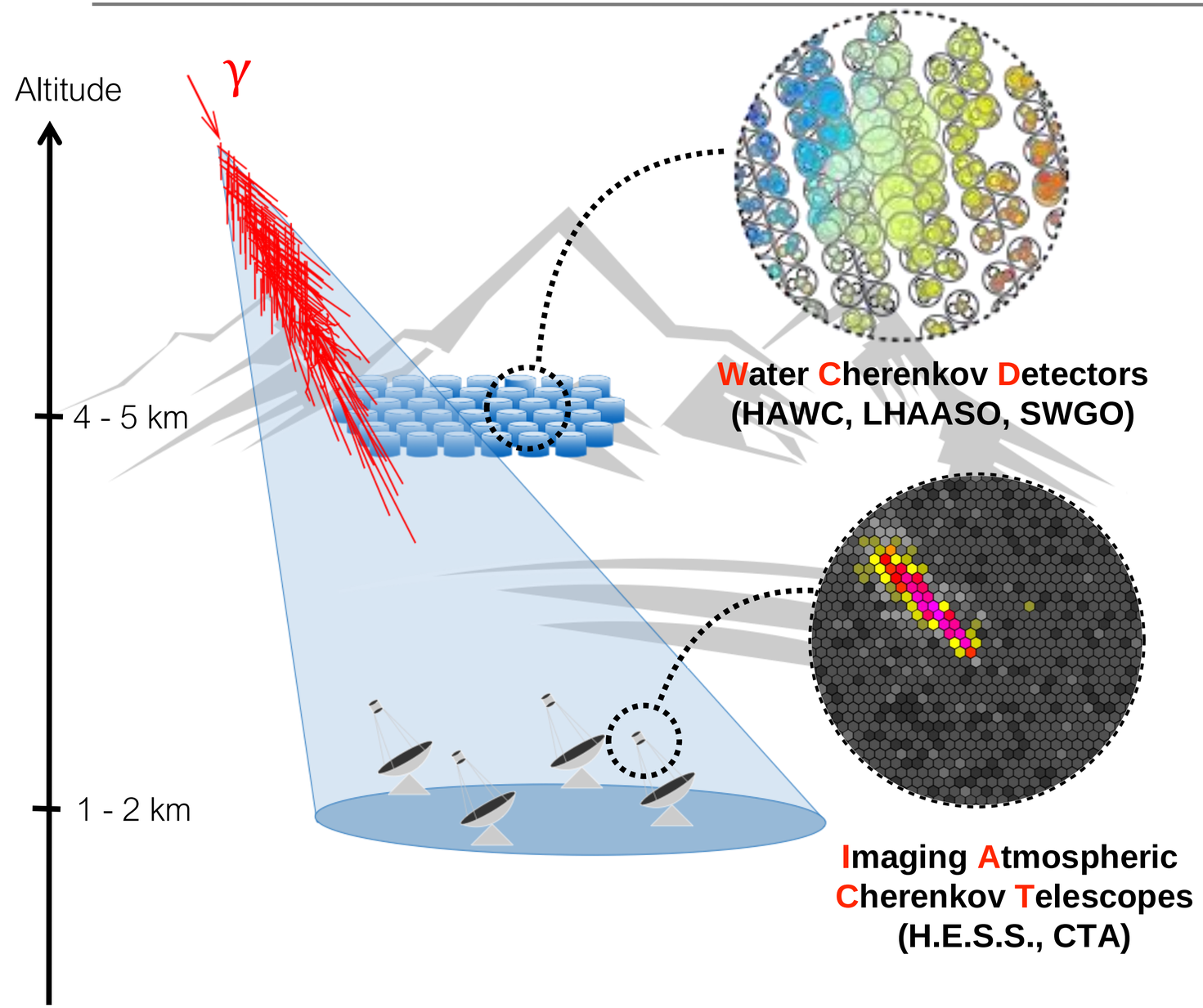
Southern Wide-field Gamma-ray Observatory

Conseil scientifique – 20 Mars 2025

- Ground based instruments
- Science cases : results from HAWC and LHAASO
- The future with SWGO
- Contribution in France and @LP2i Bordeaux

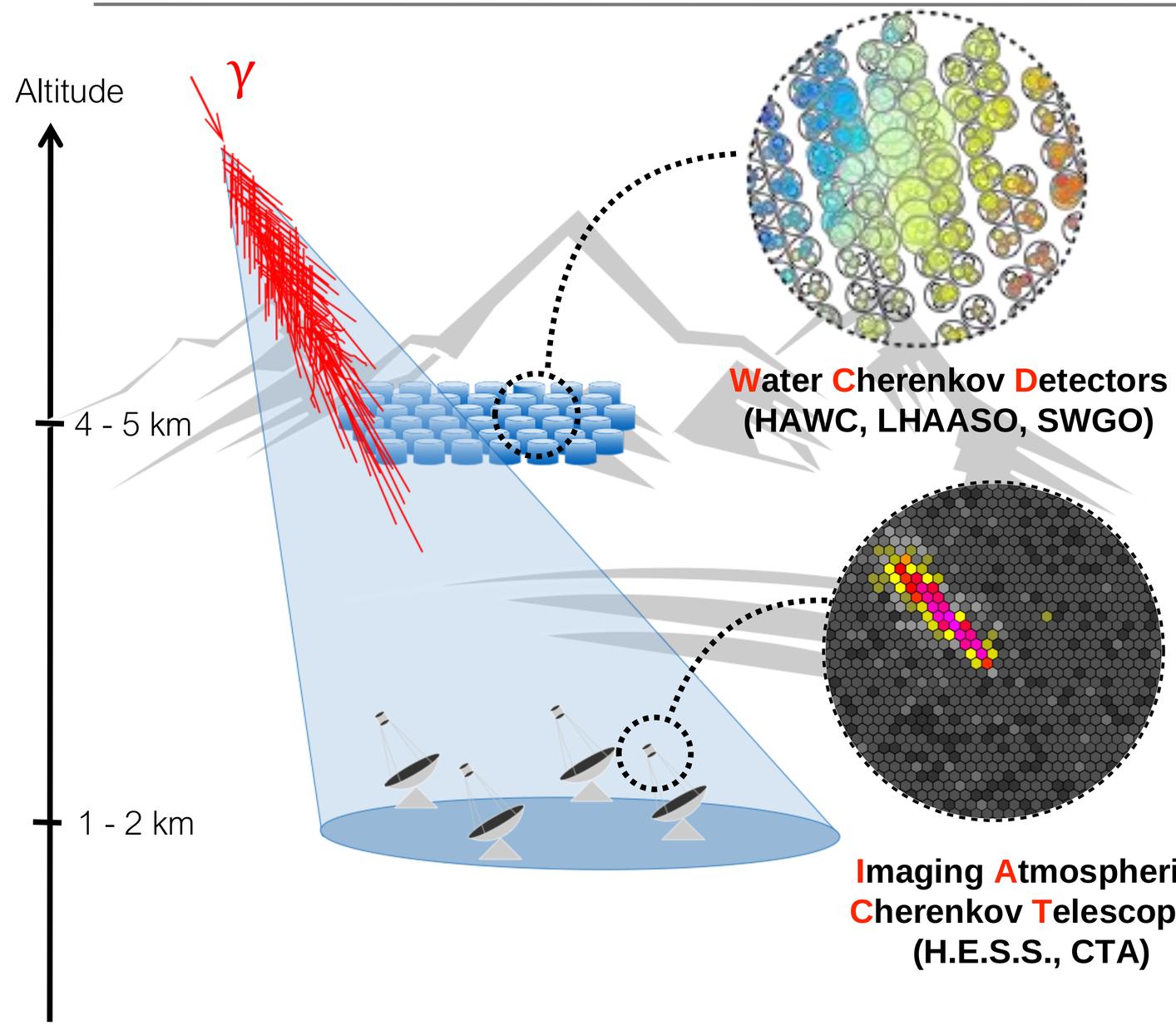
Ground based instruments



Water Cherenkov Detectors
(HAWC, LHAASO, SWGO)

Imaging Atmospheric
Cherenkov Telescopes
(H.E.S.S., CTA)

Ground based instruments



Water Cherenkov Detectors (HAWC, LHAASO, SWGO)

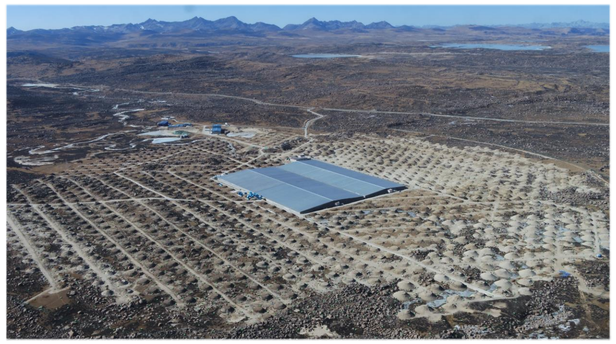
Imaging Atmospheric Cherenkov Telescopes (H.E.S.S., CTA)

	Duty cycle	Field of view	Energy range	Energy resolution	Angular resolution
Water Cherenkov Detectors	✓ ~95%	✓ 90°	✓ 0.5 - 100 TeV	✗ 20% at 1 TeV 10% at 100 TeV (on-array events)	✗ 0.8 - 0.1°
Imaging Atmospheric Cherenkov Telescopes	✗ ~10% ~1000 h/y	✗ 5°	✓ 0.03 - 100 TeV	✓ < 10% for E > 1 TeV	✓ 0.1 - 0.05°

