The Southern Wide-field Gamma-ray Observatory

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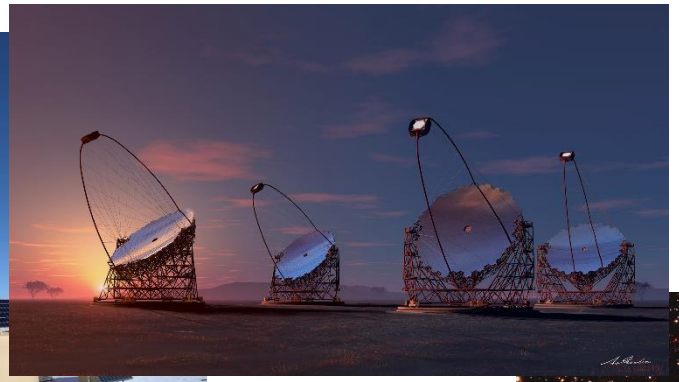
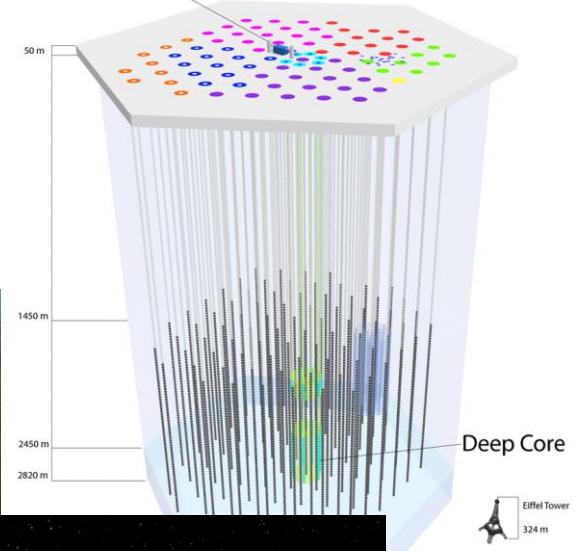
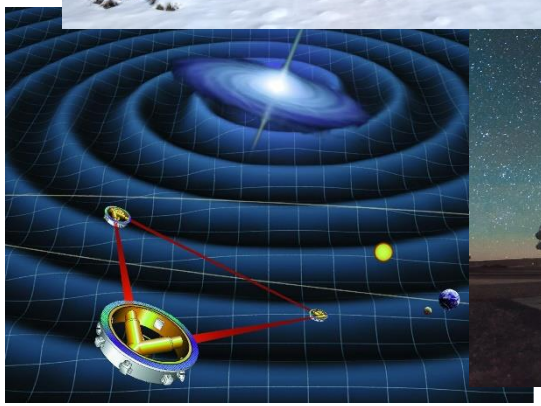
WJCF 16.6.2022

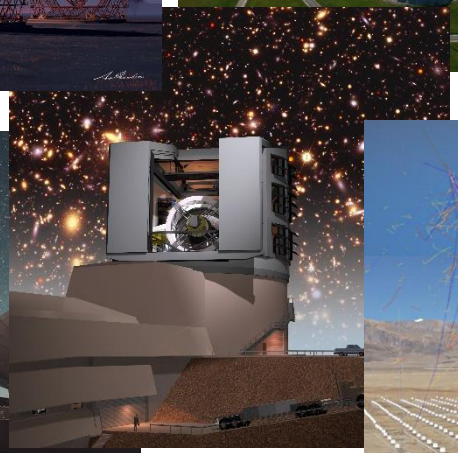
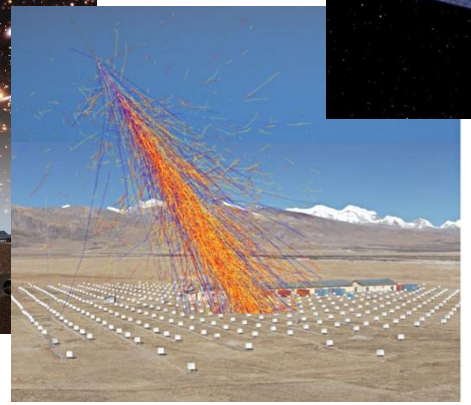
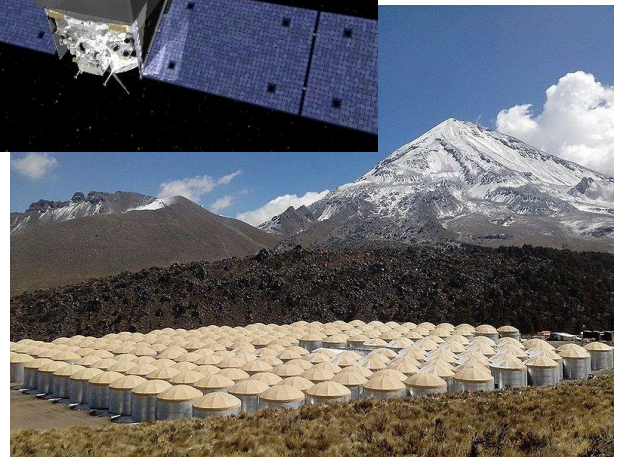
Multi-messenger era of astronomy

- Many current and upcoming experiments measuring cosmic rays, neutrinos, gamma rays and gravitational waves
- Creating a comprehensive picture about processes in/near astrophysical objects

