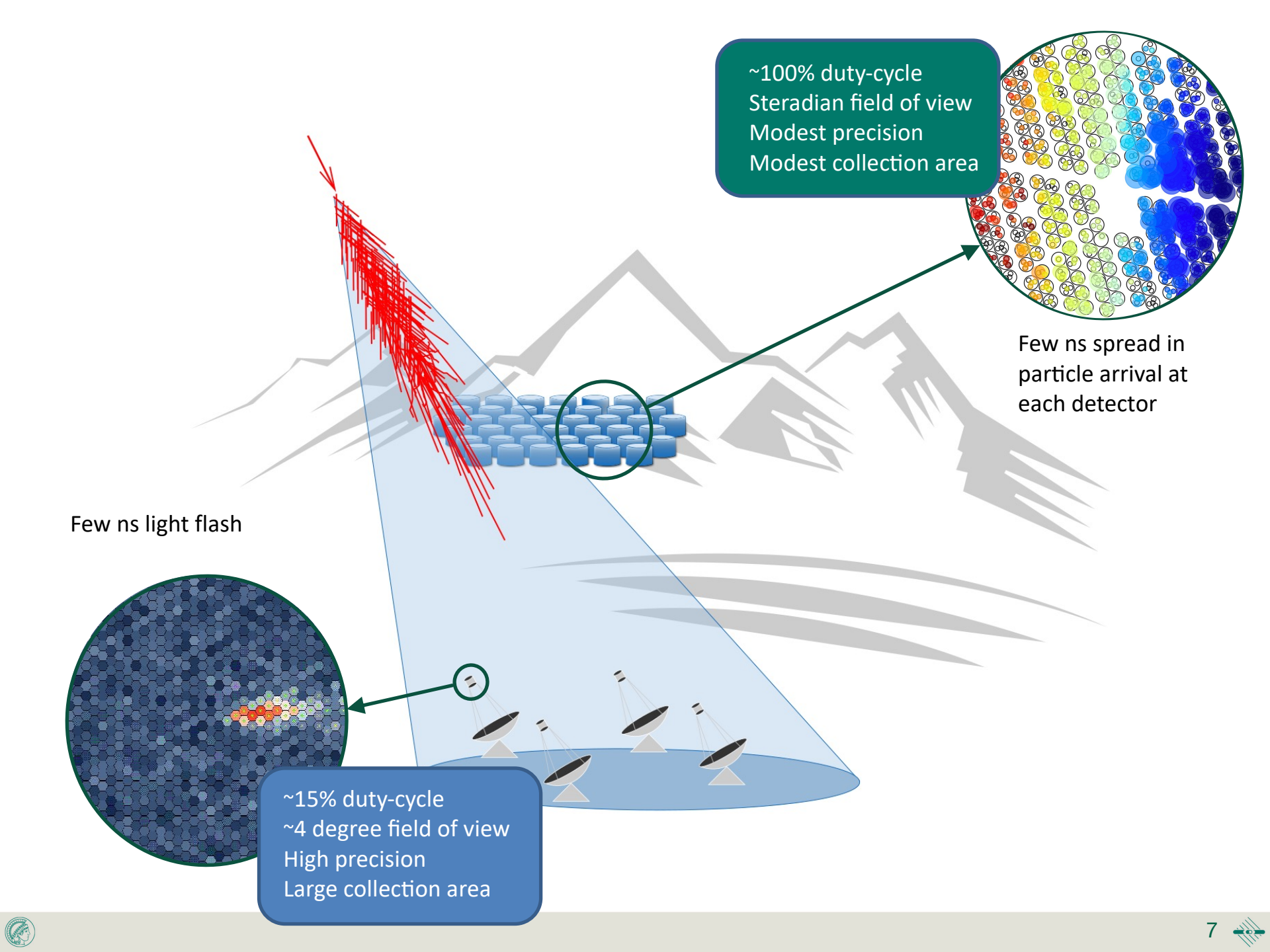


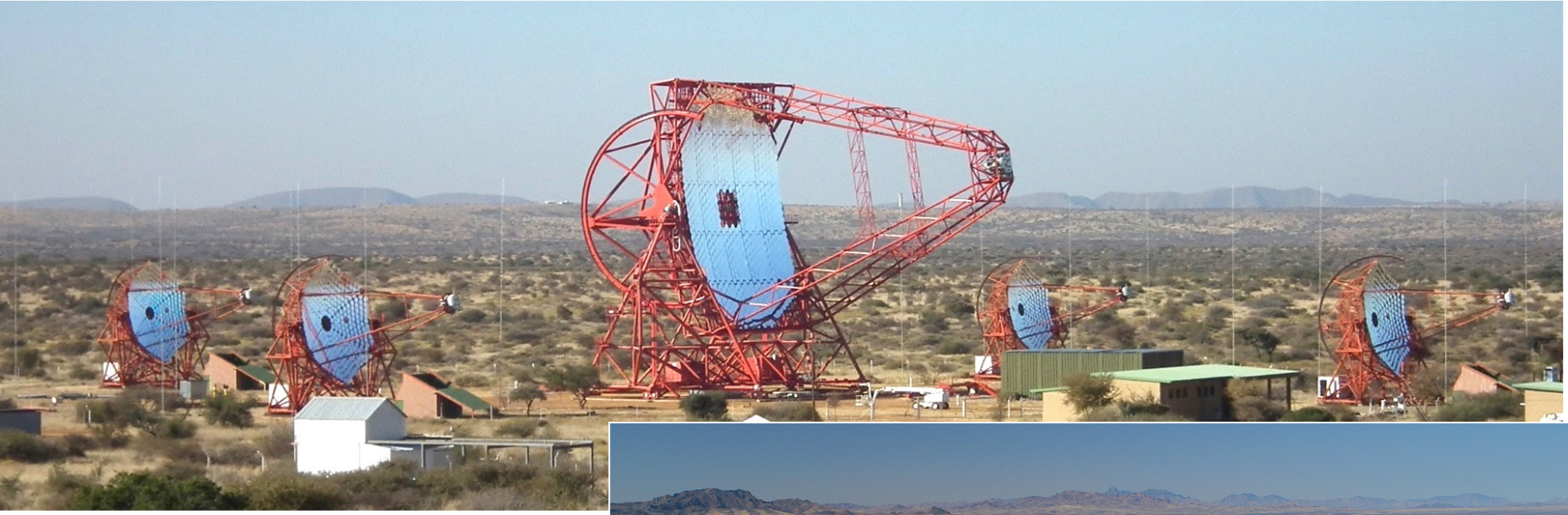




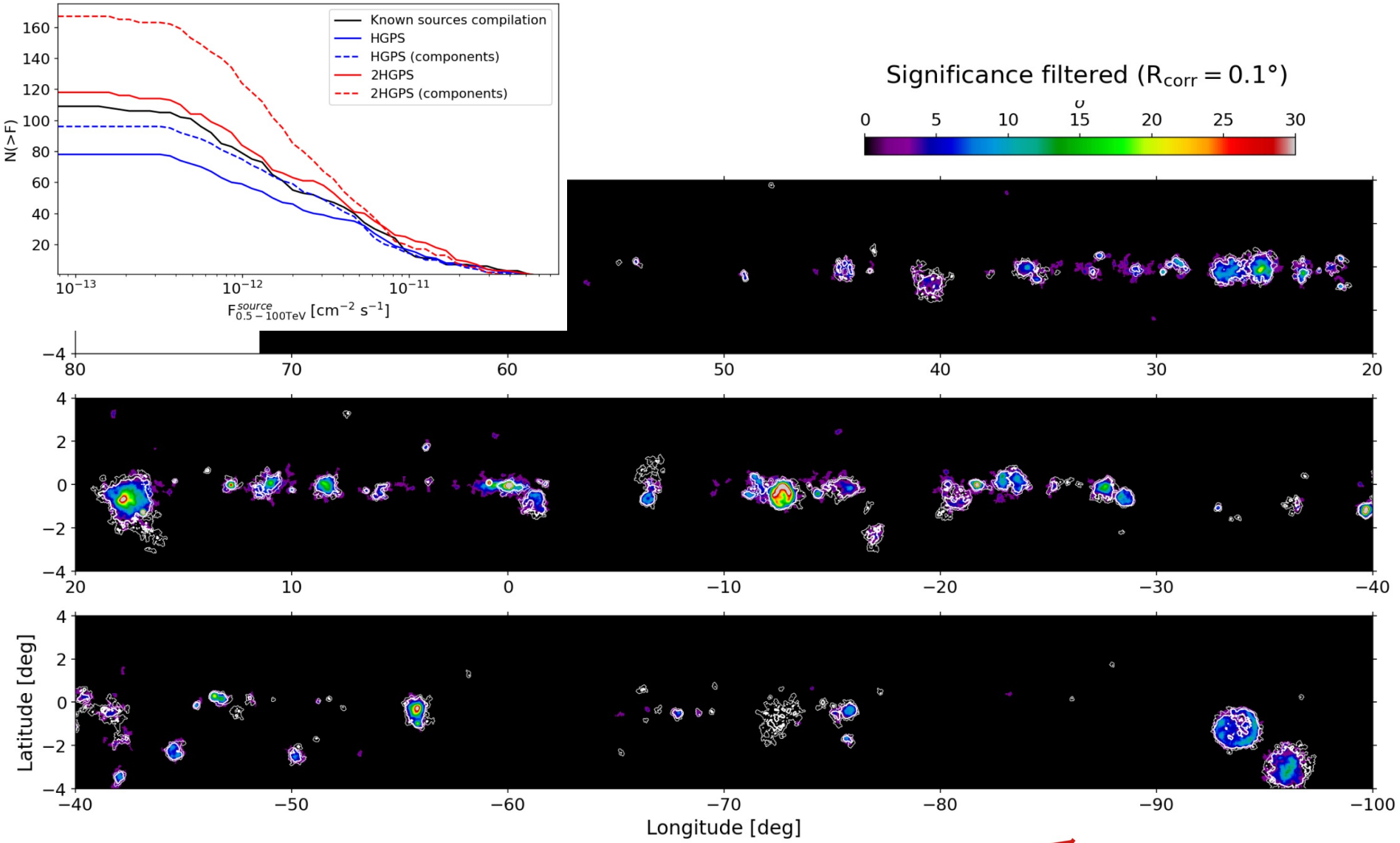





~100% duty-cycle
Steradian field of view
Modest precision
Modest collection area
Few ns spread in particle arrival at each detector
Few ns light flash
~15% duty-cycle
~4 degree field of view
High precision
Large collection area




© Daniel Lopez, IAC

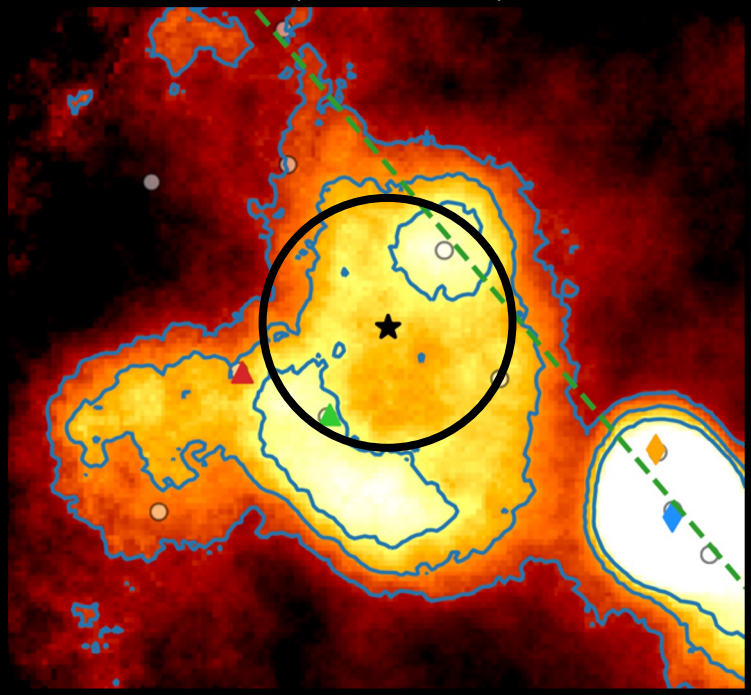


- Updated HESS Galactic Plane Survey
  - Quentin Remy (MPIK) et al (Proc. ICRC 2023)

H.E.S.S.