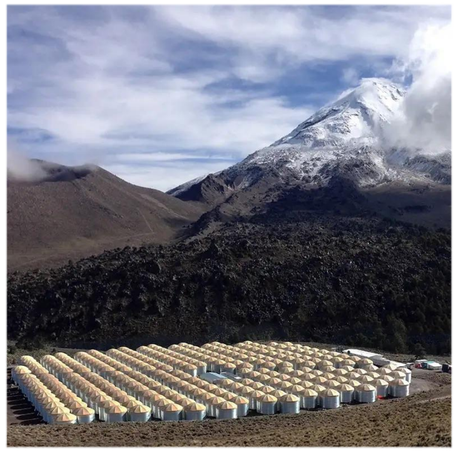
Instruments around the world

Tibet/ARGO-YBJ

LHAASO

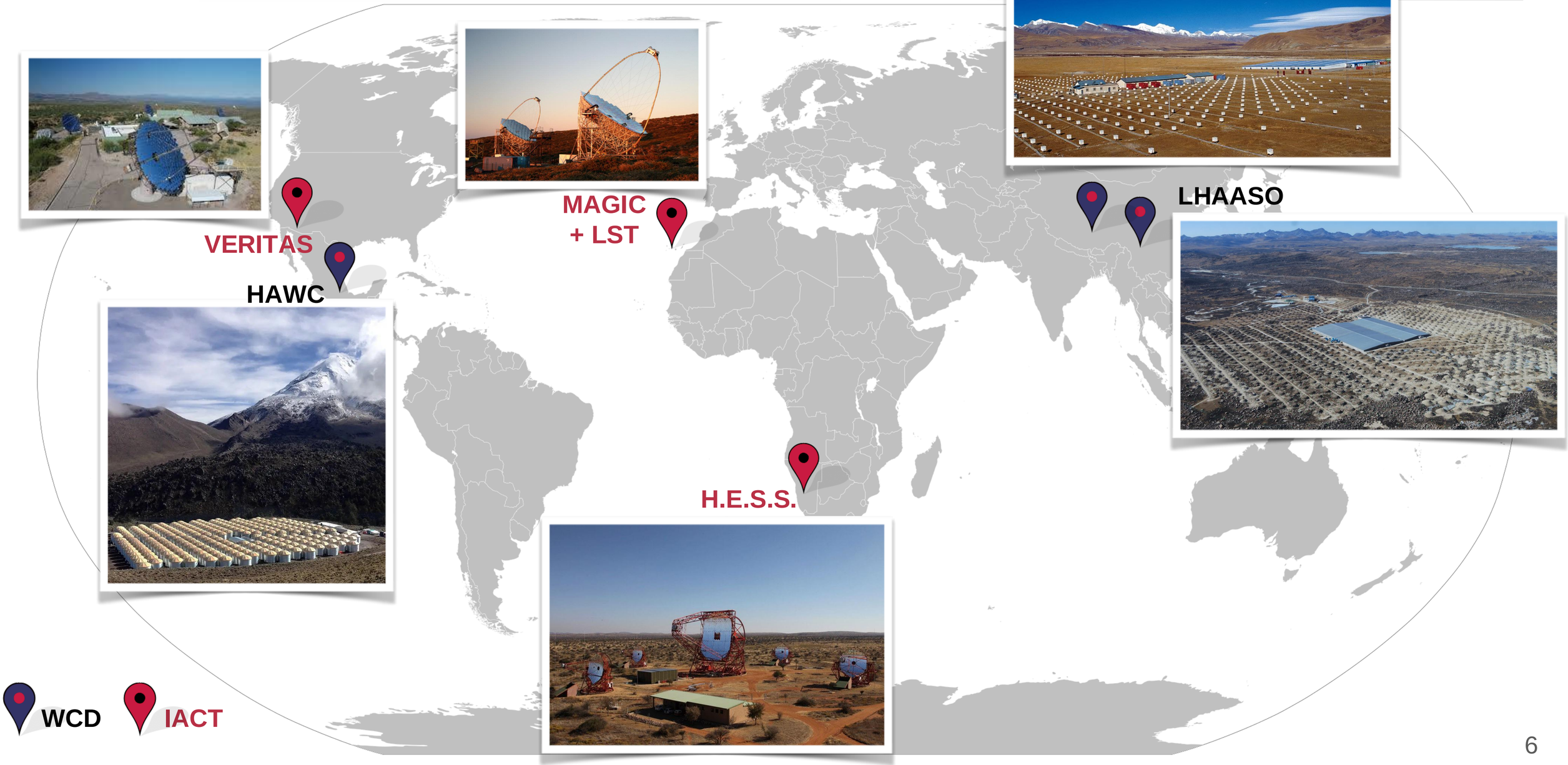


HAWC



WCD

Instruments around the world



Instruments around the world

VERITAS

HAWC

MAGIC

CTA-N

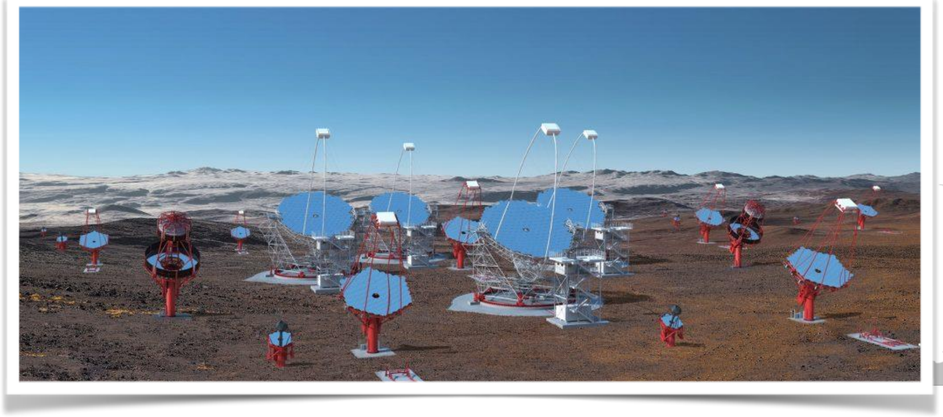
Tibet/ARGO-YBJ

LHAASO

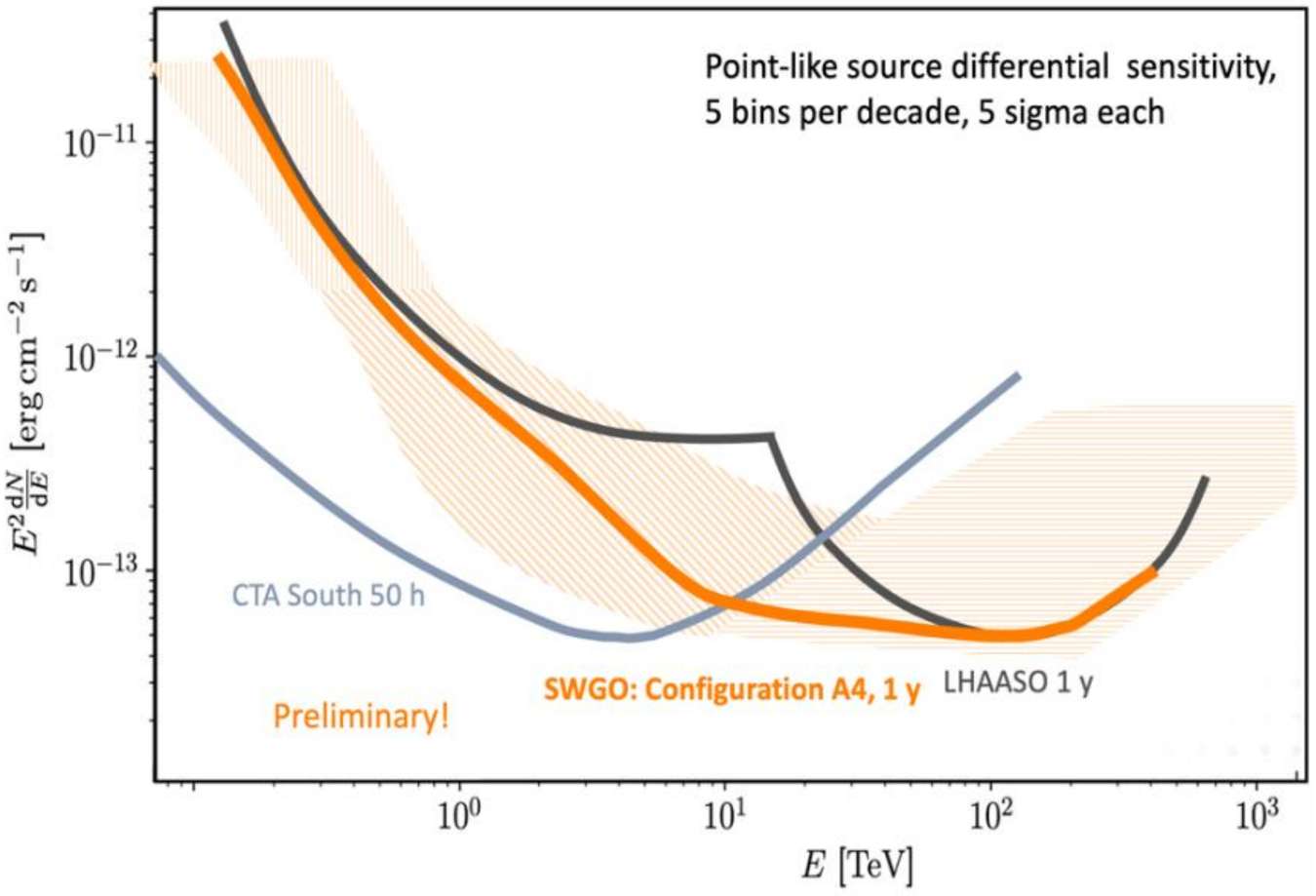
SWGO

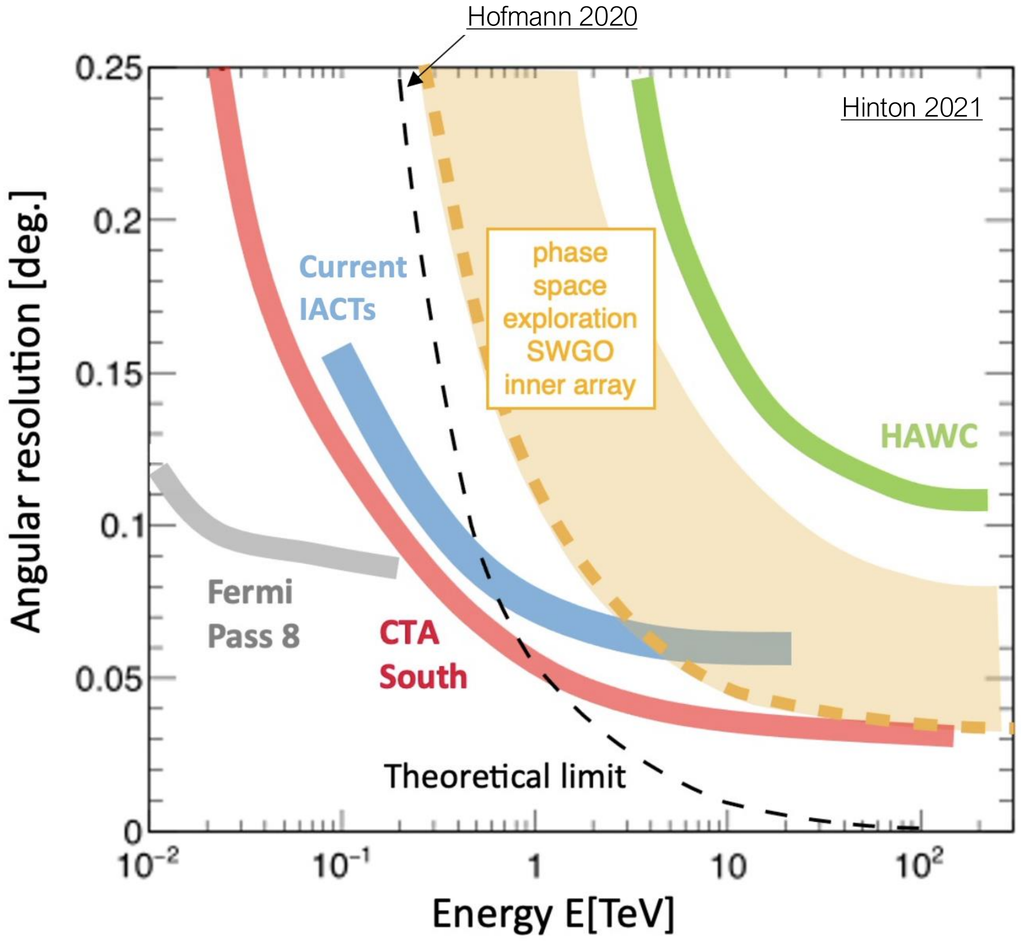
CTA-S

H.E.S.S.



Stronger together !





Ground based instruments

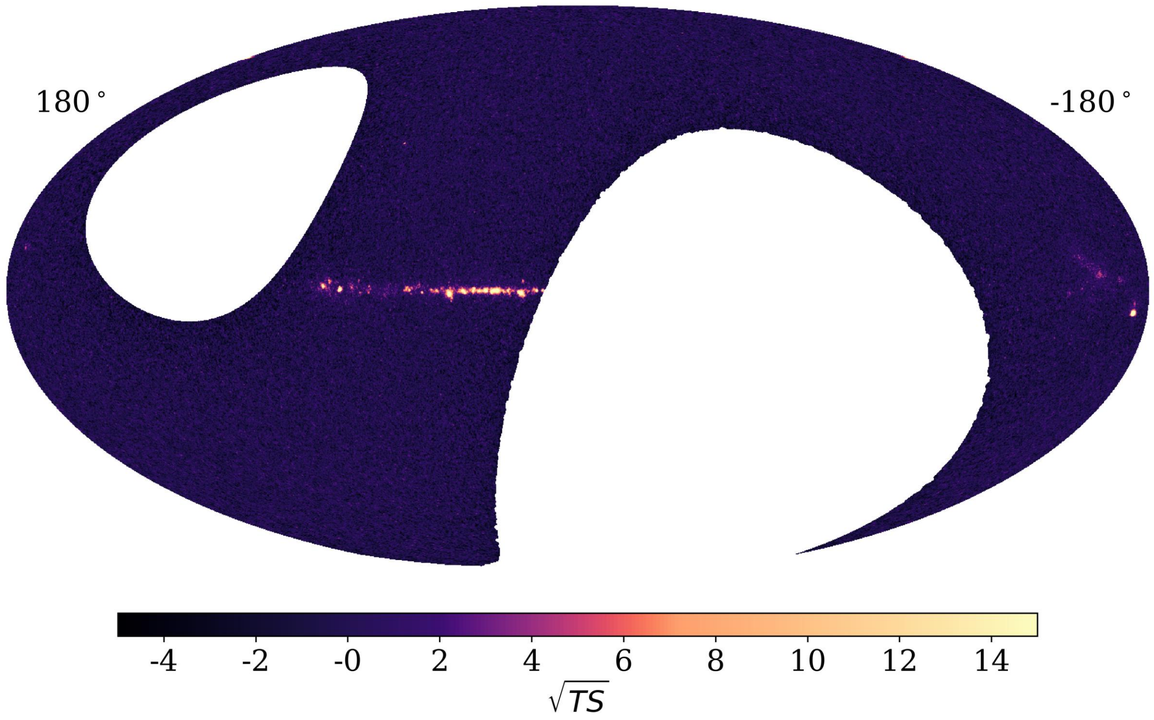
Science cases : results from HAWC and LHAASO

The future with SWGO

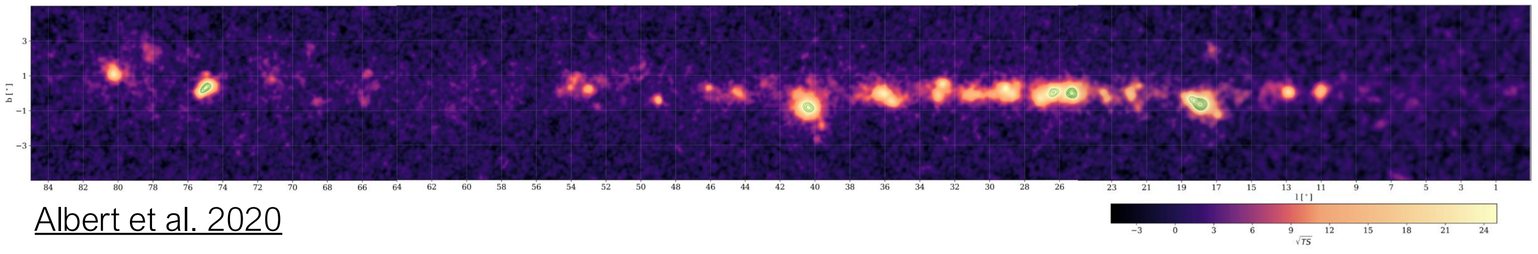
Contribution in France and @LP2i Bordeaux

Catalogue of VHE and UHE ɣ-ray sources - search for PeVatrons

65 sources reported by HAWC, including
9 sources with E > 56 TeV, 3 sources > 100 TeV



1910 days

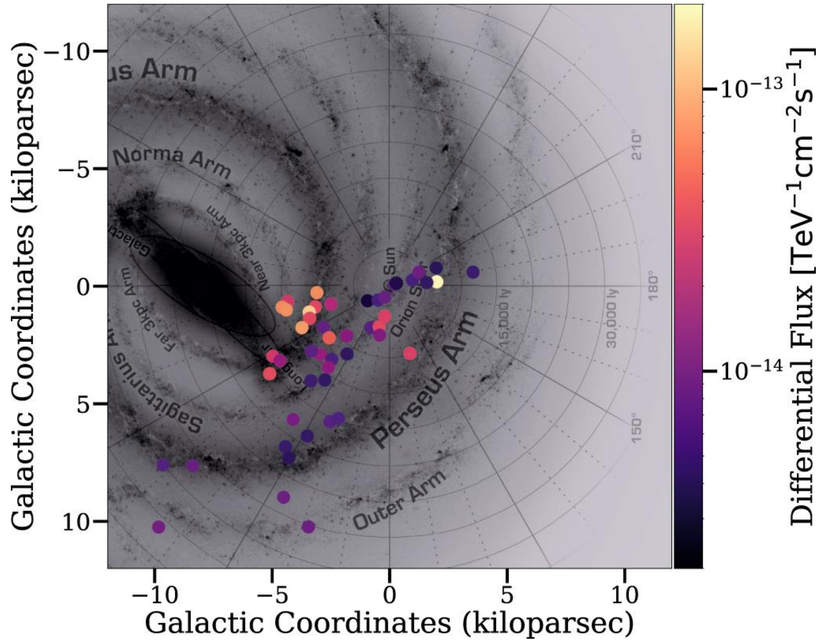


Albert et al. 2020

THE ASTROPHYSICAL JOURNAL

3HWC: The Third HAWC Catalog of Very-high-energy Gamma-Ray Sources

A. Albert[1], R. Alfaro[2], C. Alvarez[3], J. R. Angeles Camacho[2], J. C. Arteaga-Velázquez[4], K. P. Arunbabu[5], D. Avila Rojas[2], H. A. Ayala Solares[6], V. Baghmanyan[7], E. Belmont-Moreno[2]



49 HAWC sources are spatially associated with a pulsar (with available distance)

Catalogue of VHE and UHE ɣ-ray sources - search for PeVatrons

The First LHAASO Catalog of Gamma-Ray Sources

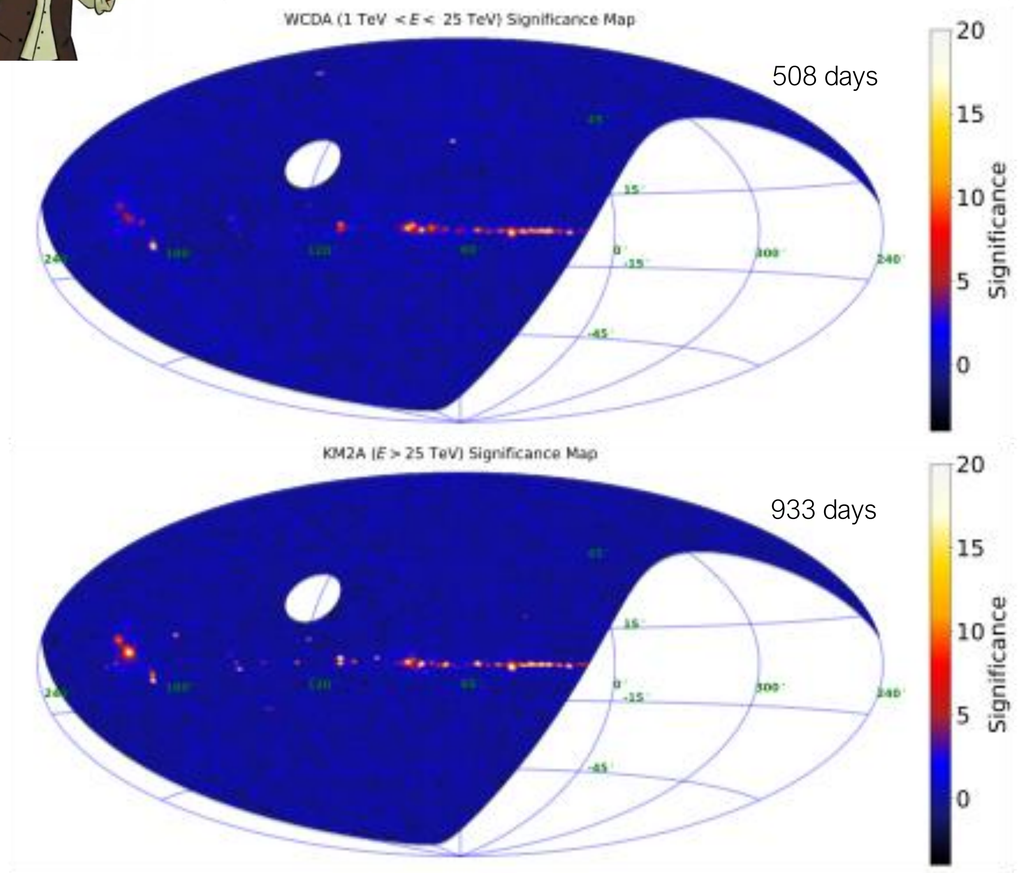
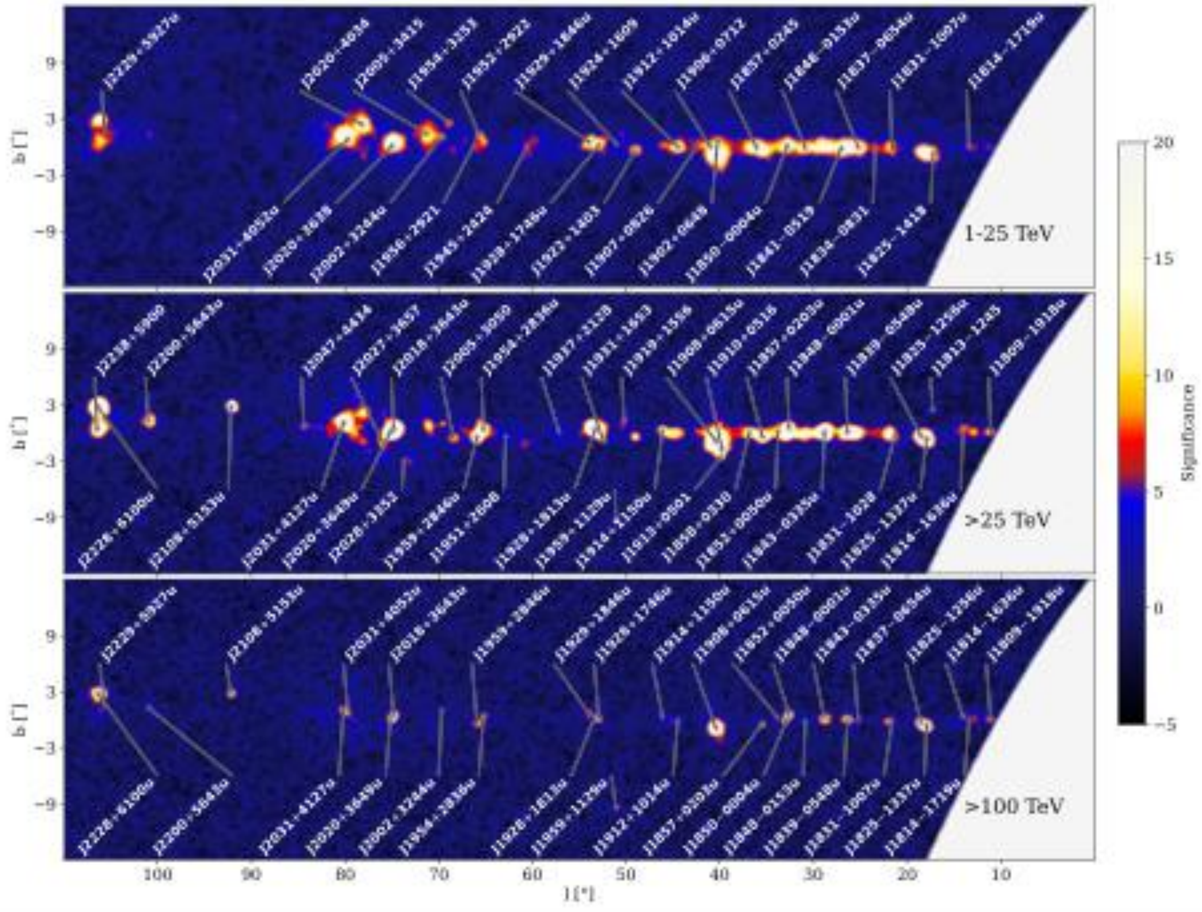


Figure 1. Significance maps of the region monitored by LHAASO. A point test source with a spectral in of 2.6 for WCDA data and 3.0 for KM2A data is used.