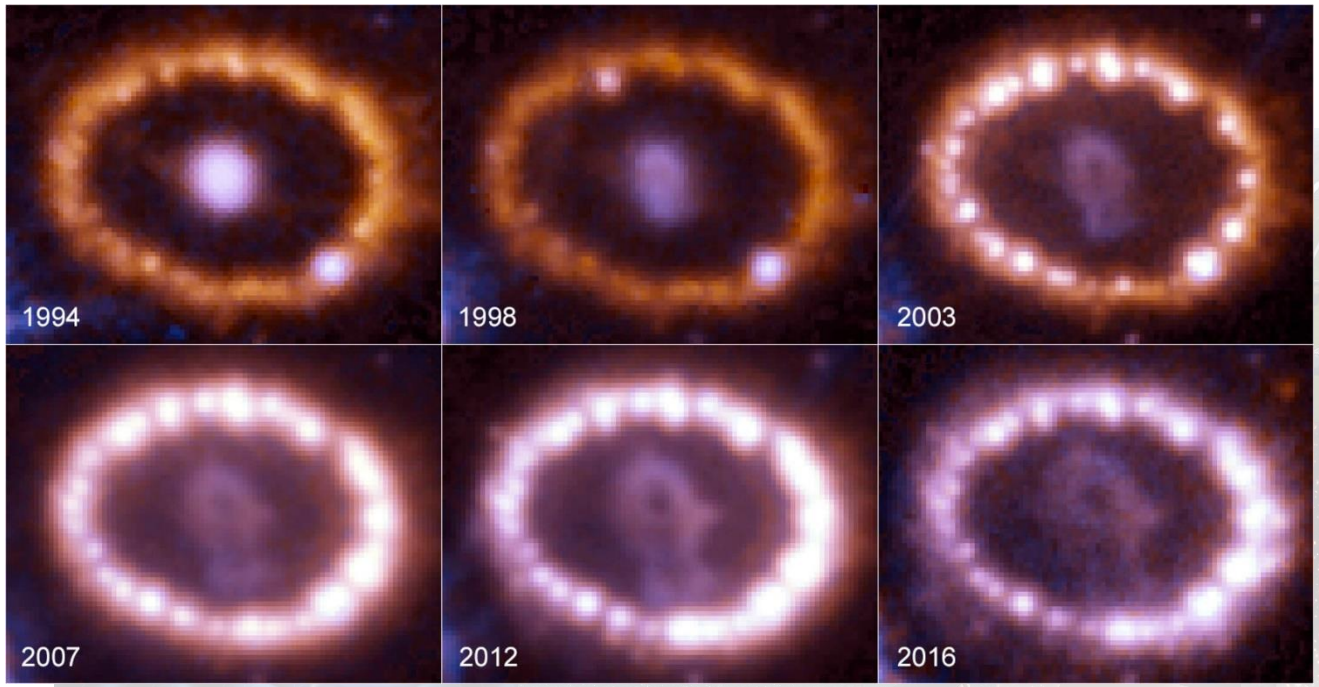


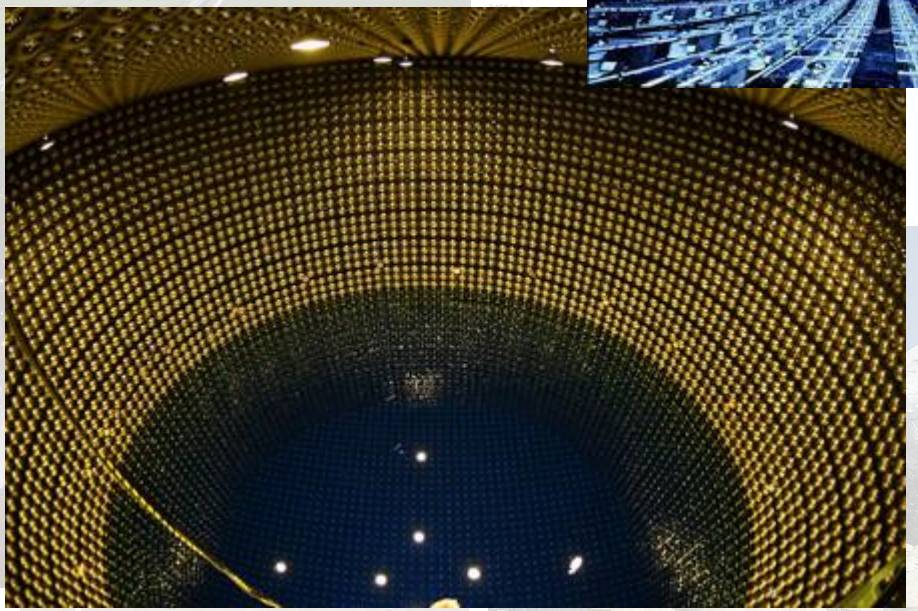



Multi-messenger era of astronomy

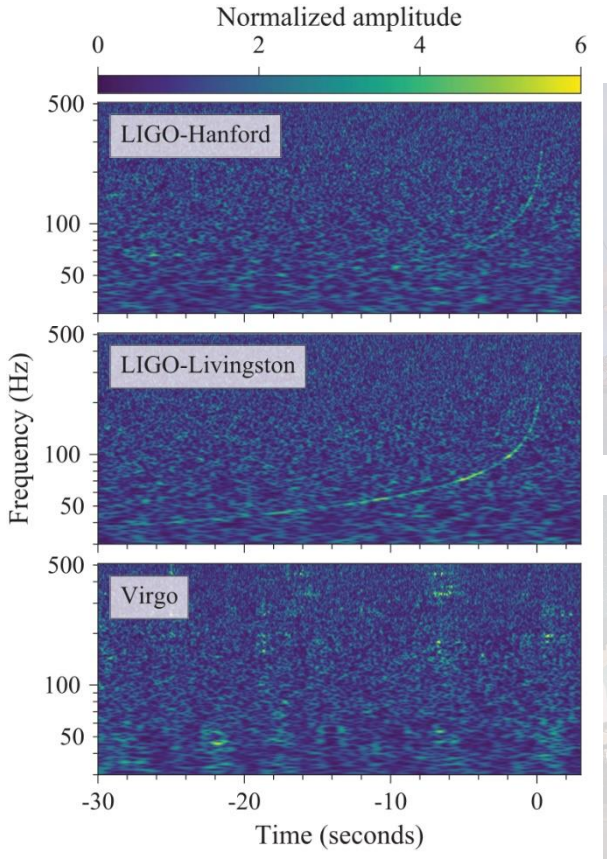
- SN 1978 A – neutrinos and electromagnetic signal

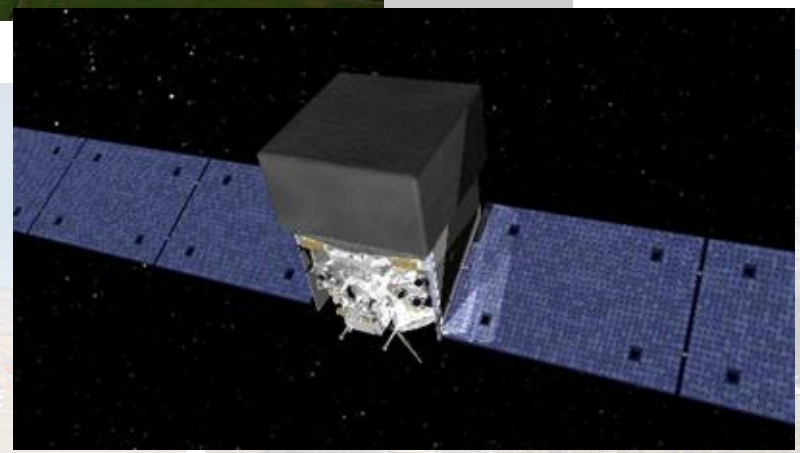




Multi-messenger era of astronomy

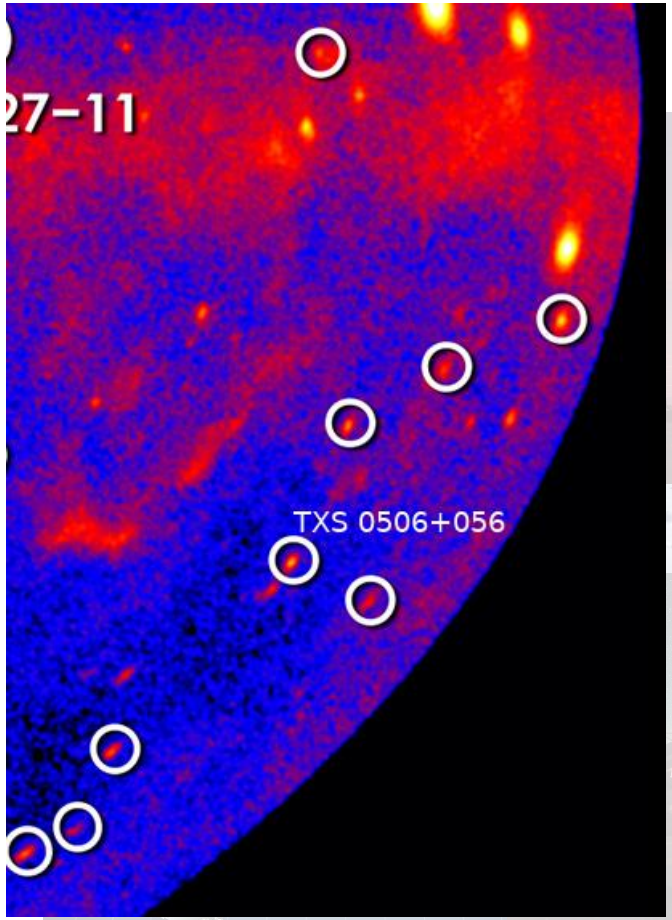
- Neutron star merger 2017
  - GW and electromagnetic signal

