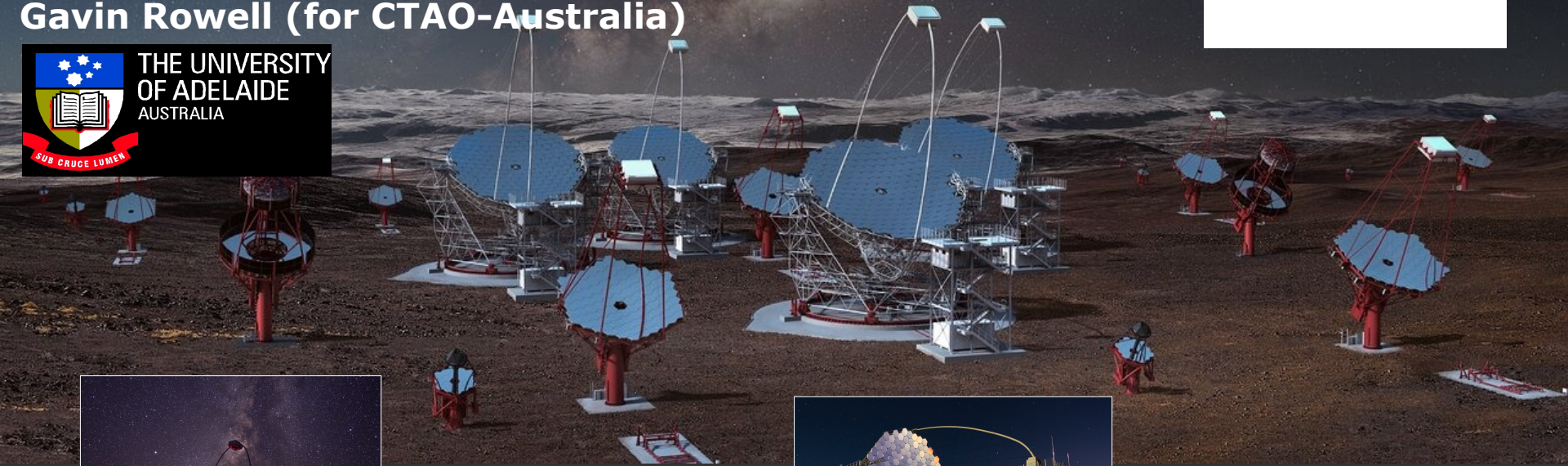


The Cherenkov Telescope Array Observatory: A new Paradigm in Gamma-Ray Astronomy and Astroparticle Physics

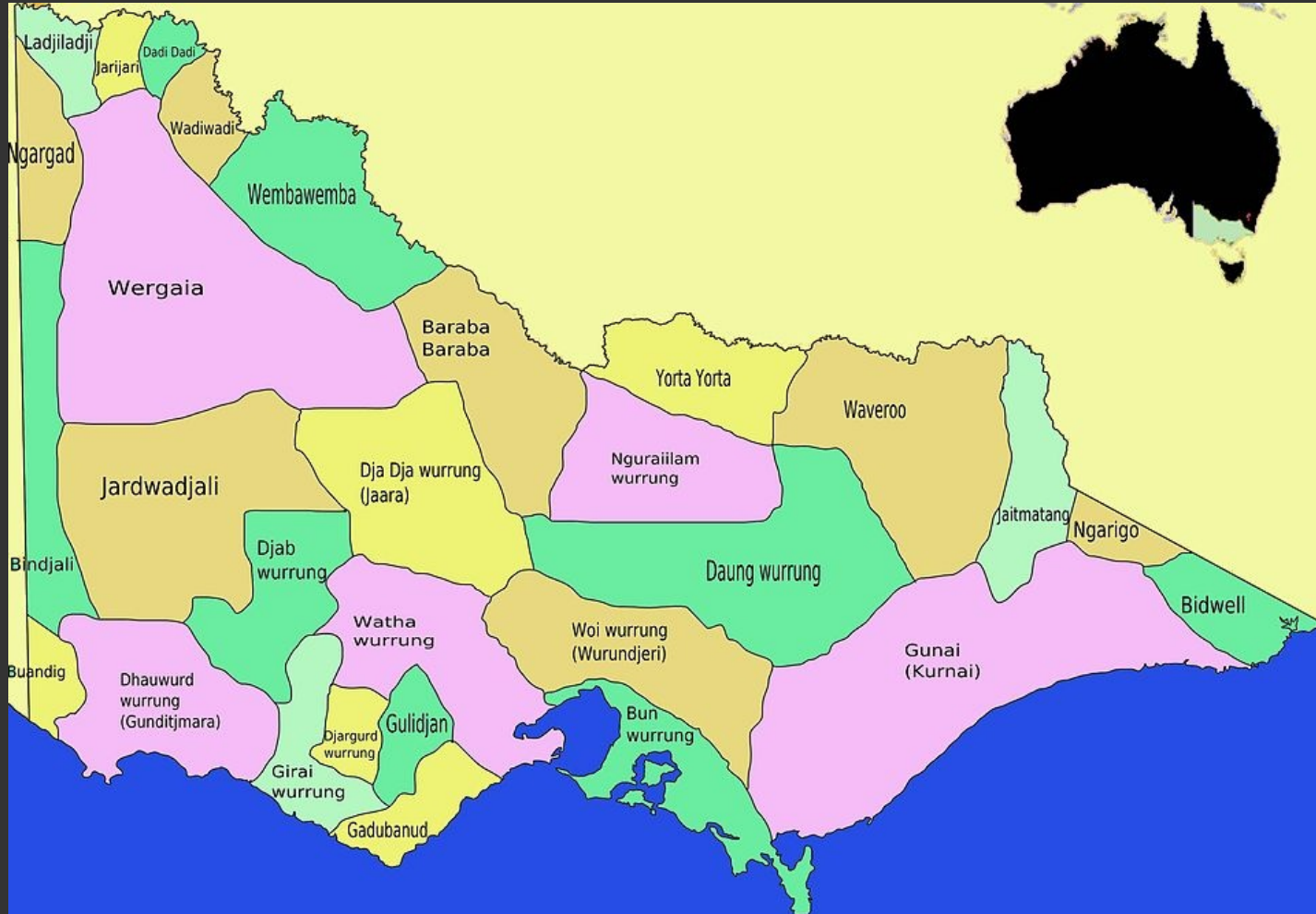
CTAO

Gavin Rowell (for CTAO-Australia)



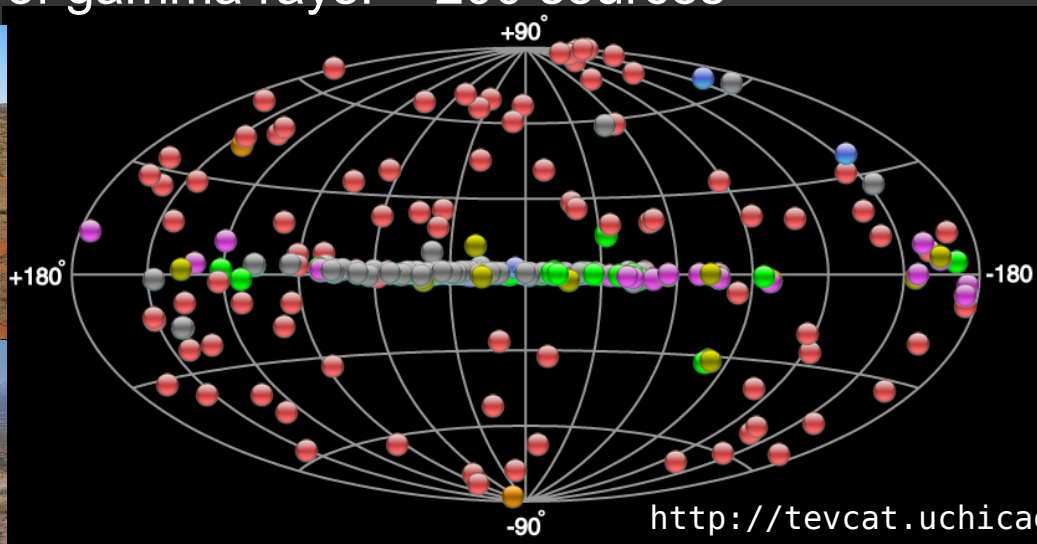
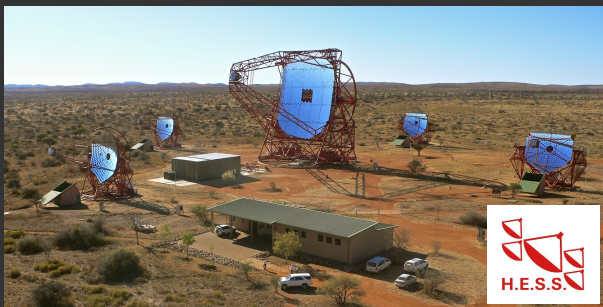
Monash Uni. Nov. 2025

We would like to Acknowledge that the land we meet on today is the traditional lands for the Wurundjeri and Boonwurrung people, who are part of the Kulin Nation. We respect their spiritual relationship with their Country. We also acknowledge the Wurundjeri and Boonwurrung people as the traditional custodians of the Melbourne region.



Gamma-rays (~ 30 GeV to ~ 500 TeV)

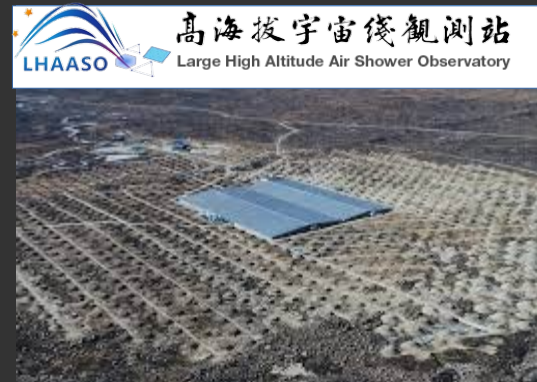
Ground-based detection of gamma rays: >200 sources



<http://tevcat.uchicago.edu/>

Source Types

- PWN TeV Halo
PWN/TeV Halo
- XRB Nova Gamma BIN
Binary PSR
- HBL IBL GRB FSRQ LBL
AGN (unknown type) FRI
Blazar
- Shell Giant Molecular
Cloud SNR/Molec. Cloud
Composite SNR
Superbubble SNR
- Starburst
- DARK UNID Other
- Star Forming Region
Globular Cluster Massive
Star Cluster BIN
uQuasar Cat. Var. BL
Lac (class unclear) WR



高海拔宇宙线观测站
Large High Altitude Air Shower Observatory

HESS/VERITAS/MAGIC/HAWC/LHAASO running $\sim 2028+$

Next generation $\rightarrow$ CTAO, SWGO.....



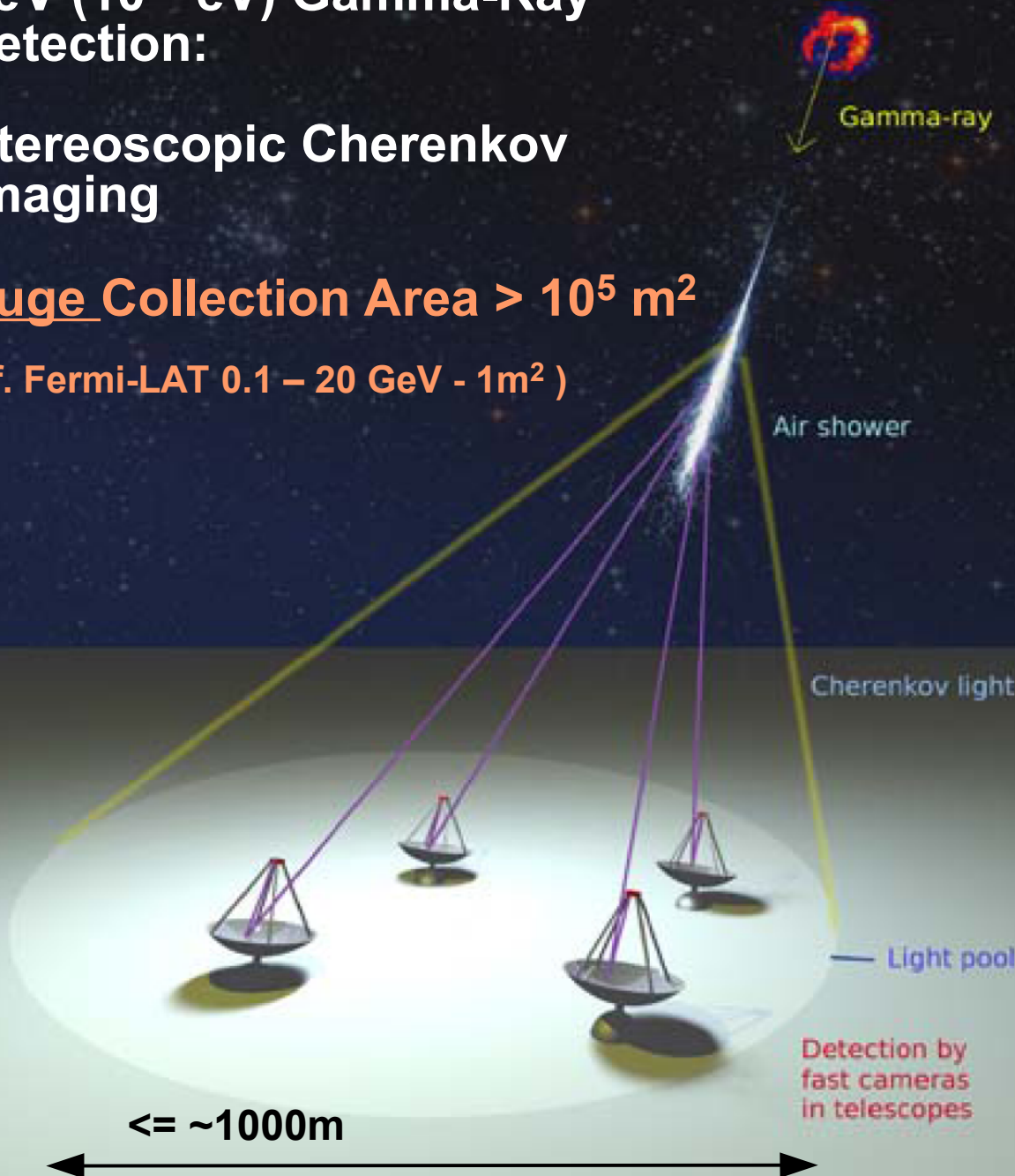
CTAO

TeV (10^{12} eV) Gamma-Ray detection:

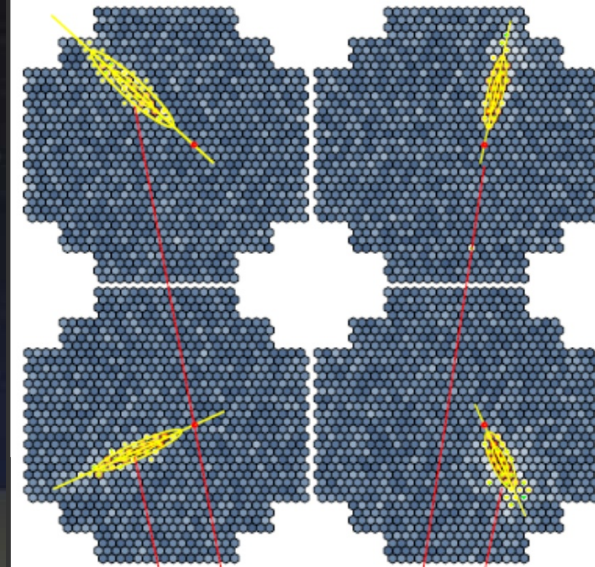
Stereoscopic Cherenkov Imaging

Huge Collection Area $> 10^5 \text{ m}^2$

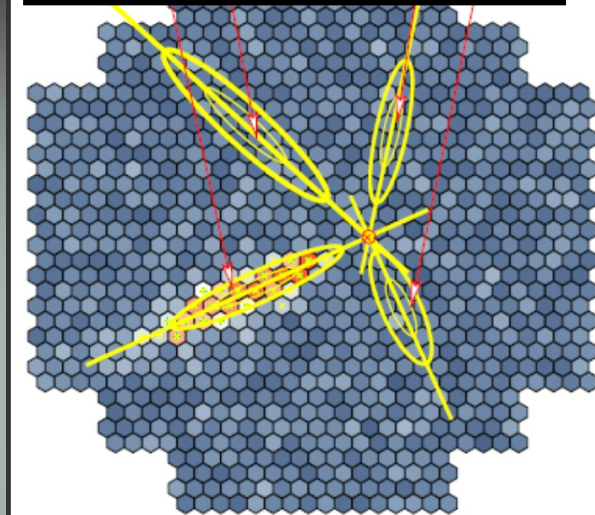
(cf. Fermi-LAT 0.1 – 20 GeV - 1 m^2)



Cherenkov 'image' as viewed by each telescope



Combination:





- ~ 10x improved sensitivity; <1 arc-min angular resolution
- ~ Transients <1hr duration >1000x better than Fermi-LAT
- Seven Australian universities involved (LIEF, NCRIS/AAL)

- **Northern Array: 4 LSTs + 9 MSTs (La Palma, Spain)** 1st telescope in operation!
- **Southern Array: 2 LSTs + 14 MSTs + 42 SSTs (Paranal, Chile)**
prep. work underway

→ construction completed ~2029/30

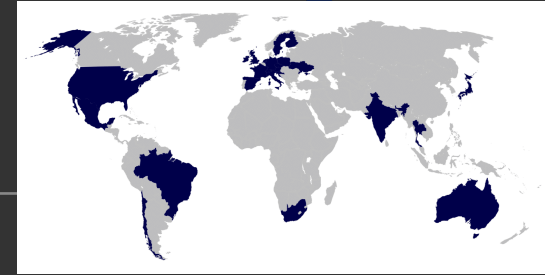
<https://www.ctao.org/>

SST – small sized telescopes
MST – mid-sized
LST – large sized



CTAO Consortium (CTAO-C)

- 25 Countries constructing telescopes and leading Key Science Programs



renkov
lescope
ay

CTA Observatory (CTAO-ERIC)

- Legal entity owning and operating CTAO telescopes at S & N sites.
[9 member countries, 1 strategic partner, 3 third parties, ESO]

CTA-Australia (U.Adelaide, WSU, ANU, UNSW, Monash, U. Syd., Curtin)

- >25 scientists, >10 students, ~3 FTE
- >2 MEuro from ARC-LIEF + NCRIS (AAL)
- CTAO 3rd party + CTAO-C member

First “open access” observatory in TeV gamma-ray astronomy

Key Science Projects ~ 40% time CTAO only

Open time ~ 30% time CTAO only

Remaining time for Chile, Spain, DDTs, ESO, guests

<https://www.worldscientific.com/worldscibooks/10.1142/10986>



CTAO-ERIC: Australian Involvement

Australia will be a “3rd Party” with AAL as Australia’s representative.



3rd Party agreement now being finalised: rights and obligations, potential regular payments and avenues for **other in-kind contributions** to CTAO-ERIC:

access to Australian radio and optical facilities to support KSPs and other CTAO science (now under discussion) → credit for CTAO access?

- ANU 2.3m telescope for optical polarimetry CTAO-Pol
- ATCA access GHz radio + other radio facilities..

CTAO-ERIC Council: James Murray, Gavin Rowell

CTAO AFC (Accounting and Finance Committee): Anne Green

CTAO-C Board: Gavin Rowell

CTAO Array Sites (South & North)



CTAO-South
51 telescopes

+ extra ~7 telescopes



CTAO-North
13 telescopes



CTAC/CTAO/CTAO-Aust News Apr+ 2025

- CTAO-ERIC commenced Jan.



- CTAO-North LST-2,3,4 construction. LST-1 physics



- CTAO-South site preparation; roads, power....