90 sources reported by LHAASO,
43 of them detected at UHE (> 100 TeV)



Cao et al. 2024

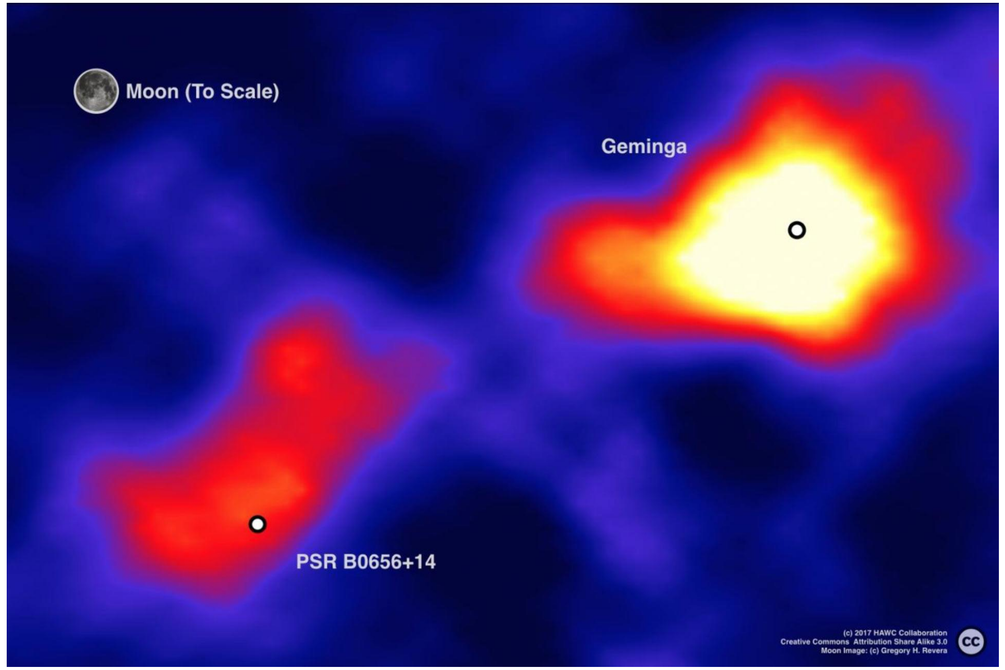
(Very) extended sources

New class of VHE ɣ-ray sources : pulsar halos

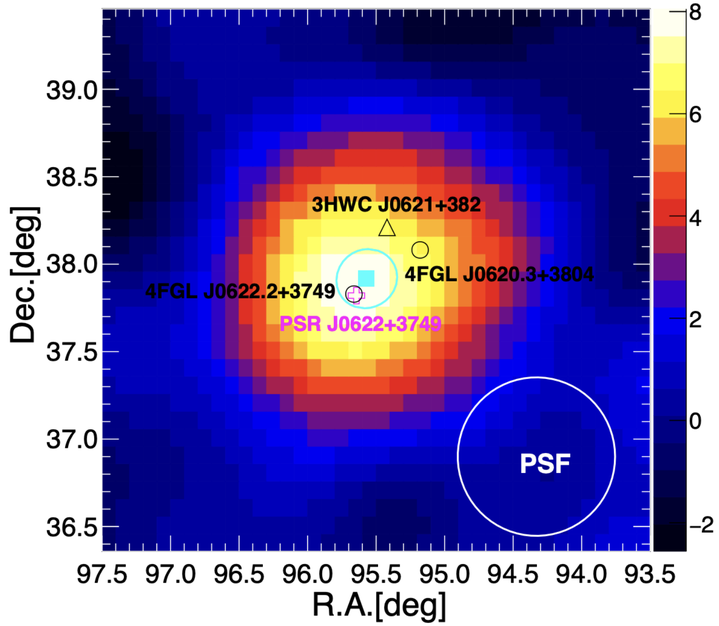
- Constrain positron excess
- Probe ISM characteristics (diffusion coefficient)
- Understand galactic pulsar population
- Find mis-aligned pulsars

Challenging for Cherenkov telescopes (but not impossible)

-> Detection of Geminga by H.E.S.S. (HESS collaboration, 2023)

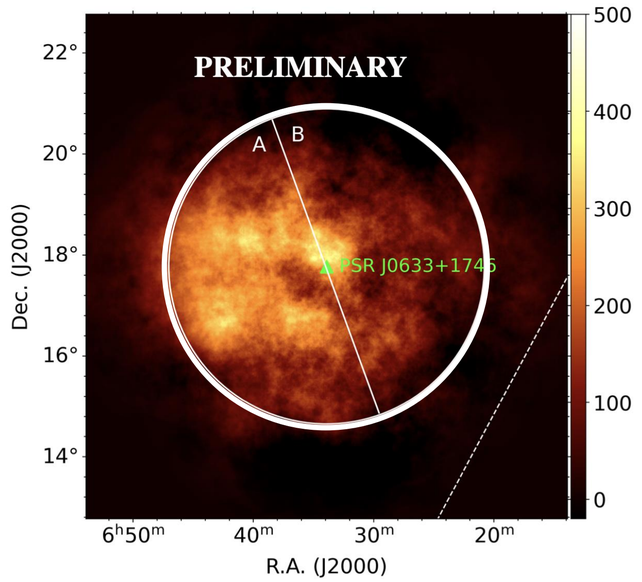


The HAWC collaboration, Science 358, 911 (2017)
First announced by MILAGRO (2009)



Aharonian et al. 2021

Mitchell et al. 2021



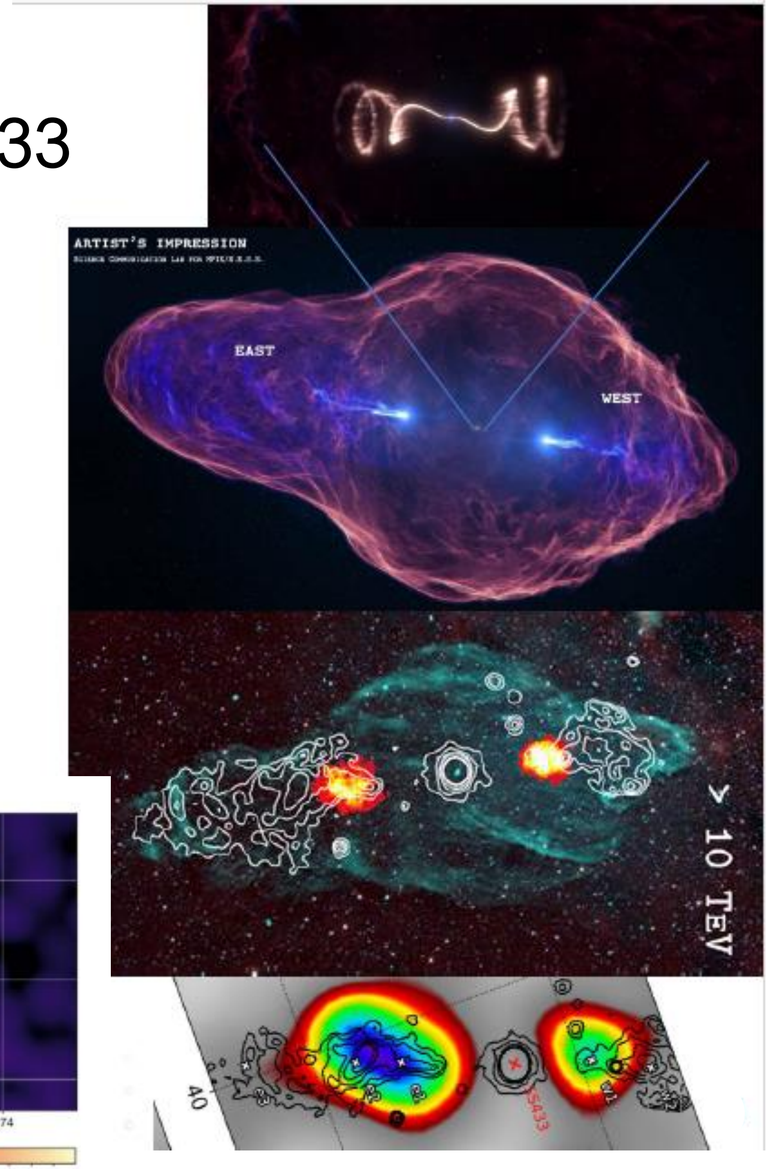
A big surprise from particle detectors: microquasars

- Accreting black hole in binary system produces jet
  - Often relativistic
- Detection of SS 443 was a game changer
  - Many previous searches focussed on time-variable emission from close to the BH
  - HAWC sensitivity at ~40 TeV needed to find it (Nature 2018)
  - HESS resolution to detect energy dependent morphology (Science 2023)

$$E_{\mathrm{Hillas}} \approx 10Z \left(\frac{B}{20\mu\mathrm{G}}\right)\left(\frac{u_1}{0.26c}\right)\left(\frac{R}{1.6\mathrm{pc}}\right)\mathrm{PeV}$$

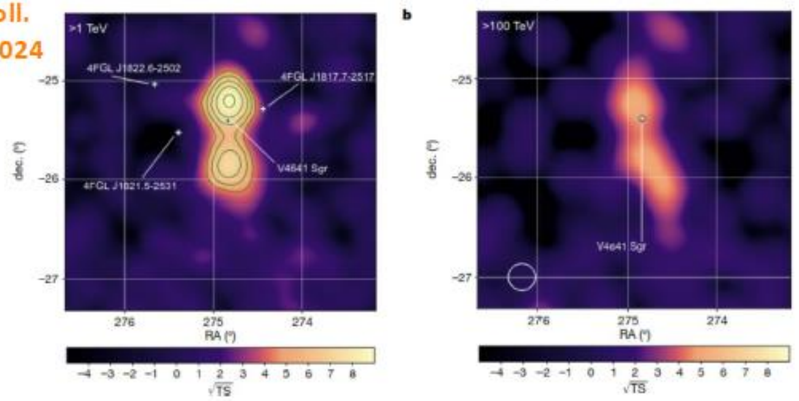
- Is SS 433 unique/alone? No:
  - V4641 Sgr (HAWC Nature 2024)
    - 5° off the galactic plane
    - Very large and consistent size with energy

SS 433



V4641 Sgr

HAWC Coll. Nature 2024



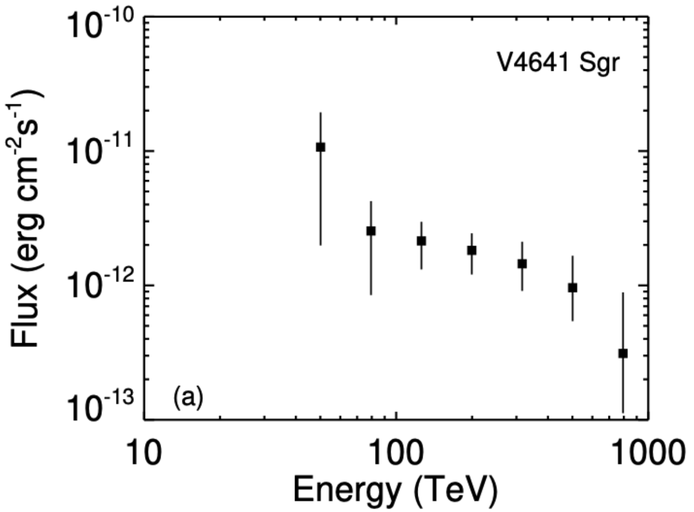
PeV acceleration from microquasars !

LHAASO now detects 5 BH-jet systems above 25 TeV : SS 433, V4641 Sgr, GRS 1915+105, MAXI J1820+070 and Cygnus X-1

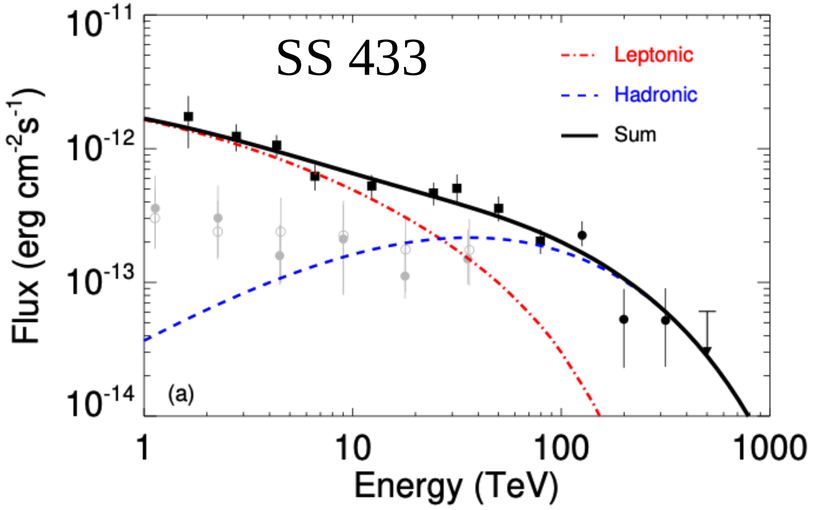
Data up to 30 TeV can be explained well via the IC radiation of electrons

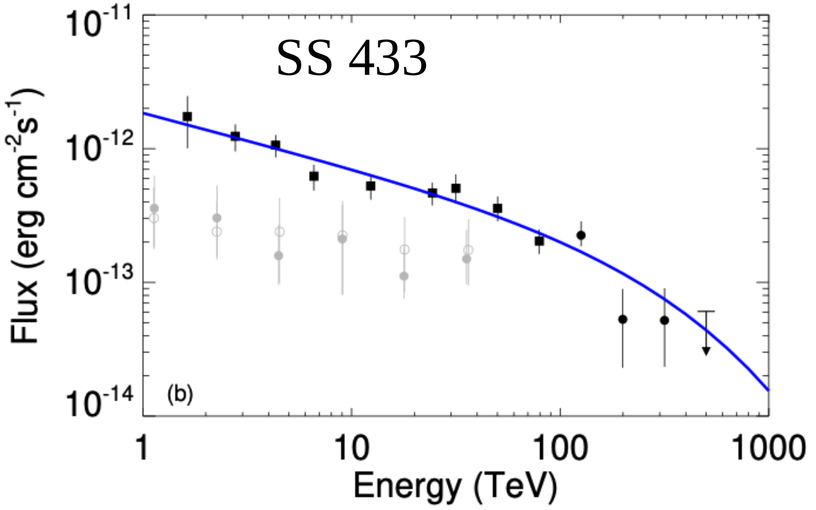
Above 100 TeV, suppression by the Klein-Nishina effect => additional hadronic component needed => SS 433 injecting PeV protons at a power of ~10^{38} erg/s ?