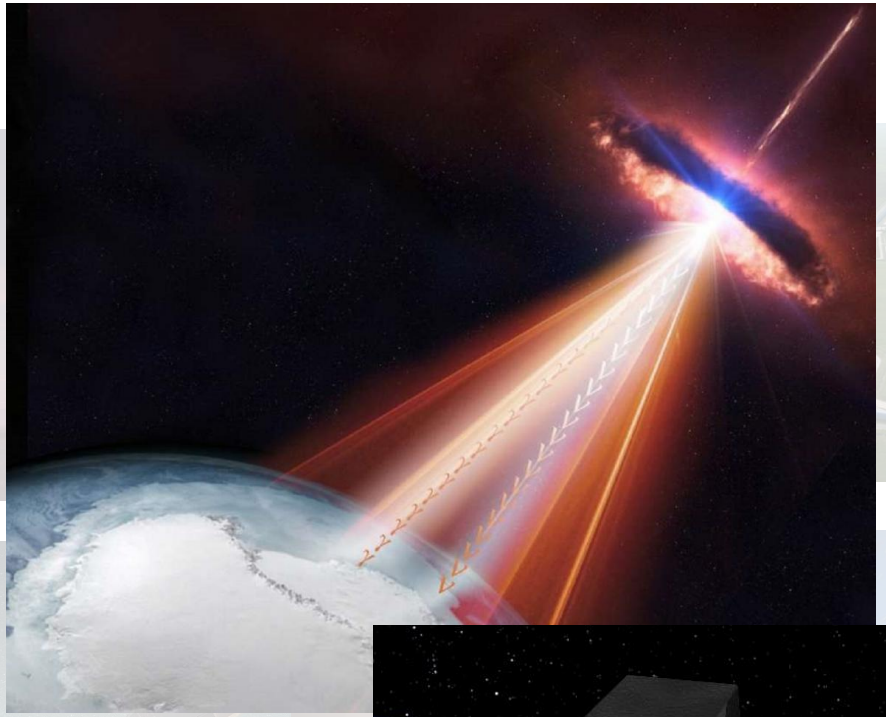


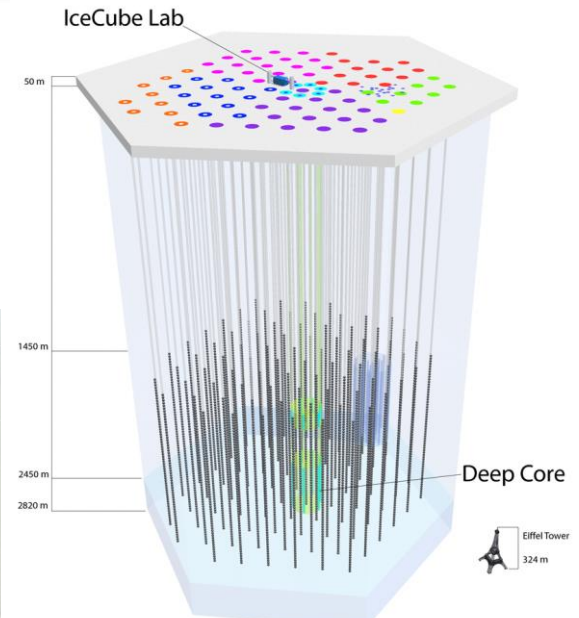


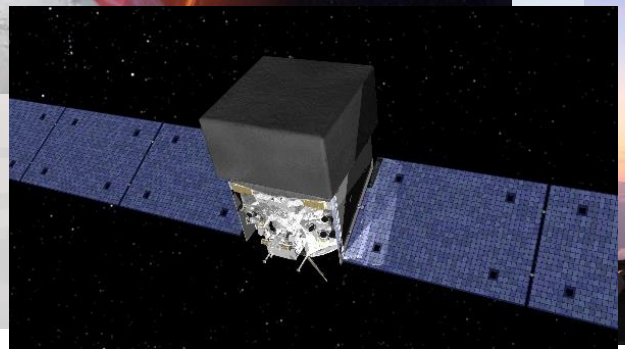
Multi-messenger era of astronomy

- Blazar TXS-0506 - neutrino and electromagnetic signal
  - 1.75 Gpc (5.7 billion light years)