- Early science from “Intermediate Arrays”: 2027+ → **get ready!**

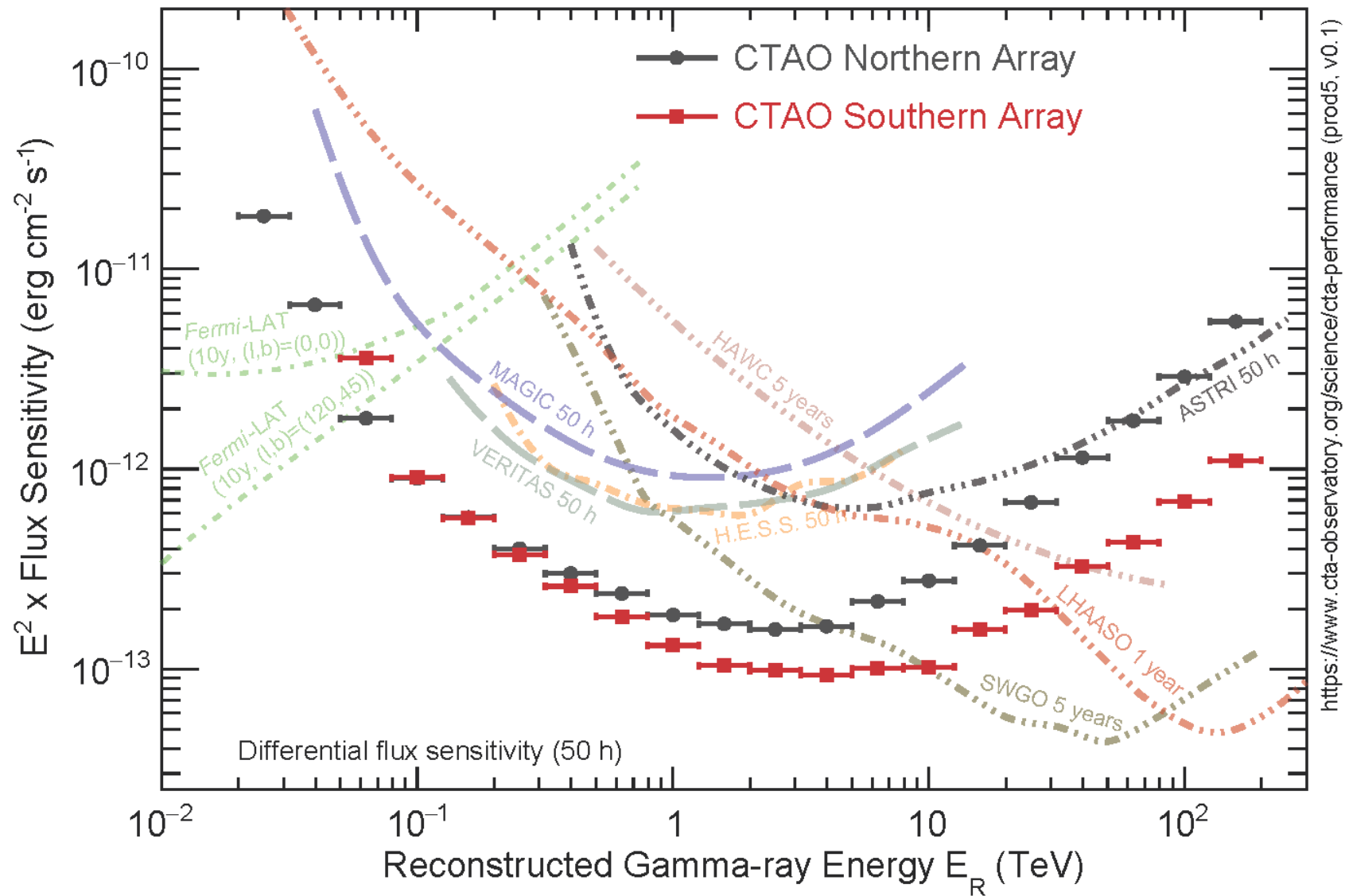
- USA \$4M funding (SSTs, SCTs)

- Key Science Projects: Planning underway!

CTAO-US Teams Awarded Nearly \$4 Million NSF Grant to Develop Small-Sized Telescope Cameras



CTAO Energy-Flux Sensitivity for 'Alpha' arrays

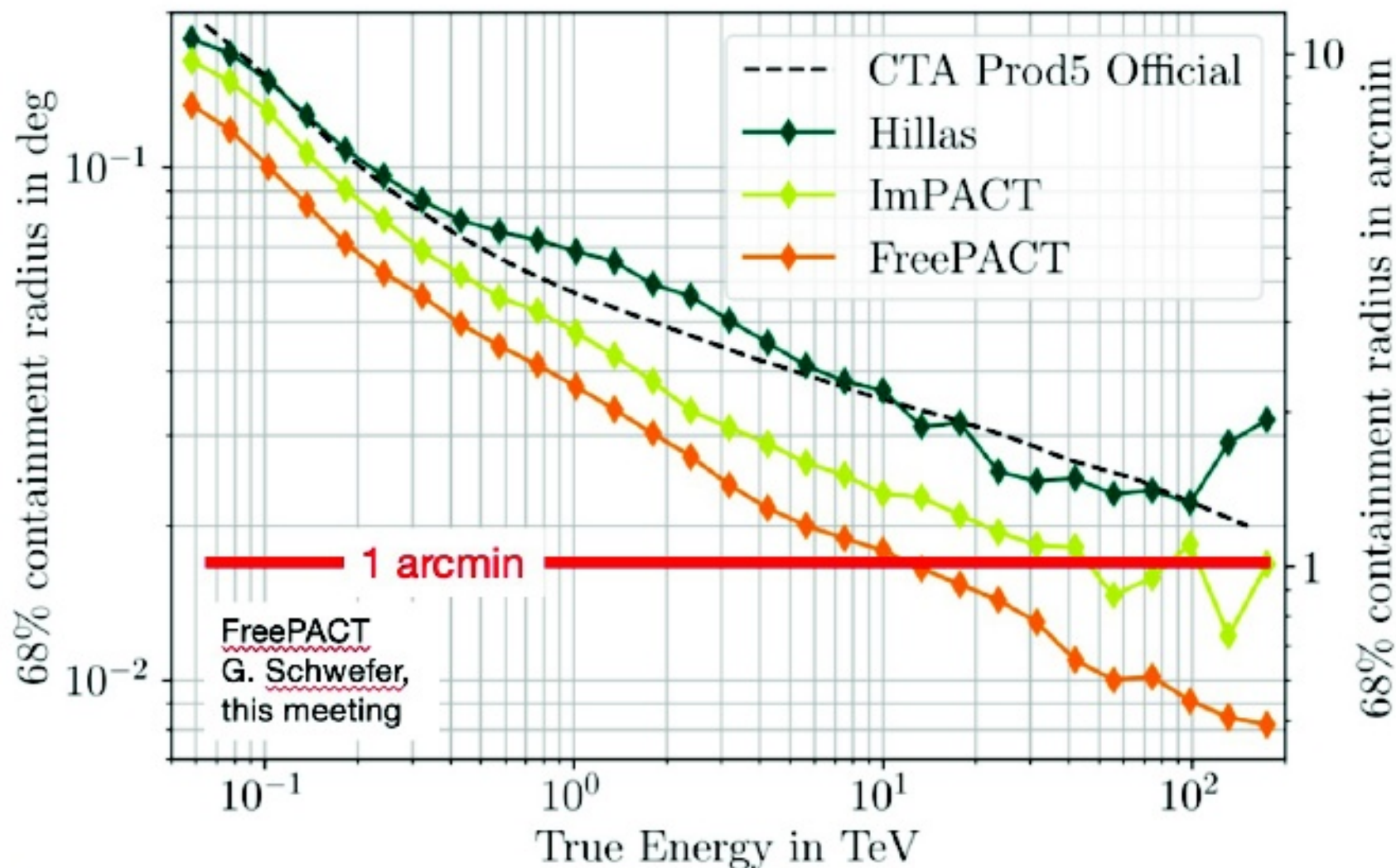


CTAO-South Performance – Improved Angular Resolution

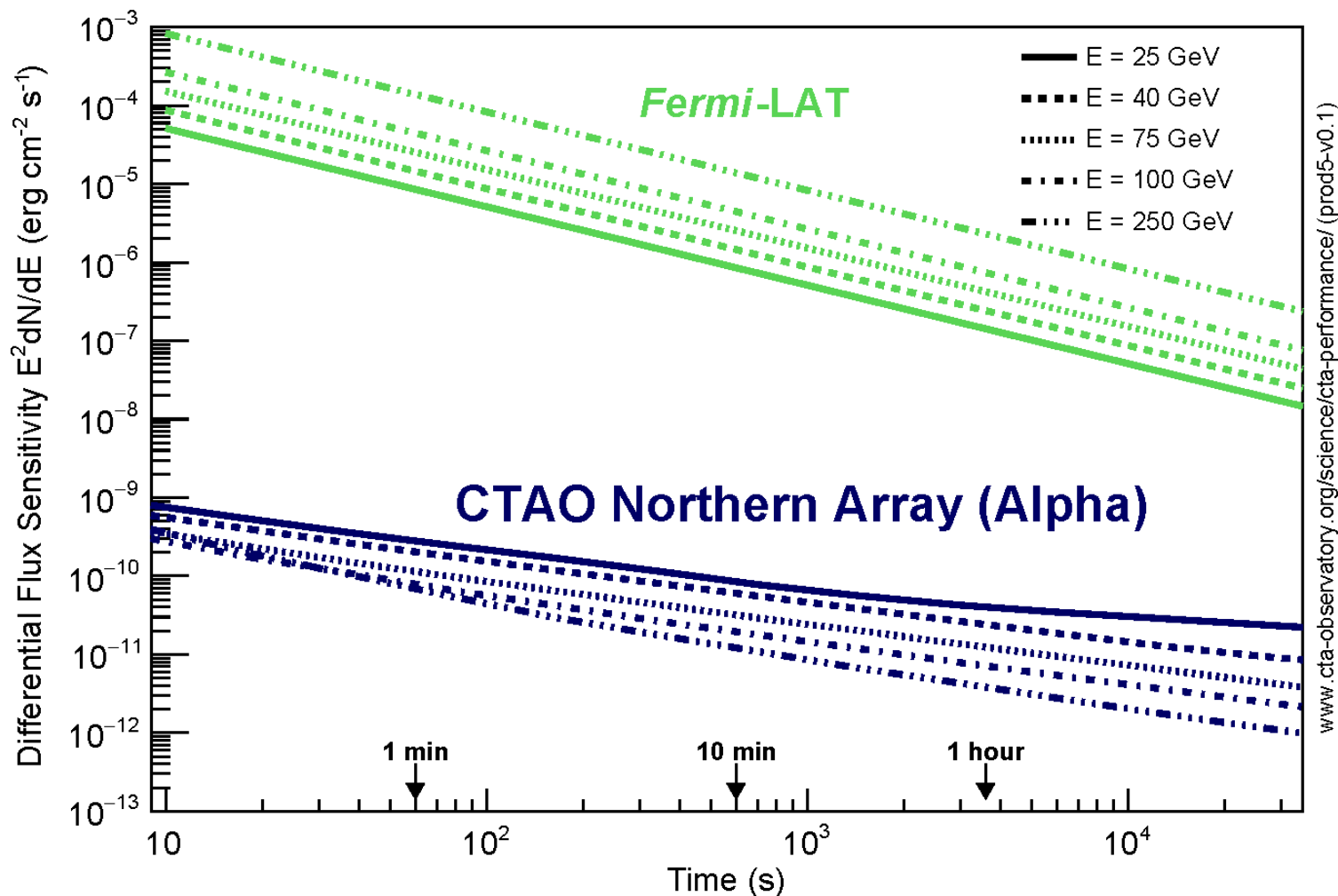
FreePACT (Likelihood free inference for pixel charge distribution)

(Schwefer et al 2024)

Angular Resolution



CTA's Prospects for Transients (CTA 2022)



- GRBs to $z \sim 4$; Light curves @ seconds time resolution
- AGN to $z \sim 2$ to 3 ;
- Kilonovae within reach (e.g. HESS 2020);
- Fermi-LAT GeV flares (e.g. 2FAV): >100 AGN flares/year detectable (Lee et al 2024)

CTAO Time Allocation

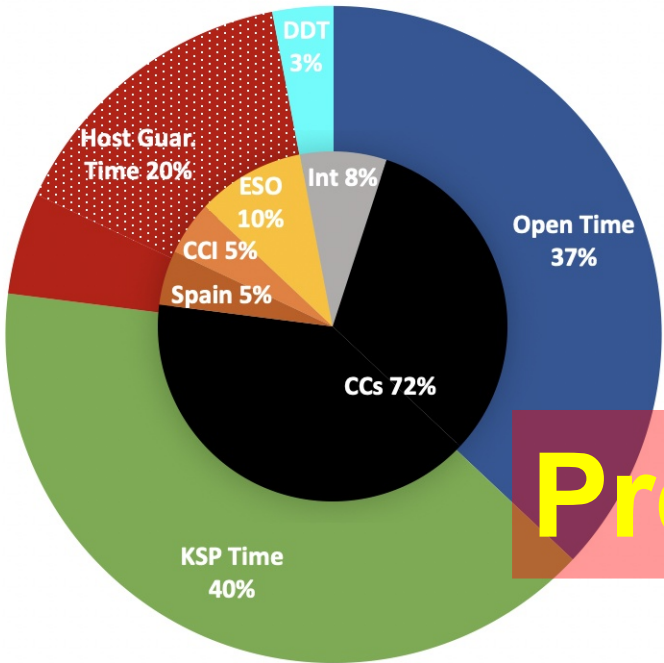
- Contributing Countries (CC) ~70% of time
- Host Time: Chile, Spain, ESO
- DDT Director's Discretionary Time
- International (Int), non-member time (~8%)



Key Science Projects (KSPs) ~40% of time (run by CTAC)
Open Time ~35% of time (proposals from CTAO countries)

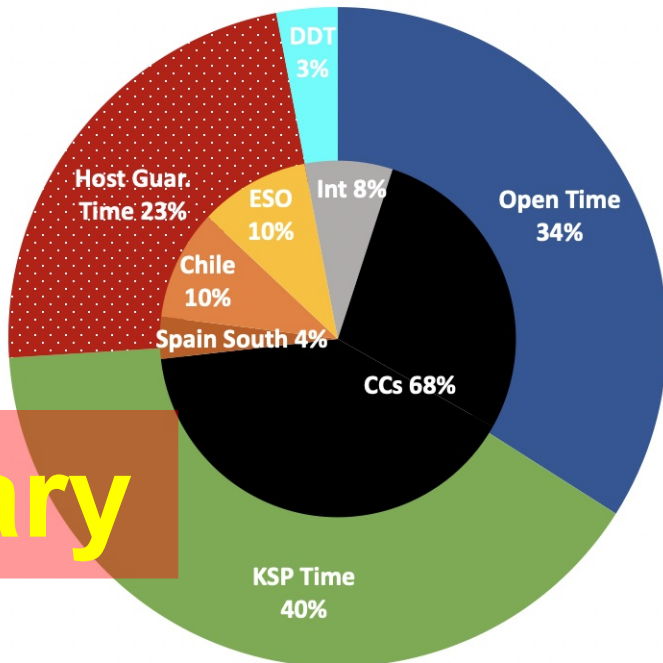
CTAO-North

(integrated over the first 10 OPs of the Operation phase)



CTAO-South

(integrated over the first 10 OPs of the Operation Phase)



Preliminary

Small-Sized Telescopes (SSTs)

Contributing Countries

Italy, Germany, France, UK, Switzerland, Japan, Australia (**), The Netherlands, Brazil

Total ~ 40 MEuro **Australia ~ 2MEuro**

** U-Adelaide, WSU, U-Sydney, ANU, Monash, UNSW, Curtin-U

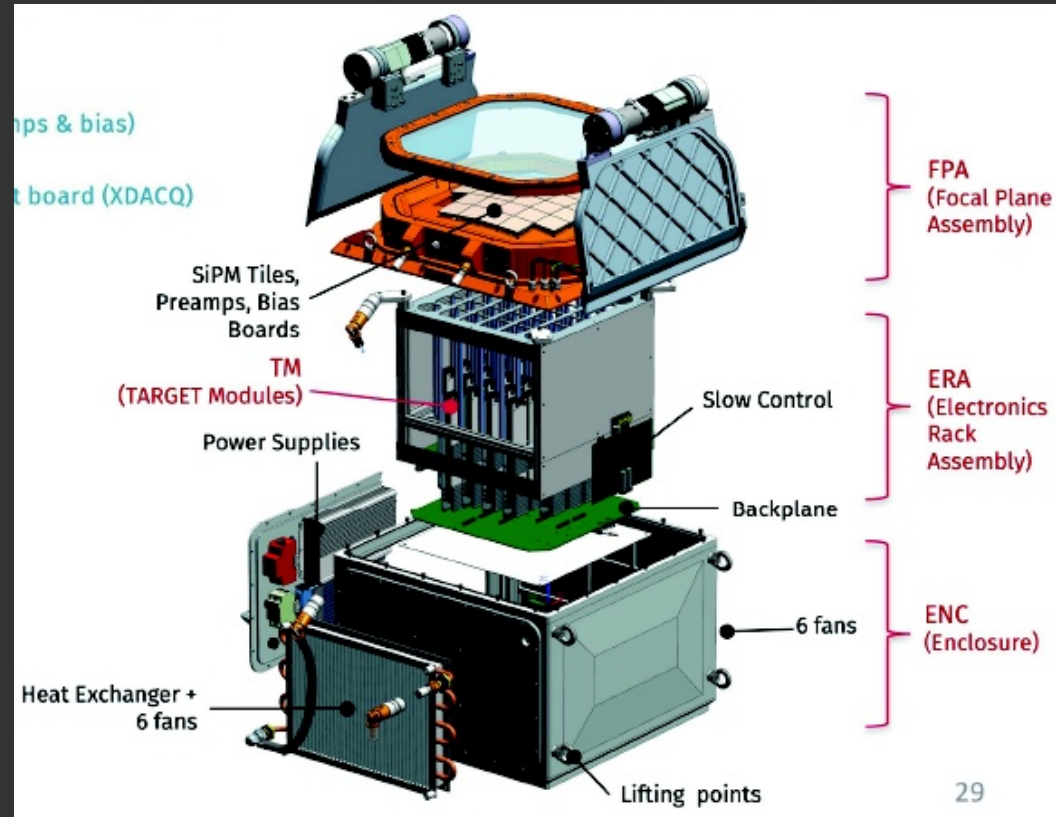


SST-Structures led by INAF Italy

- Dual-mirror Schwarzschild-Couder optic
- 9 degree field of view

SST-Camera led by MPIK Germany

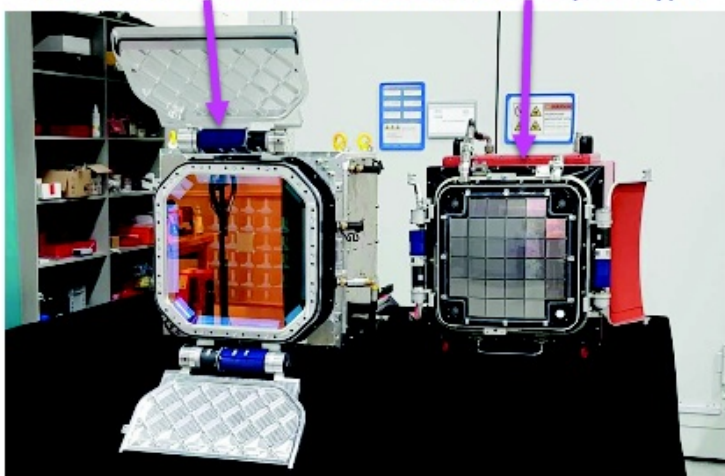
- SiPM array (2048 pixels)
- 1ns waveform sampling



CTAO Small-Sized Telescope Camera (SSTCam)

Camera Design & Development

Mechanical CAM built next to the CHEC-S prototype



Mechanical CAM mounted on ASTRI-1 in Tenerife (November 2023)



Gianpiero Tagliaferri, Richard White

Australia funds SSTCam components:

SiPM detectors (14 cameras); ASIC chips (all); Chillers (all)