HESS recent highlights (MPIK bias)

Westerlund 1 - A&A (2022 and 2023)



GRB 190829A - Science (2021)

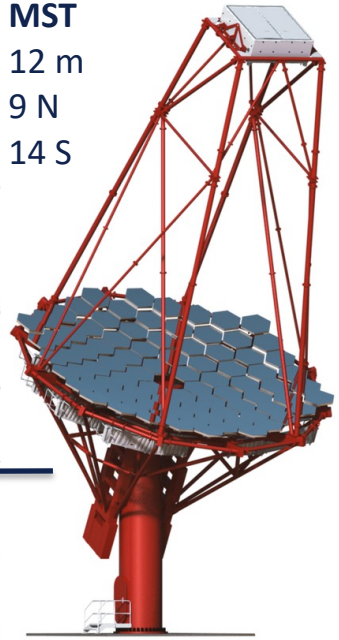
SS 433 Jets – (coming soon)

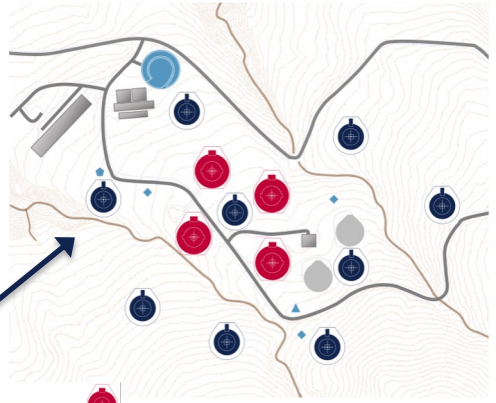
RS Ophiuchi - Science (2022)

Paranal

1 km

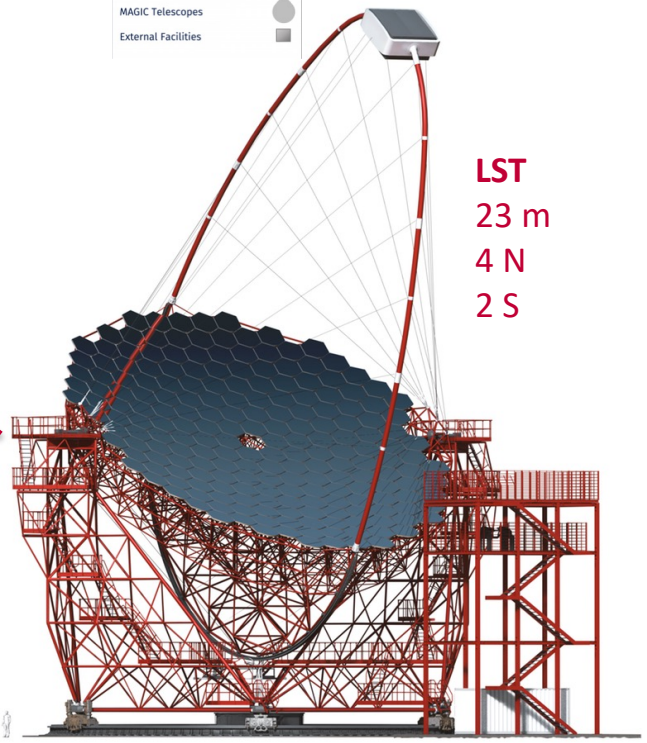
MST
12 m
9 N
14 S

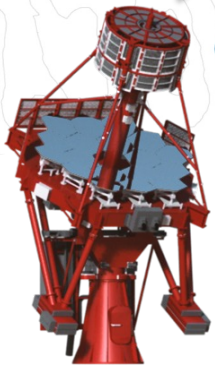




La Palma

LST
23 m
4 N
2 S





SST
4 m
42 S

cta

First LINK Workshop: Probing physics beyond the Standard Model with CTA

Friday 12 Nov 2010, 09:00 → 17:00 GB

The Cosener's House, Abingdon

Gianfranco Bertone (IAP Paris), Jan Conrad (Stockholm University), Manel Martinez (IFAE Barcelona), Subir Sarkar (University of Oxford)

Description This workshop will take stock of the physics potential of the forthcoming Cherenkov Telescope Array regarding the detection of dark matter annihilation/decay signals, tests of possible high energy violation Lorentz invariance, and other new phenomena beyond the Standard Model of particle physics.

On Thurday 11th November afternoon there will be a meeting of the Physics Working Group of the CTA Collaboration (at Rutherford Appleton Laboratory), followed by an all-day workshop on Friday 12th November (at Cosener's House).

We acknowledge support by the Astroparticle Physics Group, UK Institute of Physics and by EU Framework Programme 7.

Participants Aaron Manalaysay, Abelardo Moralejo Olaizola, Adrian Biland, Agnieszka Jacholkowski, Aimo Sillanpaa (Thu), Akira Okumura, Alan Watson*, Alberto Etchegoyen (Thu), Alicia Lopez Oramas (Thu)

Organiser: Subir Sarkar s.sarkar@physics.ox.ac.uk

...

15:40 → 16:00 **Timing properties of blazar light curves** 20m

Speaker: Dr Dimitrios Emmanoulopoulos (University of Southampton, Physics and Astronomy)

Slides

16:00 → 16:20 **Coffee break** 20m

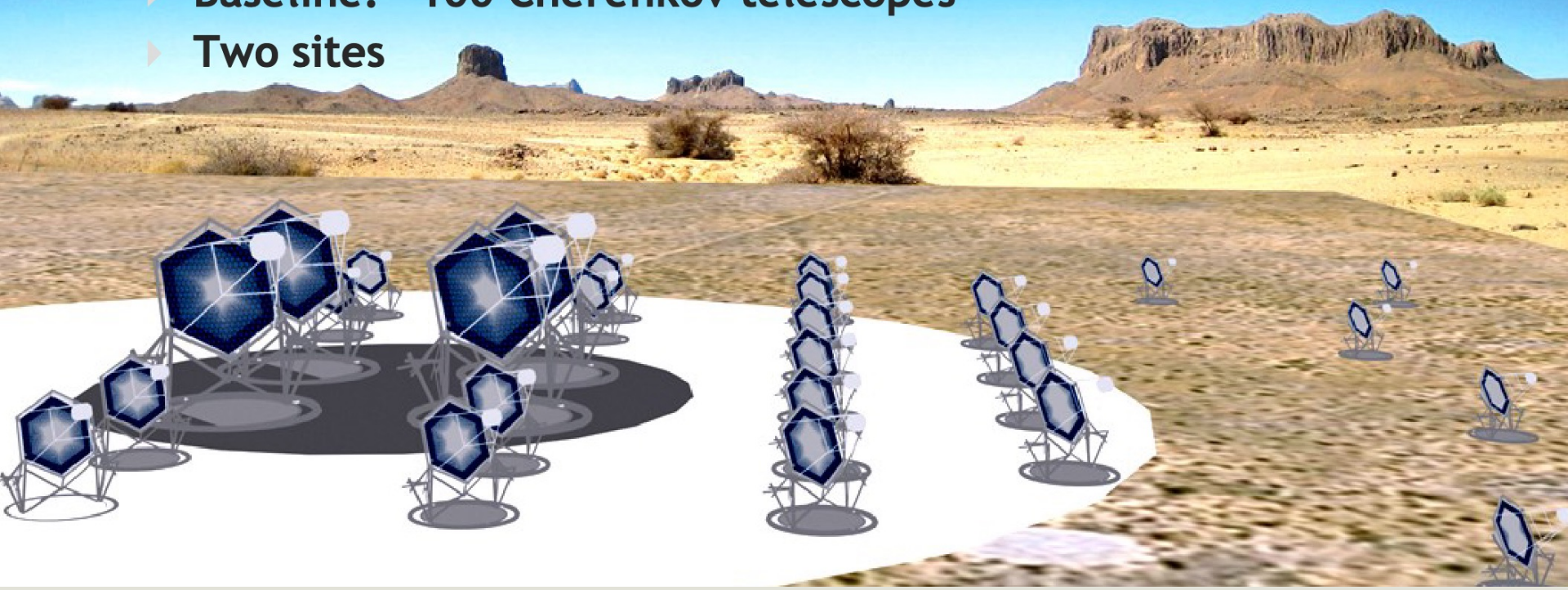
16:20 → 16:50 **Summary** 30m

Speaker: Prof. Jim Hinton (Leicester)

Slides

The Cherenkov Telescope Array

- A factor 10 more sensitive than current instruments
  - Plus - much wider energy coverage, substantially better angular and energy resolution & wider field of view
- A ~€150M international project
  - Almost 700 people (220 here this week) in 24 countries
  - Design 2008-2011, Prototyping 2011-13, Construction 2013-18
  - Baseline: ~100 Cherenkov telescopes
  - Two sites



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Slides

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15:40

16:00

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Martinez (IFAE Barcelona) ,

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Physics Working Group of the CTA Collaboration (at Rutherford Appleton
er (at Cosener's House).