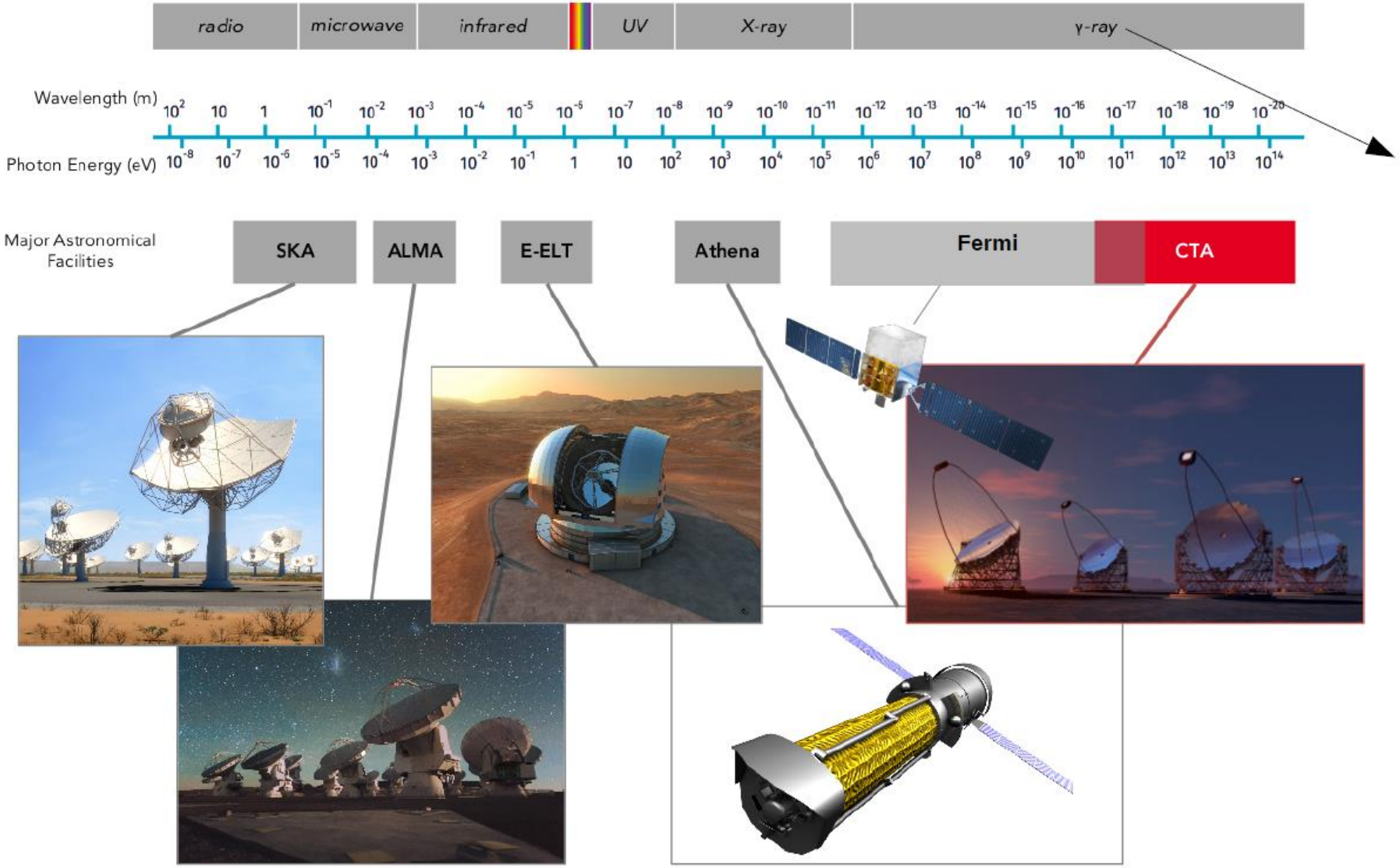








Photons at different energies

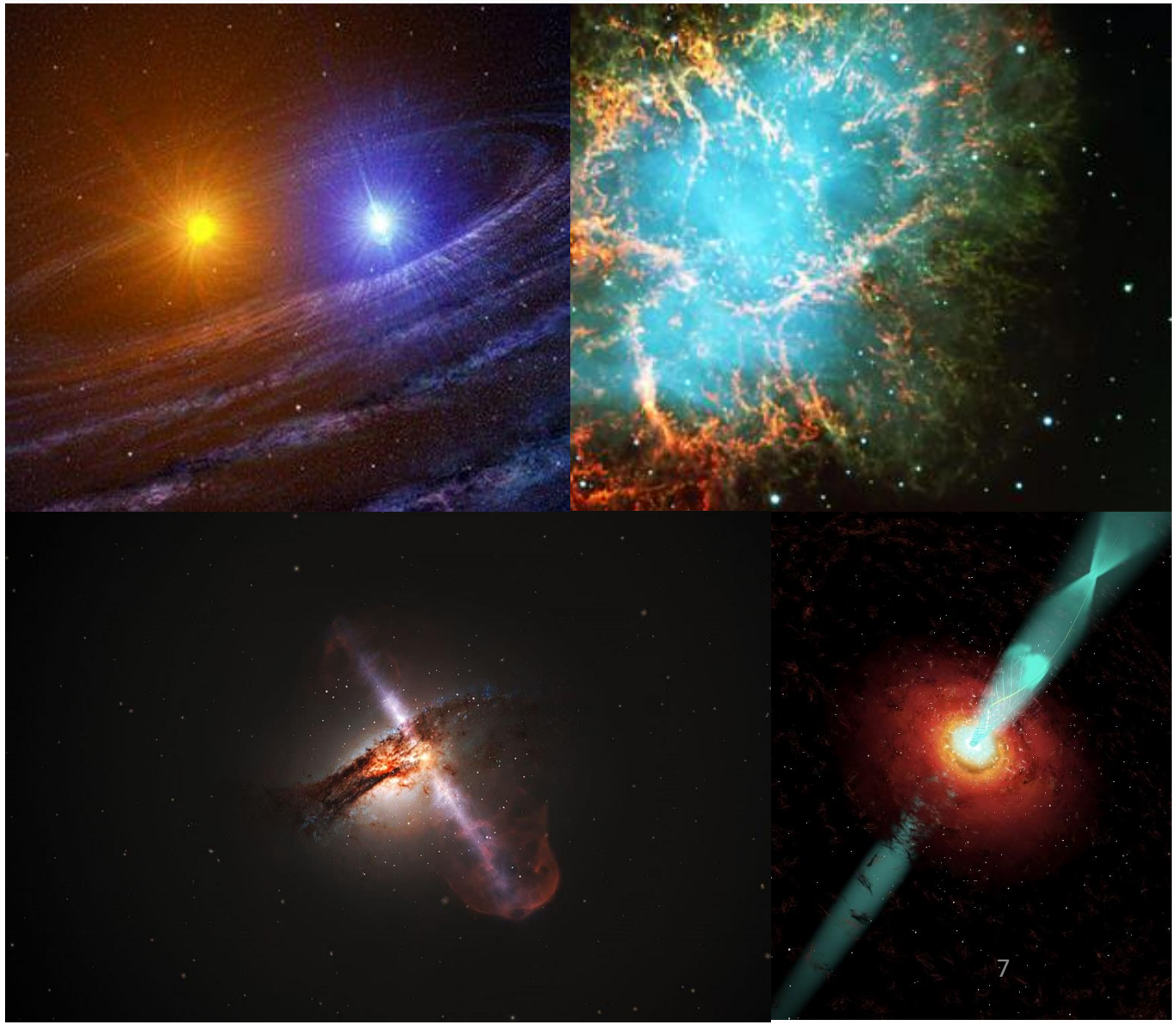


- Nonthermal origin
- Most extreme processes in the Universe
- Accompanying cosmic rays

$\pi^0 \rightarrow 2\,\gamma$

Very high energy gamma-ray sources

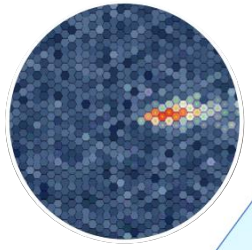
- TeV sources in Milky Way
  - Supernova remnants
  - Bombarded molecular clouds
  - Stellar binaries
  - Massive stellar clusters
  - Supermassive black hole Sgr A*
- Extragalactic TeV emitters
  - Starburst galaxies
  - Radio galaxies
  - Radio quasars
  - GRBs
  - Active galactic nuclei



Ground based Detection of high-energy gamma rays

1. Particle detector array
   - \+ wide field of view
   - \+ 100% duty cycle
   - – high altitudes

2. Cherenkov telescopes
   - \+ lower altitudes
   - \+ good resolution
   - – small field of view



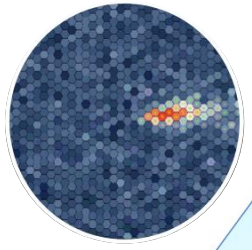
Shower image, 100 GeV γ-ray adapted from: F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

Not to scale

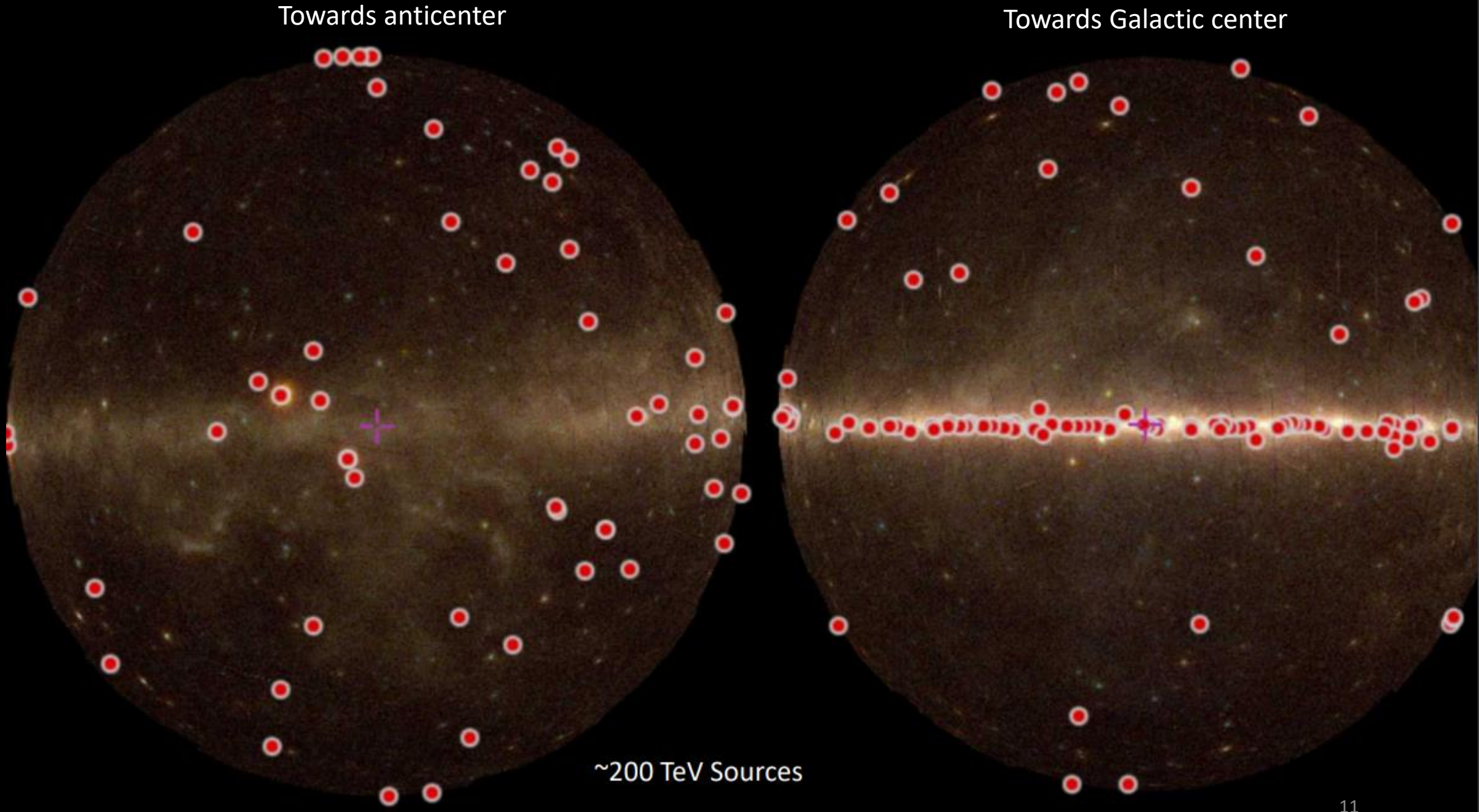
Ground based Detection of high-energy gamma rays