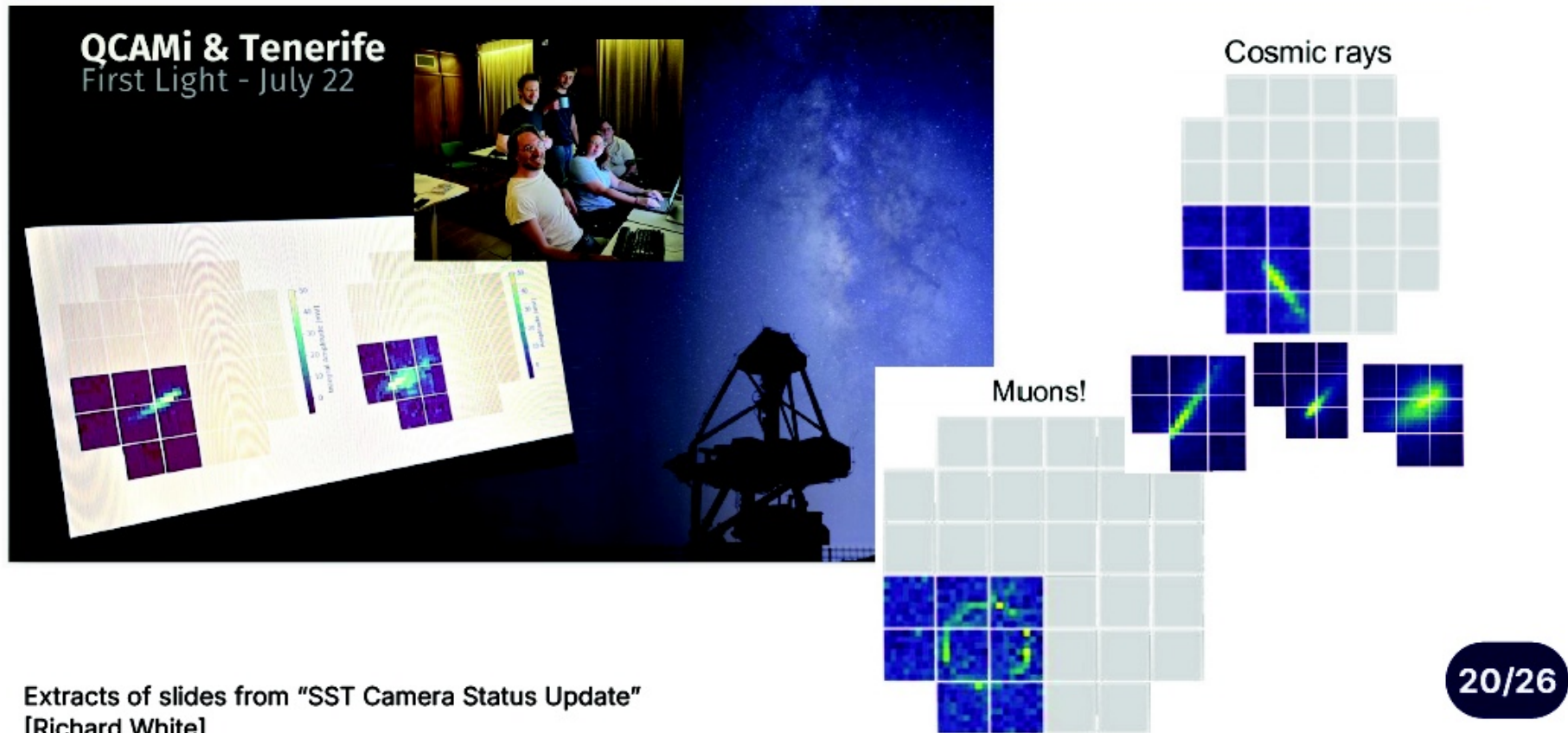
The SSTCAM team tested a quarter-camera in Tenerife



- Called "QCAM-i" (i for initial)
- 512 pixels (2048 in full camera)
- 1 GHz sampling rate
- Silicon Photomultiplier (SiPM) pixels
- Actively cooled with Australian-made chillers from LaserChill™

SSTCAM team with QCAM-i
[Richard White, I think]

QCAM-i was installed on ASTRI-2 in Tenerife for testing



SST Camera Chillers from Australian Industry

Chiller units keep the camera cool and at a stable temperature during operation:
 $\delta T < 0.2 \text{ deg}$

CTAO-Oz responsible for SSTCam chillers: ~ 600kEuro A\$950k (45 units, shipping)
Funding from LIEF #2, #3, #4

Uni. Adelaide: Gavin Rowell, Jose Bellido
Dept. Industry Liaison for ESO/SKA: Anthony Holzwart



Two companies initially chosen and are now working with LaserChill (Vic)

V1 testing at MPIK (2022/23)

- V2 LaserChill unit delivered to MPIK, Germany
- First batch order (V3) for Chile discussions now

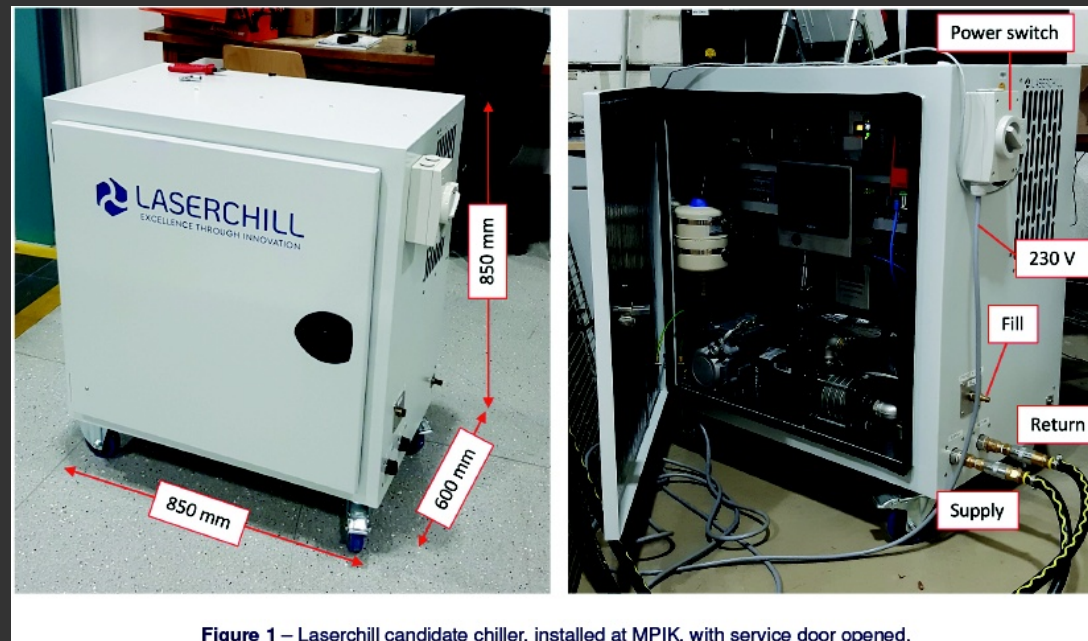
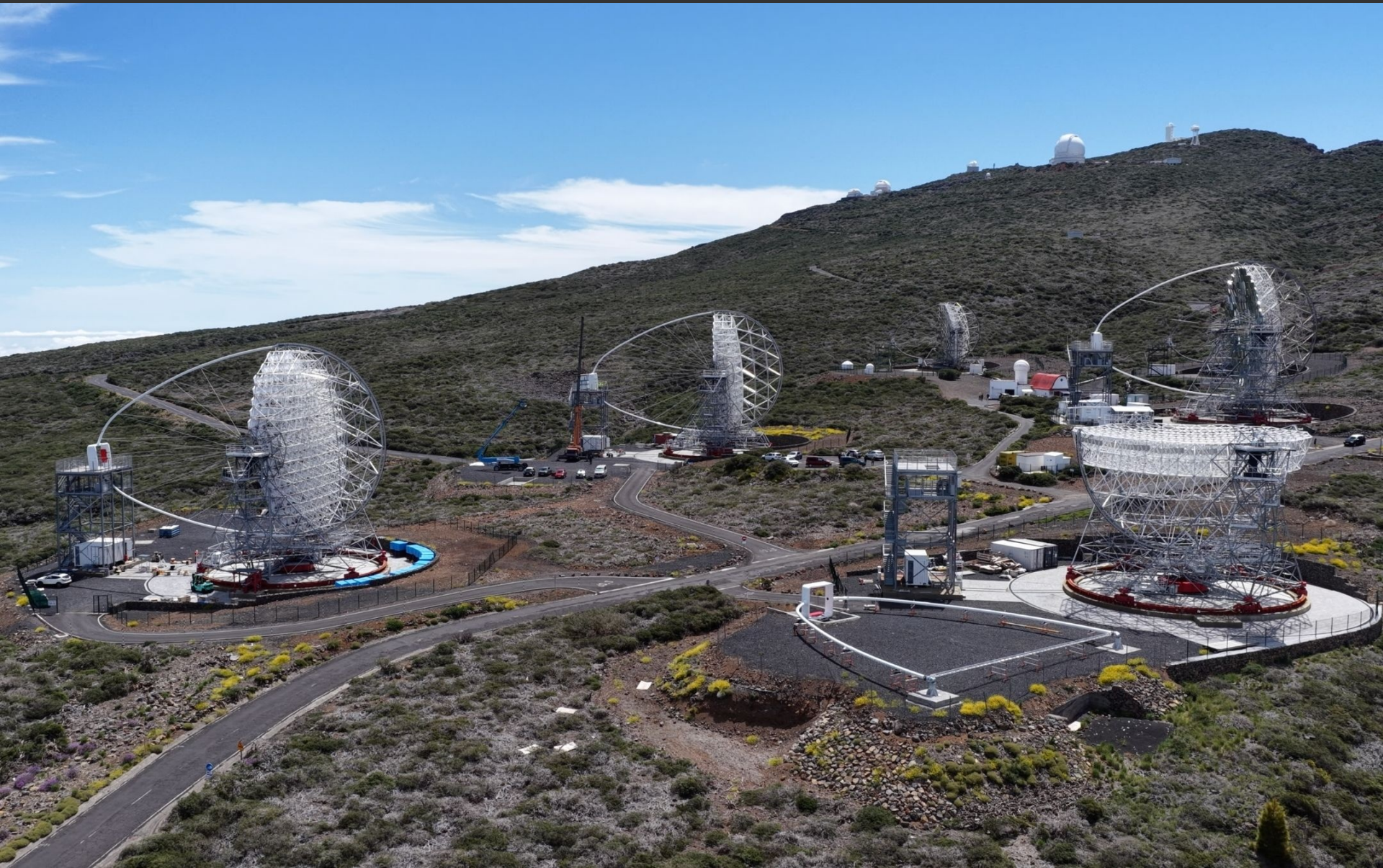


Figure 1 – Laserchill candidate chiller, installed at MPIK, with service door opened.

CTAO-North ~ August 2025

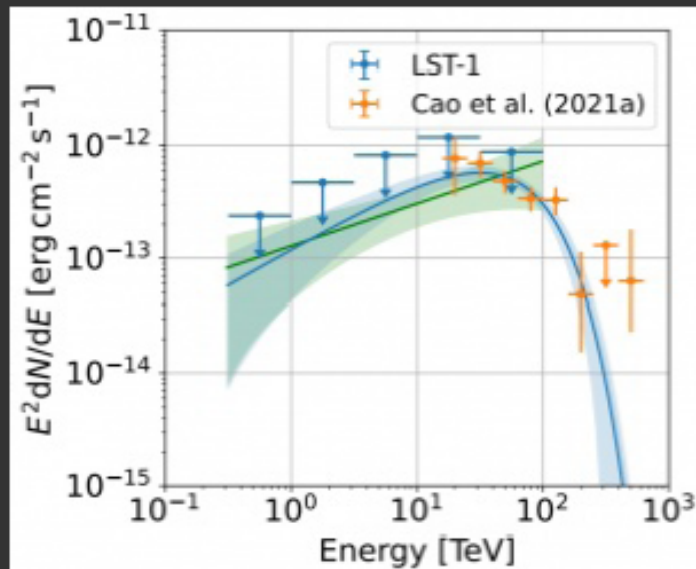


Credit: LST Collaboration



**Multi-
wavelength
study of the
galactic
PeVatron
candidate
LHAASO
J2108+5157**

A&A 2023 in press



**Detection of enhanced very-high-energy gamma-ray
emission from the radio-galaxy NGC1275 with the LST-1**

ATel #15819; *Juan Cortina (CIEMAT) for the CTA LST collaboration*
on 21 Dec 2022; 22:29 UT

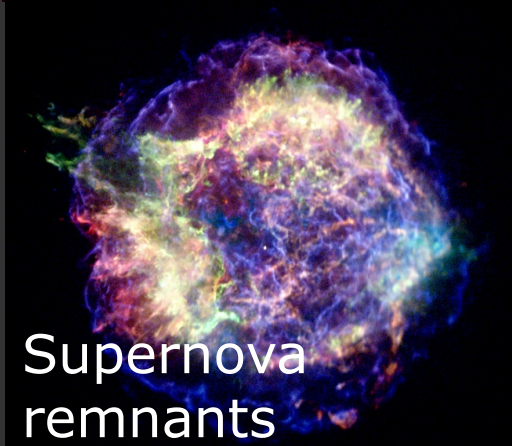
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

**Detection of very-high-energy gamma-ray emission
from BL Lac with the LST-1**

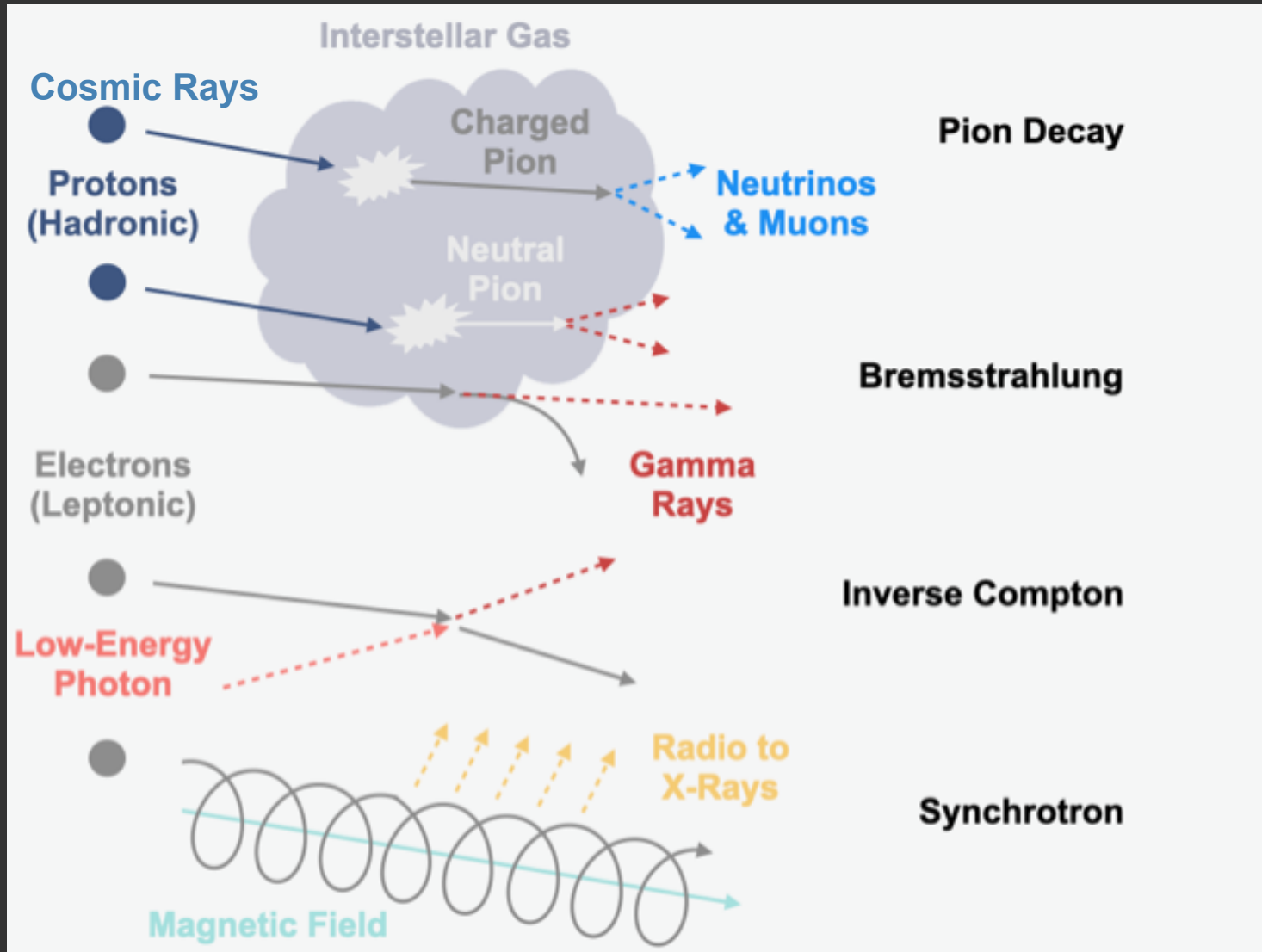
ATel #14783; *Juan Cortina for the CTA LST collaboration*
on 13 Jul 2021; 21:03 UT

Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Extreme particle accelerators in the Universe



Photons from relativistic (GeV to multi-TeV) particles



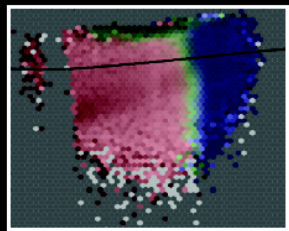
→ Clear synergies across radio, optical, X-ray, gamma-ray and neutrino astronomy (incl. ISM – radio astronomy)

CTAO-C Key Science Projects (KSPs)

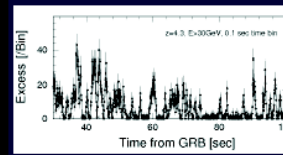
Major legacy science



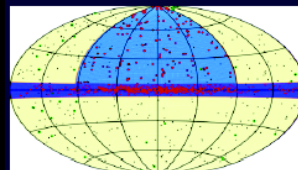
KEY SCIENCE PROJECTS



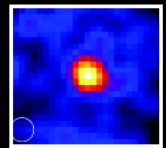
Dark Matter Programme



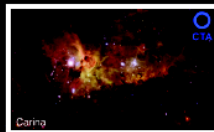
Transients



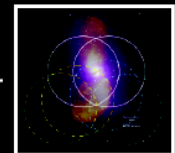
ExGal Survey



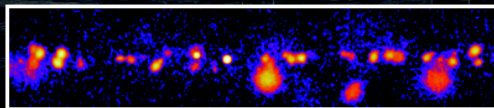
Galaxy Clusters



Star Forming Systems



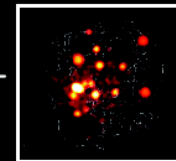
AGN



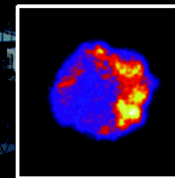
Galactic Plane Survey

Galactic

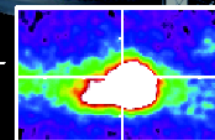
LMC Survey



PeVatrons



Galactic Centre

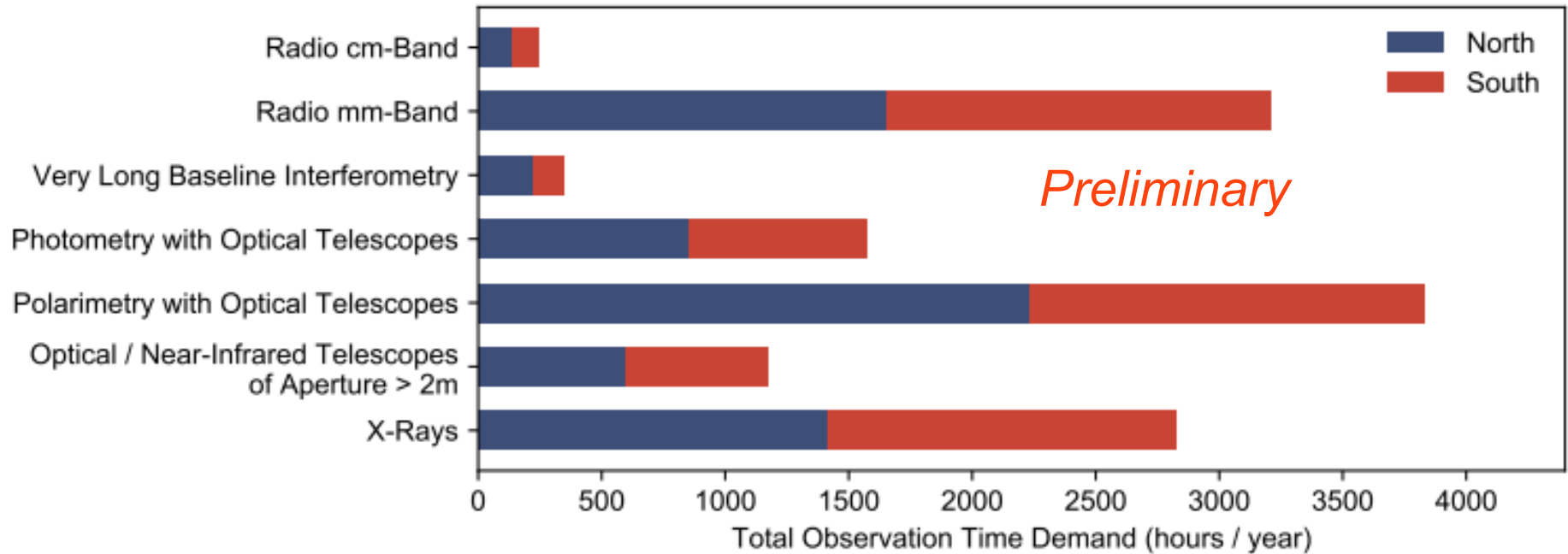


Extragalactic

MWL Needs for Key Science Projects (Transients, Variable)



Up ~1000 hr/yr for radio to-optical coverage
→ **huge potential for Australia**



- Optical polarimetry @ ANU 2.3m telescope, Vera-Rubin, ESO....
- Radio followup and monitoring (ATCA, ASKAP, MWA, SKA...)
 - measure synchrotron component

MWL Synergies – Opportunities for Australian Leadership



CTAO-SKAO MoU (29 January 2020)

<https://www.cta-observatory.org/ctao-signs-cooperation-agreement-with-the-skao/>

The CTAO Signs Cooperation Agreement with the Square Kilometre Array Organisation - Cherenkov Telescope Array

29 January 2020 – The Cherenkov Telescope Array Observatory (CTAO) and the [Square Kilometre Array Organisation](#) (SKAO) will engage in closer collaboration under a new agreement signed by the two research infrastructures. The Memorandum of Understanding (MOU) will facilitate greater sharing of knowledge and expertise in areas including engineering, science, technology and administration.