V4641 Sgr : electrons face difficulties to reproduce spectrum up to PeV => in hadronic scenario, V4641 energizes protons up to energies of ~10 PeV

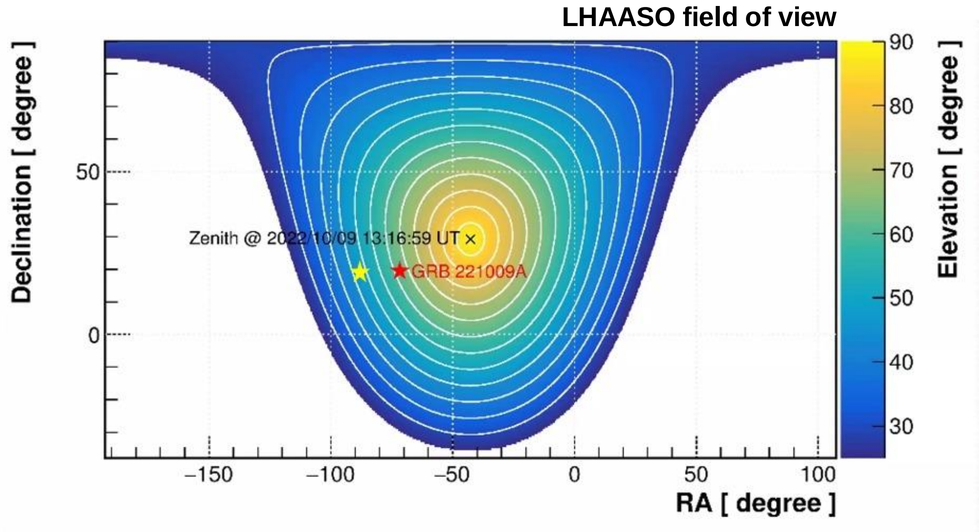


LHAASO collab., arXiv:2410.08988





Transient events




```
TITLE:    GCN CIRCULAR
NUMBER:   32677
SUBJECT:  LHAASO observed GRB 221009A with more than 5000 VHE photons up to around 18 TeV
DATE:     22/10/11 09:21:54 GMT
FROM:     Judith Racusin at GSFC  <judith.racusin@nasa.gov>

Yong Huang, Shicong Hu, Songzhan Chen,  Min Zha, Cheng Liu, Zhiguo Yao and
Zhen Cao report on behalf of the LHAASO experiment

We report the observation of GRB 221009A, which was detected by Swift (Kennea
et al. GCN #32635), Fermi-GBM (Veres et al. GCN #32636, Lesage et al. GCN #32642),
Fermi-LAT (Bissaldi et al. GCN #32637), IPN (Svinkin et al. GCN #32641) and so on.
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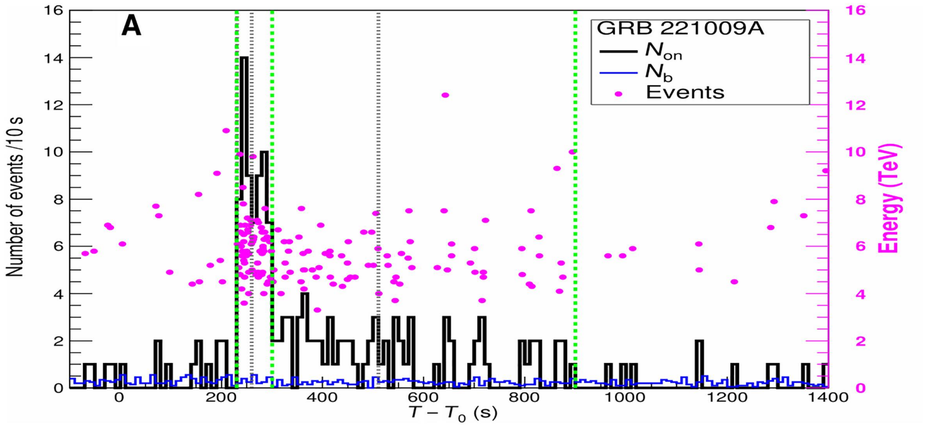
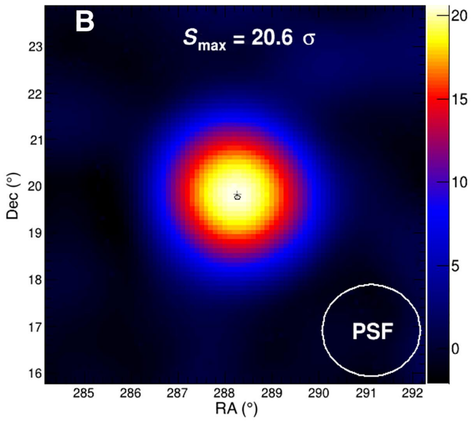
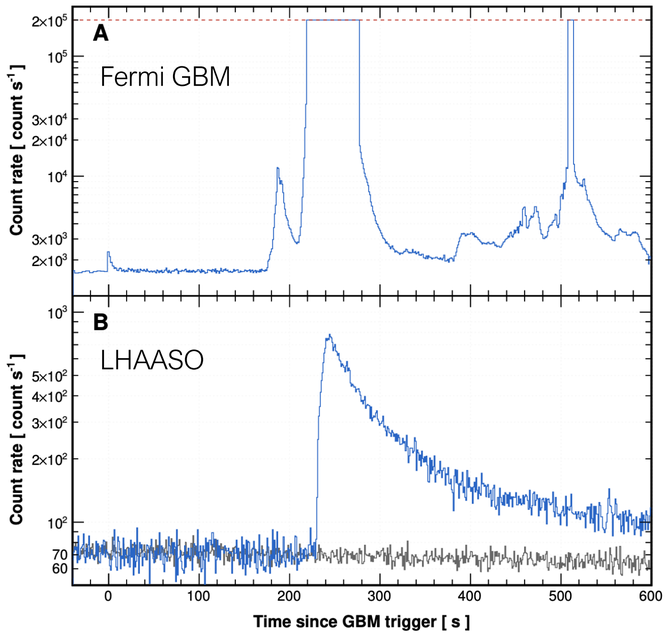
More than 64,000 photons (> 0.2 TeV) detected within the first 50 minutes







Ground based instruments

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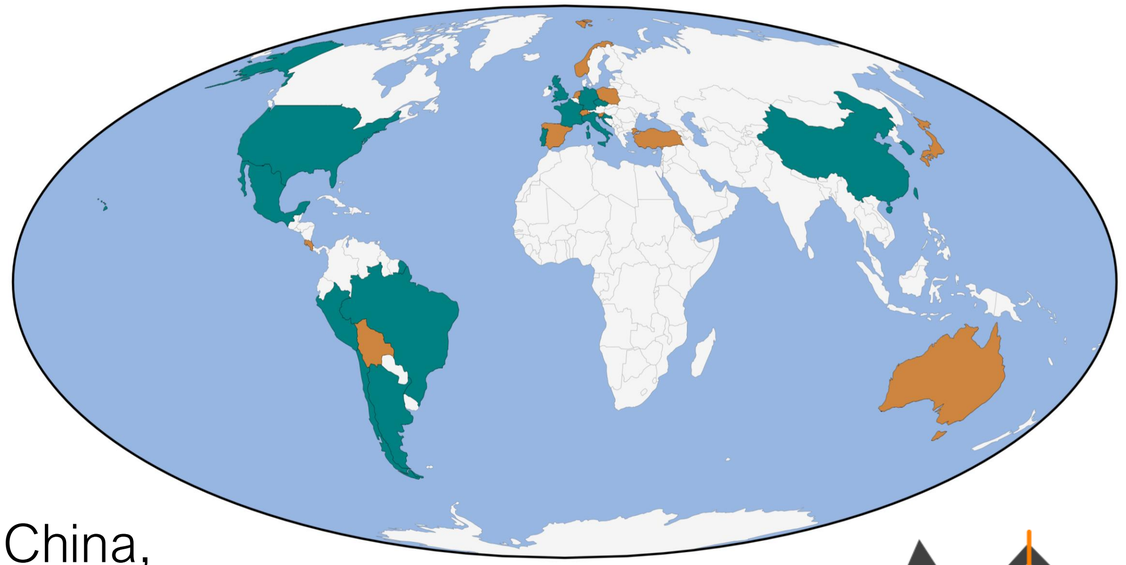
SWGO : The Southern Wide-field Gamma-ray Observatory

South We GO !



The SWGO collaboration

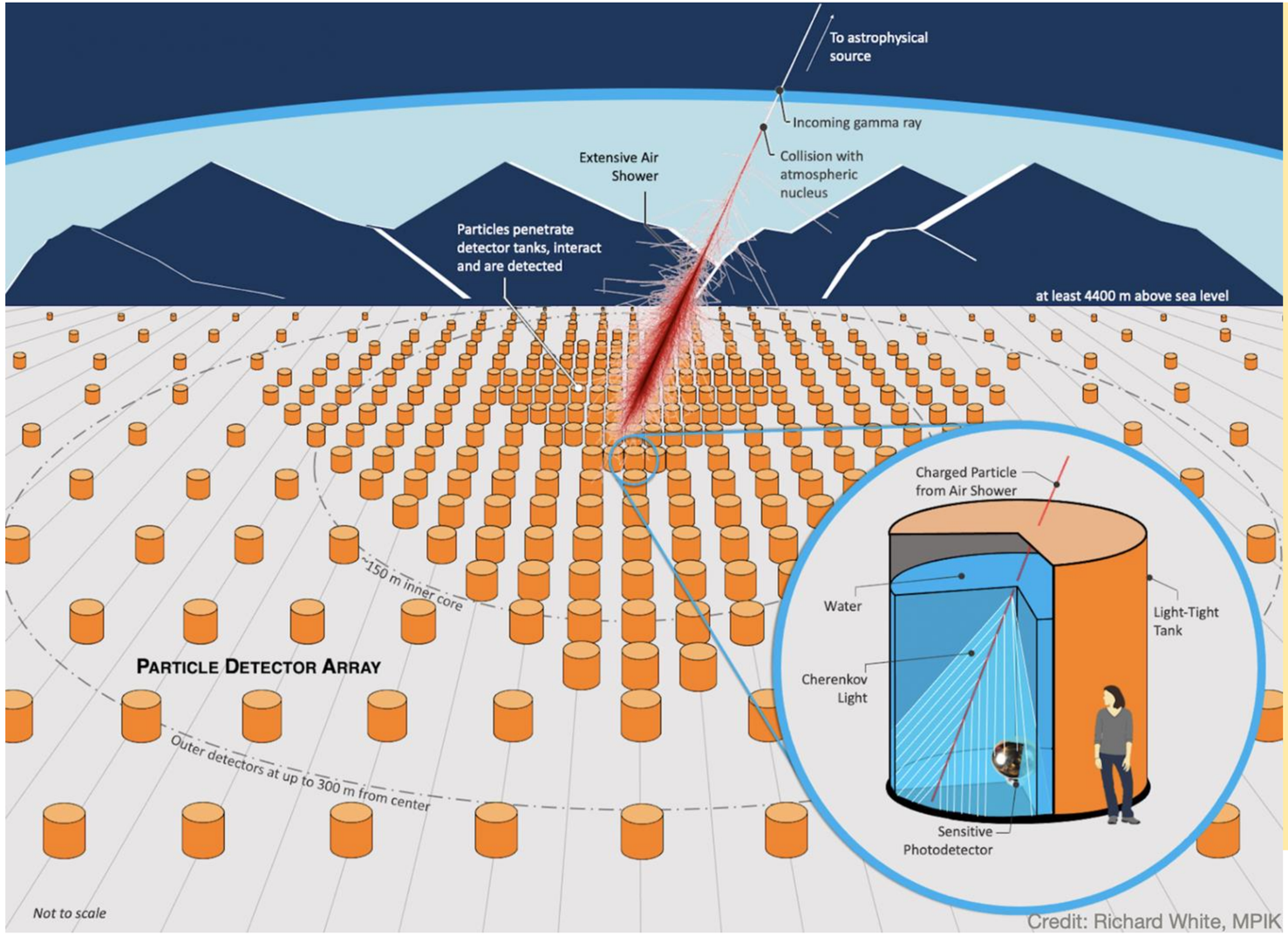
- Founded in 2019
- 90 research institutions from 15 countries
- **Full partner institutes** in Argentina, Brazil, Chile, China, Croatia, Czech Republic, France, Germany, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom and United States
- **Supporting scientists** in 10 additional countries

SWGO
The Southern Wide-field Gamma-ray Observatory

Spokesperson : Jim Hinton, MPIK Heidelberg, Germany

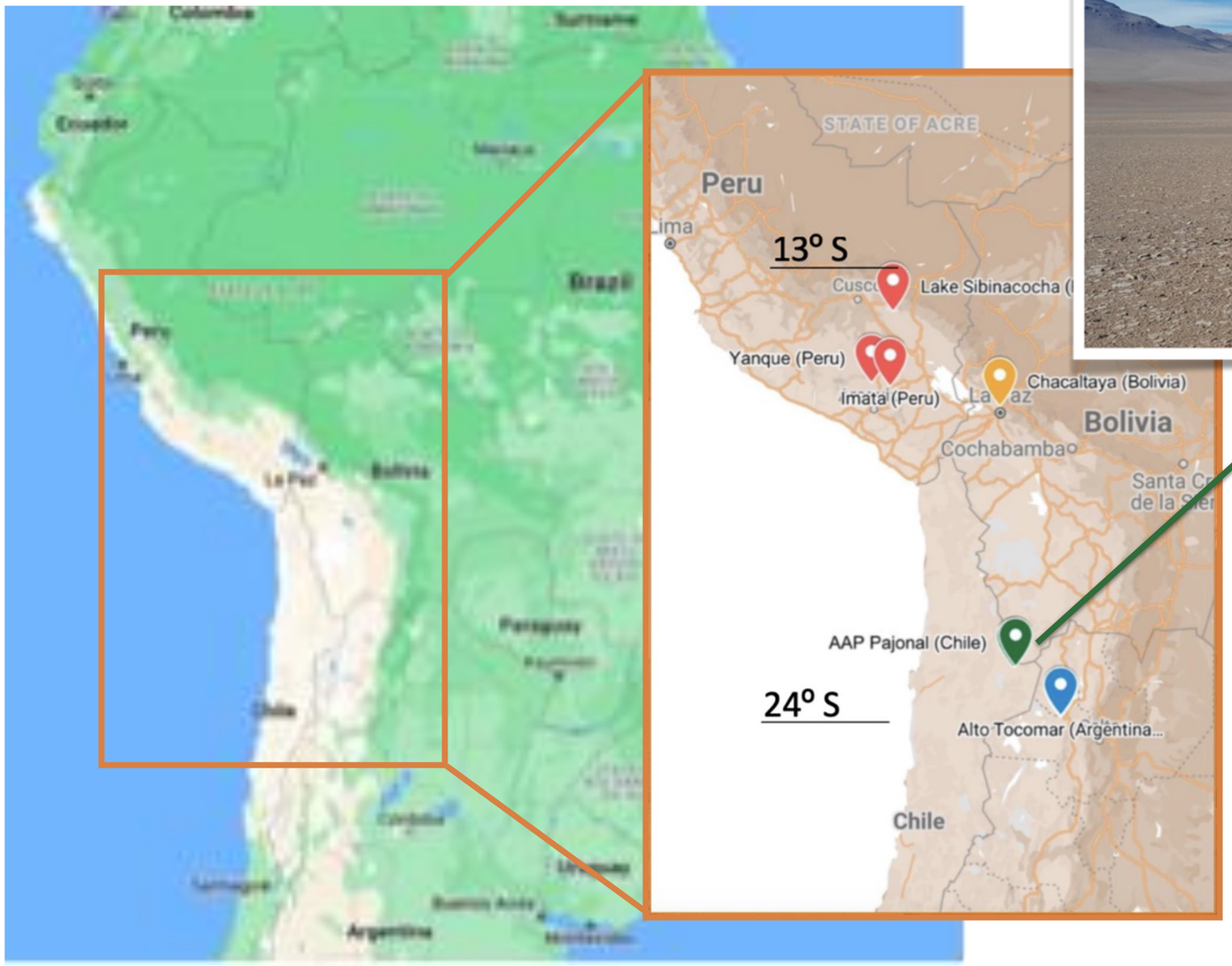
Vice-spokesperson : Petra Hüntemeyer, MTU, Michigan, US
Ulisses Barres de Almeida, CBPF, Brazil

SWGO experiment concept



- **Ground-level** particle detection
- **~100% duty cycle**
- ~1 sr wide field of view
- In: Atacama Astronomical Park, Chile
- Altitude: 4770 m.
- Energy: 100s GeV - ~PeV
- Water Cherenkov detector units.

SWGO - Site selection !



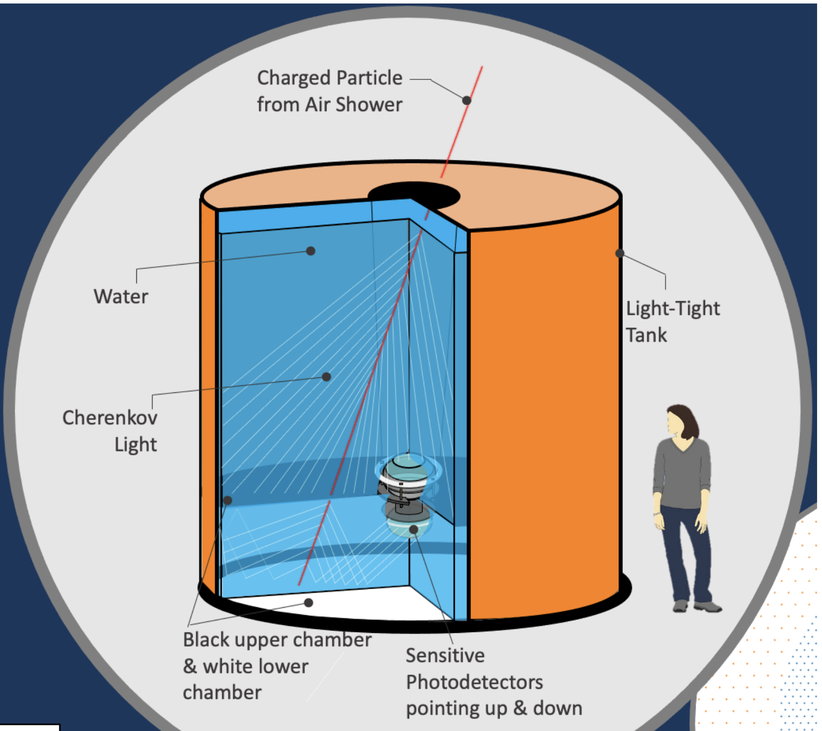
Pampa La Bola, in the Atacama Astronomical Park. Credit : Cesar Ocampo, AAP

- Pampa La Bola, Atacama Astronomical Park, Chile (neighbour of ALMA)
- altitude : 4700 m
- water from the nearby city Calama
- back-up site : Imata in Peru

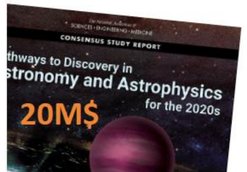
SWGO – Project status

Rapidly reaching end of R&D phase

- Excellent gamma/hadron separation from dual layer approach
- Aim for small Nb of WCDs on site during 2025
- Major funding applications in prep.



		SWGO R&D Phase Milestones
2019 ✓	M1	R&D Phase Plan Established
✓	M2	Science Benchmarks Defined
2020 ✓	M3	Reference Configuration & Options Defined
✓	M4	Site Shortlist Complete
2022 ✓	M5	Candidate Configurations Defined
✓	M6	Performance of Candidate Configurations Evaluated
2024 ✓	M7	Preferred Site Identified
→	M8	Design Finalised
	M9	Construction & Operation Proposal Complete

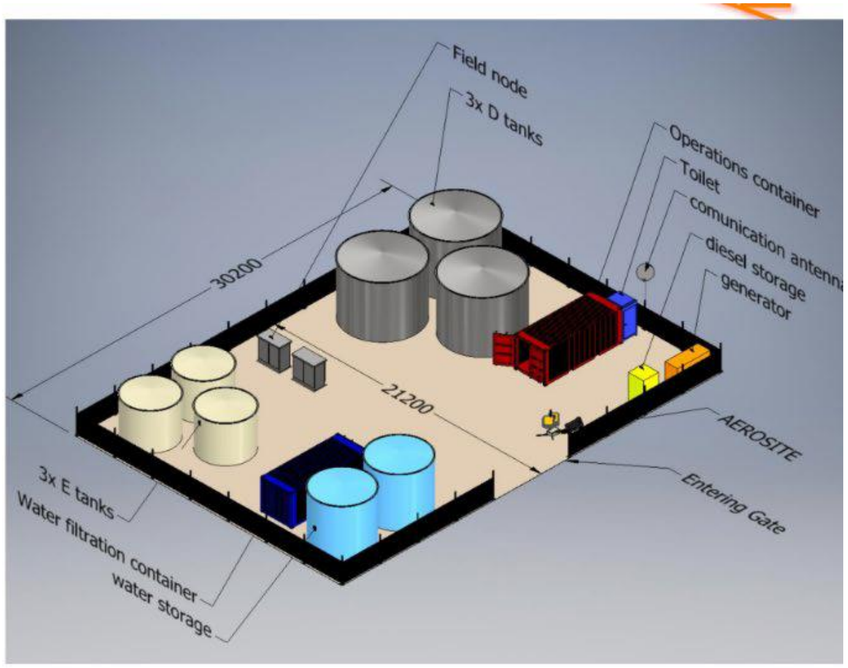


- R&D Phase
  - → Kick off meeting Oct 2019
  - → Expected completion 2025
    - ✓ Site and Design Choices made
  - → Then:
- Preparatory Phase
  - → Detailed construction planning