1. Particle detector array
   - \+ wide field of view
   - \+ 100% duty cycle
   - − high altitudes (+ **no snakes!**)

2. Cherenkov telescopes
   - \+ lower altitudes
   - \+ good resolution
   - − small field of view

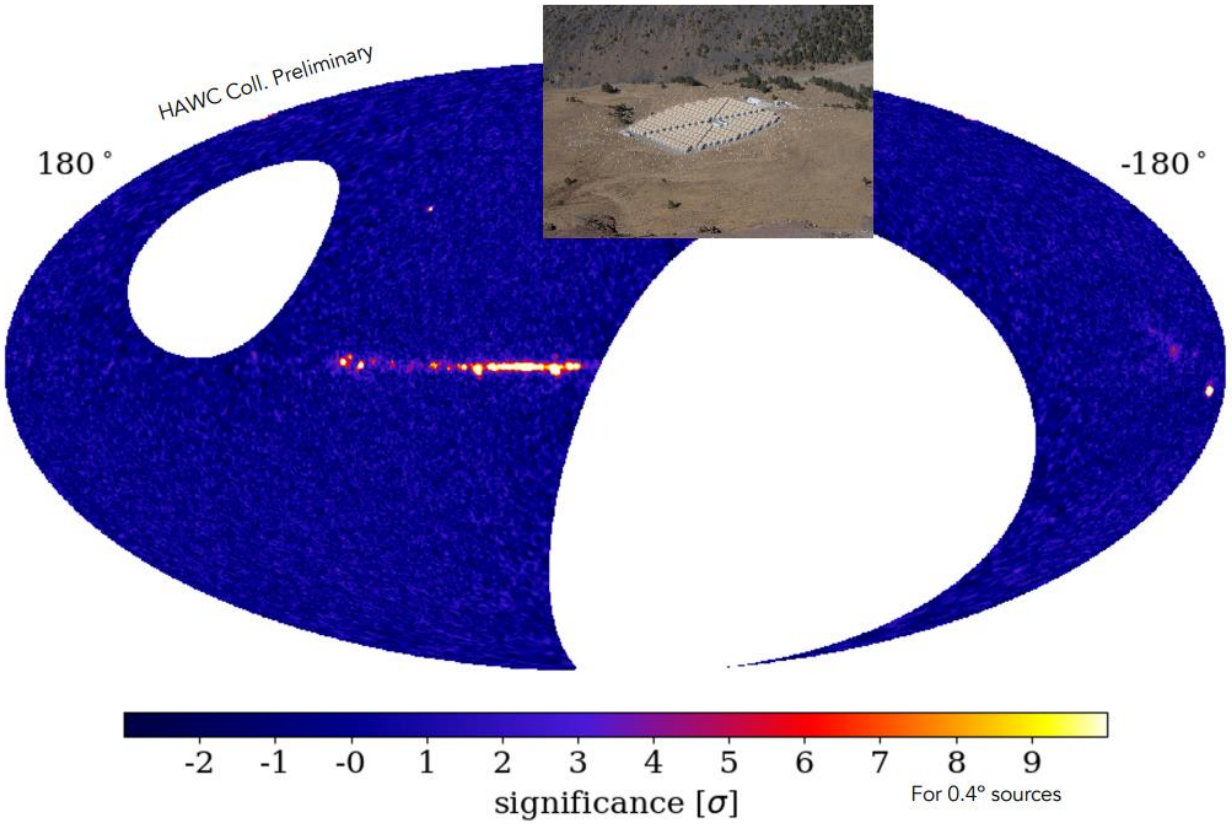


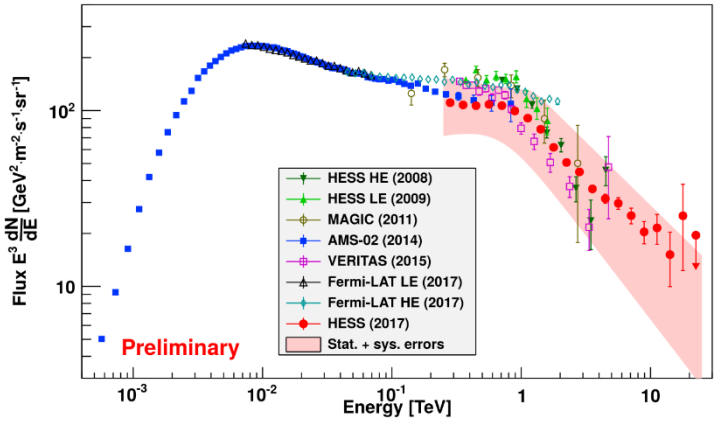
Current gamma-ray observatories

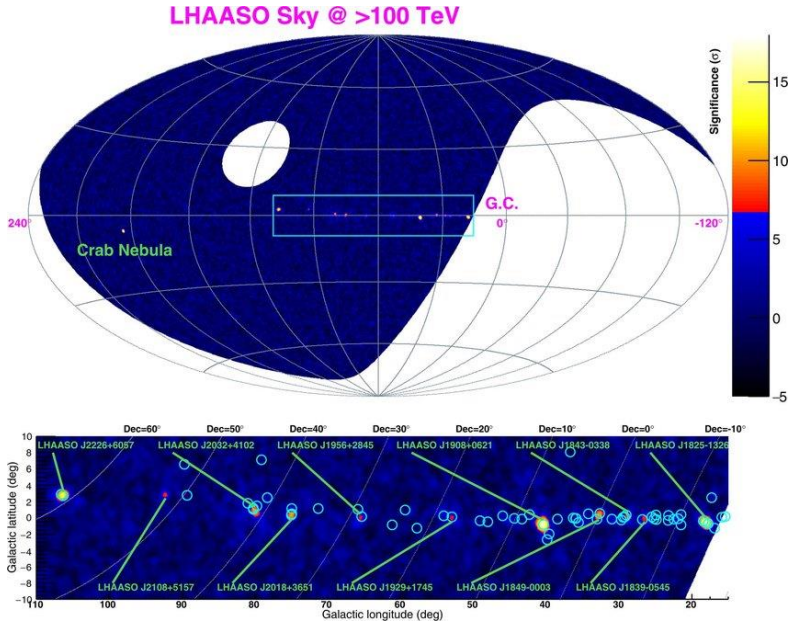

Towards anticenter
Towards Galactic center
~200 TeV Sources
Background: Fermi-LAT

Current gamma-ray observatories

- No wide-field observatory in the Southern hemisphere
- Invisible regions of high scientific interest!



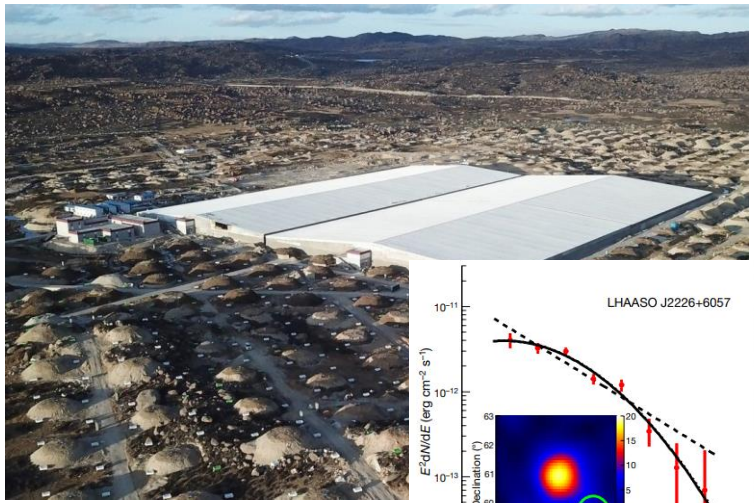




Current gamma-ray observatories

- No wide-field observatory in the Southern hemisphere
- Invisible regions of high scientific interest!