The CTAO and SKAO are both large international collaborations and have several member countries in common, including many European countries but also astronomy organisations in Australia and South Africa. Like CTA, which will have two arrays of telescopes on different continents observing gamma rays, one in Chile and one on La Palma in the Canary Islands (Spain), the SKA will also have radio telescopes in Australia and South Africa. The two observatories are due to begin delivering science within just a few years of each other.

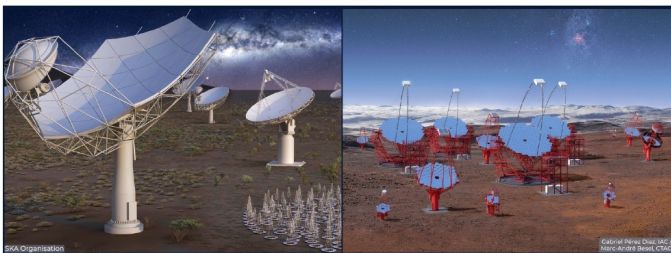
Both have also begun transitions on the governance front: the CTAO is becoming a European Research Infrastructure Consortium (ERIC), while the SKA is becoming an intergovernmental organisation or IGO.

“In this age of multi-messenger astronomy, building alliances with observatories across the spectrum is critical to achieving our common missions to expand our view and understanding of the Universe,” says Federico Ferrini, CTAO Managing Director. “The CTAO-SKAO partnership was an obvious fit due to our vast similarities, and we are looking forward to the collaboration.”

“Both the SKA and CTA are pushing the boundaries of what’s possible technically, scientifically and logistically, and some of the challenges that brings are common to both projects,” says Simon Berry, Director of Strategy for the SKA. “This MOU formalises our relationship, so we can keep learning from each other’s experiences and share expertise for the benefit of both observatories.”

While the respective telescopes will observe opposite ends of the electromagnetic spectrum, there are exciting areas of scientific synergy between them. Both radio and gamma rays are a probe of the violent and variable Universe, including the study of active galactic nuclei, transient events such as gamma-ray bursts and fast radio bursts, accretion into compact objects and gravitational wave counterparts.

As the world’s largest radio telescope, SKA is one of several next-generation facilities targeting cosmic sources by detecting other wavelengths or messengers (such as neutrinos or gravitational waves) that will be complementary to CTA. Coordinated observations between such facilities can give a more complete picture of astronomical sources and phenomena, resulting in greatly enhanced scientific discoveries.



CTAO+SKAO synergies White Paper - TBC

SKAO+gamma synergies chapter in SKAO science book – joint with INAF CTA+ group

Chapter in Advancing Astrophysics with the SKA – II



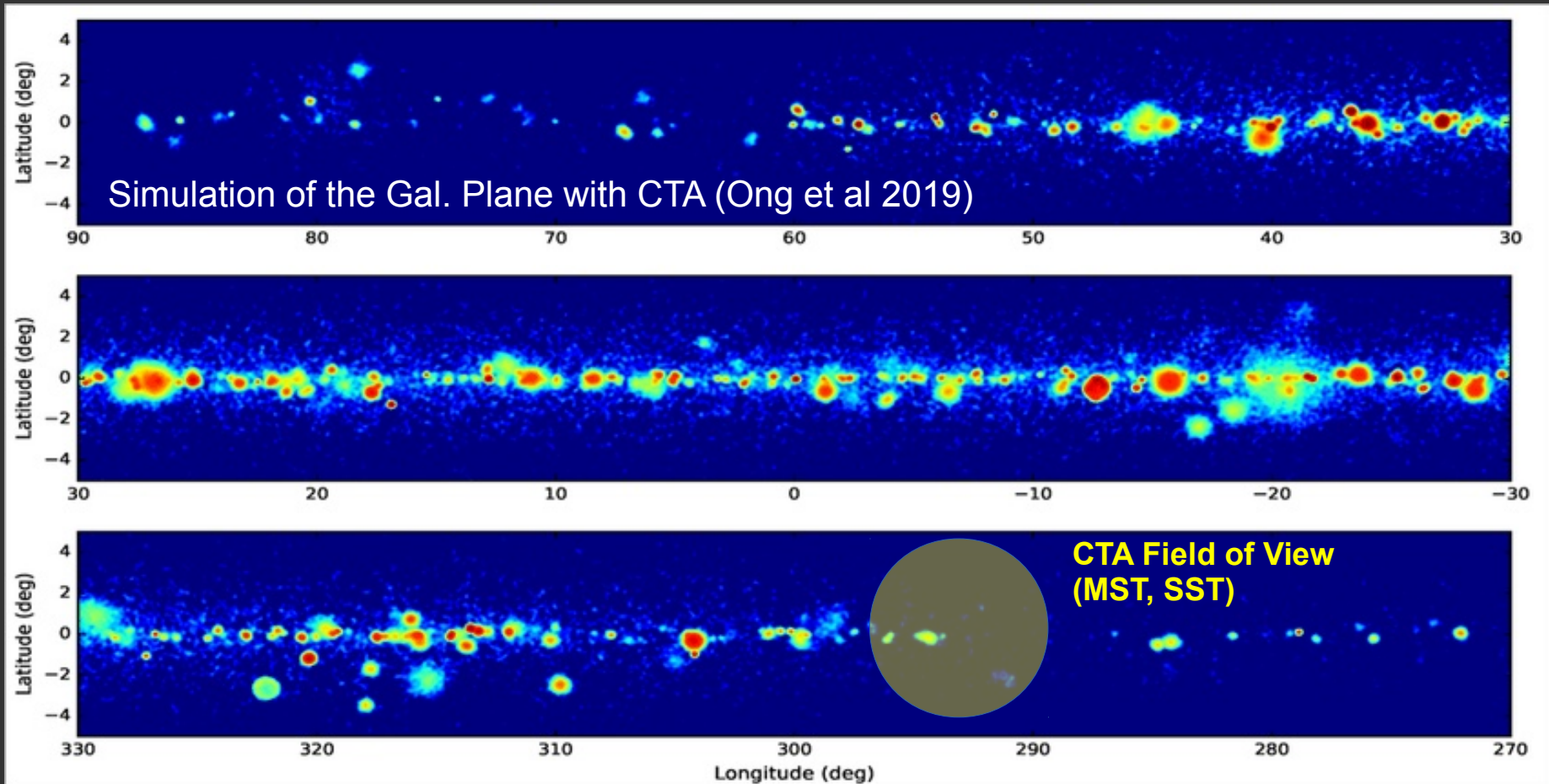
SKAO and Gamma-Ray Synergies

Gianluca Castignani^{†, 1} Gavin Rowell^{†, 2} Arnau Aguilera-Cabot,³ Gemma E. Anderson,^{4, 5} Csaba Balazs,⁶ Pol Bordes,³ Andrea Botteon,⁷ Gianfranco Brunetti,⁷ Jess W. Broderick,⁸ Ettore Carretti,⁷ Roland M. Crocker,⁹ Shi Dai,⁴ Filippo D’Ammando,⁷ Philip G. Edwards,⁴ Sabrina Einecke,² Miroslav D. Filipović,¹⁰ Marcello Giroletti,⁷ Adelle J. Goodwin,¹¹ Jimi Green,⁸ Giulia Migliori,⁷ Monica Orienti,⁷ Josep M. Paredes,³ Elena Pian,¹ Lauren Rhodes,^{12, 13} Zachary J. Smeaton,¹⁰ Nick Tothill¹⁰ and Martin White¹⁴

CTAO+ESO synergies White Paper - TBC

Galactic Plane: Excitement & Challenges!

CTA will see a confusing mix of local and large-scale diffuse emission



Local: Particles escaping from local sources (Einecke et al 2023, Mitchell et al 2021)

Large-scale diffuse: Diffuse cosmic rays permeating the MW (e.g. Marinos et al 2022)

CTA Field of View 8 deg Diameter: → Commensal science with **many** surveys

Synergies with Radio Surveys

- Radio synchrotron & TeV gamma-rays are often 'relics' of earlier particle acceleration.

- Old SNRs & PWNe
 - AGN jets
 - ORCs
 - Gal. Clusters
 - Diffuse Emission
 - ISM Surveys (Mopra)
- e.g. Braiding etal 2018, Cubuk etal 2023

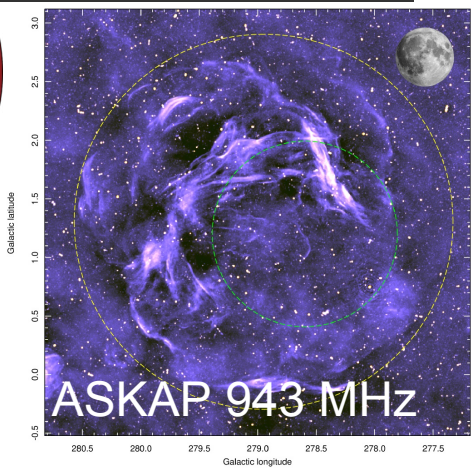


Mopra (ISM)

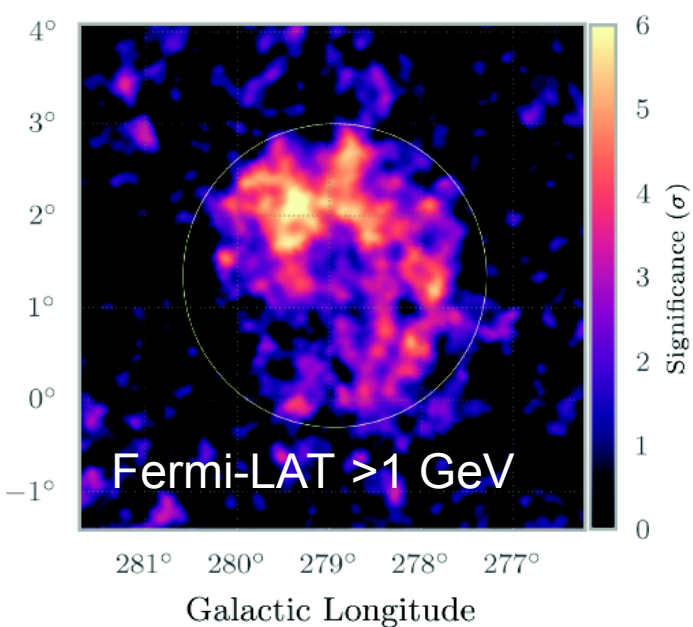
MWA: GLEAM + GLEAM-X



ASKAP: EMU, POSSUM, SCORPIO, RACS, GASKAP



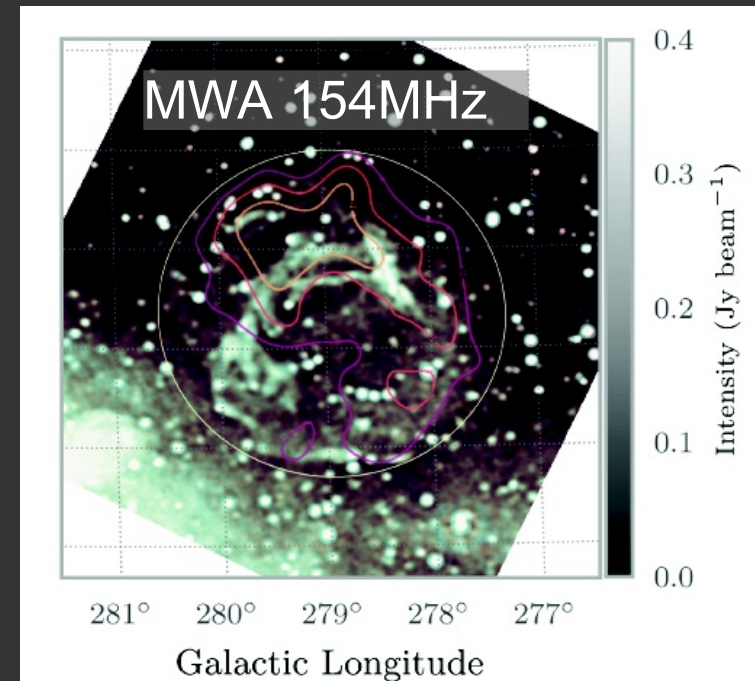
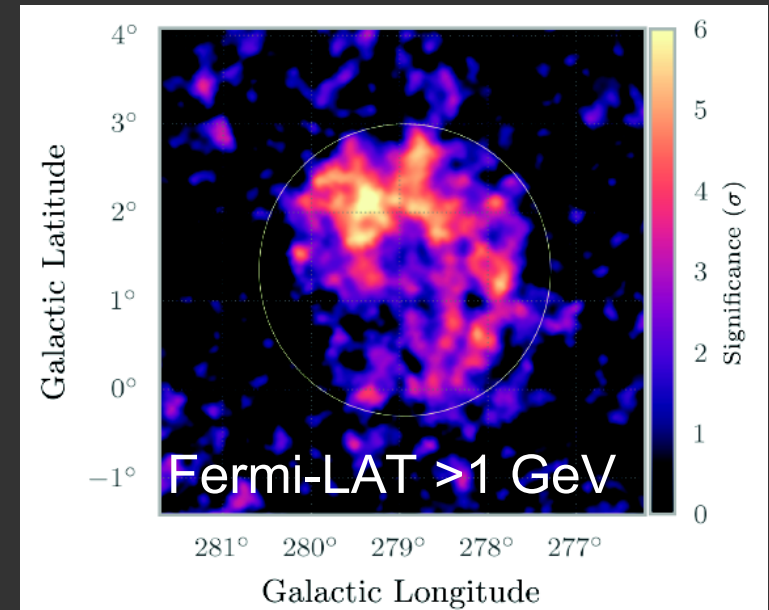
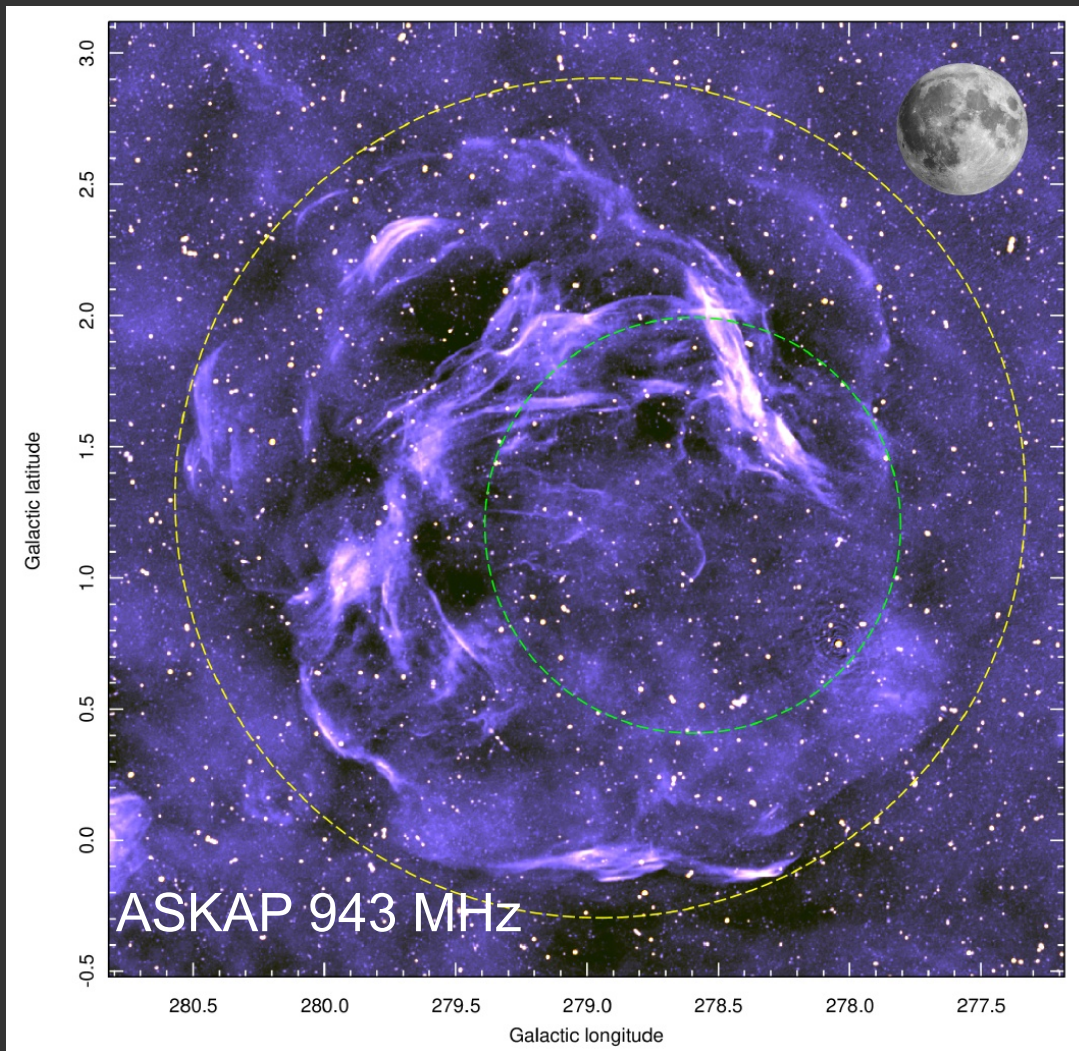
Filipovic et al. 2024



McConnell et al. 2020, Hale etal. 2021, Duchesne etal 2023, Thomson etal. 2023, Dickey etal 2013, 2022, McClure-Griffiths 2018....