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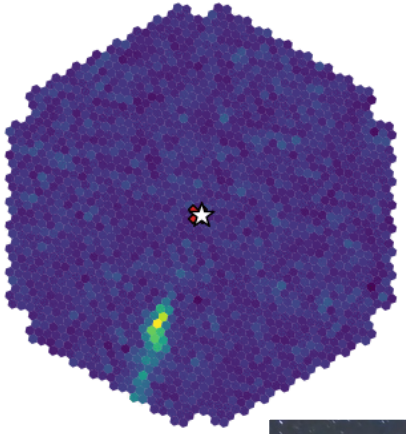
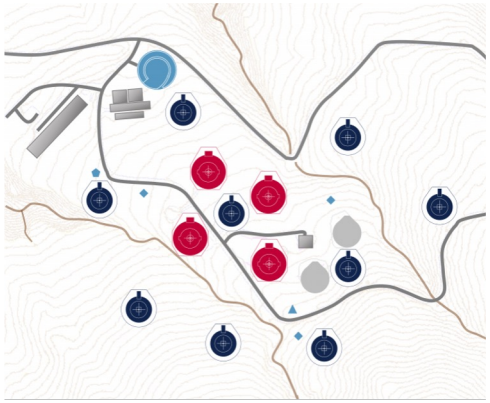
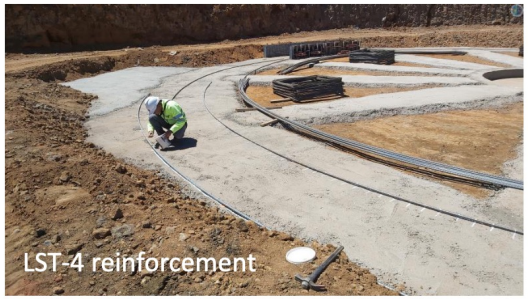
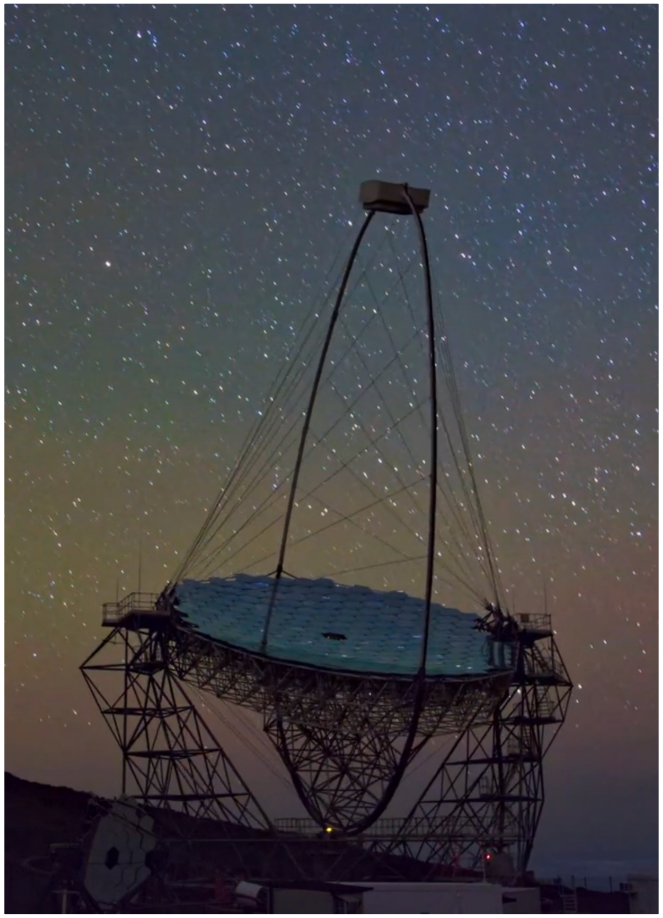
Status



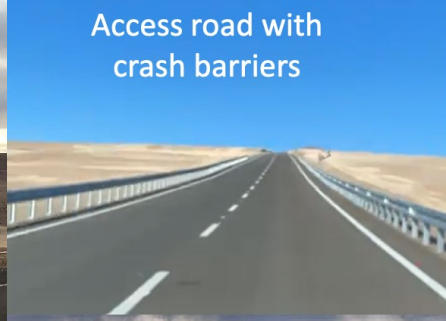


- CTA North: La Palma
  - Advanced planning/preparation of infrastructure and MSTs
  - LST-1 running for several years
  - LST-2-4 under construction

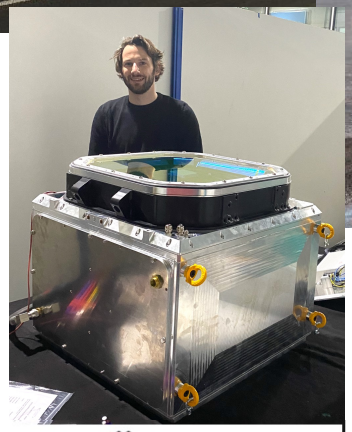


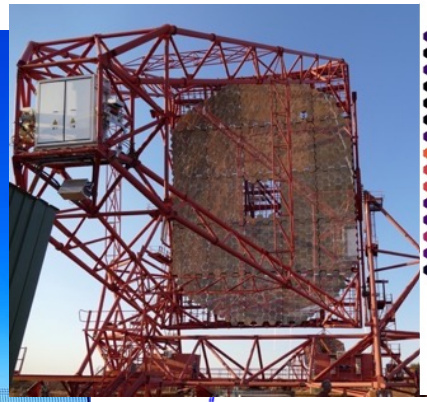


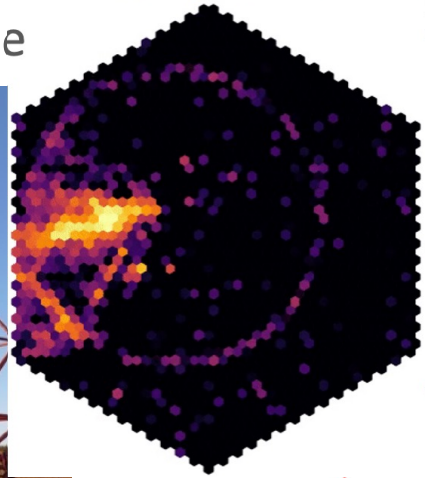
Status

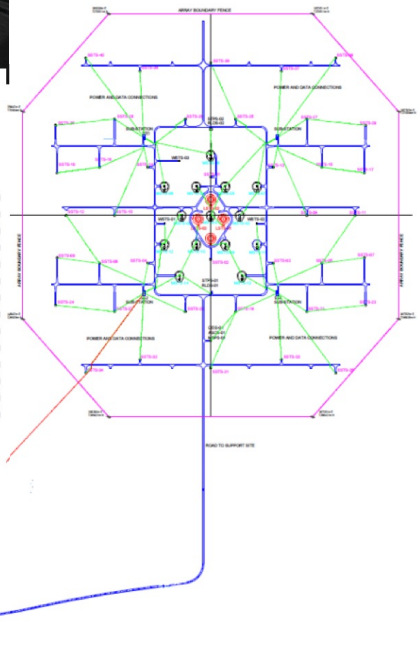


- CTA South: Paranal/Chile
  - Access road constructed
  - Power system being implemented
  - Intensive preparations
- Telescopes/cameras destined for CTA-South extensively tested at other sites
  - And final design adjustments being made

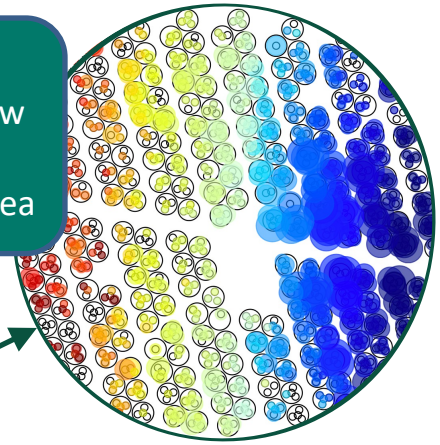






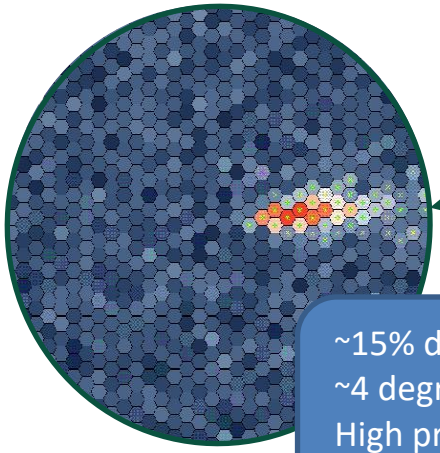


~100% duty-cycle
Steradian field of view
Modest precision
Modest collection area



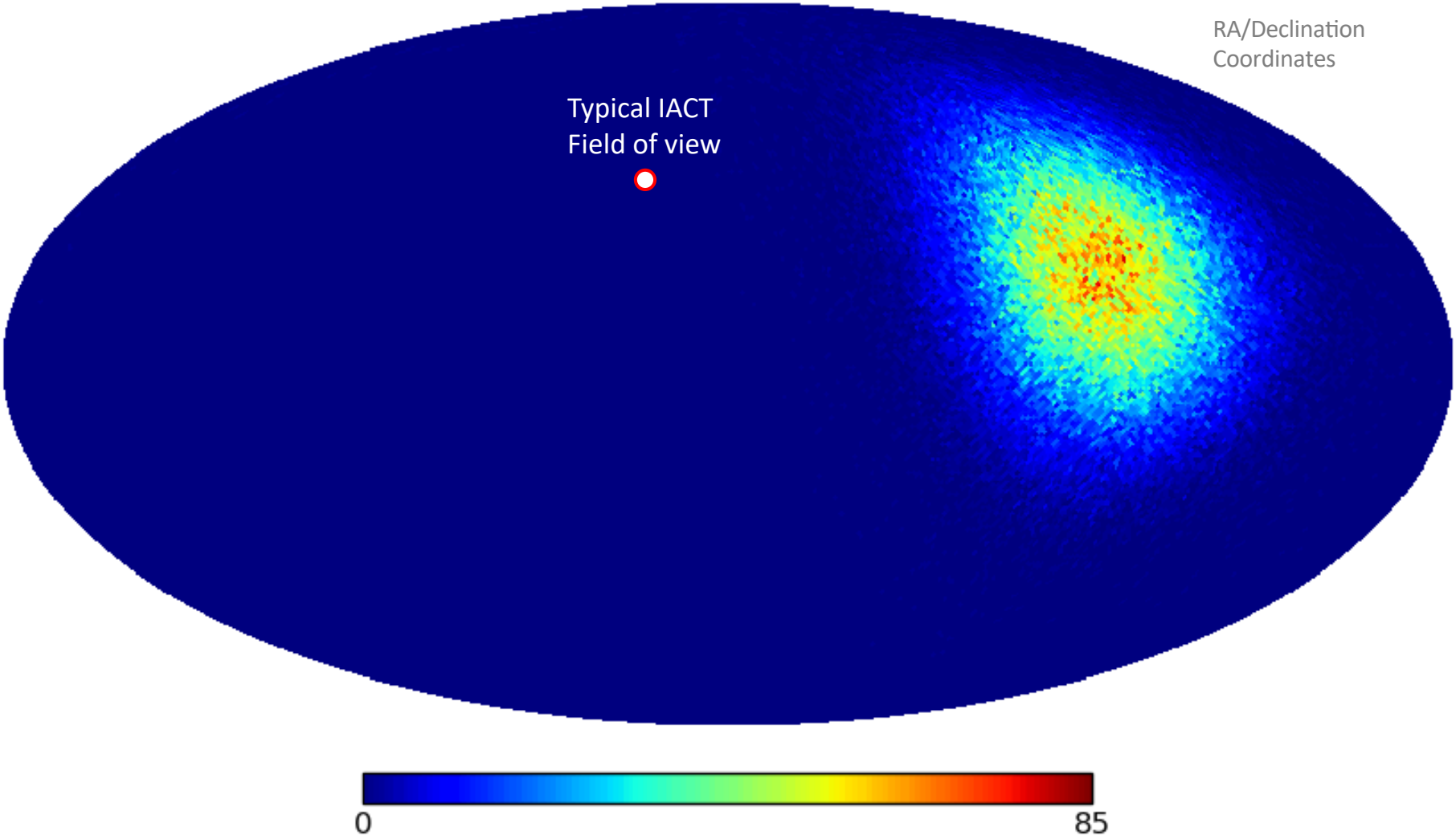
Few ns spread in particle arrival at each detector