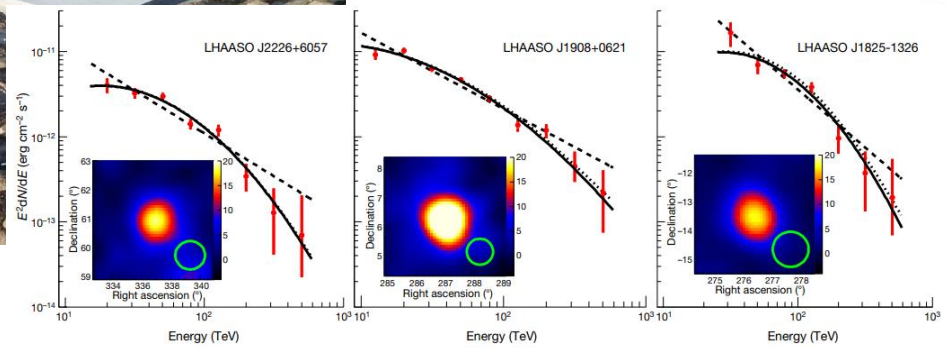
Not even two years of observations and LHAASO experiment announces 12 Galactic PeVatrons

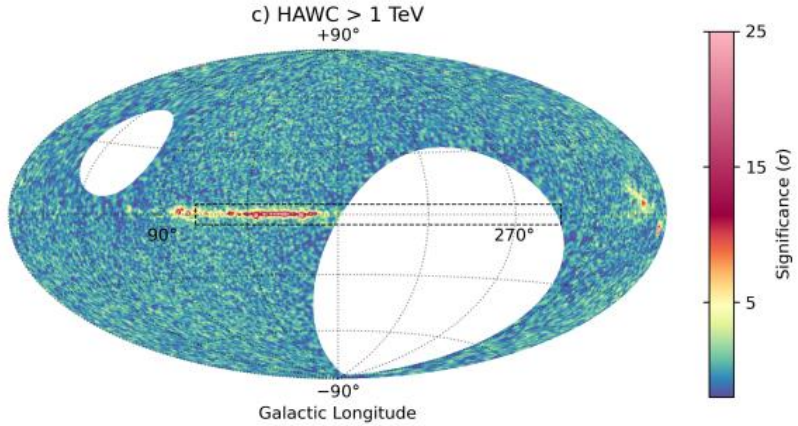


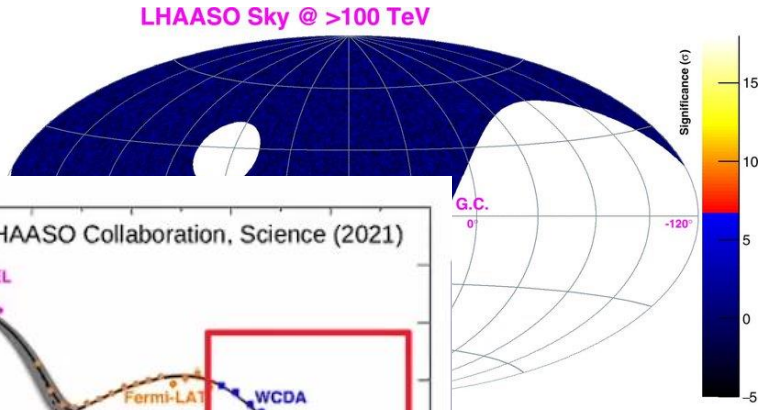
Article

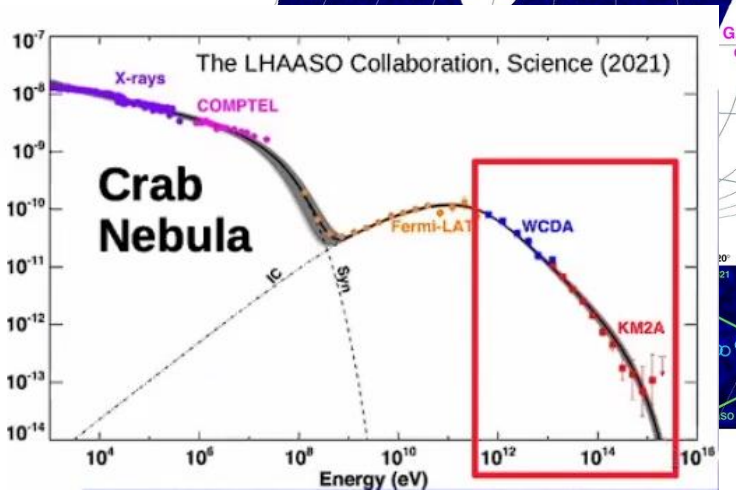
Ultrahigh-energy photons up to 1.4 petaelectronvolts from 12 γ-ray Galactic sources

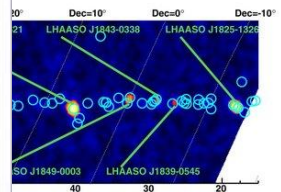
https://doi.org/10.1038/s41586-021-03498-z A list of authors and affiliations appears at the end of th