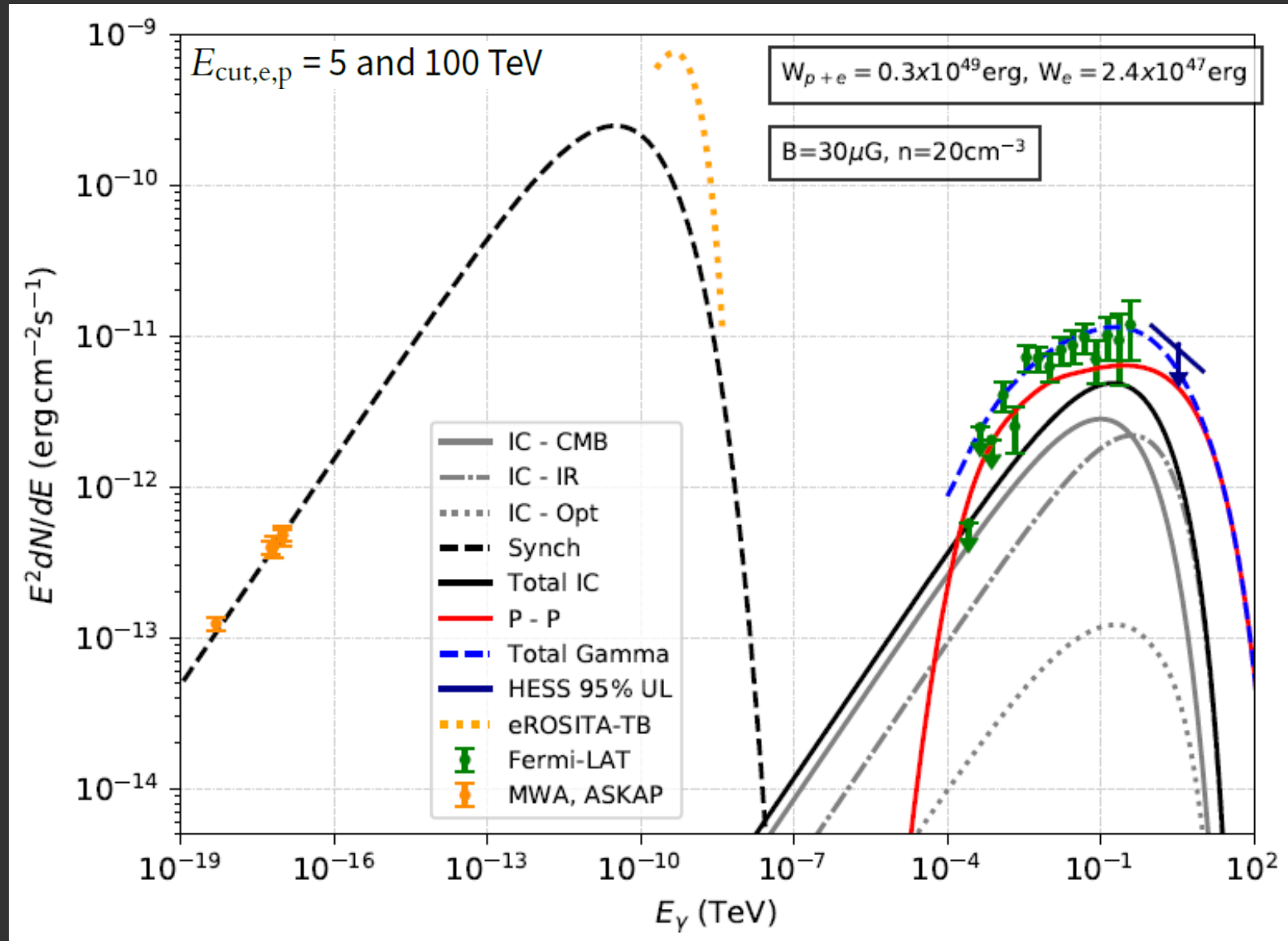
Old Supernova Remnants - G278.94+1.35 “Diprotodon”

- Radio synchrotron & GeV gamma-rays

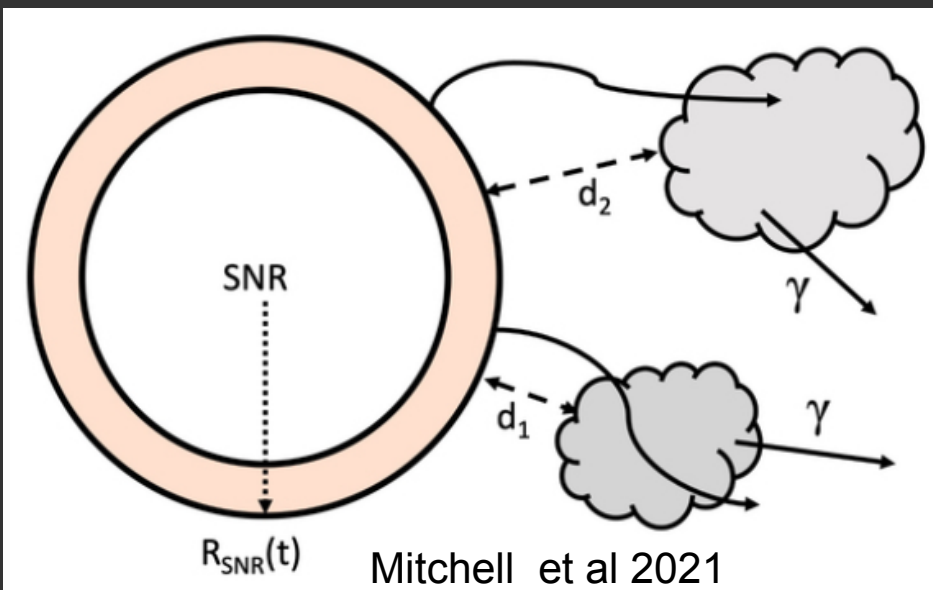


Old Supernova Remnants - G278.94+1.35 “Diprotodon”

- Radio synchrotron + Gamma Rays from electrons **and/or** protons



Local accelerators (e.g. SNRs) and their “escaping” CRs



- Cosmic rays escape expanding SNR with radius $R_{\text{SNR}}(t)$ (Truelove & McKee 1999)
- Assume SNR in Sedov phase; age $\sim 10^2$ to 10^5 yr (e.g. Reynolds 2008)

(see Aharonian & Atoyan 1996, Casanova et al 2010, Gabici & Aharonian 2007, Mitchell et al 2021)

$$\frac{\partial n}{\partial t} = -\nabla \cdot (D(\mathbf{r}, \gamma) \cdot \nabla n) + \frac{\partial}{\partial \gamma} (\dot{\gamma} n) + S(\gamma, \mathbf{r}, t)$$

Physics needed:

- Particle ‘escape’ into ISM vs. time
 - 3D gas maps down to ~ 30 arc-sec scales
 - Particle diffusion, advection, and radiative losses
 - B field strength and direction down to 30 arc-sec
- e.g. ASKAP POSSUM



→ Perfect way to search for cosmic-ray accelerators in the Milky Way!

→ e.g. “PeVatrons” > 1 PeV cosmic-rays

$$f(E, R', t') \approx \frac{f_0}{\pi^{3/2} R_d^3} \exp \left[-\frac{(\alpha - 1)t'}{\tau_{pp}} - \frac{R'^2}{R_d^2} \right] \quad (t > t_{\text{esc}}(E))$$

$$f_0 = \frac{\sqrt{\pi} R_d^3}{\left(\sqrt{\pi} R_d^2 + 2\sqrt{\pi} R_{\text{SNR}}^2 \right) R_d + 4 R_{\text{SNR}} R_d^2}$$

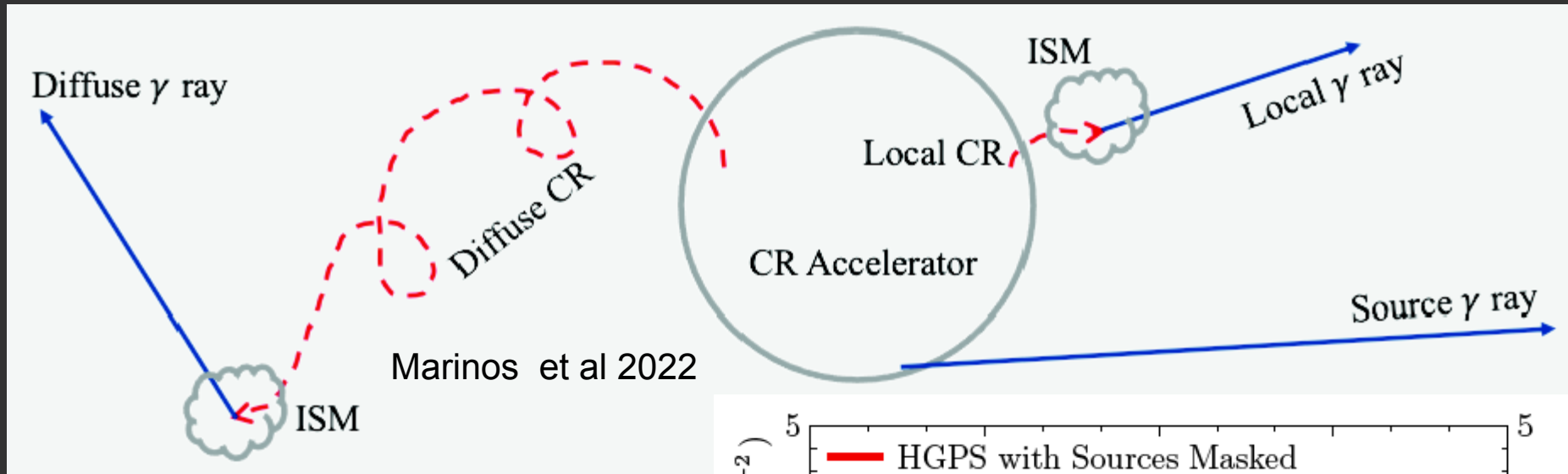
$$R_d(E, t') = 2 \sqrt{D(E) t' \frac{\exp(t' \delta / \tau_{pp}) - 1}{t' \delta / \tau_{pp}}}$$

$$t_{\text{esc}}(p) = t_{\text{sed}} \left(\frac{p}{p_M} \right)^{-1/\beta}$$

$$D(E) = \chi D_0 \left(\frac{E/\text{GeV}}{B(n)/3\mu\text{G}} \right)^\delta$$

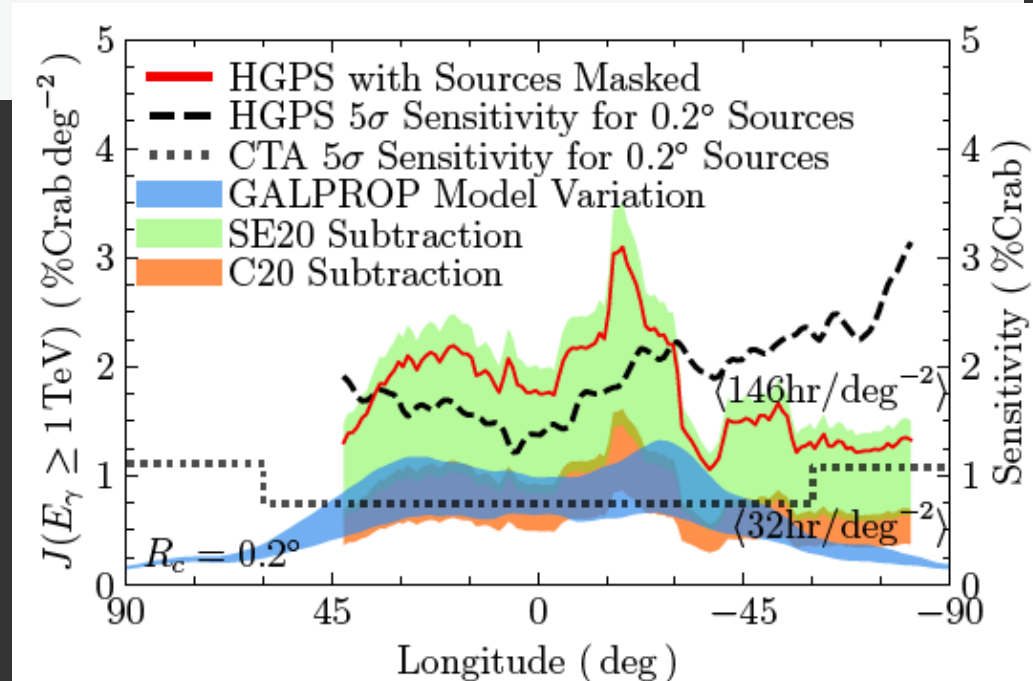
Galactic Plane: A major astrophysical challenge for CTA

The 'large-scale diffuse' component: Cosmic rays permeating the Milky Way after travelling >100 s pc from their accelerators $\rightarrow$ interacting with ISM $\rightarrow$ gamma rays



GALPROP predictions >1 TeV

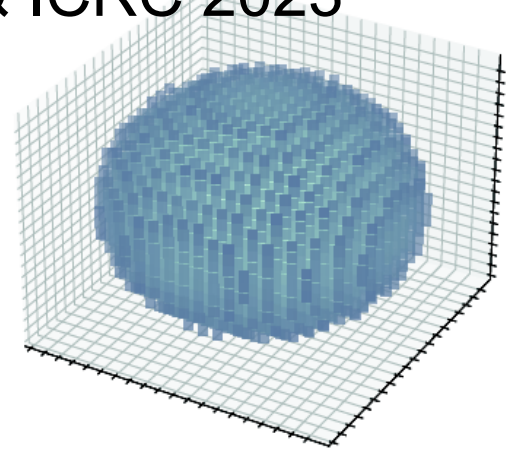
- Subtract discrete sources from HESS Gal. Plane Survey & estimates of unresolved sources.
 - $\rightarrow$ estimate of TeV diffuse emission
- Compare to GALPROP under variety of inputs (blue region)
 - $\rightarrow$ **CTA will detect this emission**



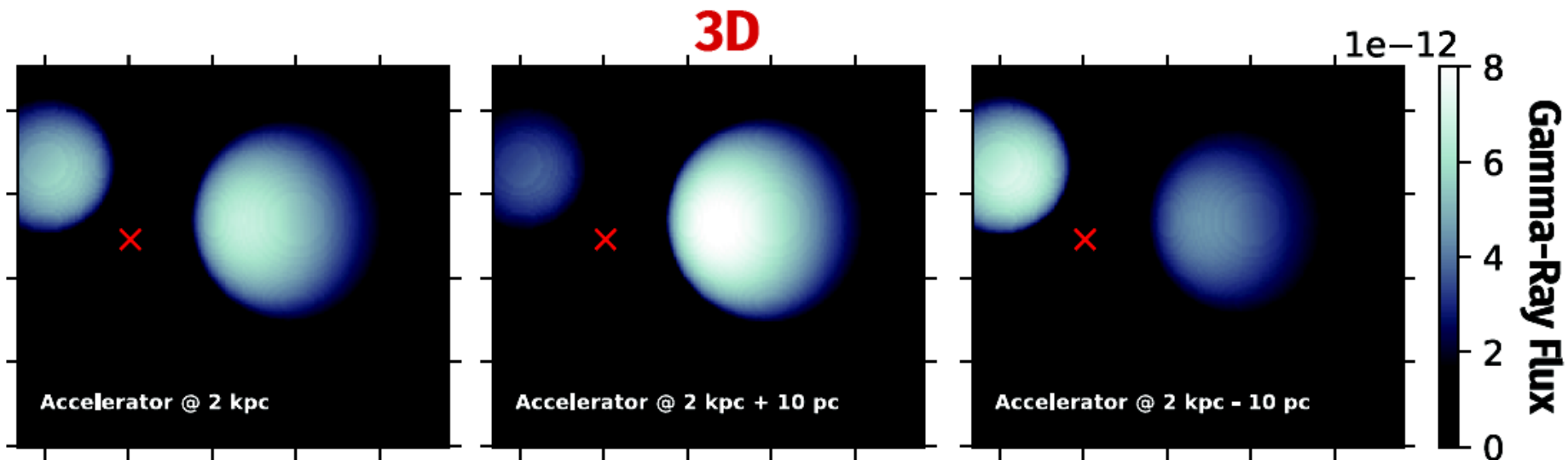
MODELLING IN 3D Einecke et al 2023 in prep & ICRC 2023

*3D ISM gas + 3D CRs = 3D gamma rays / neutrinos
(2D: integrated over z axis)*

- 3D grid for example based on resolution of ISM gas (arcminute scale $\approx$ parsec scale)
- CR distribution calculated for specified grid (considering fields, such as magnetic field, of the same grid)



IMPORTANCE OF MODELLING IN 3D



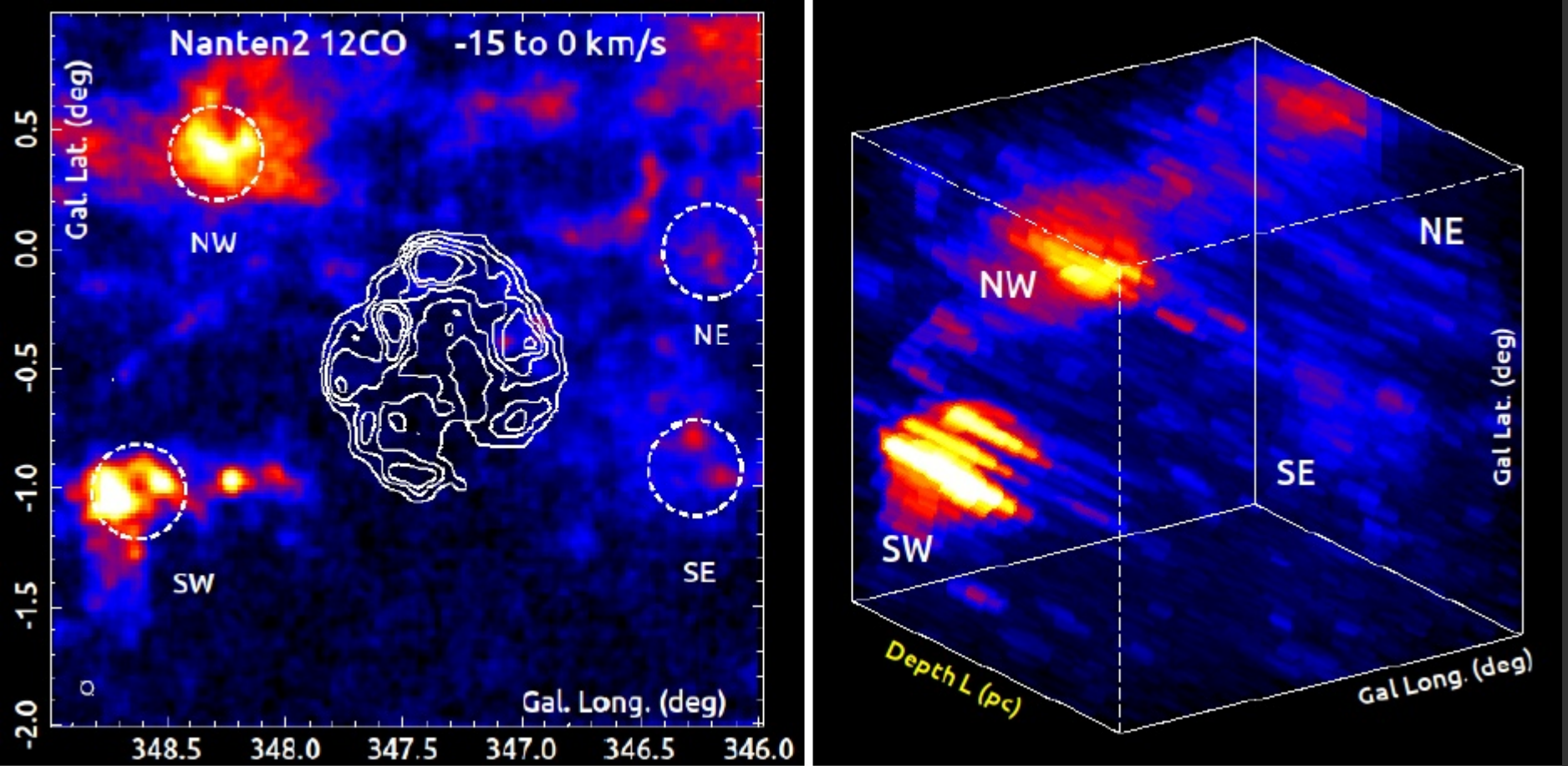
→ Application to W28 (mature SNR) + adjacent ISM

RXJ1713.7-3946: Young SNR (1600yr)

Rowell et al 2023 in ICRC

Model gamma-ray spectra from escaping CRs in 3D

Assume acceleration up to 1 PeV, $t_{\text{Sedov}} \sim 650$ yr, $R_{\text{SNR}} = 8.6$ pc, $E_{\text{CR}} = 1.5 \times 10^{50}$ erg