  - → **Engineering Array in 2026**
- (Full) Construction Phase
  - → From 2027

- Roadmaps
  - → US Decadal Review
  - → SNOWMASS, APPEC, Astronet

SWGO – The pathfinder

- 2x E tank + 2x D tank (+1 for each as expansion)
- 2x containers 20ft (water filtration + operations)
- 2x 50kl tank for dirty water (total of approx. 1x D-tank)
- 2x field node in MPIK version (1,8x1,2m concrete base)
- Toilet (1,4x1,2x2,5m)
- Generator (model to be defined actual 1x2,6x1,5m)
- Generator diesel tank (1,2x1,2x2m)
- Draft for antenna near operations container
- Fencing with entering gate 6m width (need to define specs of fencing)
- AEROSITE positioned far from metal (>2m) and no shadowing area
- Approx 30x21 area



Timeline :

R&D plan

Site selection

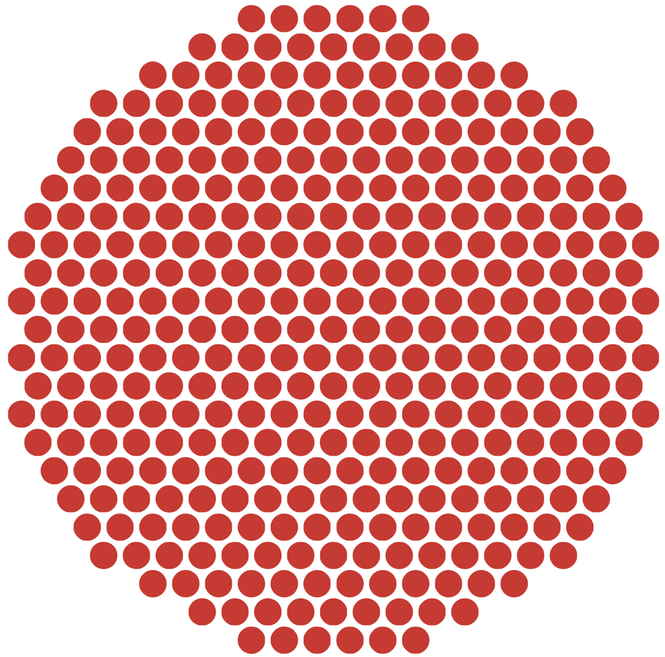
Design finalisation

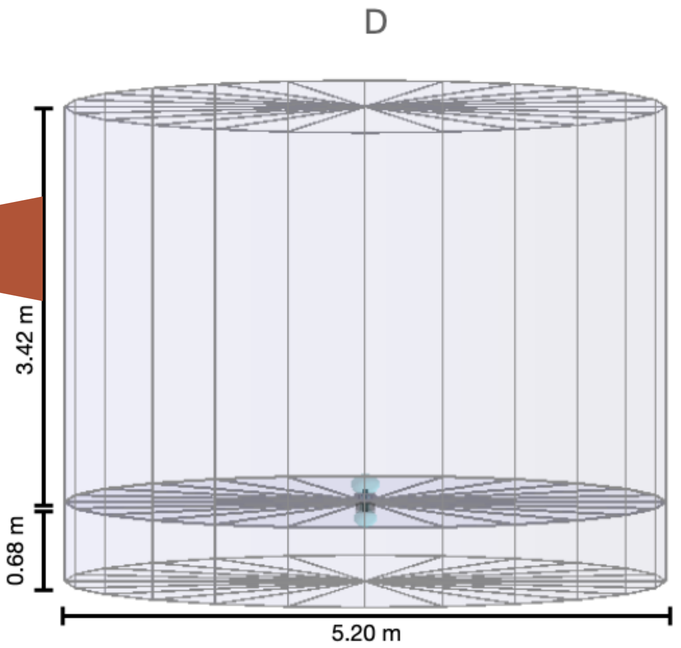
Funding applications

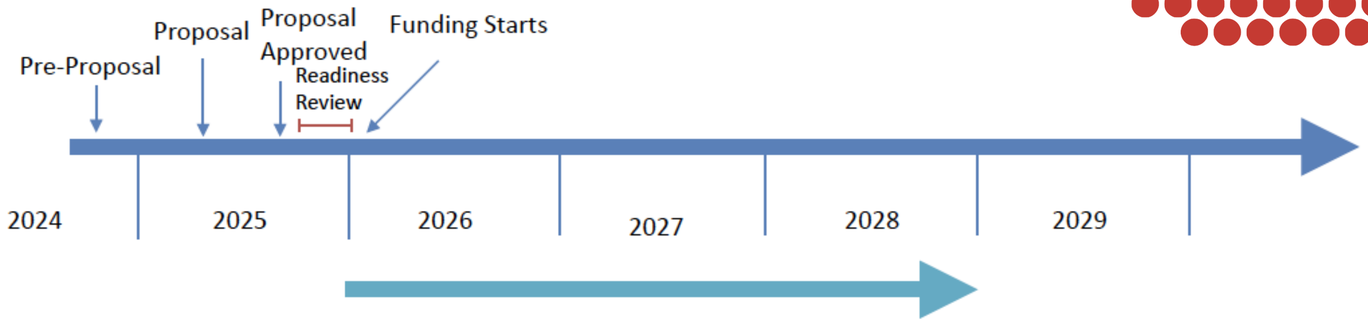
Building of an engineering array (1-10%)

Full construction phase

SWGO-A





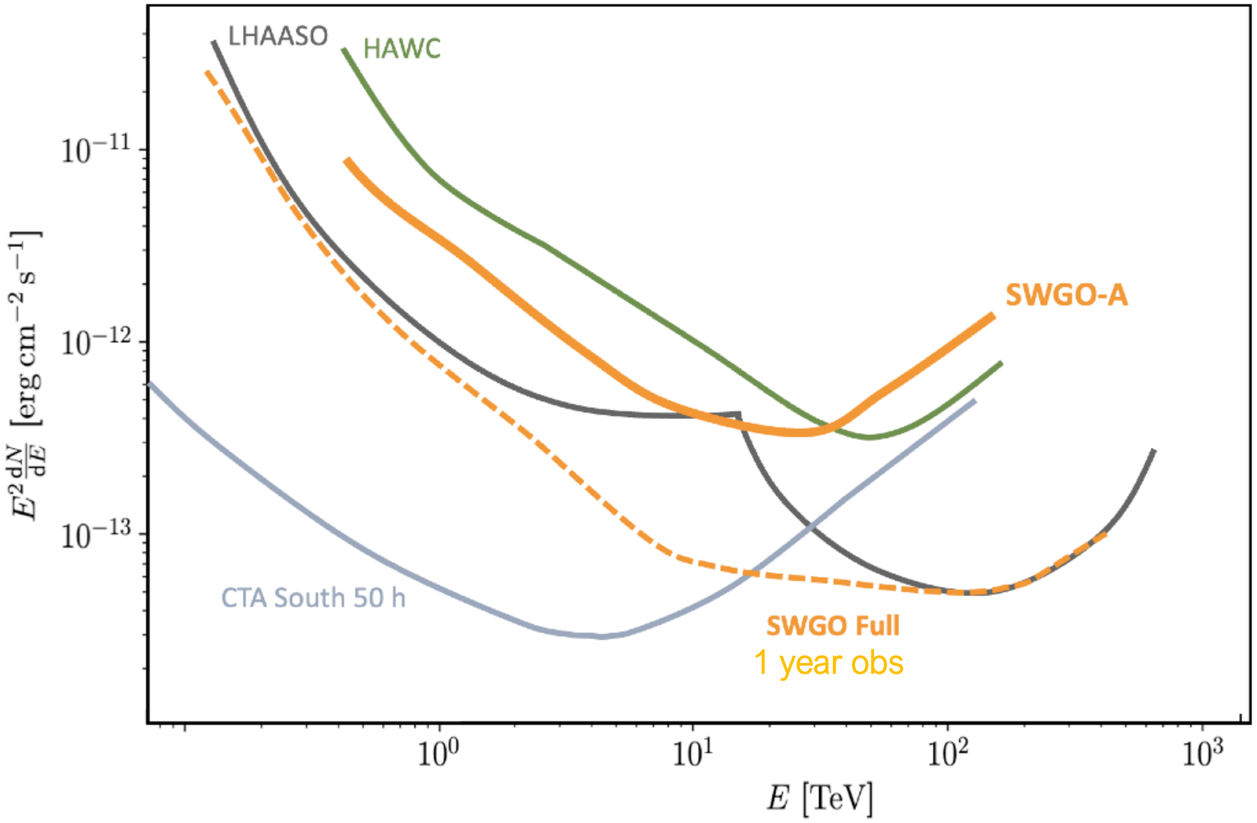


- 3-year schedule:
- PY1: Hire needed people, Prepare site, Prepare for purchases.
- PY2: Build majority of tanks: ~2/day rate
- PY3: Complete tanks, Integrate all components, complete

Schedule dependent on Funding proposals under review (NSF, Brazil…)

Sensitivity of SWGO-A

Between HAWC and LHAASO (1 – 20 TeV)



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French contribution

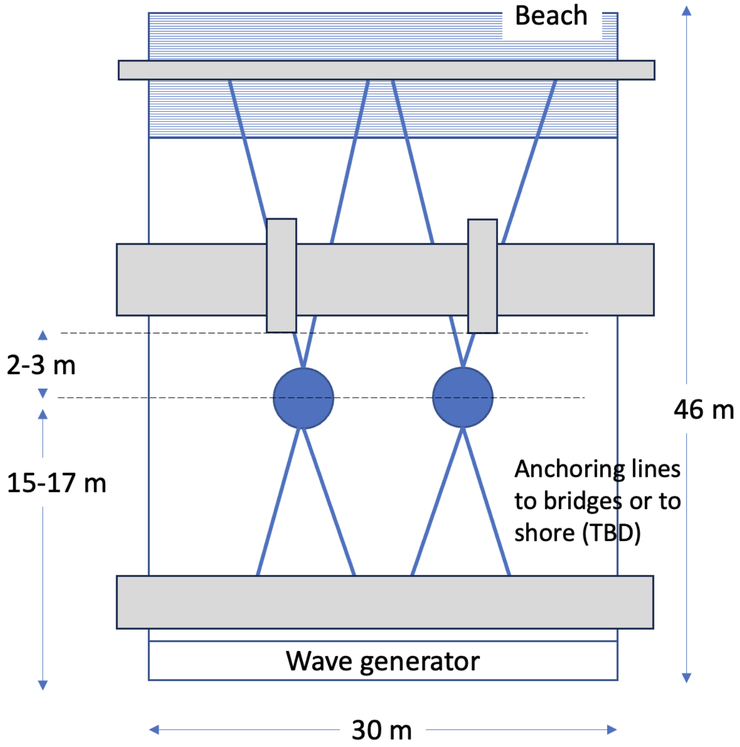
- 4 French researchers joined the SWGO collaboration in June 2024 + 1 supporting scientist :
  - Marianne Lemoine-Goumard (french representative) and Armelle Jardin-Blicq (LP2iB),
  - Régis Terrier and Bruno Khélifi (APC) - Lead Developer and Project Manager of gammapy,
  - Fabian Schlüsser (CEA, supporting scientist)

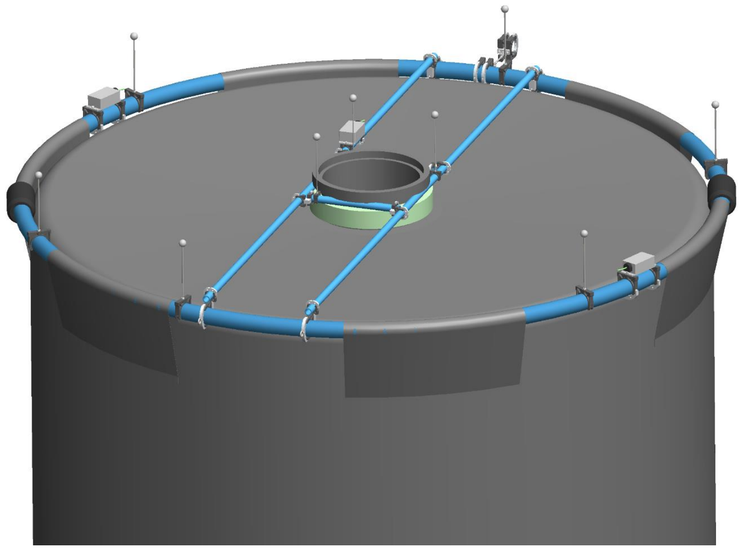
- **Master Projet IN2P3 since June 2024**

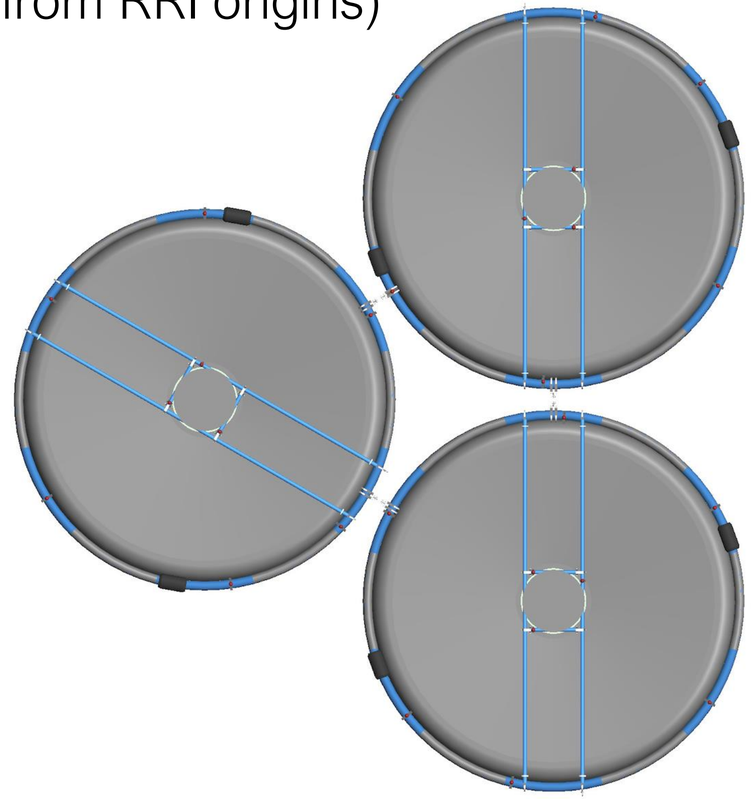
- Contributions :
  - Instrumentation : coordination with Central Nantes for bladder tests in wave basins,
    : recycling of PMTs from Antares (ECAP, Erlangen),
    : help with electronic tests and prototypes in Chile
    : computer cluster on site and real time analysis for flare alerts (ANR rejected)
    : solar system powering the cluster for the pathfinder (AAP under review)
  - Software : implementation of IRFs and background models in gammapy,
  - Science topics : extended sources (SNR, PWNe, pulsar halos),
    : star forming regions,
    : variable sources (microquasar, novae, gamma-ray bursts)
    -- synergy with CTAO --

Tests of the bladders in Nantes

- Idea @MPIK to have a 2nd phase focusing on the PeV domain using a lake (natural or artificial)
- Bladders deployed near the surface => require to test the performance/durability of the set up and material against potential wind/waves
- Armelle, Thierry & Marianne involved in the discussion since June 2024
- Tests from March 30th to April 4th: Thierry & Marianne on site (funding from RRI origins)







Synergy CTAO - SWGO

PeVatrons

Inputs

- A common open data format: GADF (the VHE standard)
- IRFs of CTA and SWGO
- An open library: Gammapy

Goals

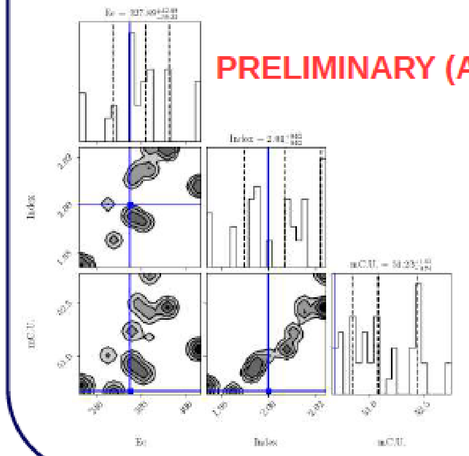
- Ability to detect a 0.1° source with a spectrum made with a PowerLaw and an ExponentialCutoff

Parameters

- Flux: 5% Crab Unit above 1TeV