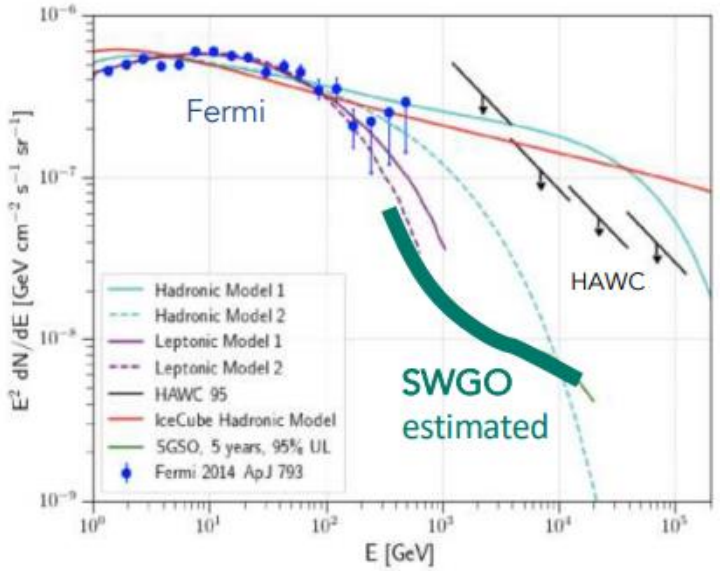




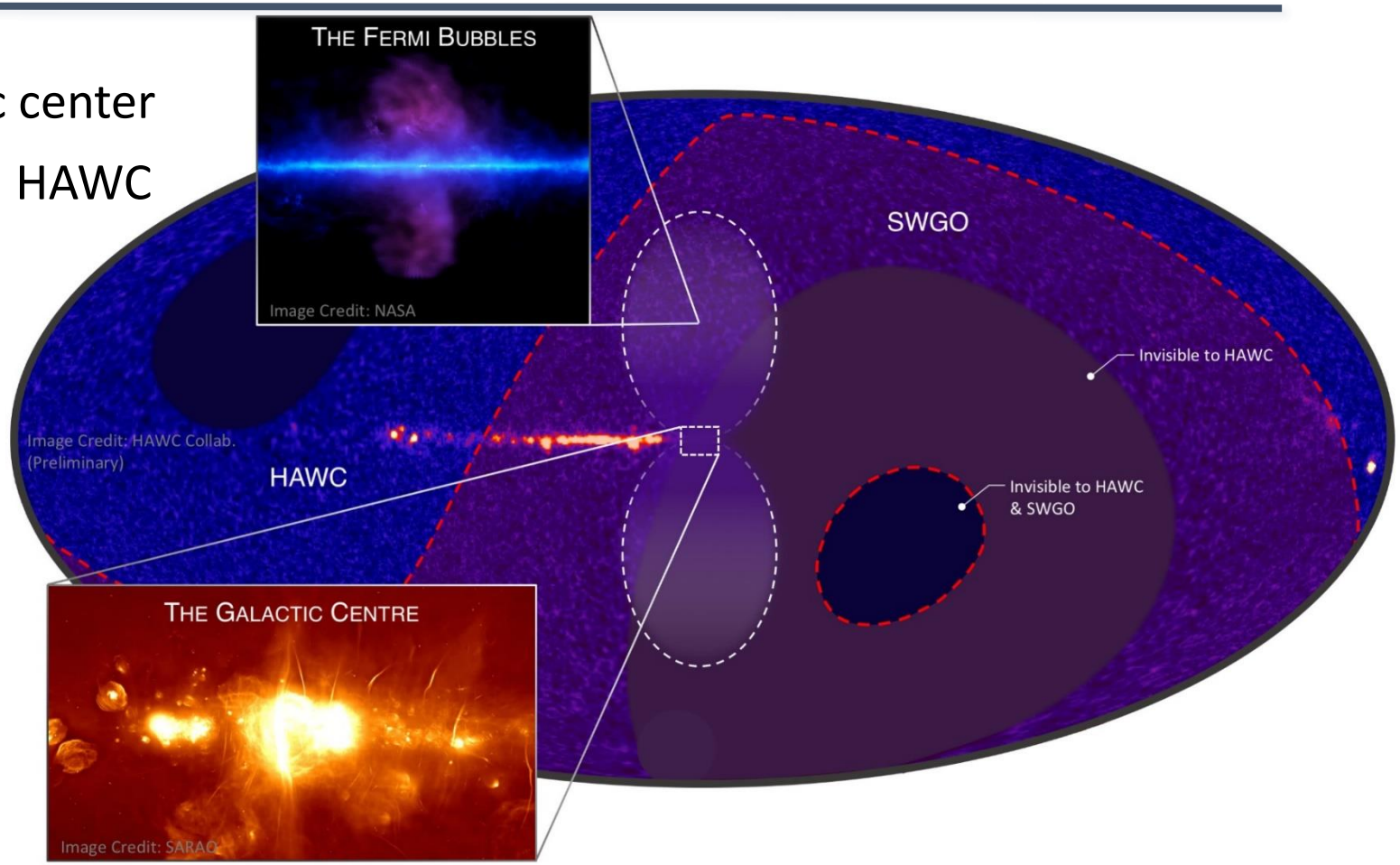


Wide-field observatory in the south

- Access to Galactic plane and Galactic center
- Complementary view of the sky with HAWC and LHAASO



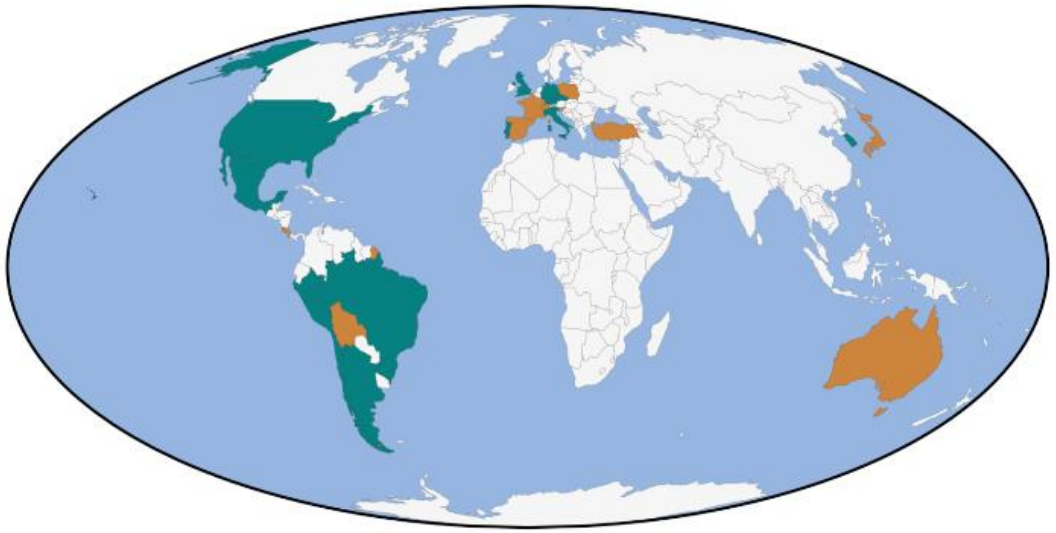
SWGO will complement the view of the Galaxy towards the highest energies and will greatly expand our reach to study Galactic high-energy accelerators.



Covering an energy range from 100s of GeV to 100s of TeV - PeV.

SWGO collaboration

- Established in 2019
- Currently in R&D phase
- Scientists from 12 countries and more than 50 institutes
- Expertise from HAWC, ARGO, MAGIC, HESS, Auger, ...



Countries in SWGO

Institutes

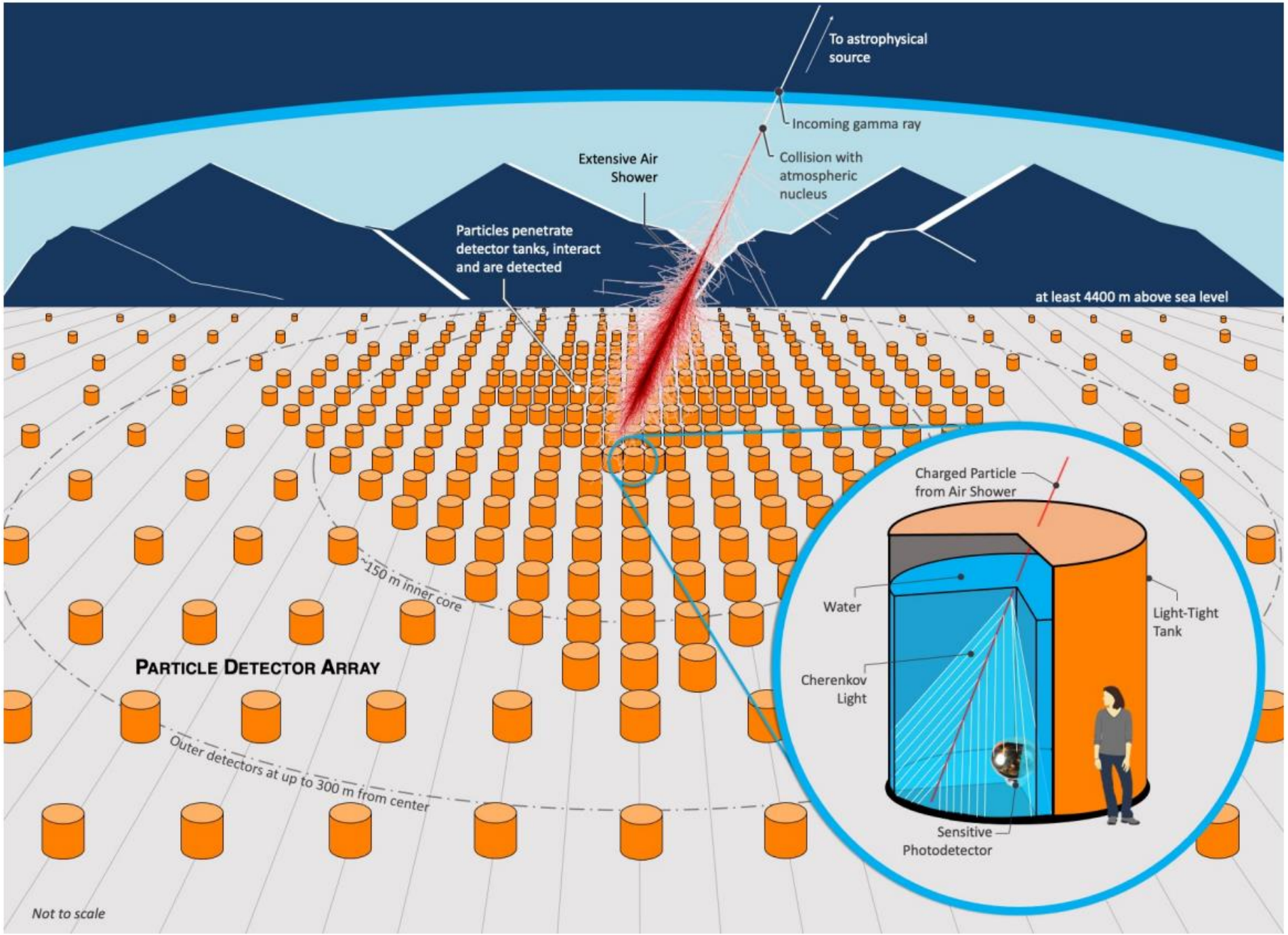
Argentina*, Brazil, Chile, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom, United States*