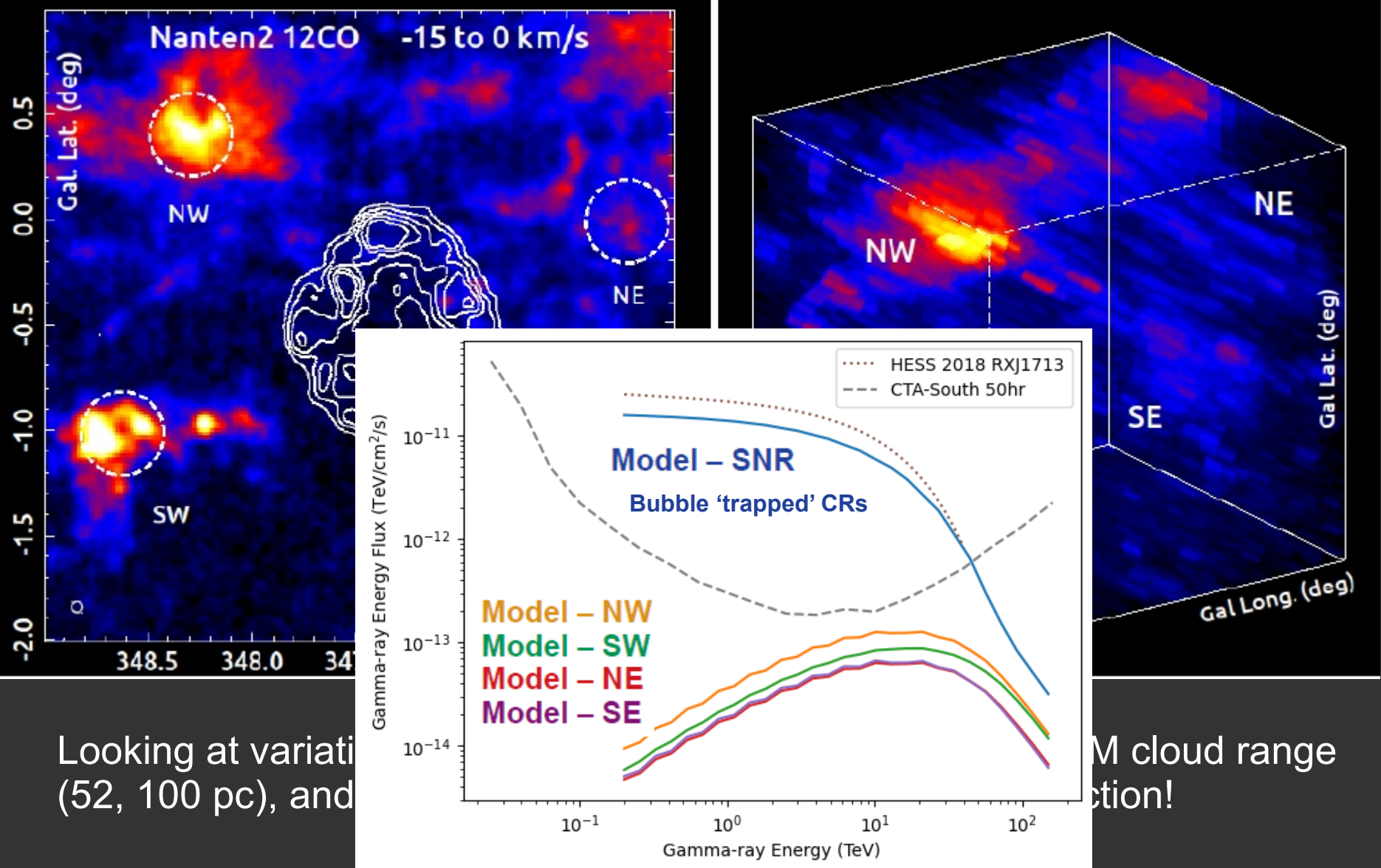
Looking at variations in diffusion suppression χ , depth of ISM cloud range (52, 100 pc), and $t_{\text{Sedov}} > 1000$ yr $\rightarrow$ potential for CTA detection!

RXJ1713.7-3946: Young SNR (1600yr)

Rowell et al 2023 in ICRC

Model gamma-ray spectra from escaping CRs in 3D

Assume acceleration up to 1 PeV, $t_{\text{sedov}} \sim 650$ yr, $R_{\text{SNR}} = 8.6$ pc,



Looking at variation
(52, 100 pc), and

M cloud range
function!

Novae are now also TeV sources!

[[Previous](#) | [Next](#) | [ADS](#)]

Detection of VHE gamma-ray emission from the recurrent nova RS Ophiuchi with H.E.S.S.

ATel #14844; *Stefan J. Wagner, for the H. E. S. S. collaboration*
on 10 Aug 2021; 18:34 UT

Credential Certification: *Stefan J. Wagner (swagner@lsw.uni-heidelberg.de)*

Subjects: Gamma Ray, >GeV, TeV, VHE, Binary, Nova

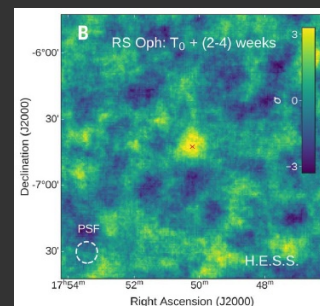
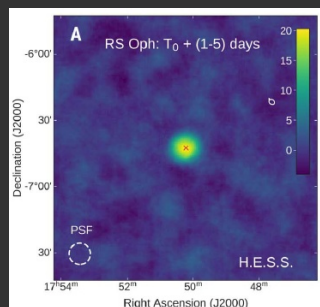
Referred to by ATel #: 14845, 14846, 14848, 14849, 14851, 14855, 14857, 14858, 14860, 14882, 14885, 14886, 14894, 15169



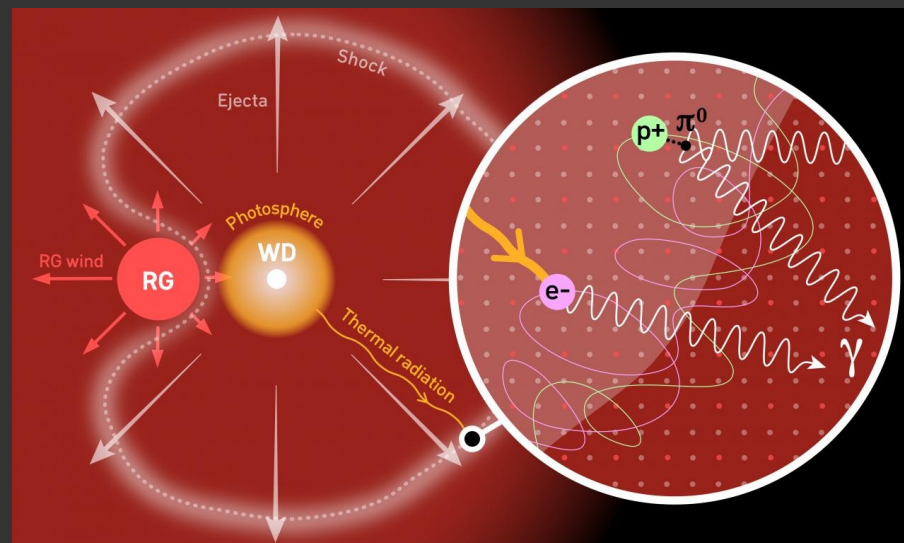
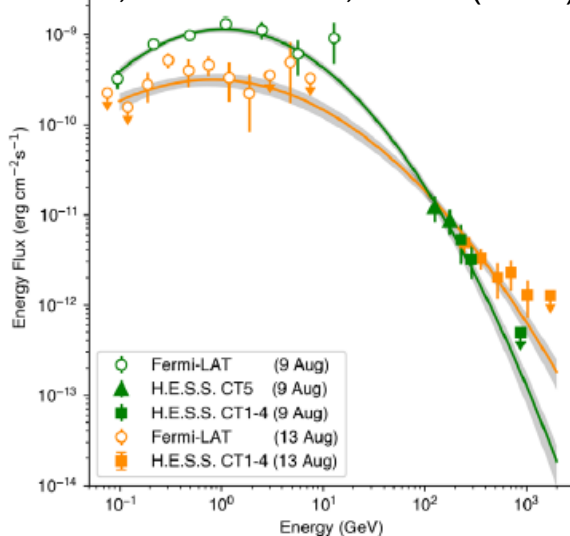
Tweet

The H.E.S.S. array of imaging atmospheric Cherenkov telescopes was used to carry out observations of the recurrent nova RS Ophiuchi currently in outburst and detected with Fermi/LAT (Cheung et al, ATel #14834). RS Ophiuchi is a high-mass WD/red giant binary with an orbital period of 455d that undergoes an outburst approximately every 15-20 years, with the previous one occurring in February 2006. The current outburst is associated with a high-velocity outflow (Taguchi et al., ATel #14838, Munari et al., ATel #14840)// H.E.S.S. Observations started on August 9 at 18:17 UTC, lasted until 22:41 UTC and were taken under good conditions. A preliminary onsite analysis of the obtained data shows a >6 sigma very-high-energy gamma-ray excess compatible with the direction of RS Ophiuchi.

RS-Oph recurrent nova



HESS, Science 376, 6588 (2022)



MAGIC Collab. (Science 2022)

Active Galaxy Nuclei (AGN) “Blazars” : Radio to Gamma

Inner Structure of an Active Galaxy

0.1 lightyears

Relativistic Jet

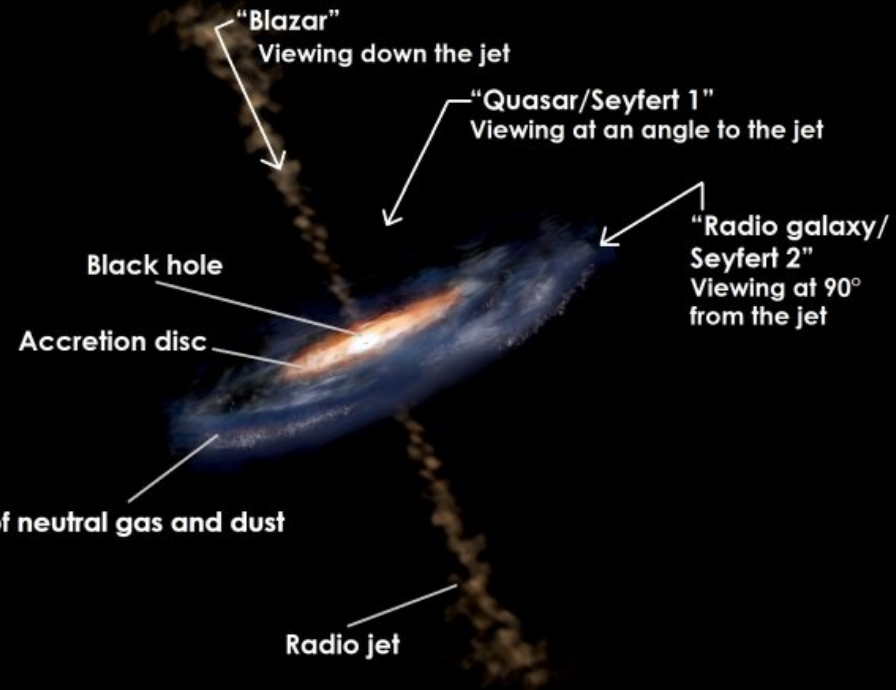
Shock

Supermassive
Black Hole

Accretion Disk

Opaque Torus
(Inner Regions)

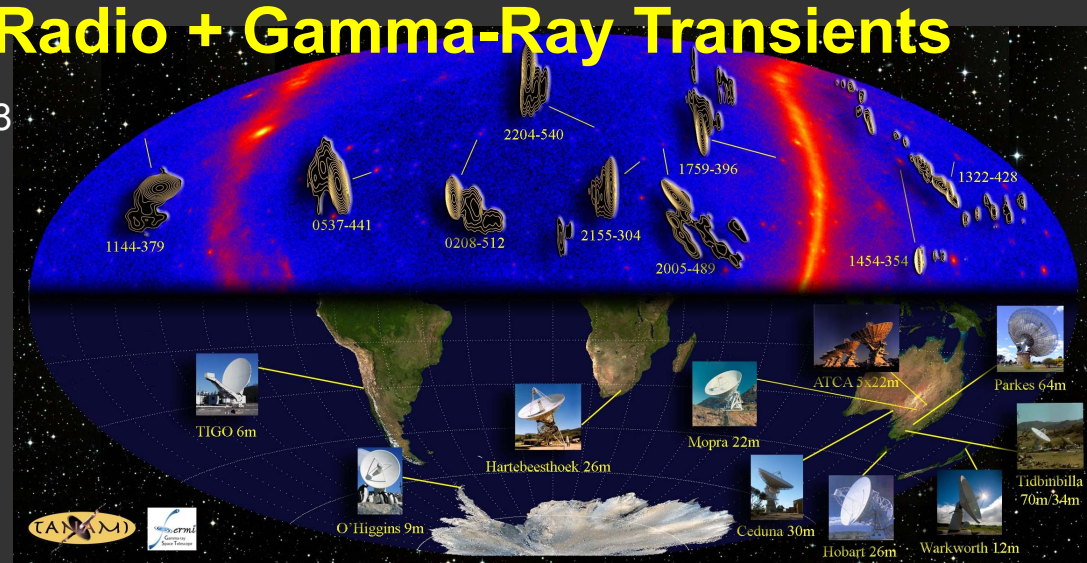
wiki





Ojha et al 2010,
Mueller et al 2018

Radio + Gamma-Ray Transients



Radio monitoring of >100 AGN
(southern) + some gamma-ray binaries

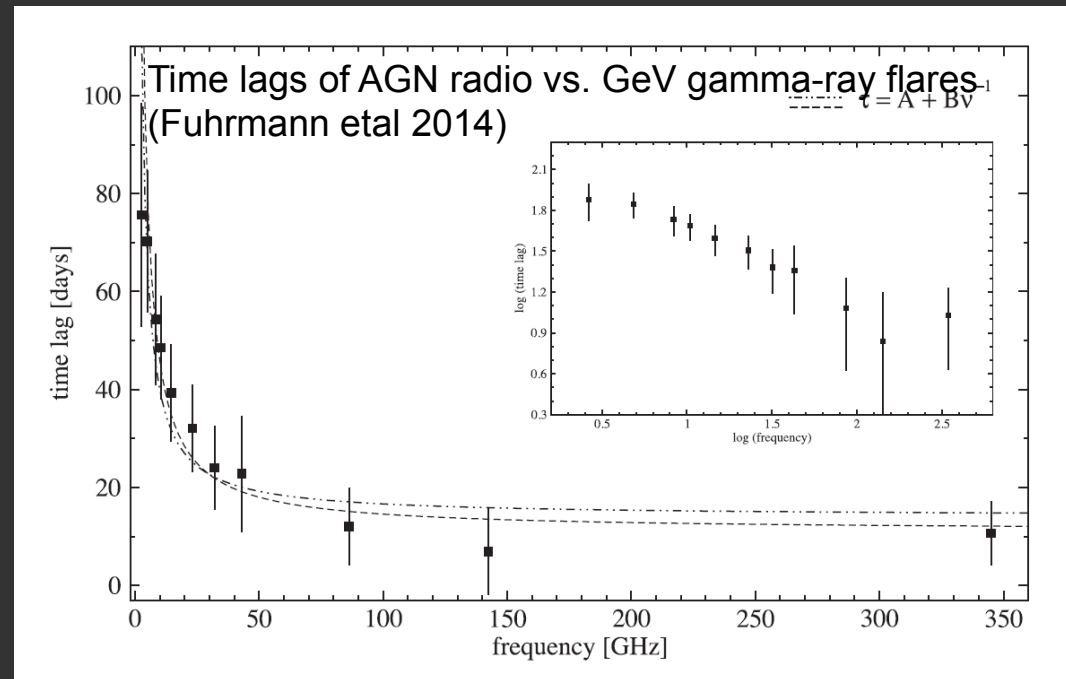
[northern - MOJAVE Lister et al 2018]

- Radio monitoring + VLBI >1 GHz
- X-ray to gamma-rays

Triggered by activity in radio, X-ray
and GeV gamma-rays (Fermi-LAT)

New triggers:

- AGN overlapping IceCube
neutrino events
- TeV-active AGN with HESS,
and eventually, CTA.
- High-freq radio v. important

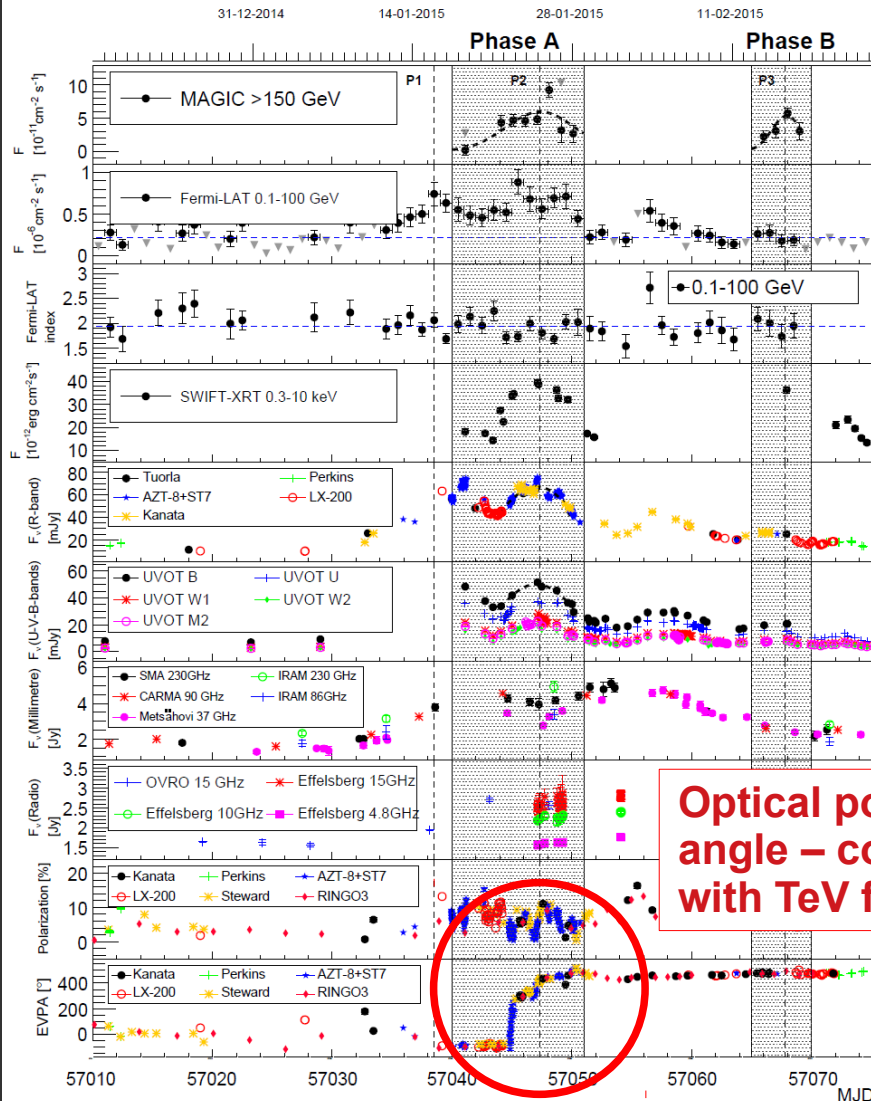


High freq favoured for radio-gamma correlation
(although there are exceptions!).