- Index: -2
- Ec: 300 TeV (from the knee)
- 10h of CTA, 1yr of SWGO

SWGO

N_{sim}=231 - N_{fitted}=231 (100%)
N_{PL}=188 (81.4%)
N_{ExpPL}=43 (18.6%)



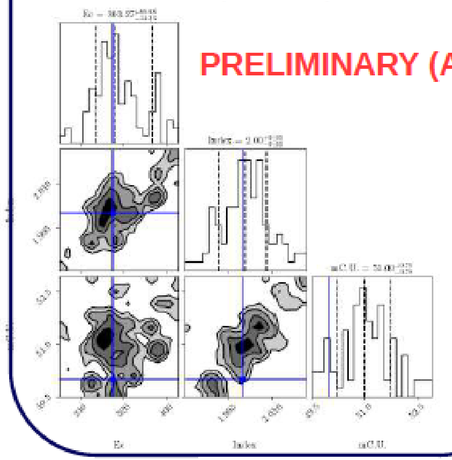
PRELIMINARY (A4)

CTA

N_{sim}=231 - N_{fitted}=231 (100%)
N_{PL}=231 (100%)
N_{ExpPL}=0 (0%)

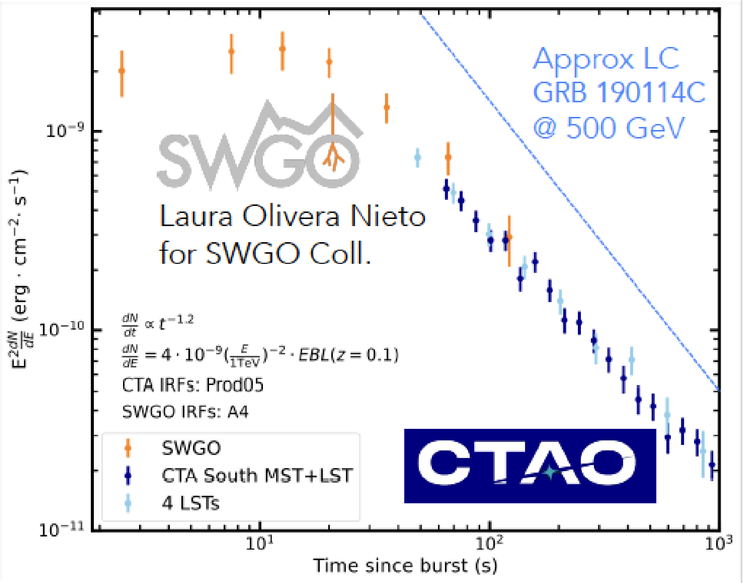
CTA + SWGO

N_{sim}=116 - N_{fitted}=116 (100%)
N_{PL}=18 (15.5%)
N_{ExpPL}=98 (84.5%)



PRELIMINARY (A4)

Transients



- IACTs
  - **Sensitivity**: day-timescale afterglow measurements (HESS, GRB 190829A)
  - **Low energy access**: high redshift early times (MAGIC, GRB 190114C)
- Ground particle
  - **No trigger needed, high duty cycle:** early stages (LHAASO: BOAT)
- CTAO+SWGO is fantastic combination

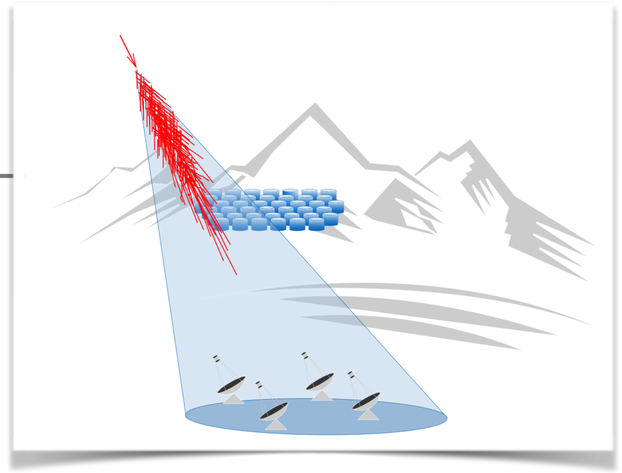
Human ressources @ LP2i Bordeaux

- Contribution to SWGO slowly increases
- Higher contribution to CTAO
- Stay involved in Fermi at least until 2028 for MWL coverage

			Fermi				HESS				CTA				SWGO				Total			
NOM	**Prénom**	**Statut**	**2025**	**2026**	**2027**	**2028**	**2025**	**2026**	**2027**	**2028**	**2025**	**2026**	**2027**	**2028**	**2025**	**2026**	**2027**	**2028**	**2025**	**2026**	**2027**	**2028**
CLEMENT	Aimie	Doct.	0,5																0,5	0	0	0
DUMORA	Denis	UBx	0,1	0,1	0,1	0,1					0,4	0,4	0,4	0,4					0,5	0,5	0,5	0,5
FAUVERGE	Paul	Doct.	0,5	0,5			0,5	0,5											1	1	0	0
GRONDIN	Marie-Hélène	UBx	0,2	0,2	0,2	0,2	0,15	0,15	0,1	0	0,15	0,15	0,2	0,3					0,5	0,5	0,5	0,5
JARDIN-BLICQ	Armelle	CNRS					0,35	0,3	0,3	0,3	0,6	0,6	0,6	0,6	0,05	0,1	0,1	0,1	1	1	1	1
LEMOINE-GOUMARI	Marianne	CNRS	0,35	0,3	0,3	0,25	0,4	0,35	0,25	0,2	0,2	0,2	0,25	0,3	0,05	0,15	0,2	0,25	1	1	1	1
LOTT	Benoit	CNRS	1	1															1	1	0	0
REPOSEUR	Thierry	CNRS									0,8	0,45							0,8	0,45	0	0
Somme des FTEs:			2,65	2,1	0,6	0,55	1,4	1,3	0,65	0,5	2,15	1,8	1,45	1,6	0,1	0,25	0,3	0,35	6,3	5,45	3	3

NB: *T. Reposeur passera au 4/5e en 2025 et prendra sa retraite en milieu d'année 2026*

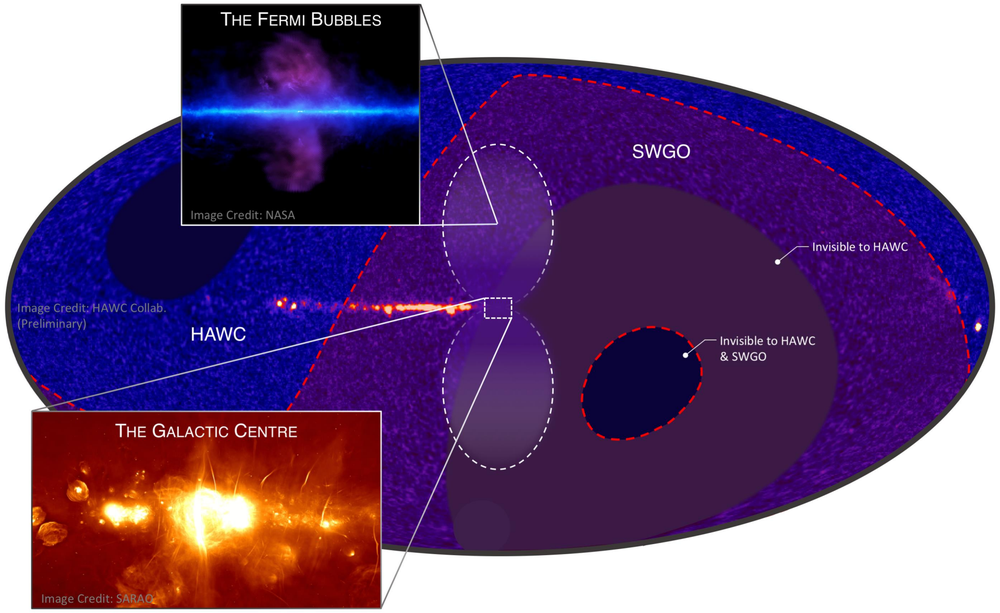
Conclusions



- **Two complementary detection techniques to detect γ rays from the ground**
- HAWC and LHAASO covering the Northern hemisphere.
  SWGO will join in the Southern hemisphere in a few years.
- Complementarity with CTAO for transient, very extended

  sources and PeVatrons) ; synergy with neutrino and GW alerts
- Estimated cost : ~65 M USD - NSF application for 20 M USD

  Preliminary proposal accepted ! Full proposal for June 5th
- 4 French members, 2 @ LP2i Bordeaux



- Up to now, **no French institute involved in WCD experiments** (only a few individual contributions)

Thank you for your attention

Instruments around the world

VERITAS

HAWC

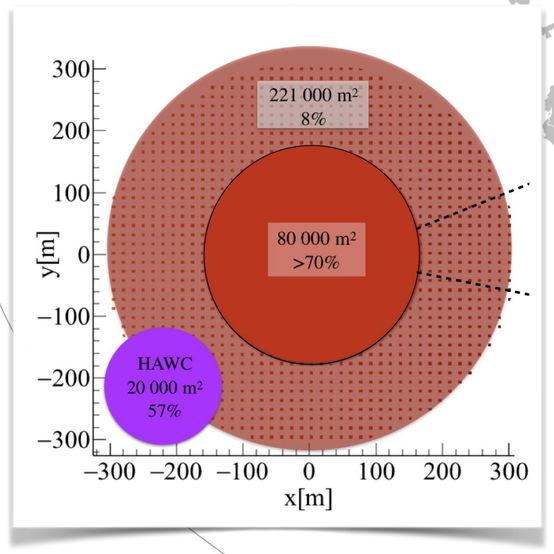
MAGIC

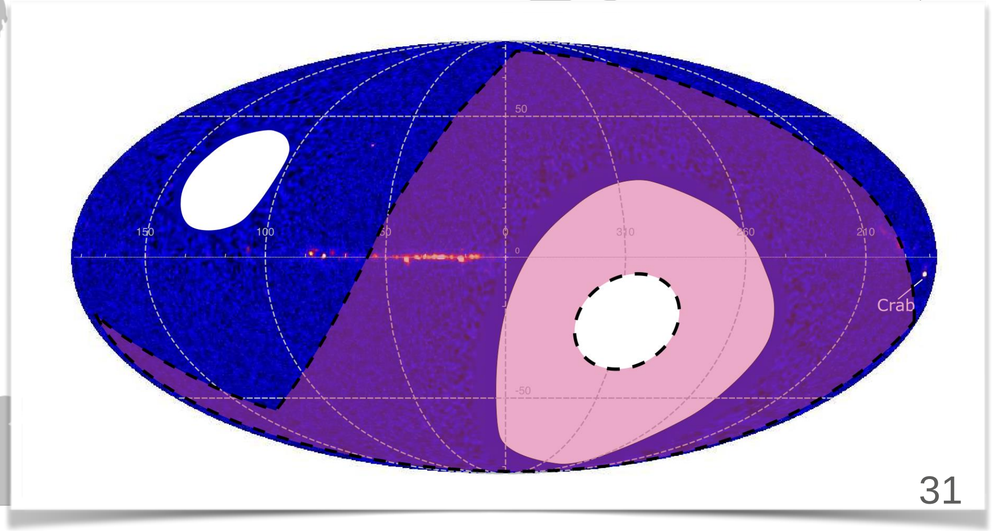
SWGO

H.E.S.S.

Tibet/ARGO-YBJ

LHAASO





WCD IACT

SWGO-A total cost

			Nominal			Upper bound		
			Pampa La Bola	Alto Tocomar	Imata	Pampa La Bola	Alto Tocomar	Imata
Construction								
1. Detectors								
	1.1 Water Cherenkov Detector Mechanics	1.1.1 Procurement	3,024	3,024	3,024	3,629	3,629	3,629
		1.1.2 Transport	19	29	19	21	32	21
		1.1.3 Assembly	118	120	52	165	167	84
		1.1.4 Filling with water	134	136	60	187	190	95
	1.2 Photo-detectors	1.2.1 Procurement	1,316	1,316	1,316	1,580	1,580	1,580
		1.2.2 Transport	6	10	6	7	11	7