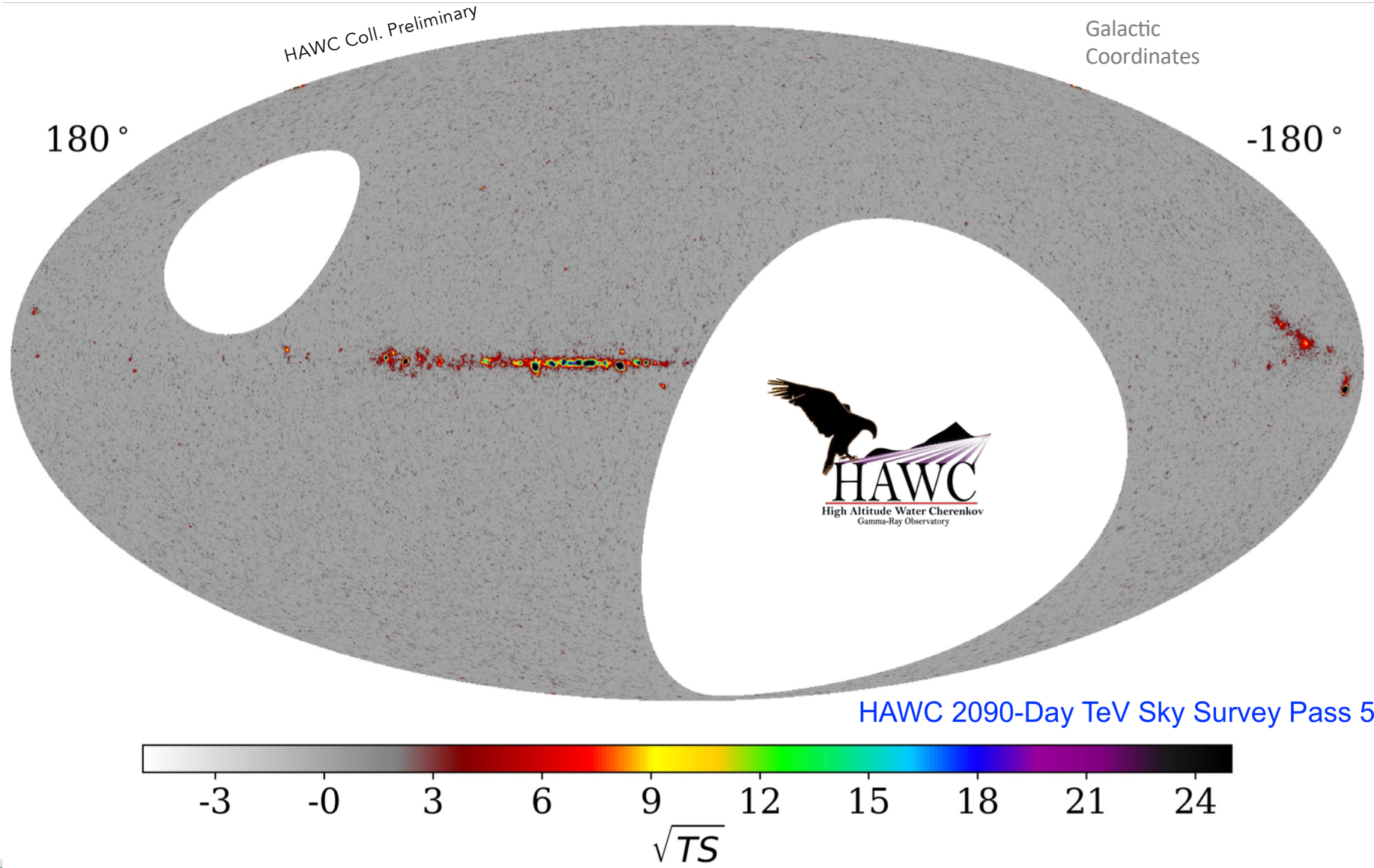
Few ns light flash

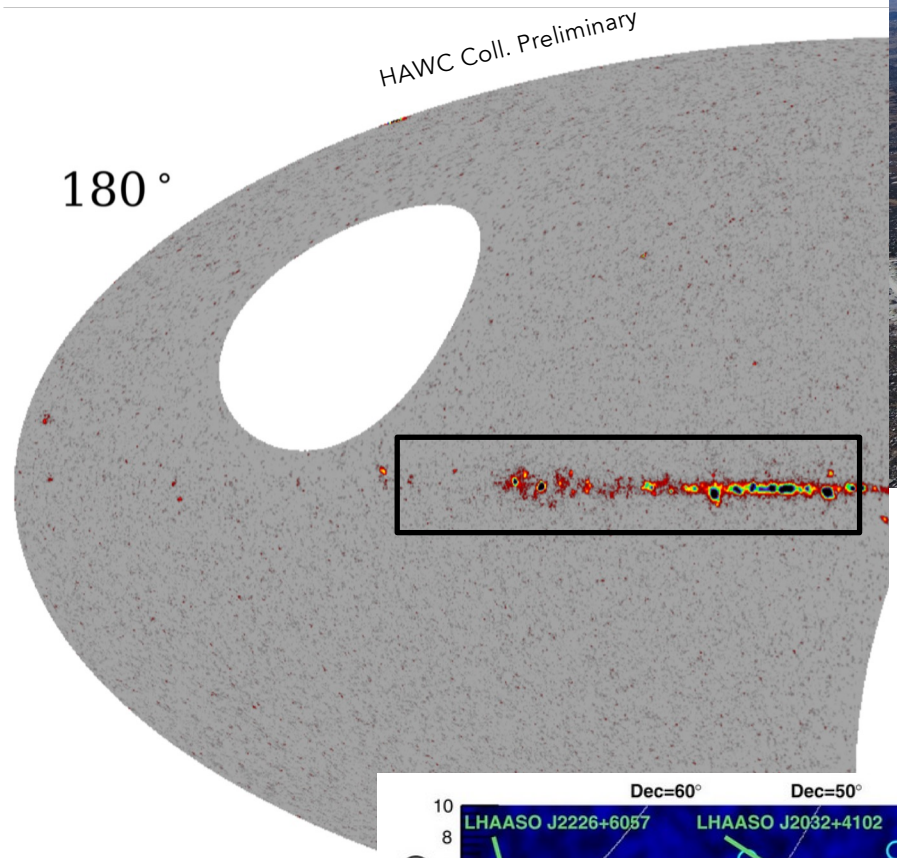


~15% duty-cycle
~4 degree field of view
High precision
Large collection area

e.g. HAWC



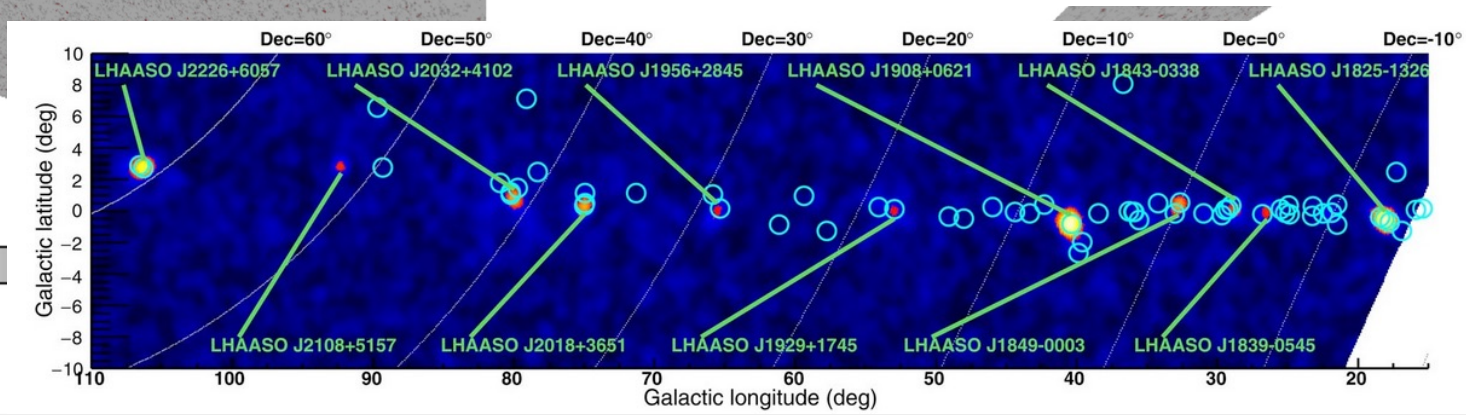

HAWC Coll. Preliminary
Galactic
Coordinates
180 °
-180 °
HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory
HAWC 2090-Day TeV Sky Survey Pass 5
-3
-0
3
6
9
12
15
18
21
24
√TS



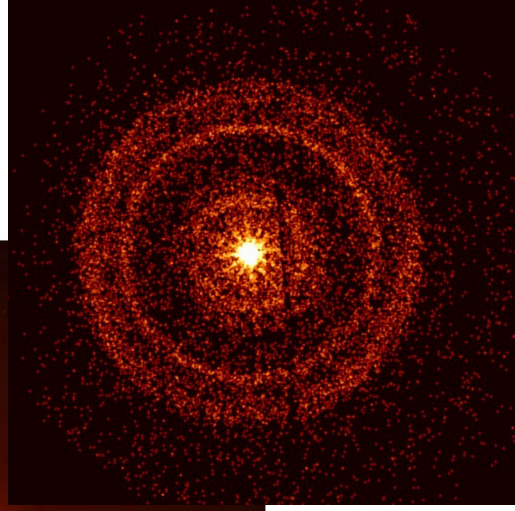
Ultrahigh-energy photons up to 1.4 petaelectronvolts from 12 γ-ray Galactic sources

Zhen Cao ✉, F. A. Aharonian ✉, [...]X. Zuo

Nature **594**, 33–36 (2021) | Cite this article



GRB 221009A



Scientists Detected A NEW MASSIVE Explosion In Space [NEVER BEFORE SEEN]