AGN Blazar Flares: MWL Synergies

MWL light-curve (MAGIC 2018)

BL-Lac S5 0716+714



Enhanced HE and VHE gamma-ray activity from the FSRQ PKS 0346-27

ATel #15020; *S. Wagner (U. Heidelberg, Germany), for the H. E. S. S. collaboration and B. Rani (KASI, S. Korea), on behalf of the Fermi Large Area Telescope Collaboration on 6 Nov 2021; 18:38 UT*

Credential Certification: *Stefan J. Wagner (swagner@lsw.uni-heidelberg.de)*

Subjects: Gamma Ray, >GeV, VHE, AGN, Blazar, Quasar

Referred to by ATel #: 15092



The Large Area Telescope (LAT), one of the two Instruments on the Fermi Gamma-ray Space Telescope, has observed enhanced gamma-ray activity from a source positionally consistent with the flat-spectrum radio quasar PKS 0346-27, also known as 4FGL J0348.5-2749 (The Fermi-LAT collaboration 2020, ApJS, 247, 33), with coordinates RA=03h 48m 38s, Dec=-27d 49' 14" (J2000; Beasley et al. 2002 ApJS, 141, 13), and a reported redshift of $z=0.991$ (White et al. 1988 ApJ, 327, 561).

The H.E.S.S. array of imaging atmospheric Cherenkov telescopes was used to carry out observations of PKS 0346-27. On November 03 (MJD 59521.9), a two hour observation shows a >5 sigma excess in the very-high-energy gamma-ray band compatible with the direction of PKS 0346-27. Preliminary analysis shows a very soft power law (photon spectral index > 4). H.E.S.S. observations are ongoing.

Flux Density Time Series

Show:

2100

5500

17000

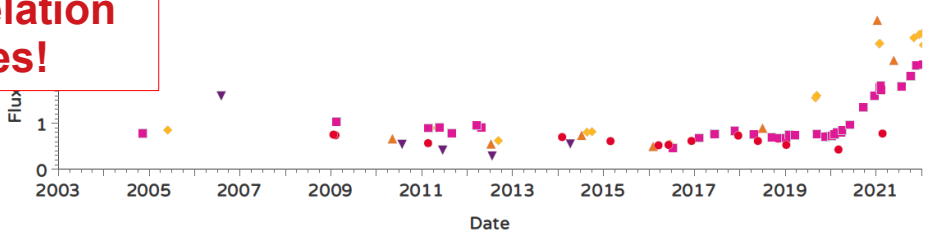
33000

93000

[what is this?](#)

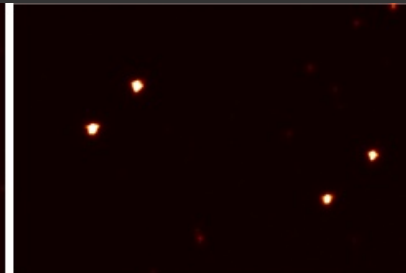
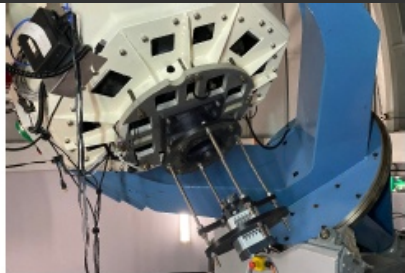
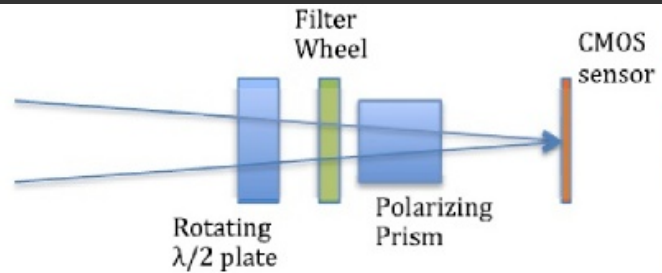
0346-27

ATCA 'Calibrator' Database



Synergies with Optical Astronomy

- Transient follow-up and monitoring of AGN, XRBs, Novae, SGRs, GWe...
 - Optical polarisation (synchrotron) linked to gamma-ray flaring.
 - Development of polarimeter for ANU 2.3m telescope
- PICSARR concept (Bailey et al 2023) adapted to fainter targets (AGN)



- Led by WSU team (Nick Tothill et al)
- Testing prototype at Penrith Obs.
→ User instrument on ANU 2.3m tel.
@ Cassegrain focus

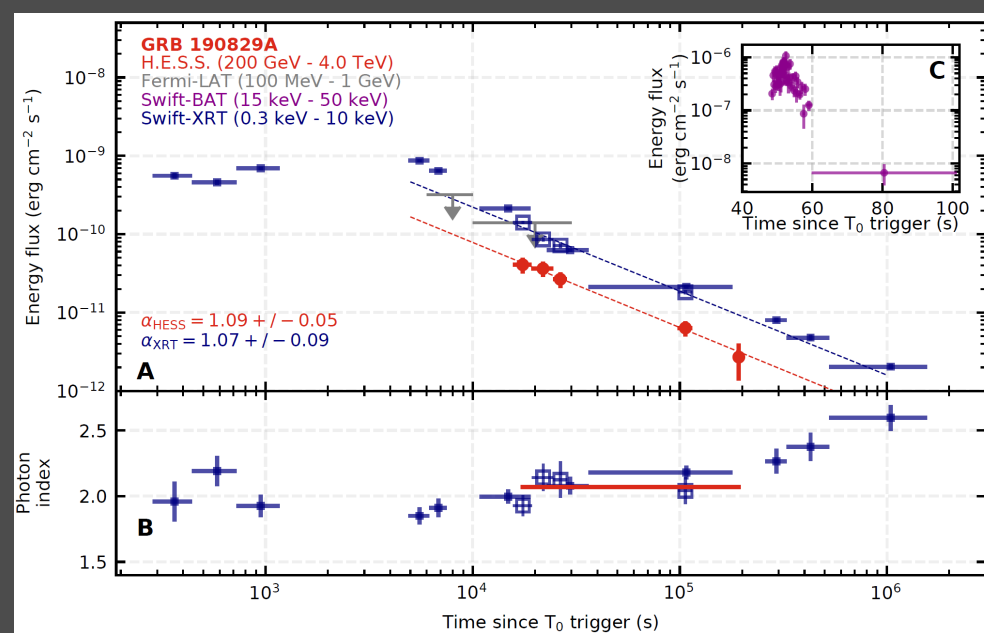
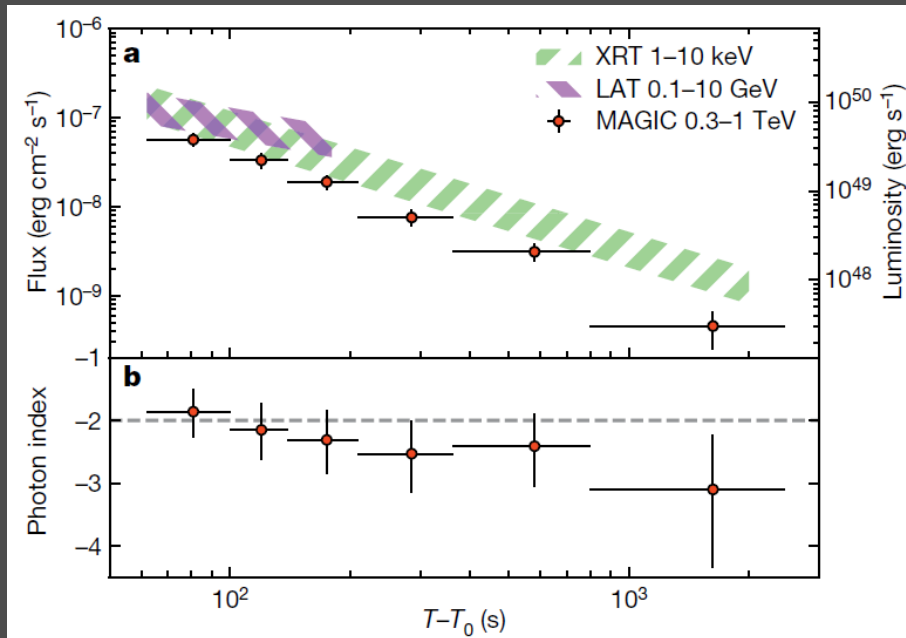
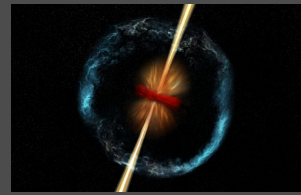


- Vera Rubin Obs. >1000's of transients/night
Use Fink broker to filter :<https://fink-portal.org/>



TeV Gamma Ray Bursts : A Growing Population!

(MAGIC 2019, 2021, 2023; HESS 2019, 2021, LHAASO 2023)



- Five Long GRBs GRB180720B, GRB190114C, GRB1900829A, GRB221009A, GRB201216C

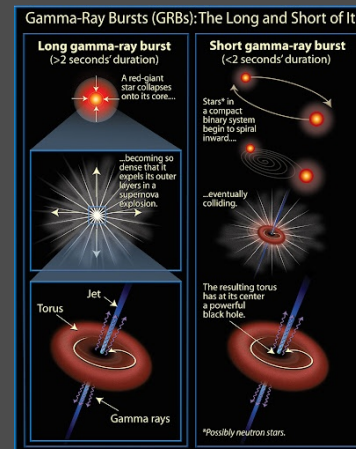
$z = 0.653$ 0.424 0.079 0.151 1.1

- One Short GRB GRB160821B ($z=0.162$) marginal!

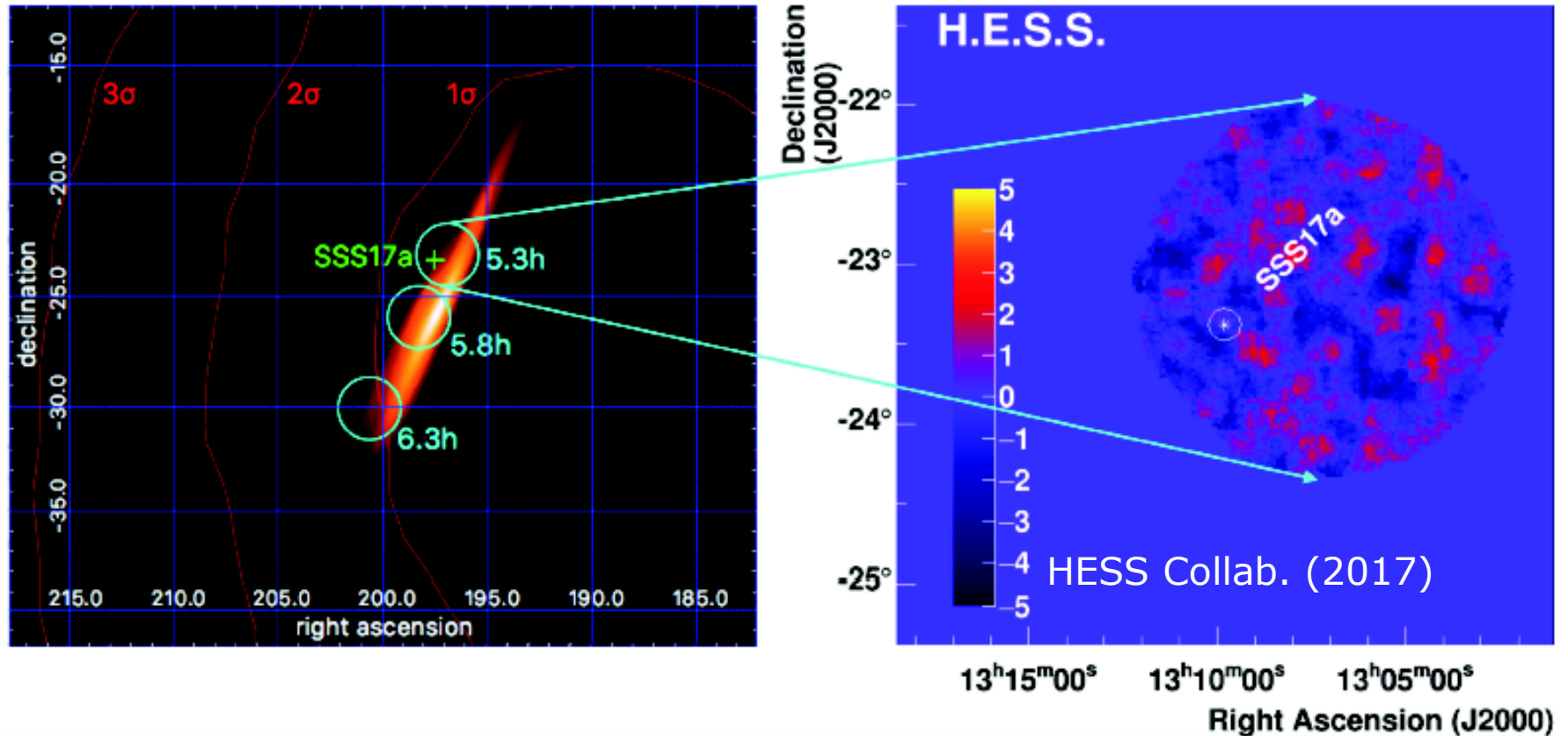
- GRB190114C & GRB1900829A >1000's photons > 50 GeV
→ spectra on hourly timescales

- GRB221009A up to 18 TeV!

- Rapid radio follow-up in place (HESS+ATCA; Anderson et al)



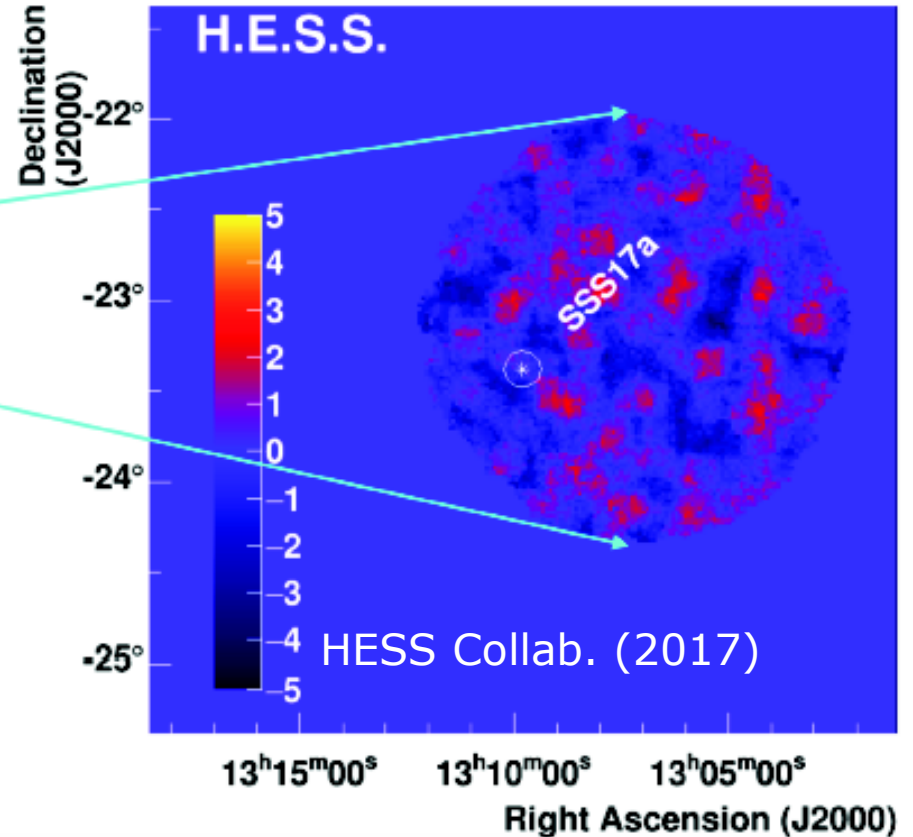
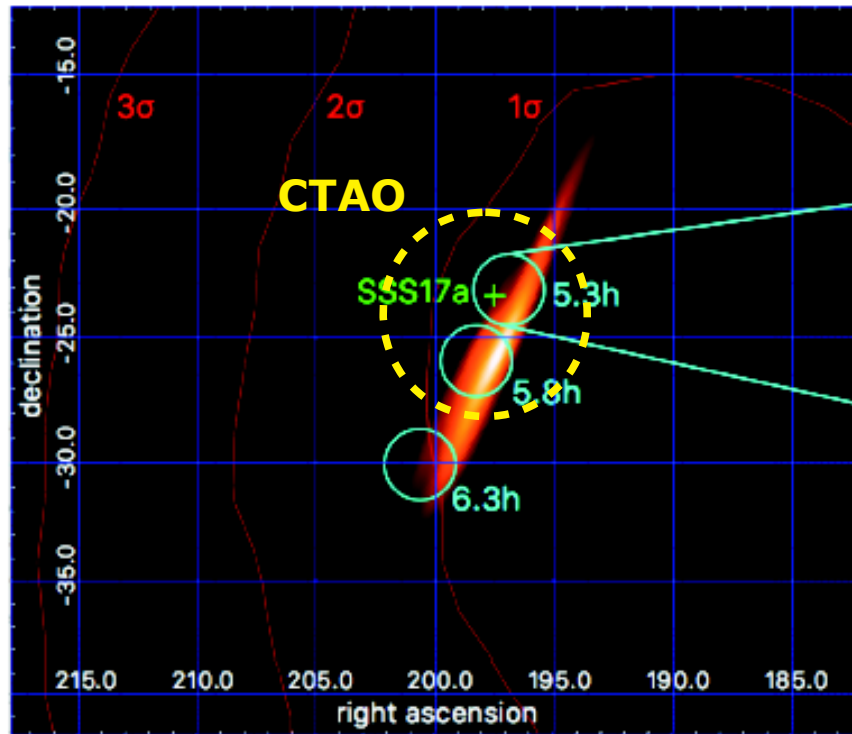
GW170817 (ns-ns) – followup by H.E.S.S.



FoV FWHM: HESS ~ 3.0 deg

Several pointings required to cover best likelihood region.

GW170817 (ns-ns) – followup by CTAO



FoV FWHM: **CTA 5.0 ~ 7.0 deg**

Single pointing!

GW170817



- HESS prompt follow-up (only upper limit)

HESS, ApJ Lett 850, L22 (2017)

But after ~ 100 days, strong X-ray synchrotron emission seen with Chandra Troja et al (2017)

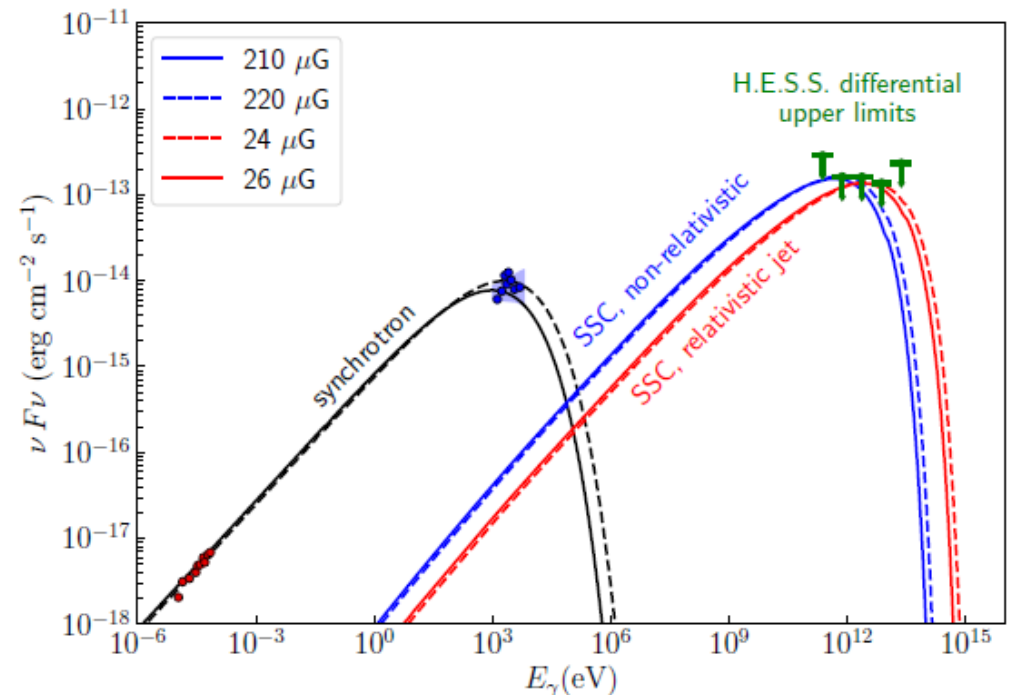
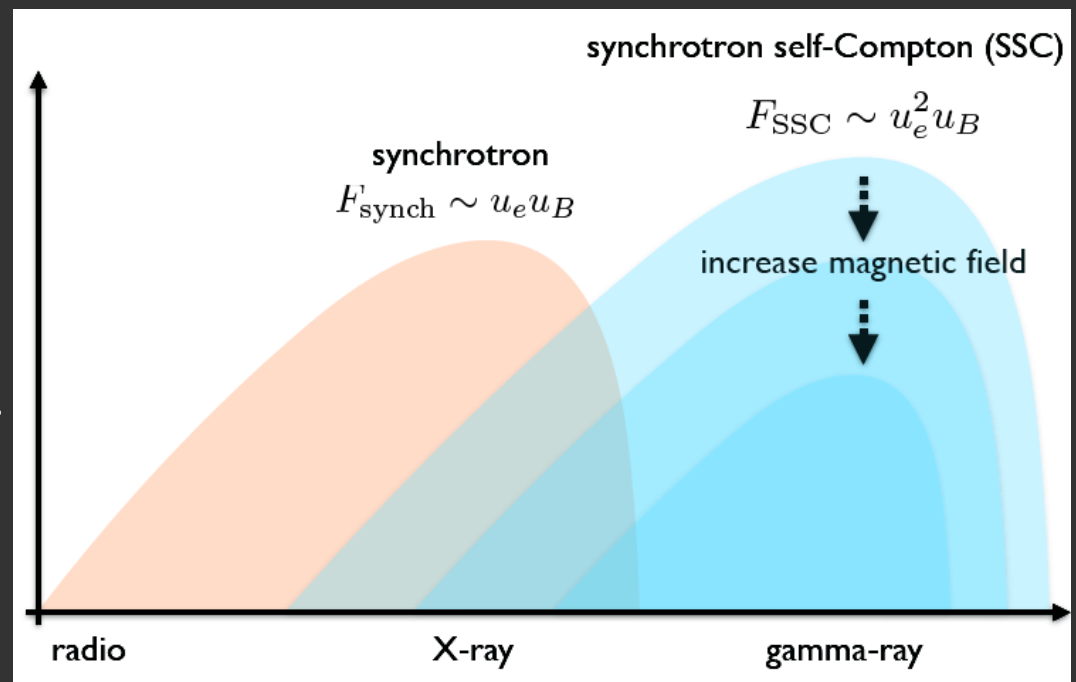
→ TeV synch-self-Compton (SSC) prediction

Isotropic non-relativistic wind or relativistic jet (observed slightly off-axis at 20 degrees)

(Takami et al 2014, Rodrigues et al 2019, HESS 2020)

→ Near miss TeV detection?