		1.2.3 Deployment in WCD	11	11	5	15	15	8
	1.3 Electronics Chain	1.3.1 Procurement	312	312	312	467	467	467
		1.3.2 Transport	3	5	3	4	5	4
		1.3.3 Deployment	1	1	0	1	1	0
		Total	**4,943**	**4,963**	**4,798**	**6,075**	**6,098**	**5,895**
2. Site & Infrastructure								
	2.1 Access	2.1.1 Access road	272	218	101	326	305	201
		2.1.2+2.1.3 Security	3	0	2	702	720	720
	2. 2 Power	2.2.1+2.2.2 Power solution inc. backup	1,000	2,000	550	1,400	3,200	770
	2.3 Computing & Network	2.3.1 Computing Farm	800	800	800	1,600	1,600	1,600
		2.3.2 Field Network	20	20	20	36	40	40
		2.3.3 Off-site data transfer solution	160	331	411	192	463	822
		2.3.4 Monitoring & control connection	0	0	3	0	0	4
	2.4 Water	2.4.1 Proc. & Transport	1,048	456	35	1,968	836	70
		2.4.2 Purification	600	600	600	960	840	960
		2.4.3 Storage	8	8	8	14	14	14
	2.5 Ops Buildings	2.5.1-3 Operations buildings	333	360	146	533	576	233
	2.6 Support Facilities	2.6.1 Storage building	50	105	47	80	168	75
	2.7 WCD deployment preparations	2.7.1-2 Levelling / ground prep.	420	384	192	2,023	839	532
		2.7.3 Cable trenches	50	48	11	70	86	16
		Total	**4,764**	**5,329**	**2,924**	**9,904**	**9,687**	**6,056**
		Construction Total	**9,707**	**10,292**	**7,722**	**15,979**	**15,785**	**11,951**

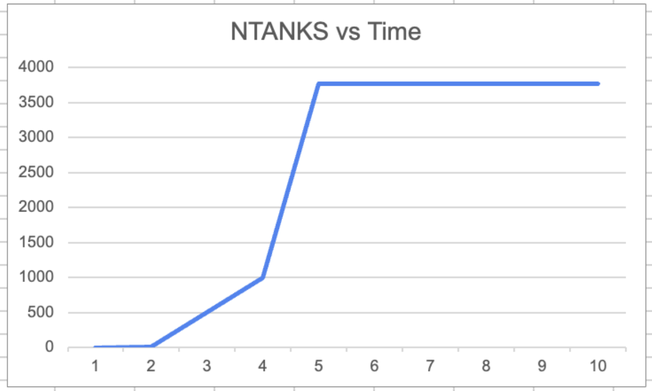
SWGO Total cost

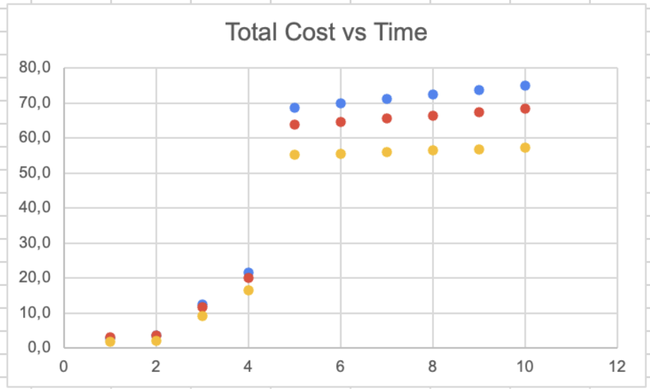
- Chile: 75 M$ cost estimate at year 10

most expensive, less risky, best LE science

Site	Altitude (m)	Relative Science Performance for Ref. Config.		Total Cost (MUSD)					Relative Performance at Fixed Cost				Risk Score
				Reference Config / Fixed UHE performance		At fixed Low Energy performance		Host Contribution	Scenario Low MUSD: 50		Scenario High MUSD: 80		
		Low Energy	U. High Energy	Nominal	Upper Bound	Nominal	Upper Bound	(not considered elsewhere)	Nominal	Upper Bound	Nominal	Upper Bound	
Alto Tocomar	4420	0,98	1,00	68	92	79	106	1,8	0,63	0,37	1,26	0,80	133
Imata	4450	1,00	1,00	57	75	65	81	0,7	0,83	0,55	1,59	1,10	116
Pampa La Bola	4770	1,20	1,00	75	106	75	102	0,0	0,54	0,30	1,10	0,65	91
Green Reference	-	1,20	1,20	55	55	55	55	5,0	0,9	0,9	1,6	1,6	48
Red Reference	-	0,80	0,80	110	110	110	110	0,0	0,25	0,25	0,6	0,6	176

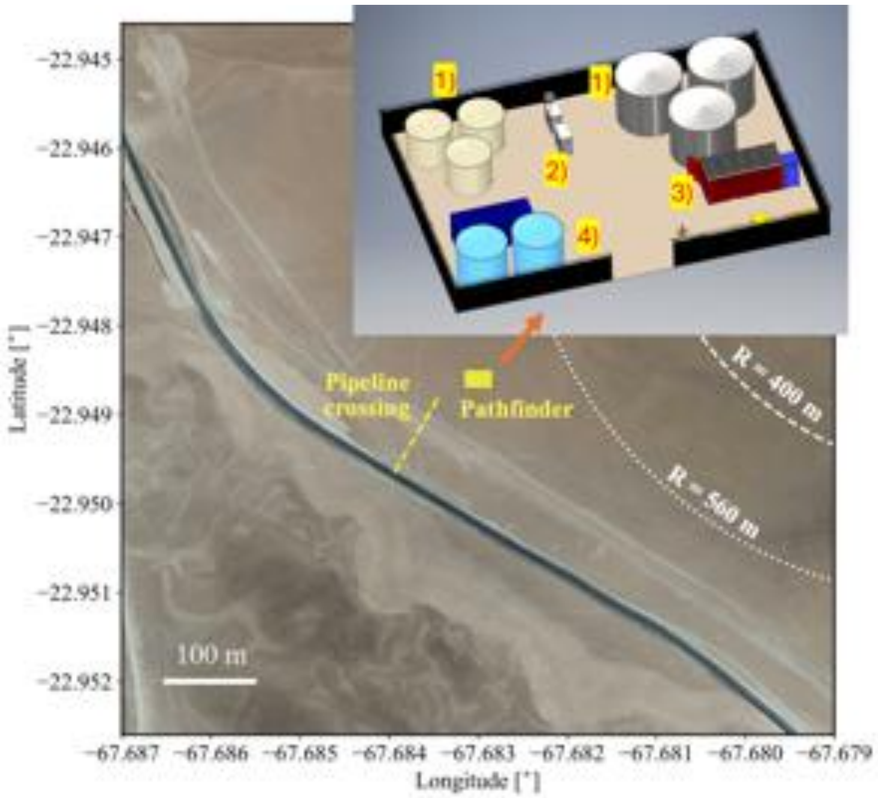
							Chile						Argentina						Peru						Relative	
Year	NTANK	Total water (m^3)	Total # Containers for Tanks	Total # Containers for PMT	#FN	Total # Containers for FN	Chile Offset Con	Chile Annual Ops	Chile Detector	Chile S&I	Chile Ops	Chile Total	Arg. Offset	Arg. Offset Ops	Arg. Detector	Arg. S&I	Arg. Ops	Argentina	Peru Offset	Peru Offset Ops	Peru Detector	Peru S&I	Peru Ops	Peru	C/P	A/P
1	0	0	0	0	0	0	2107	720	0	0	0	2,8	2455	524	0	0	0	3,0	1511	240	0	0	0	1,8	1,6	1,7
2	5	457	1	1	1	1	2107	720	76	13	1	3,6	2455	524	81	8	1	3,6	1511	240	75	2	1	2,1	1,8	1,7
3	500	45660	21	3	5	1	2107	720	6737	1271	212	12,5	2455	524	6783	775	150	11,7	1511	240	6629	210	76	9,1	1,4	1,3
4	1000	91320	42	6	10	1	2107	720	13472	2542	566	21,6	2455	524	13561	1551	399	20,1	1511	240	13255	420	204	16,4	1,3	1,2
5	3763	343636	157	20	38	4	2107	720	50683	9565	2662	68,6	2455	524	51015	5835	1876	63,8	1511	240	49868	1579	960	55,1	1,2	1,2
6	3763	343636	157	20	38	4	2107	720	50683	9565	3194	69,9	2455	524	51015	5835	2251	64,7	1511	240	49868	1579	1151	55,6	1,3	1,2
7	3763	343636	157	20	38	4	2107	720	50683	9565	3727	71,1	2455	524	51015	5835	2626	65,6	1511	240	49868	1579	1343	56,0	1,3	1,2