Factnomenal
804K subscribers
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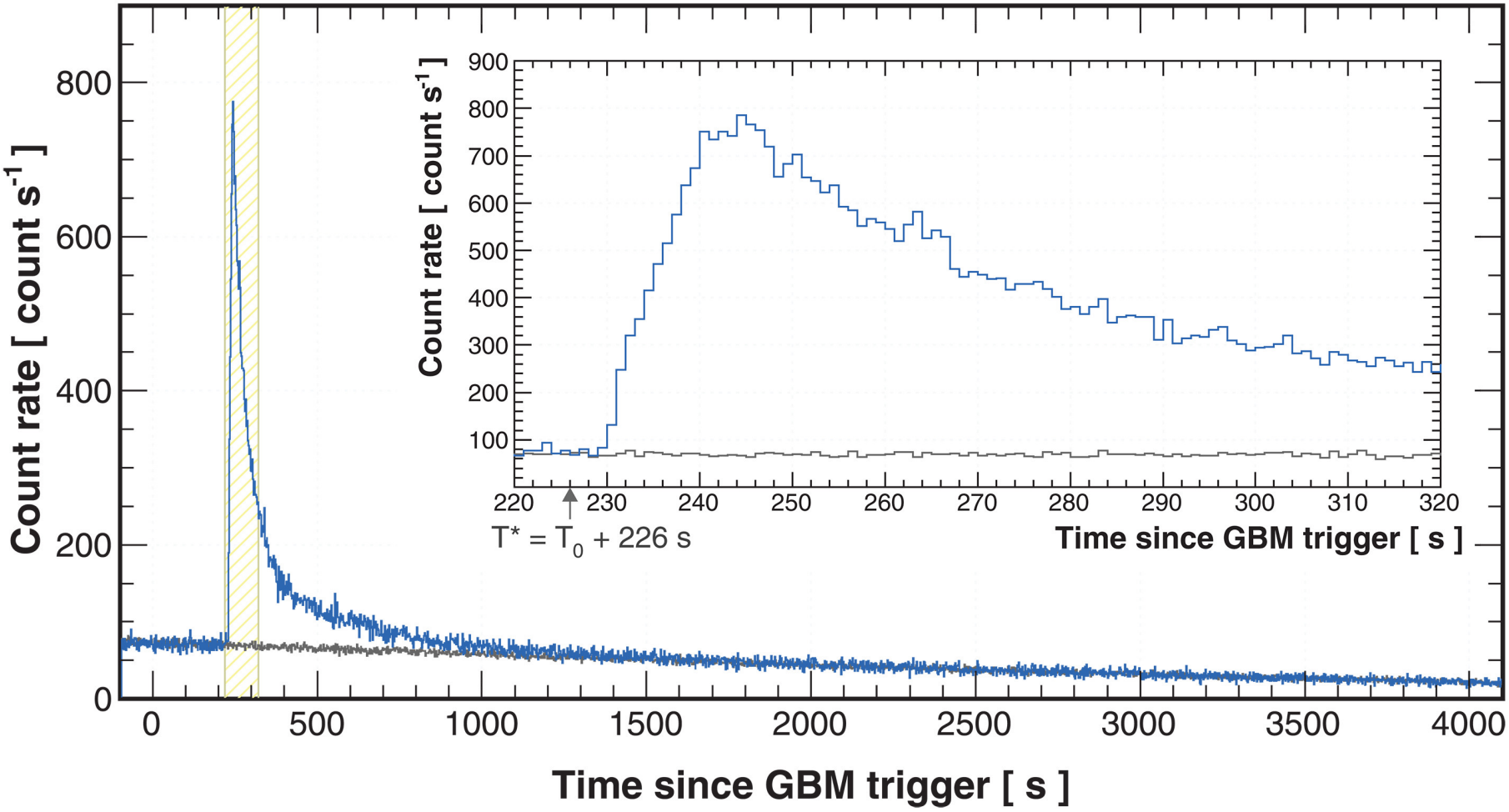
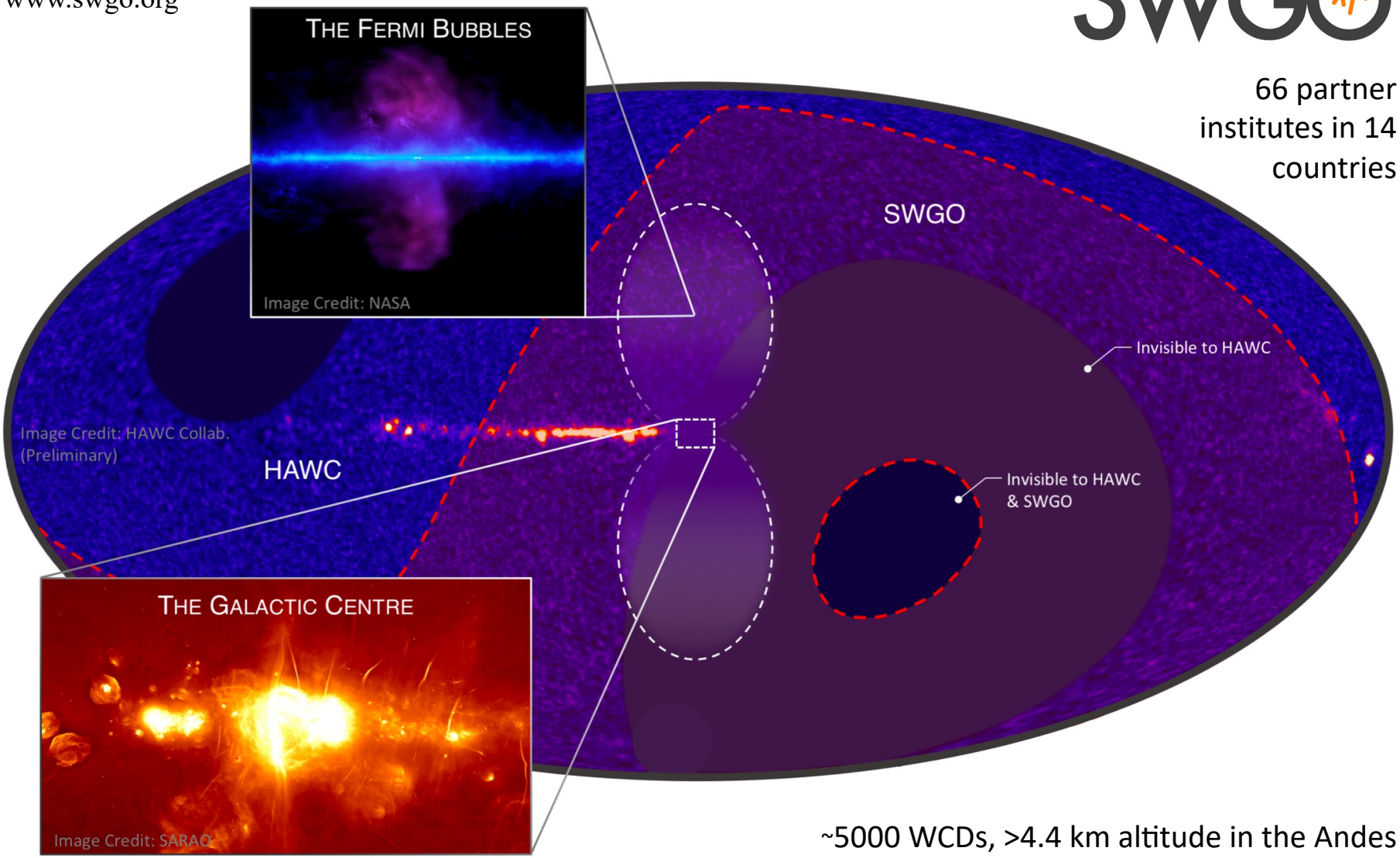
Cao et al, Science 2023