HESS, ApJ Lett 894, L16 (2020)



Other Transients Studies in TeV Gammas (with HESS, MAGIC...)

SGR/Magnetar flares

HESS, ApJ 919, 106 (2021)

- Triggers from Swift-BAT, Fermi-LAT
- SGR1935+2154 ‘Cluster’ of X-ray bursts in 2021
 - First links to repeating FRBs!

Fast Radio Bursts

HESS, MNRAS 515, 1365 (2022)

- Triggers from UTMOST & Parkes-SUPERB
- Campaigns on three repeating FRBs with MeerKAT, eMERLIN, & Swift

X-Ray Binaries (Low-Mass)

HESS, MNRAS 517, 4736 (2021)

- MAXI J1820+070 2018 outburst
- HESS, MAGIC, VERITAS campaign
 - constraints on B field and emission region

Nearby Core-Collapse Supernovae

HESS, MNRAS 626, A57 (2019)

- Ten SN 4 to 54 Mpc distant (incl. SN2016adj in CenA)
- Constraints on mass loss rates $\text{few} \times 10^{-5}$ to 10^{-3} M_{sun}/yr

Tidal Disruption Events

- Focus on TDEs with radio jets & non-thermal emission

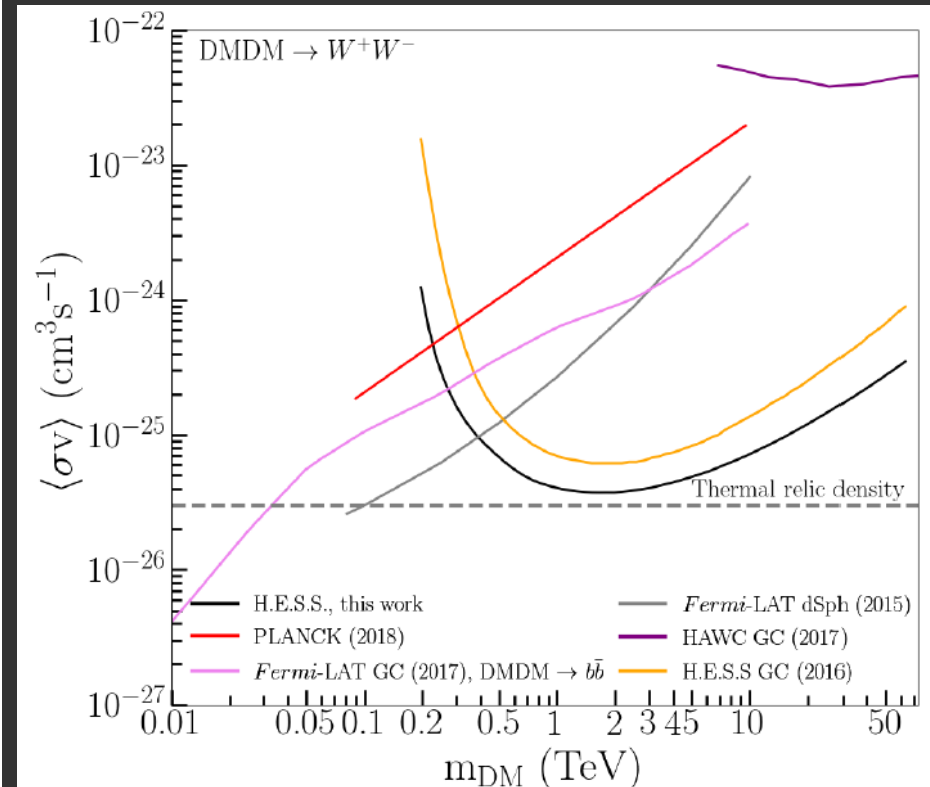
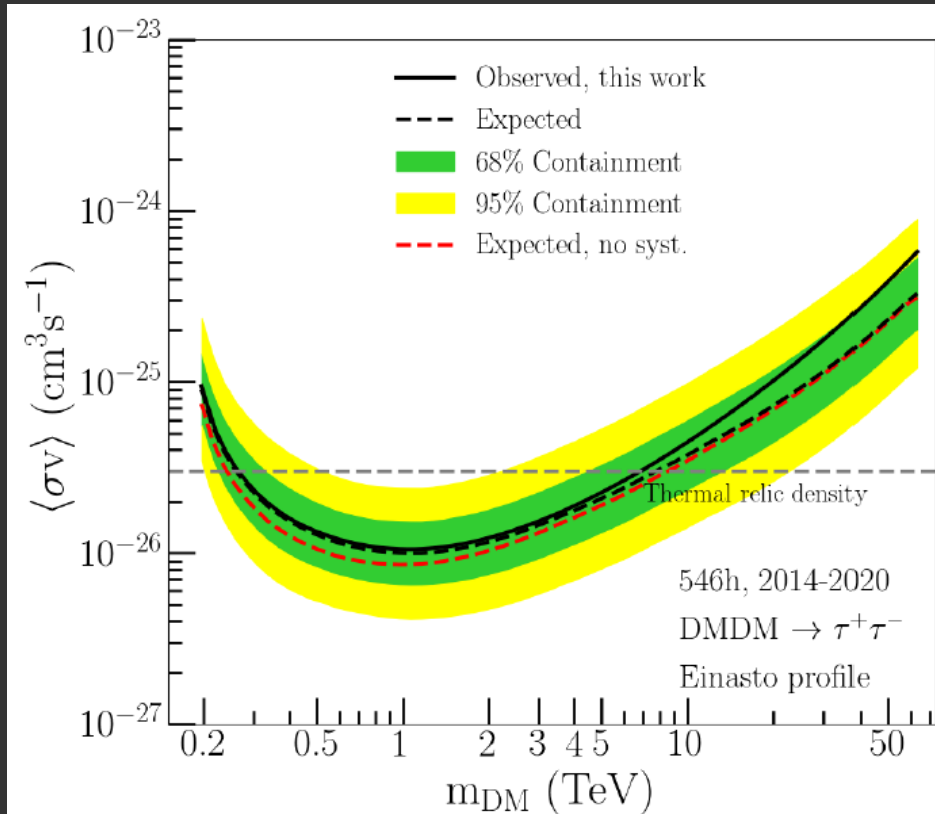
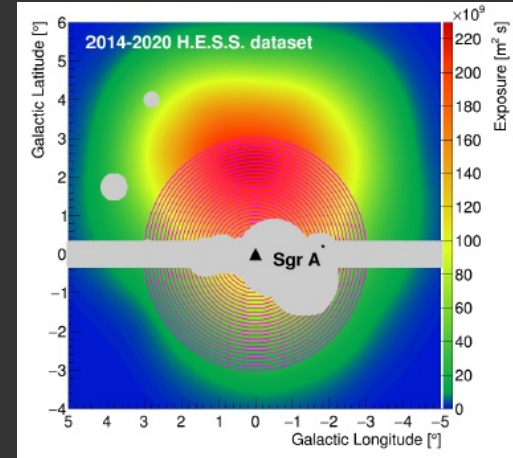


Dark Matter Search (e.g. Galactic Centre)

HESS, PRL 129, 111101 (2022)

- WIMP self-annihilation into quark, lepton, gauge boson and Higgs channels.
- Best constraints for $\tau^+\tau^- \rightarrow$ below thermal relic density
- HESS most sensitive constraints >0.5 TeV from gamma

→ **severe tests of WIMP theories expected from CTAO!**
(Mangipudi, Balazs, Thrane 2022, Abe et al 2024, 2025)



Summary

- CTAO is rapidly constructing now!
- Full array (South) completed by 2029/30
- Early science already CTAO-North
- Early science from CTAO-South 2026/27+
- CTAO-Australia is preparing for early science and Key Science Projects
- Linkages with many radio + optical facilities in Australia in place and ready to go!

Thankyou

contact: gavin.rowell@adelaide.edu.au

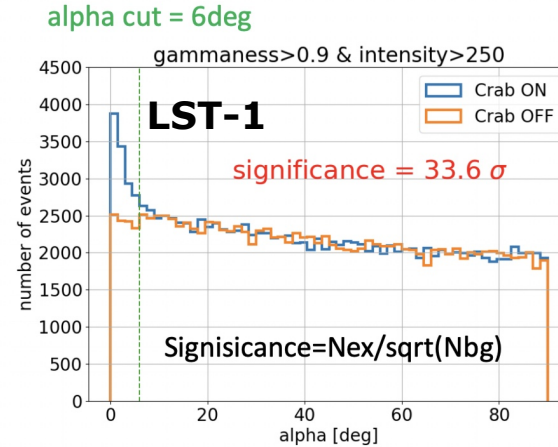
CTAO's First Telescopes – They Work!

ie. real Cherenkov images; Detection of the Crab nebula, Crab pulsar and some AGN

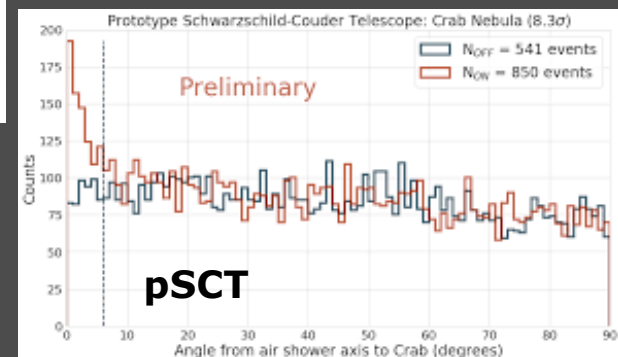
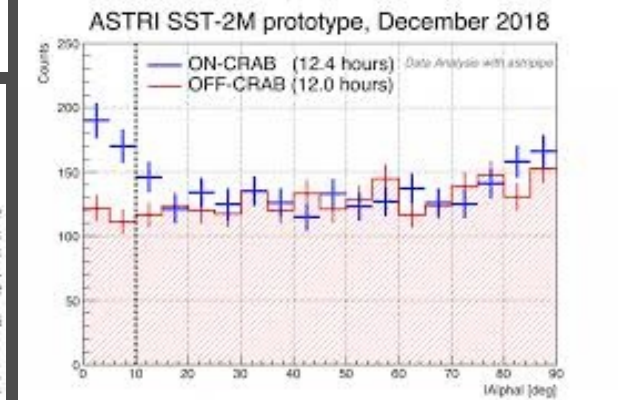
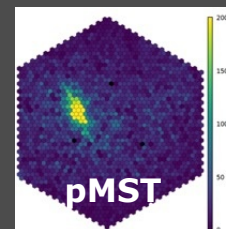
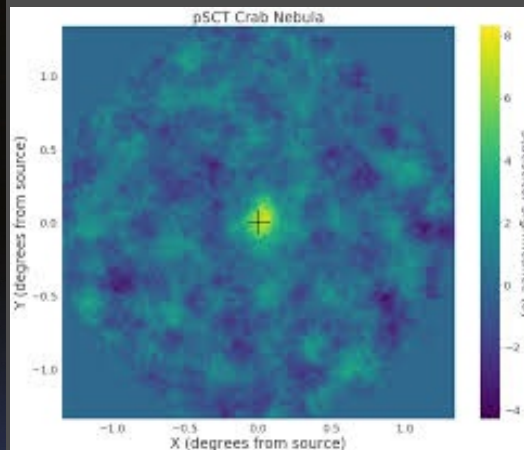
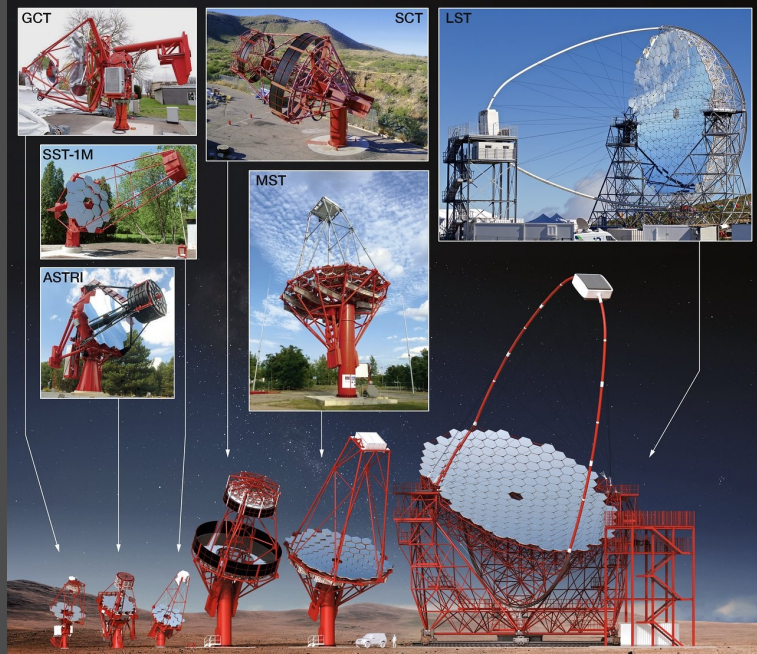
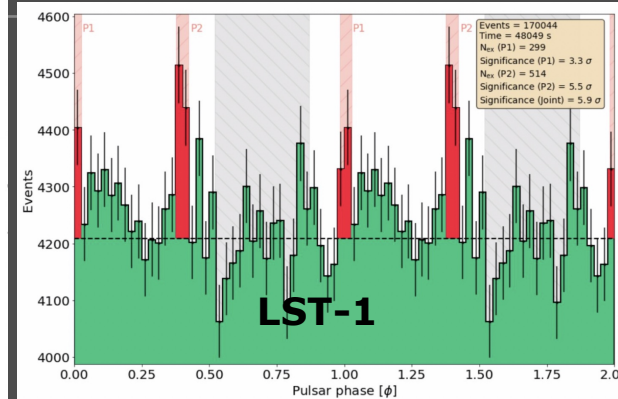


cherenkov
telescope
array

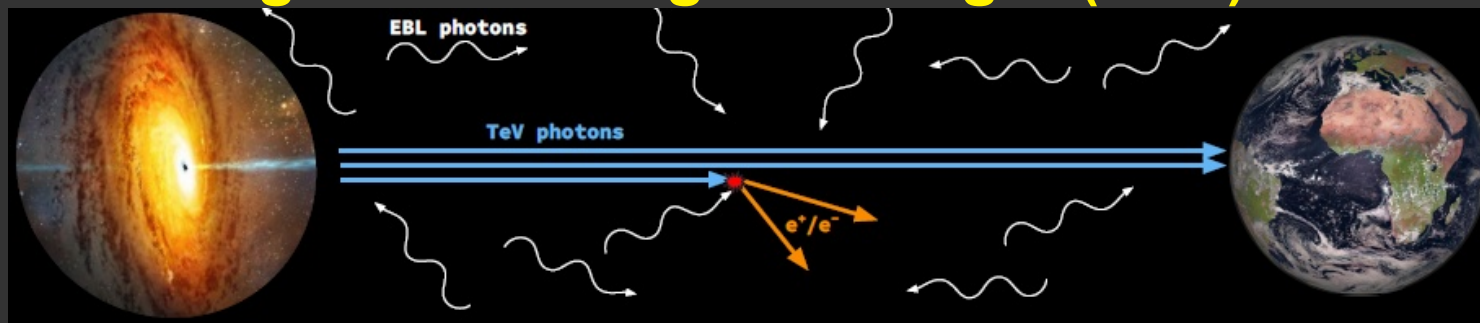
LST-1
(CTA-North)



Excess = 29.0/min

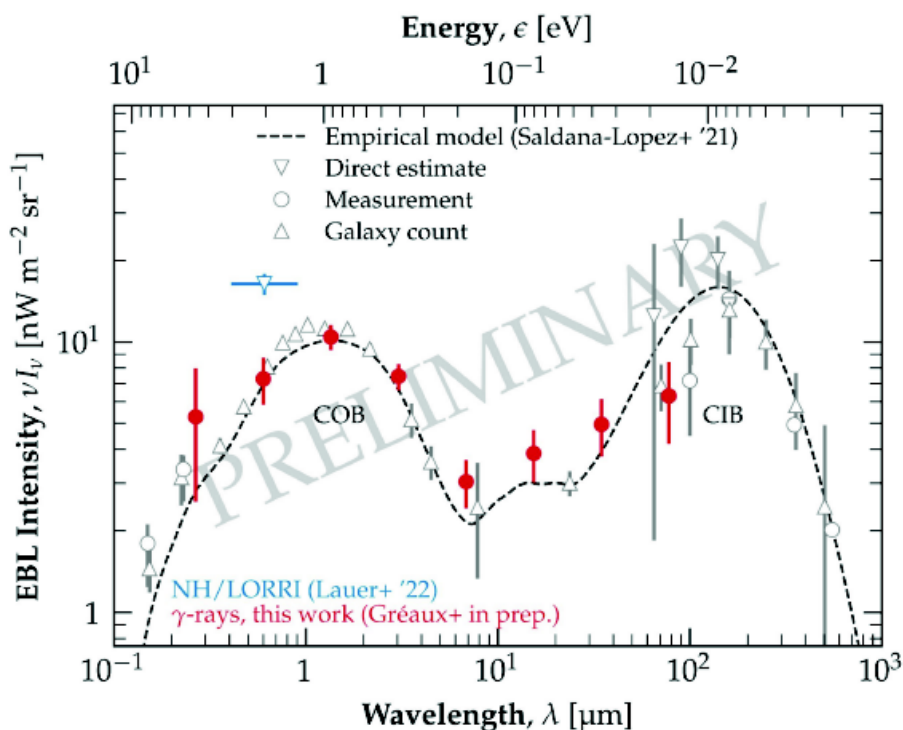


CTAO Extragalactic Background Light (EBL) Constraints



Current predicted EBL precision (see [CTAC21])

- Frequentist fit of **simulated DL3 data**
- EBL modeled with $\tau(E, z, \alpha) = \alpha \times \tau_{\text{ref}}(E, z)$
- **~5%** statistical uncertainties for $z < 0.4$



Greaux, Biteu (CTAO Symp)