8	3763	343636	157	20	38	4	2107	720	50683	9565	4259	72,4	2455	524	51015	5835	3001	66,5	1511	240	49868	1579	1535	56,4	1,3	1,2
9	3763	343636	157	20	38	4	2107	720	50683	9565	4791	73,6	2455	524	51015	5835	3377	67,4	1511	240	49868	1579	1727	56,8	1,3	1,2
10	3763	343636	157	20	38	4	2107	720	50683	9565	5324	74,9	2455	524	51015	5835	3752	68,3	1511	240	49868	1579	1919	57,3	1,3	1,2

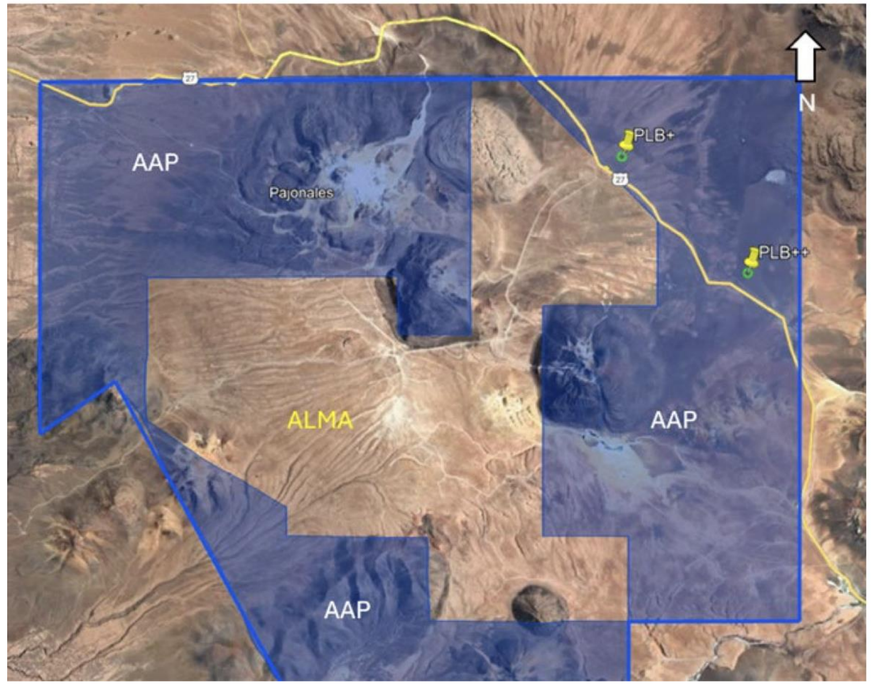


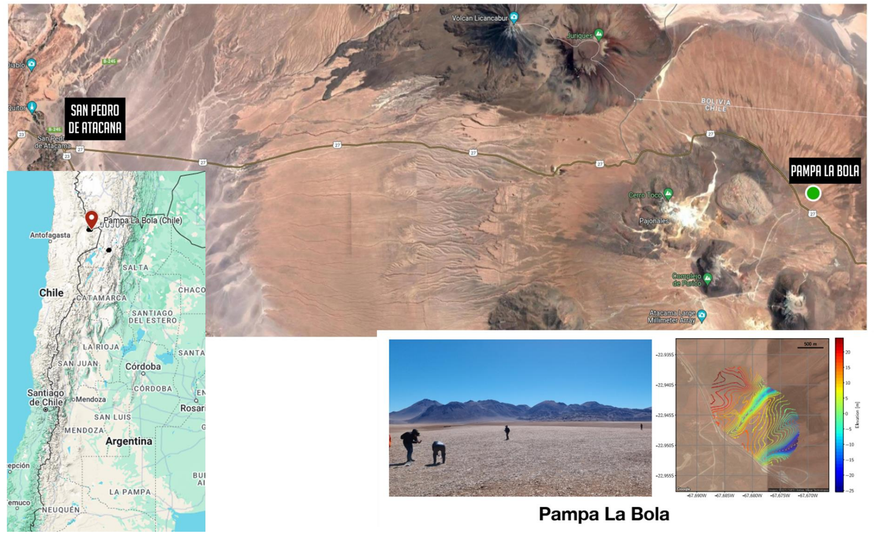


Pampa la Bola

- SWGO site PLB+ and PLB++
- Within the Atacama Astronomical Park
- Close to the ALMA Observatory: connect SWGO to a fiber optic

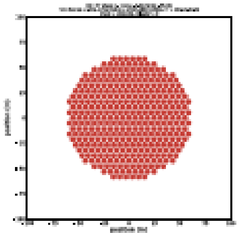


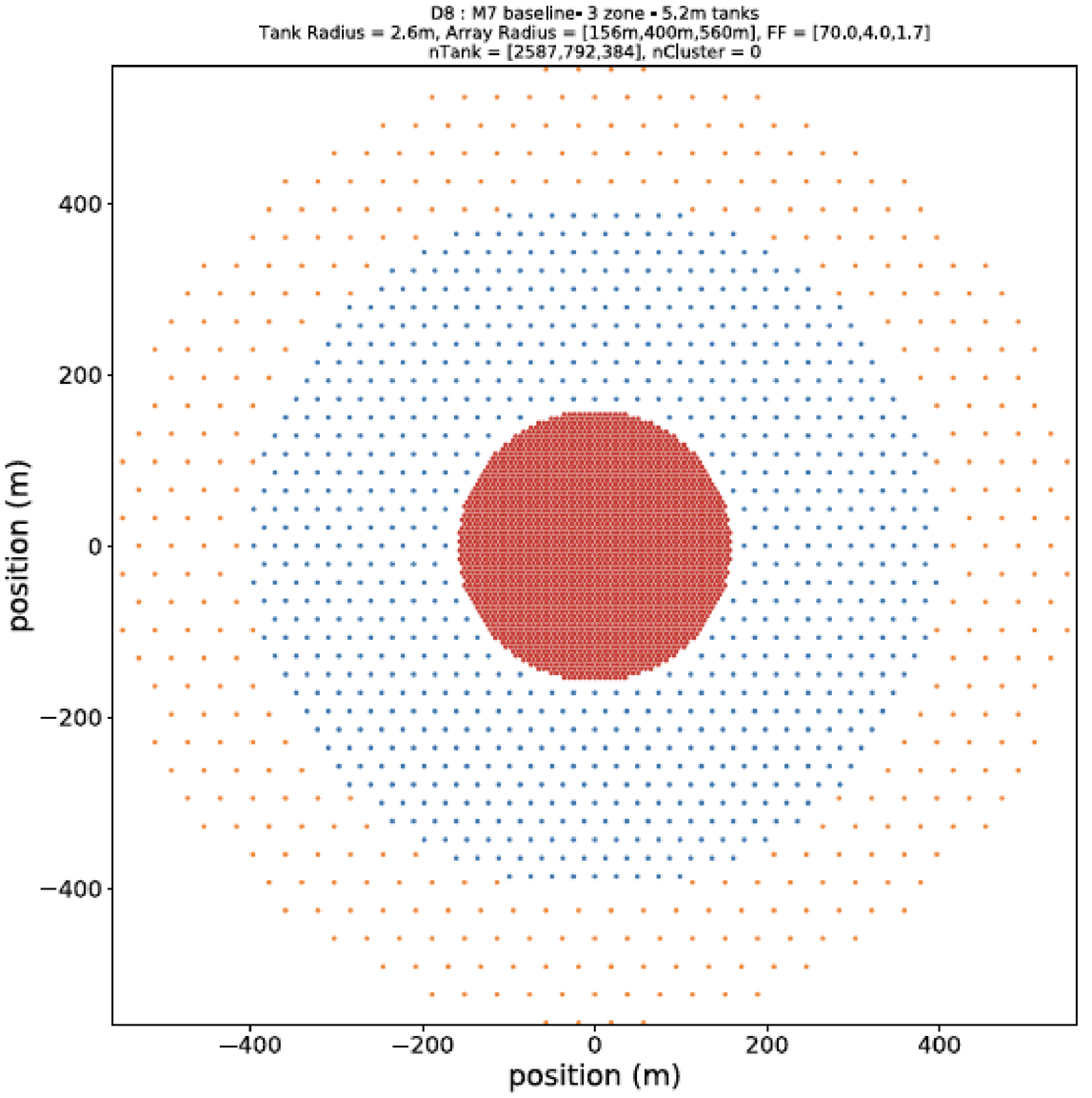




Pampa La Bola

SWGO (D8) vs SWGO-A (D9)



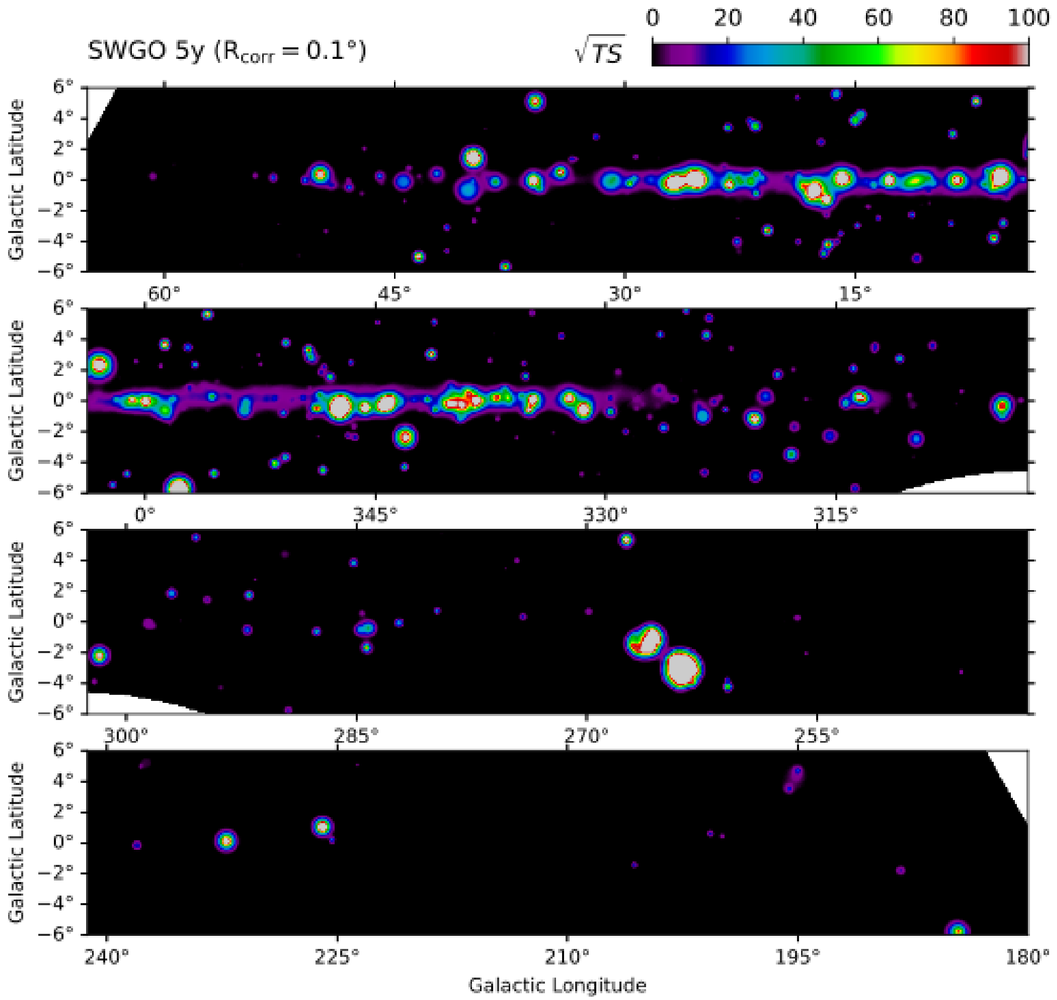


SWGO Galactic Plane Survey

- Number of detections of CTA-GPS matched by SWGO in 5 years !
- 70% sources in common => increase total number of detections by joint analysis

Table 1: Sources detectable above TS> 25 toward the Galactic plane in SWGO FoV ($-180° < l < 70°$ and $|b| < 6°$)

Catalogue	Detected sources
HGPS[(a)]	96
3HWC[(b)]	48
1LHASSO[(c)]	54
Future surveys	**Expected detections**
CTA-GPS[(d)]	461
SWGO-A (D9) 1y	66
SWGO (D8) 1y	357
SWGO (D8) 5y	488
SWGO (D8) 10y	533
SWGO (D8) 10y + CTA-GPS[(e)]	603

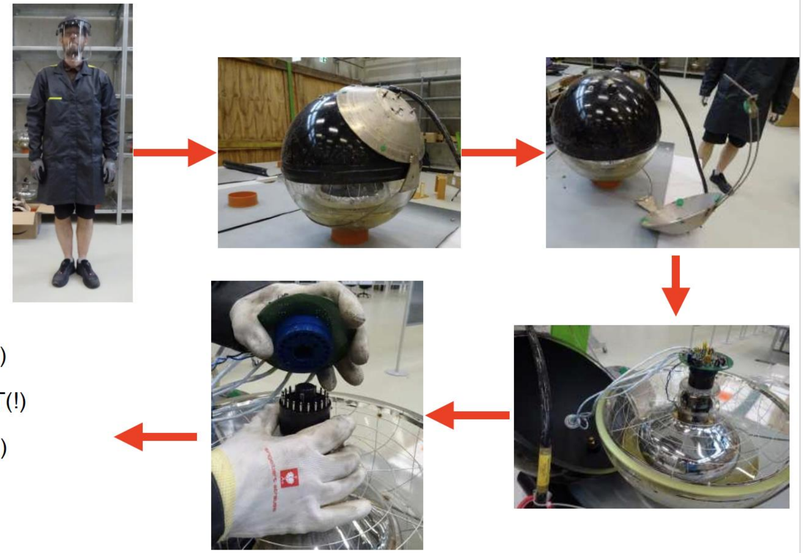


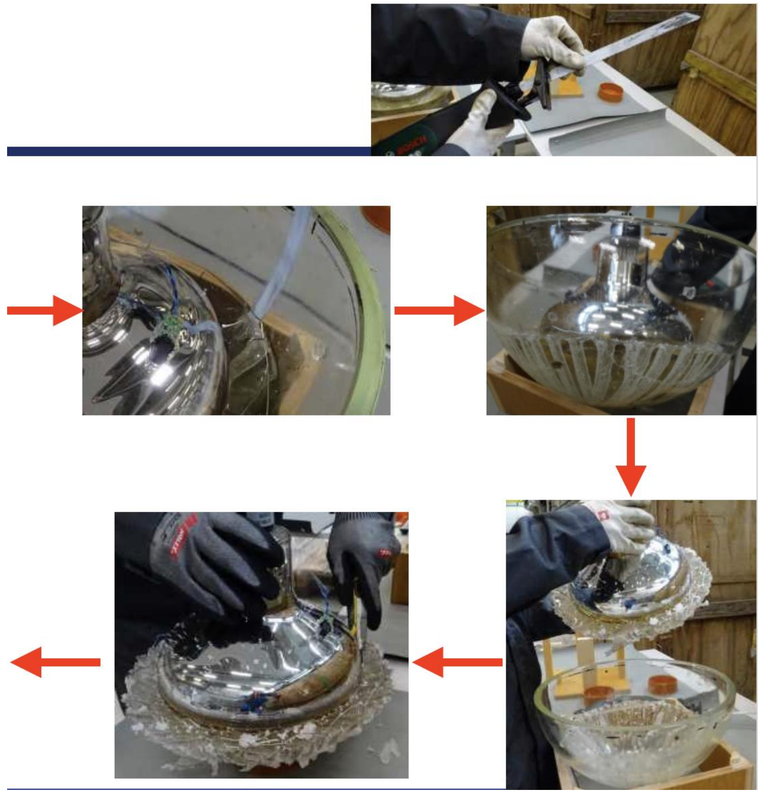
PMT extraction procedure (abridged)

Kay Graf

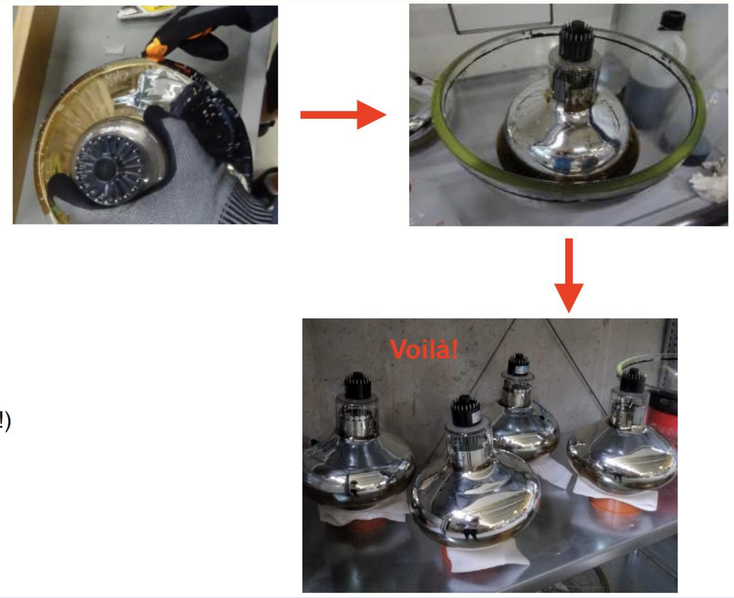
Safety is paramount!

- Open module
- Release metal holder
- Depressurise OM and remove tape
- Remove black hemisphere
- Unplug circular board
- Wire cutting (calibration LED & cage)
- Curved metal cage embedded within gel (tricky!)
- —> Use a saw close to glass; do not touch PMT(!)
- —> Cut gel close to PMT surface (do not touch!)
- Scrape surface (gently & carefully!)
- Finish with chemical solution (DIGESIL)





(!)



The GMCA tool

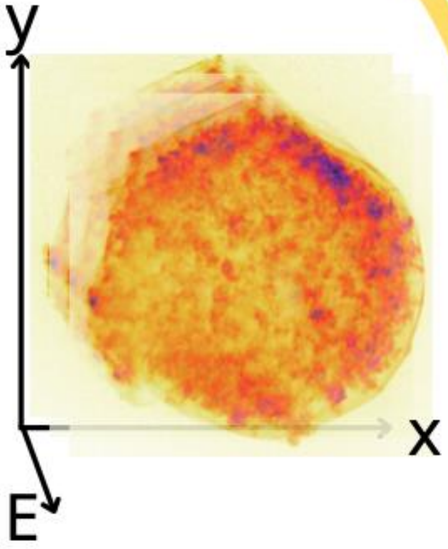
$$Cube = \sum_i Spectrum_i \; Image_i$$

General Morphological Components Analysis (GMCA) : Blind source separation in a linear combination of spectrums and images

Bobin et al, 2015

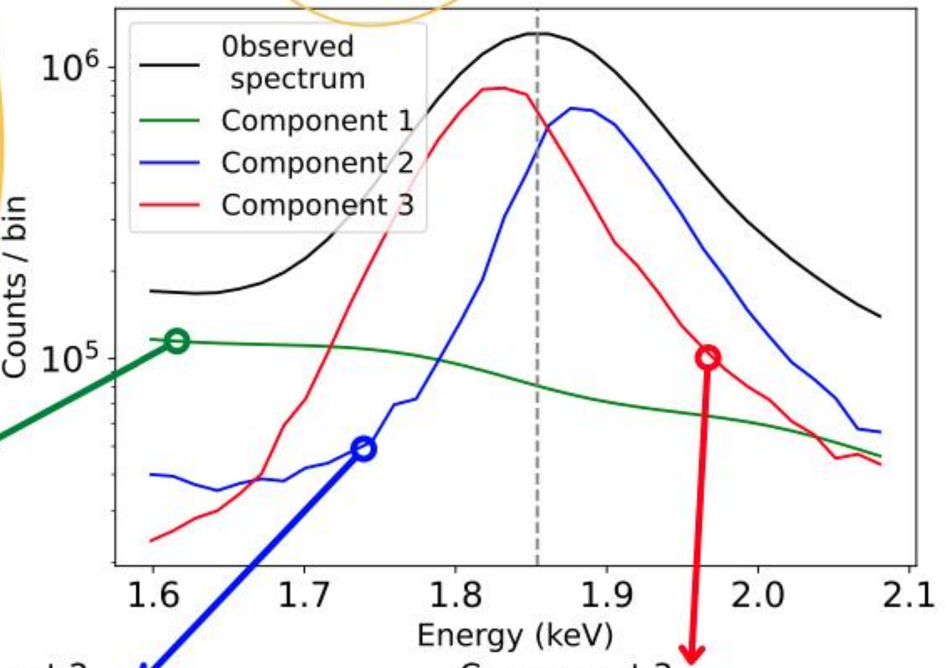
Picquenot et al, 2021

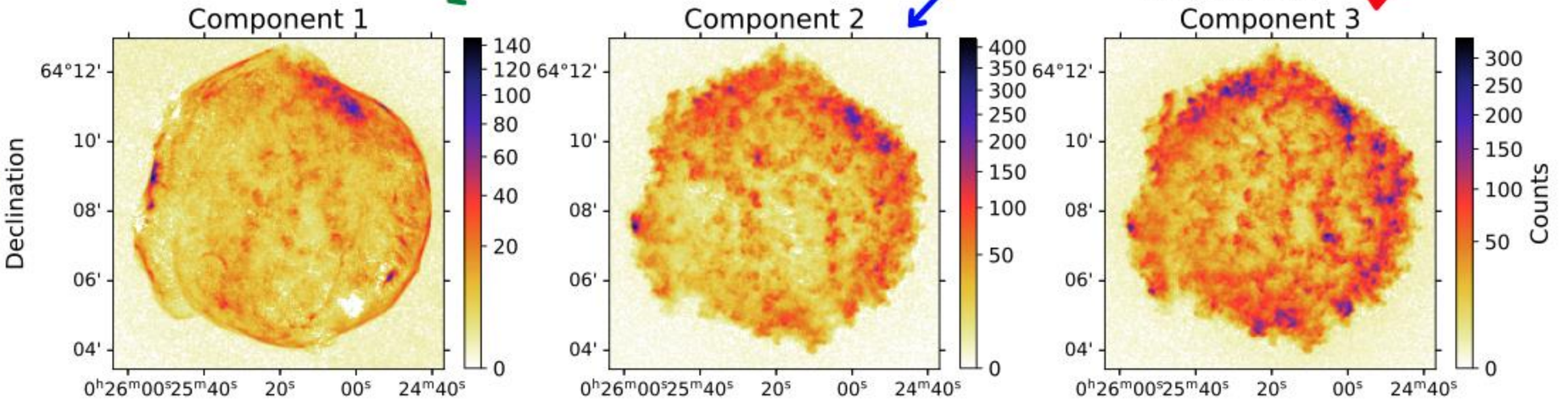
Inputs



Cube of Tycho SNR, 2009
Si line
(1.6 - 2.1 keV)
Chandra telescope

Results





Demandes de financement / thèses

- 2 Missions à Nantes financées par le RRI Origins
- ANR rejetée (PI M Lemoine) => re-soumission pour 2026
- Marie Curie Joint-doctorate submitted (co-PI M Lemoine, 4 theses dont 1 sur SWGO)
- AAP Département SMR: 9.5 keuros (PI M Lemoine)
- Projet Emergence UPC (40 keuros, PI M. Cerutti)
- Demande de these Infinity2 en 2026
- P. Cristofari intéressé par SWGO => financement du transport des OMs du CPPM vers ECAP ?
- …..

AAP SMR : Panneaux solaires

2 kW en continu jour et nuit avec de l'énergie solaire
    48 kWh sur 24 heures alimenté par une production solaire effective pendant 5 heures
10 kW de panneaux solaires
24 kWh de batteries pour le stockage
un onduleur hybride 10 kW

Demandes financières	
Détail des dépenses	**Equipements prévus**
20 panneaux solaires 500W	1600 euros
onduleur hybride 10kW	1400 euros
5 batteries 5kWh	6000 euros
Câbles et connectiques	500 euros

Total (€) : 9500 €