- z = 0.1505, photons up to (reconstructed) energy of **18 TeV**

arXiv:2111.13158v1
www.swgo.org



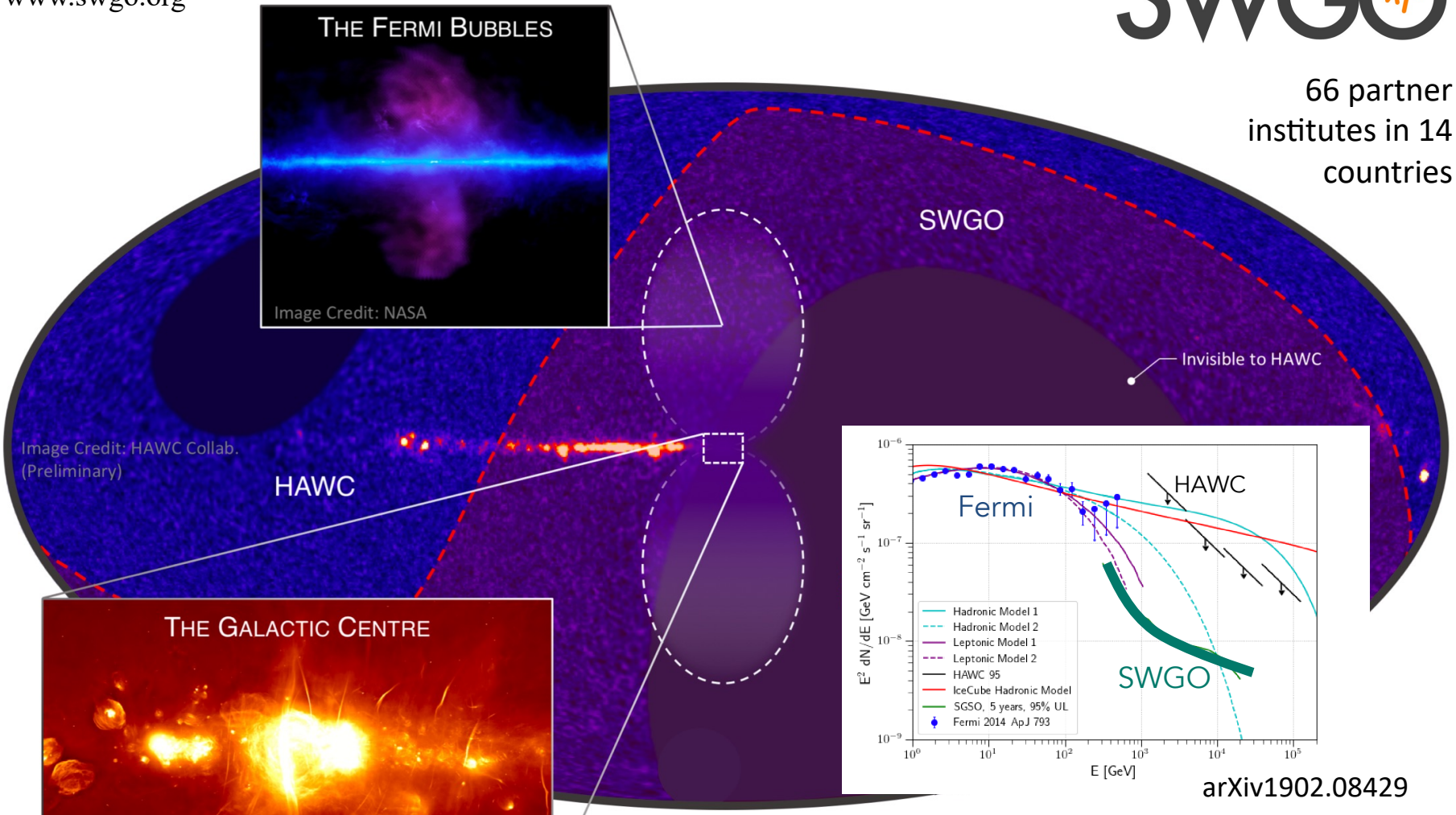
66 partner institutes in 14 countries

~5000 WCDs, >4.4 km altitude in the Andes

Collaboration formed in 2019

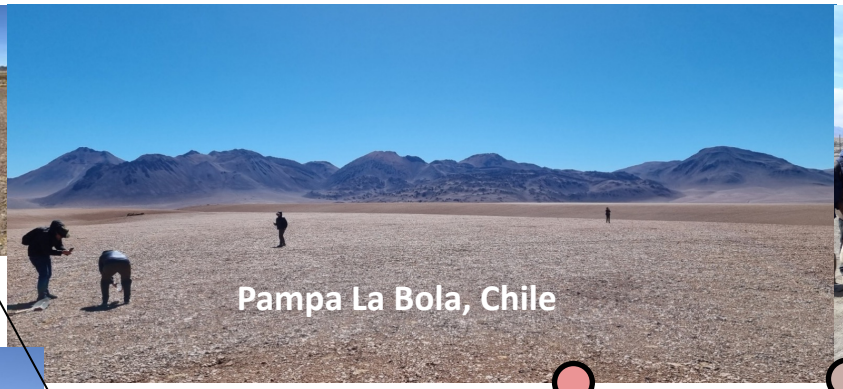
arXiv:2111.13158v1
www.swgo.org

66 partner institutes in 14 countries

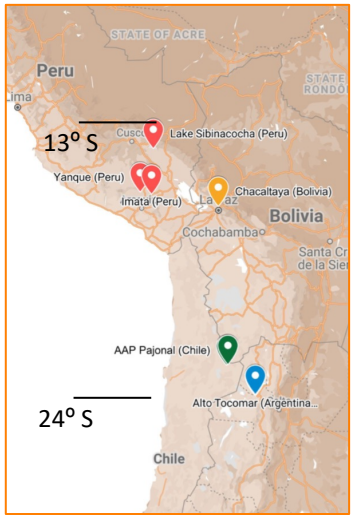


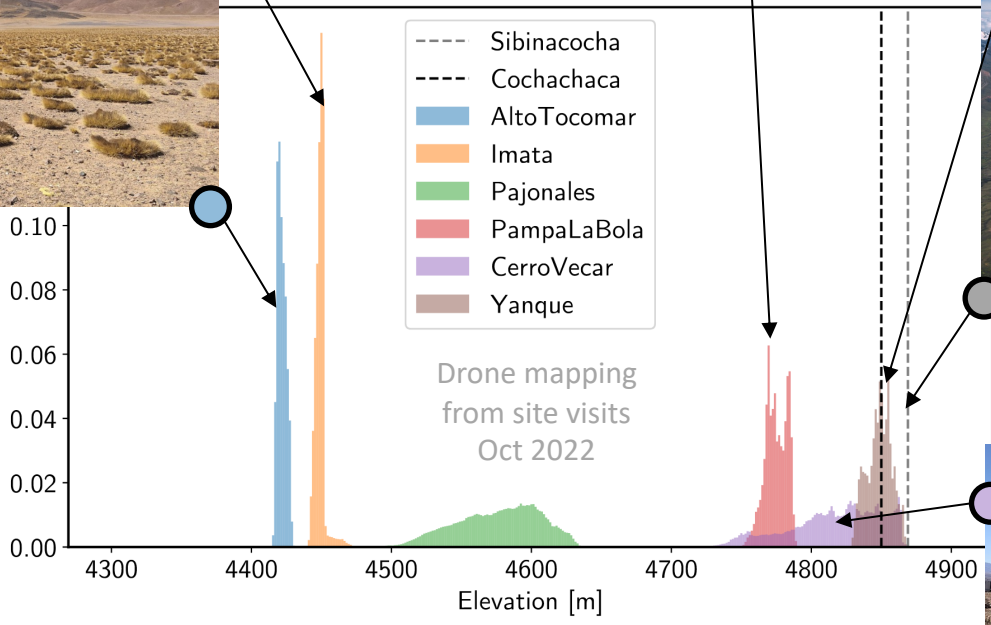
arXiv1902.08429

~5000 WCDs, >4.4 km altitude in the Andes
Collaboration formed in 2019

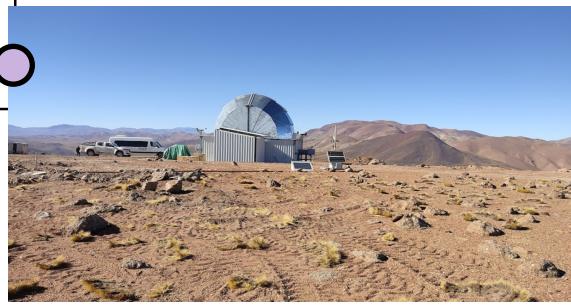


Sibinacocha, Peru

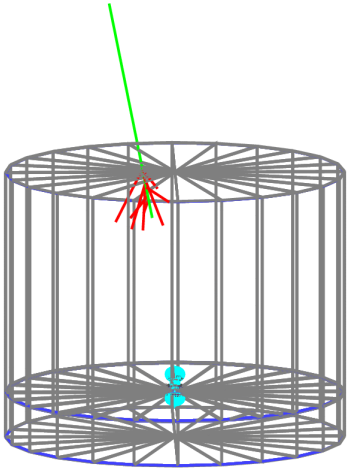


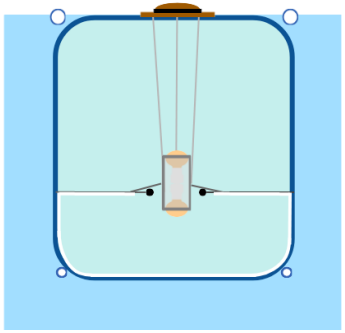


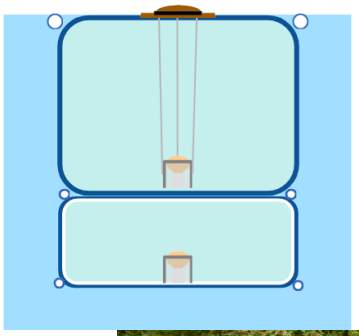
Cerro Vecar, Argentina

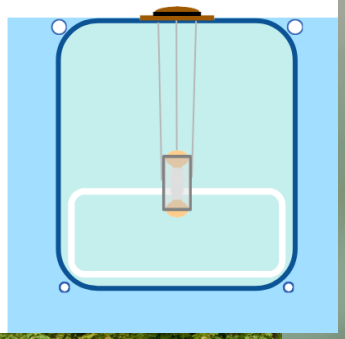


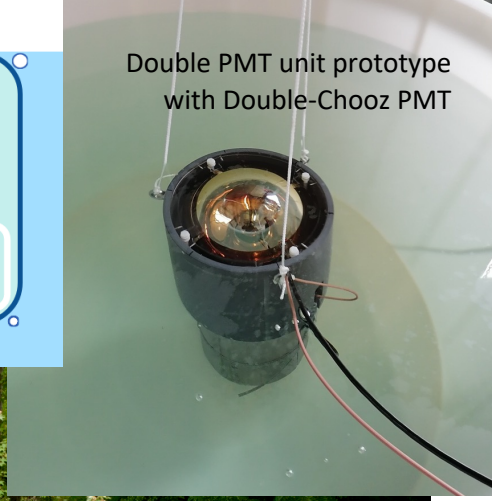
Decision planned for 2024











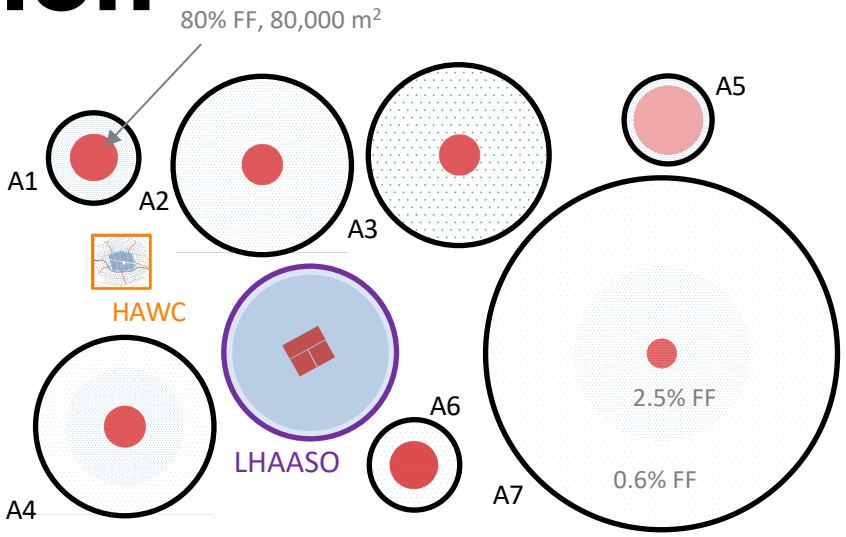
Samridha Kunwar

Gewässersimulationstank!
Ø10 x 7m at MPIK

Laguna Sibinacocha,
Peru@ 5 km a.s.l

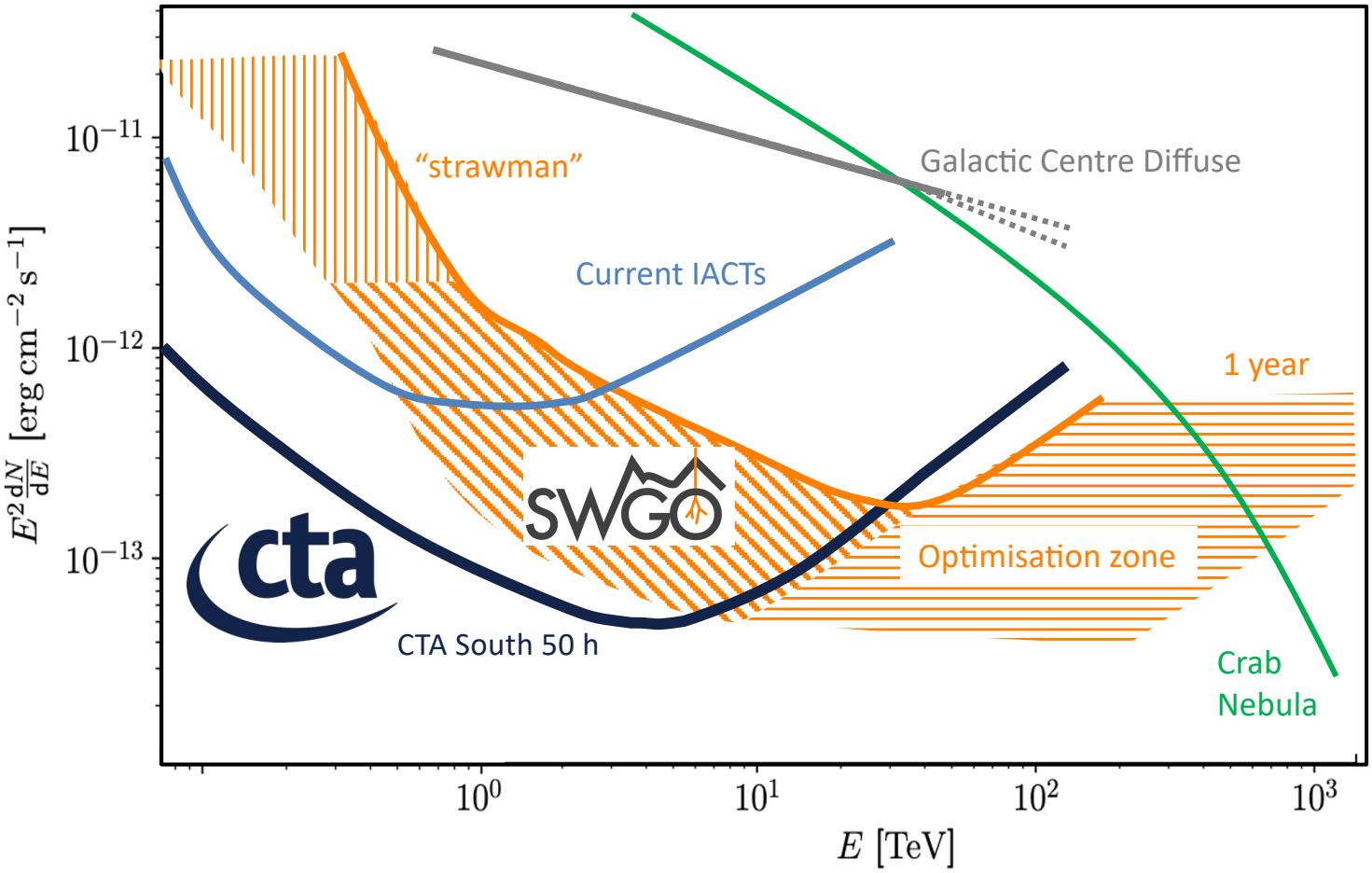
Towards Construction

- Full scope
  - ~6000 WCD units, $60M nominal cost
  - Nominal funding plan 1/3 US, 1/3 Europe, 1/3 Rest of world
- Goal timeline
  - R&D phase completed end 2024
    - Site and key technology decisions made
  - Engineering array 2025-26
    - 1-10% scale – at final site
    - Potentially HAWC-like sensitivity in new hemisphere
    - 600 10” PMTs available (in hand) from previous experiments
  - Build phase 2027-31



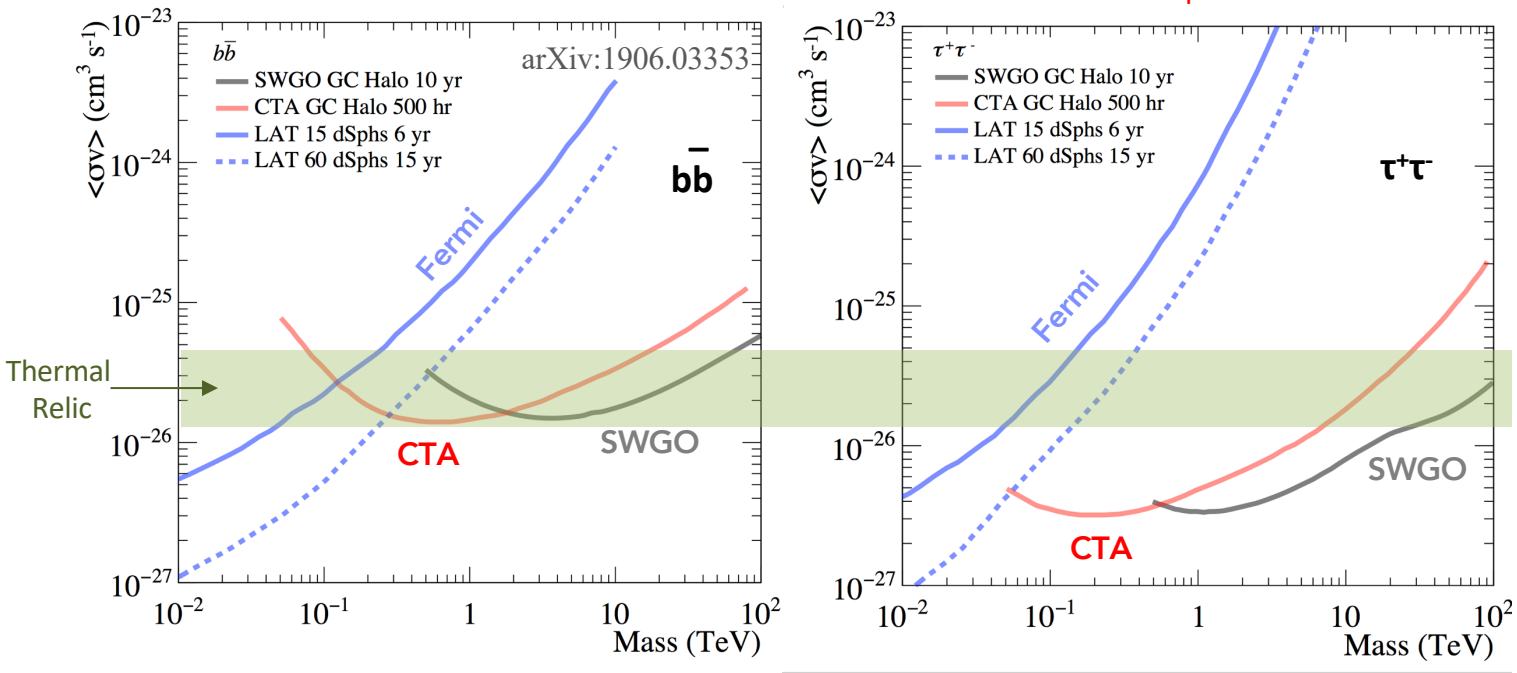
Candidate configurations (13 total)

Point-source differential sensitivity (5 bins per decade, 5 sigma)



WIMPs?

NB – CTA sens. updated in the meantime



SWGO Strawman Sens.

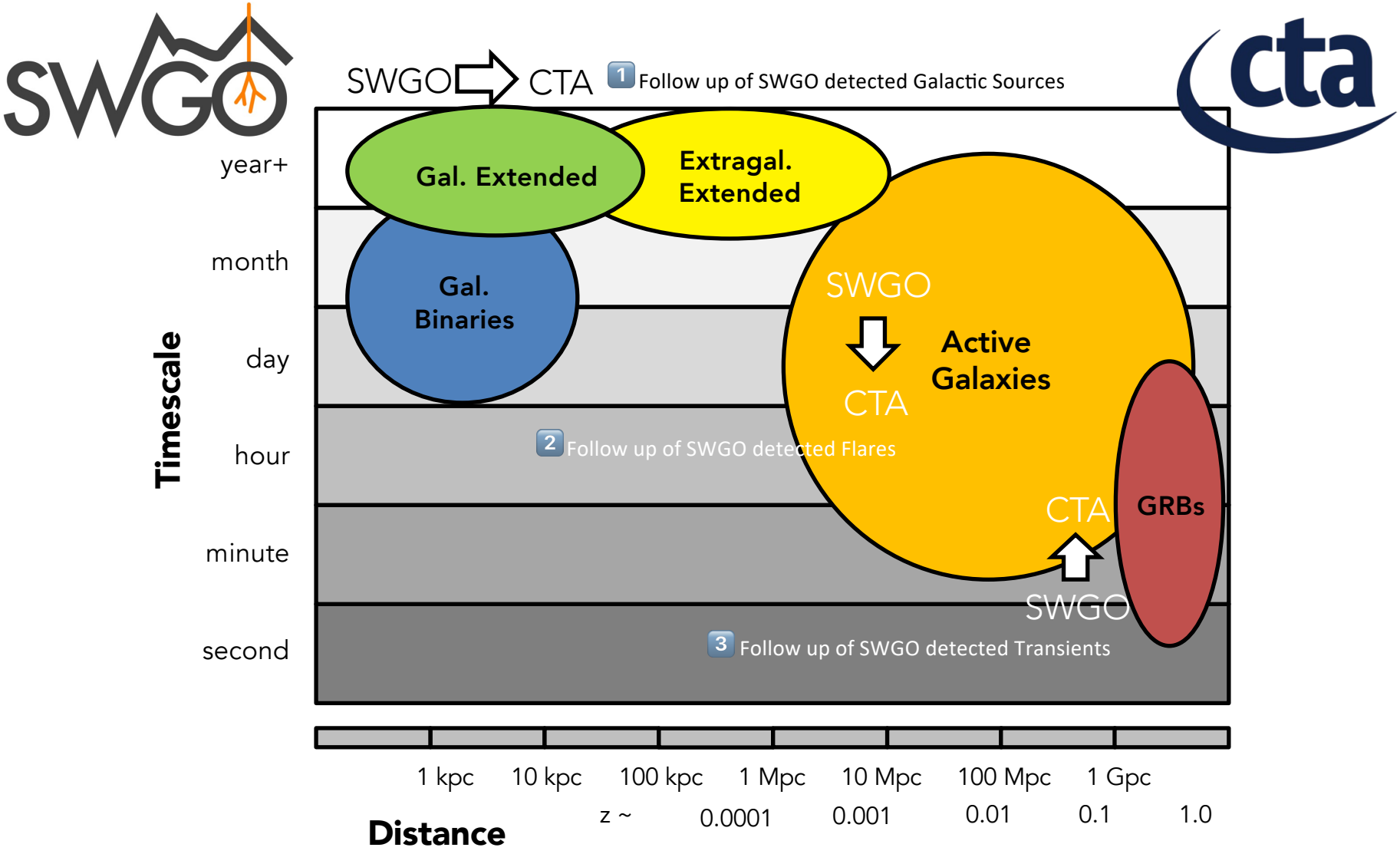
- **Fermi+CTA+SWGO will reach the critical sensitivity**
- Thermal relic WIMP accessible over a very wide mass range via Galactic Centre/Halo observations @ VHE*

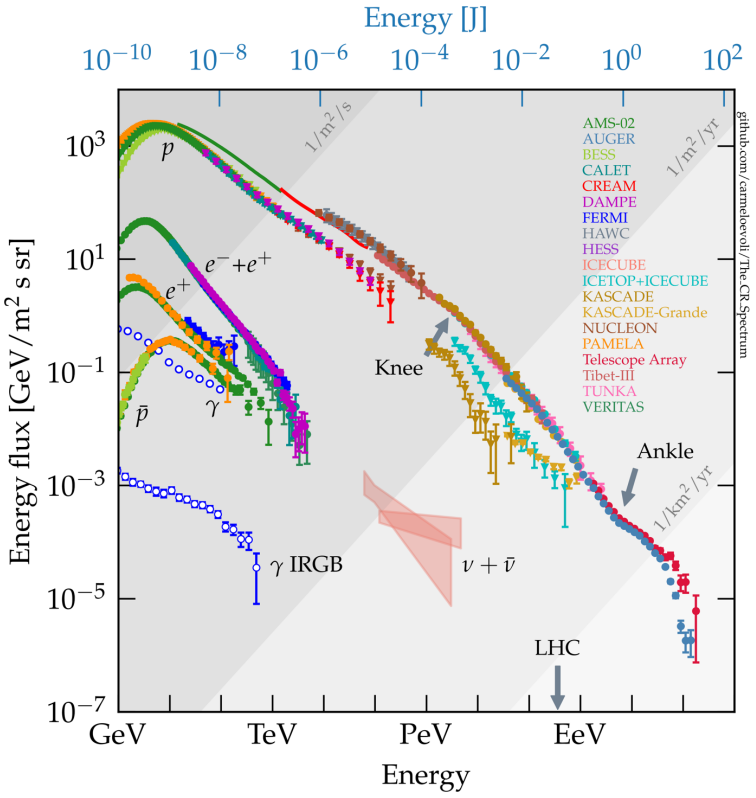
*As long as the universe is not too unkind w.r.t. halo shape + Sommerfeld etc etc

Summary

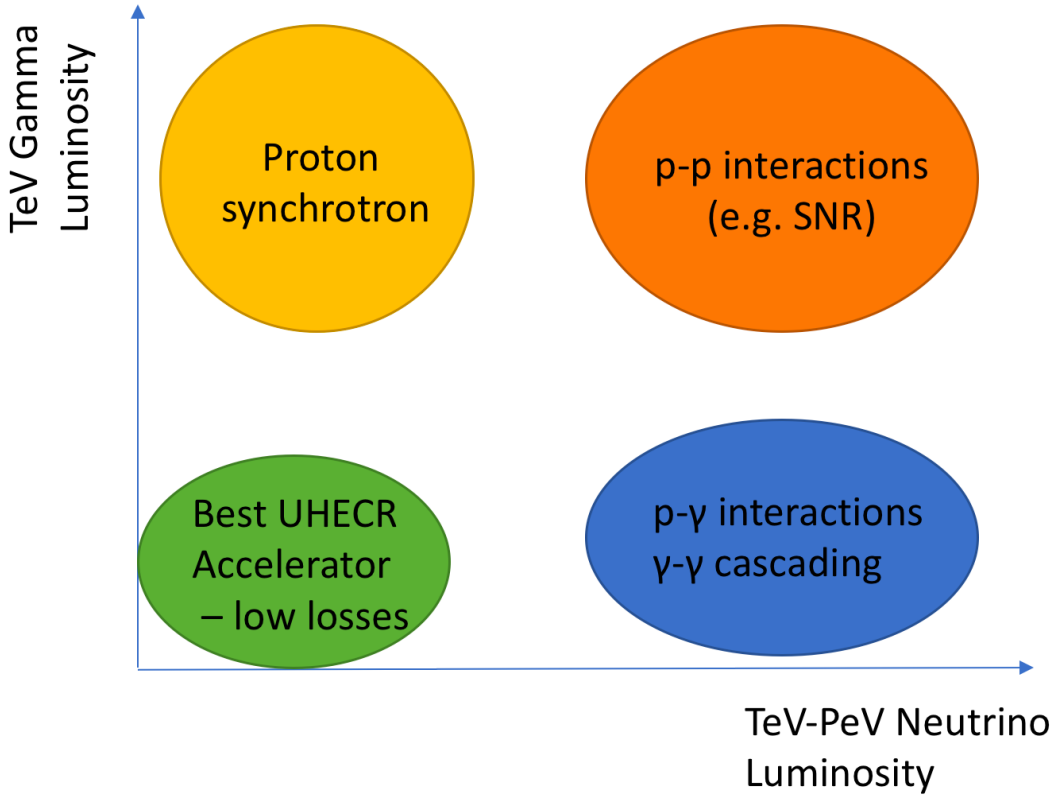
- VHE photons are a powerful probe of the non-thermal universe: particle acceleration is common in nature
  - Still surprises emerging (regularly!) from the old generation of Cherenkov Telescope arrays (e.g. HESS)
- UHE field emerging
  - Wide field / shower particle detectors demonstrating their UHE capabilities (HAWC→LHAASO)
- New generation instruments
  - **CTA** construction underway – will have transformational impact
  - **SWGO** – strongly complementary (large scales, highest energies and transient phenomena) and moving quickly
    - LHAASO+SWGO strongly complement IceCube+KM3Net – Galactic emission

80th (?) Birthday Present for Subir: BSM physics with CTA+SWGO!


SWGO
CTA
SWGO CTA
1 Follow up of SWGO detected Galactic Sources
year+
month
day
hour
minute
second
Timescale
Gal. Extended
Extragal. Extended
Gal. Binaries
SWGO
CTA
Active Galaxies
2 Follow up of SWGO detected Flares
CTA
GRBs
SWGO
3 Follow up of SWGO detected Transients
1 kpc
10 kpc
100 kpc
1 Mpc
10 Mpc
100 Mpc
1 Gpc
z ~
0.0001
0.001
0.01
0.1
1.0
Distance

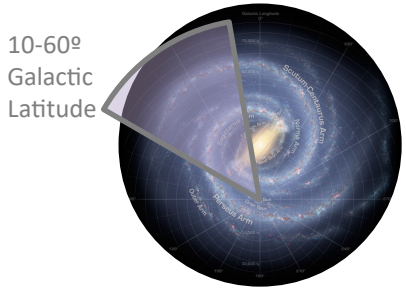


Emission associated with accelerated protons and nuclei

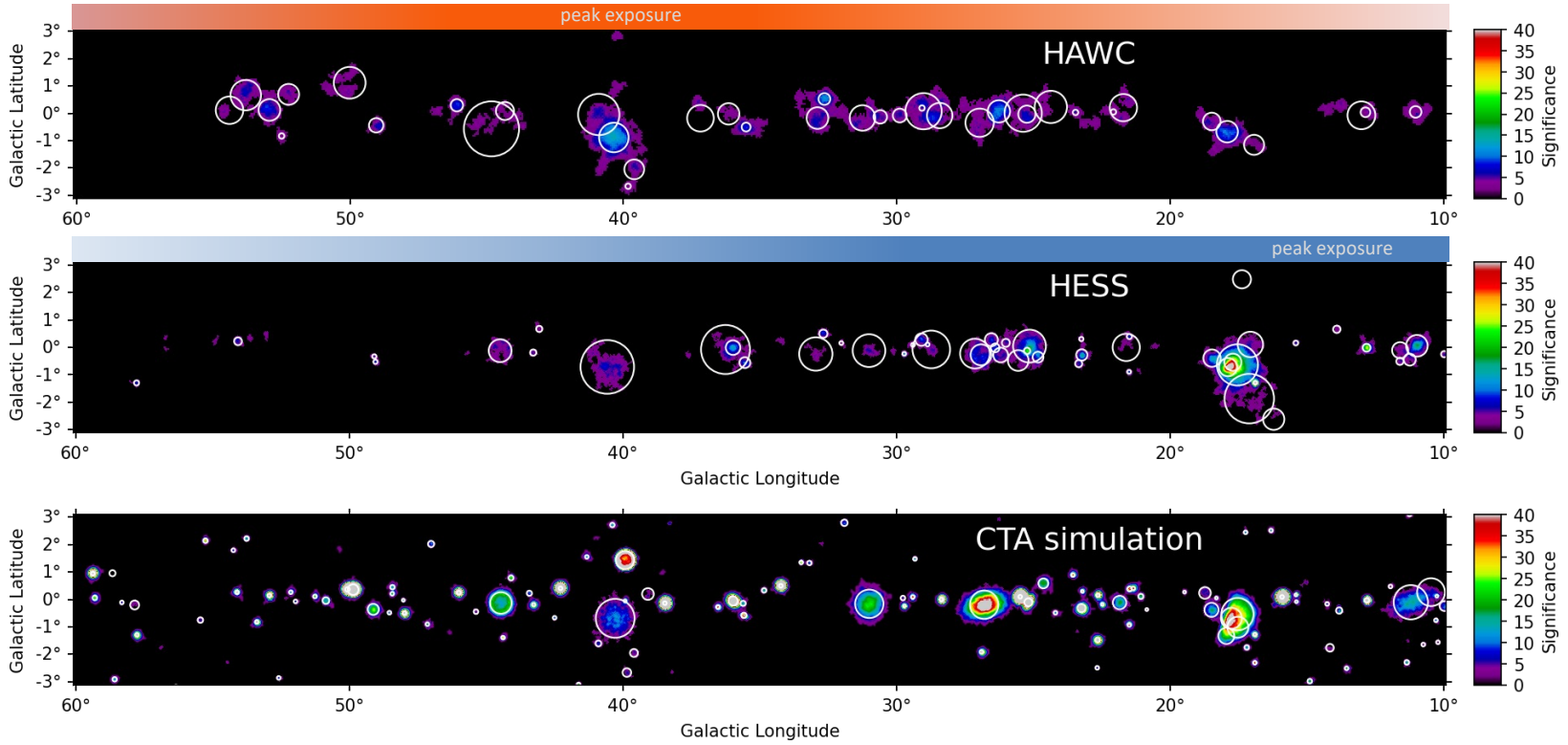


- Complementary probes: brightest sources in each domain unlikely to be the same
- UHECR accelerators should not produce a lot of TeV-PeV neutrinos or gammas (losses!)
  - But with sensitive enough TeV gamma and neutrino detectors – we will see them

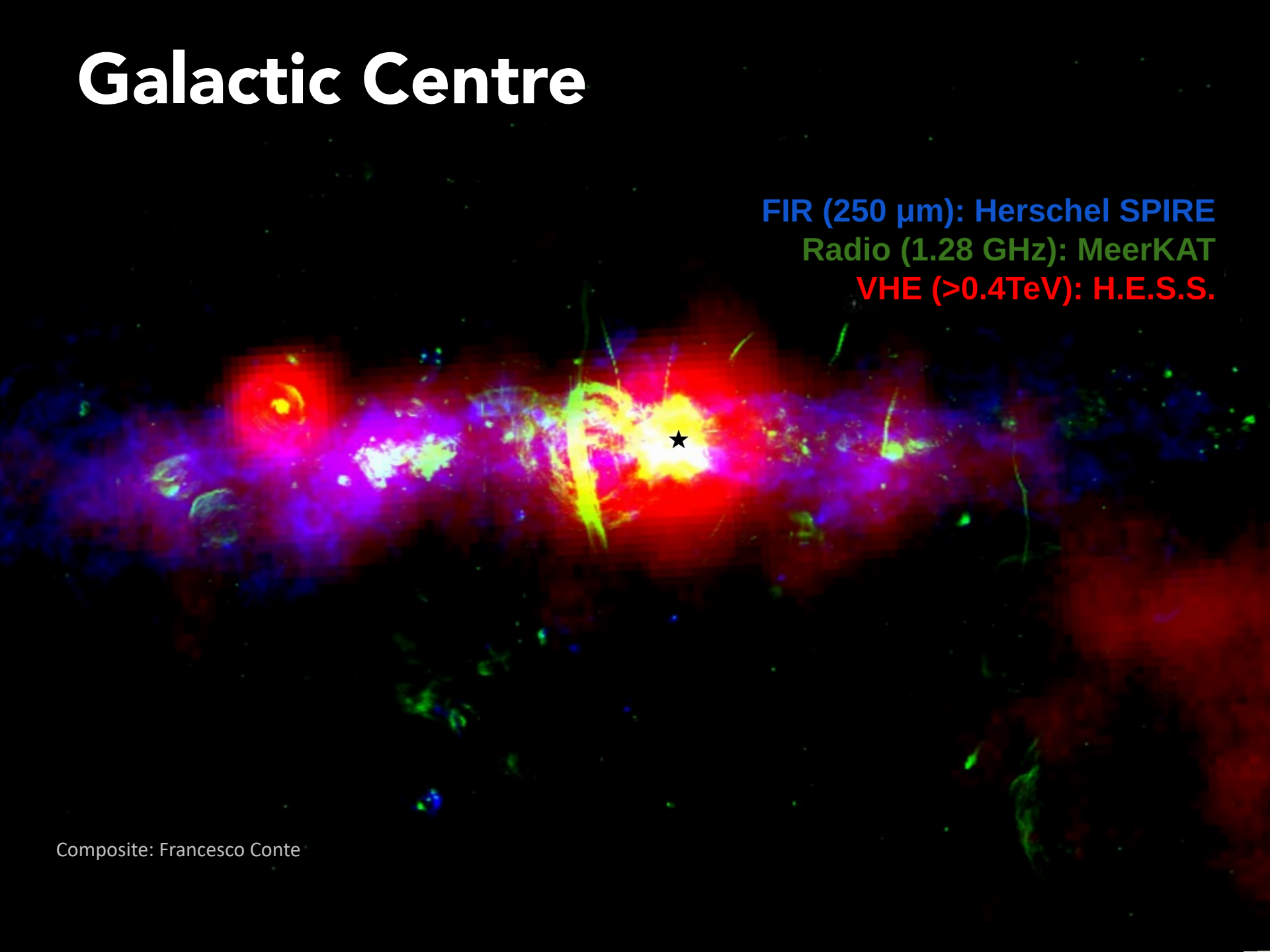
Catalogue Pipeline



- Quentin Remy (MPIK)



Galactic Centre



Composite: Francesco Conte

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Massive star cluster origin for the galactic cosmic ray population at very-high energies

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