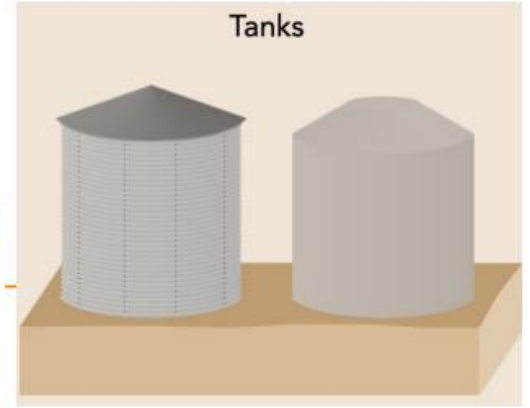
Supporting scientists

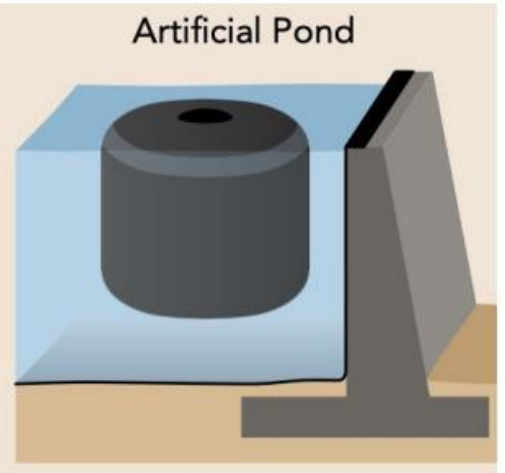
Australia, Bolivia, Costa Rica, France, Japan, Poland, Slovenia, Spain, Switzerland, Turkey

**also supporting scientists*

- Multiple working groups established
  - Science WG
  - Site WG
  - Analysis & Simulation WG
  - Detector WG
  - Outreach & Communication WG


To astrophysical source
Incoming gamma ray
Collision with atmospheric nucleus
Extensive Air Shower
Particles penetrate detector tanks, interact and are detected
at least 4400 m above sea level
150 m inner core
PARTICLE DETECTOR ARRAY
Outer detectors at up to 300 m from center
Not to scale
Charged Particle from Air Shower
Water
Cherenkov Light
Light-Tight Tank
Sensitive Photodetector


Tanks

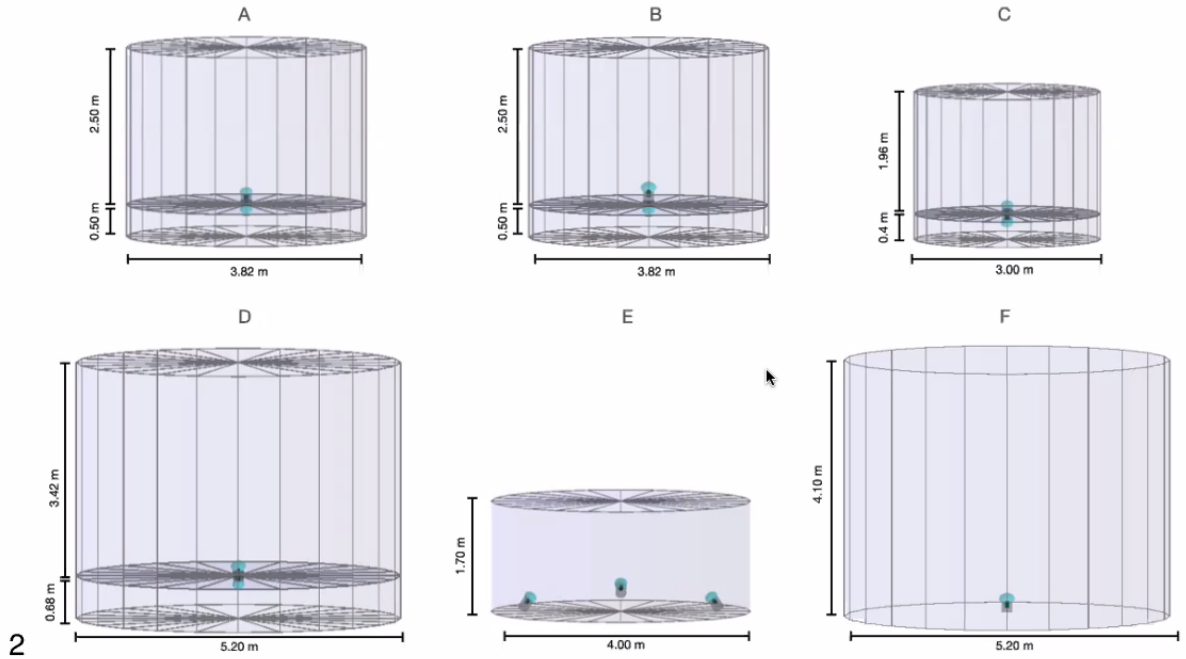

Artificial Pond

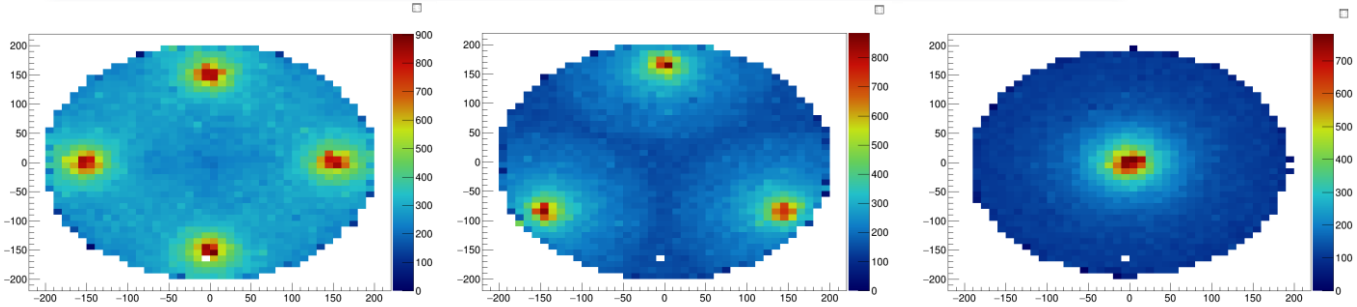

Natural Lake

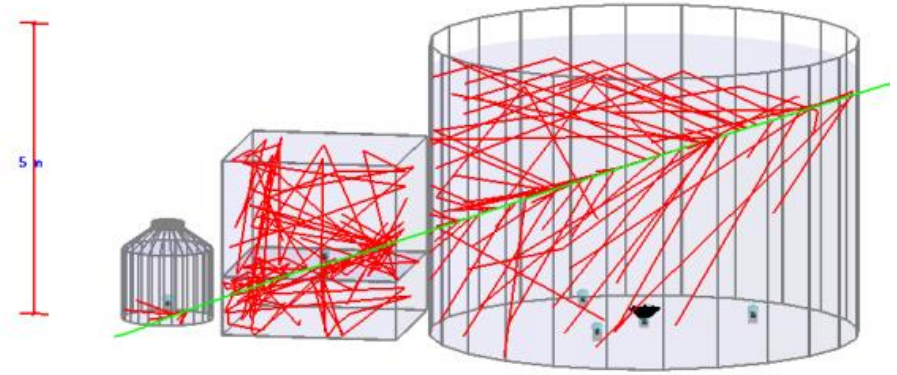
Towards the SWGO concept

WCD designs

A. Reference double layer design
B. Reference with larger PMTs
C. Smaller double layer
D. Larger double layer
E. Mercedes single layer shallow
F. Large single layer 1 PMT

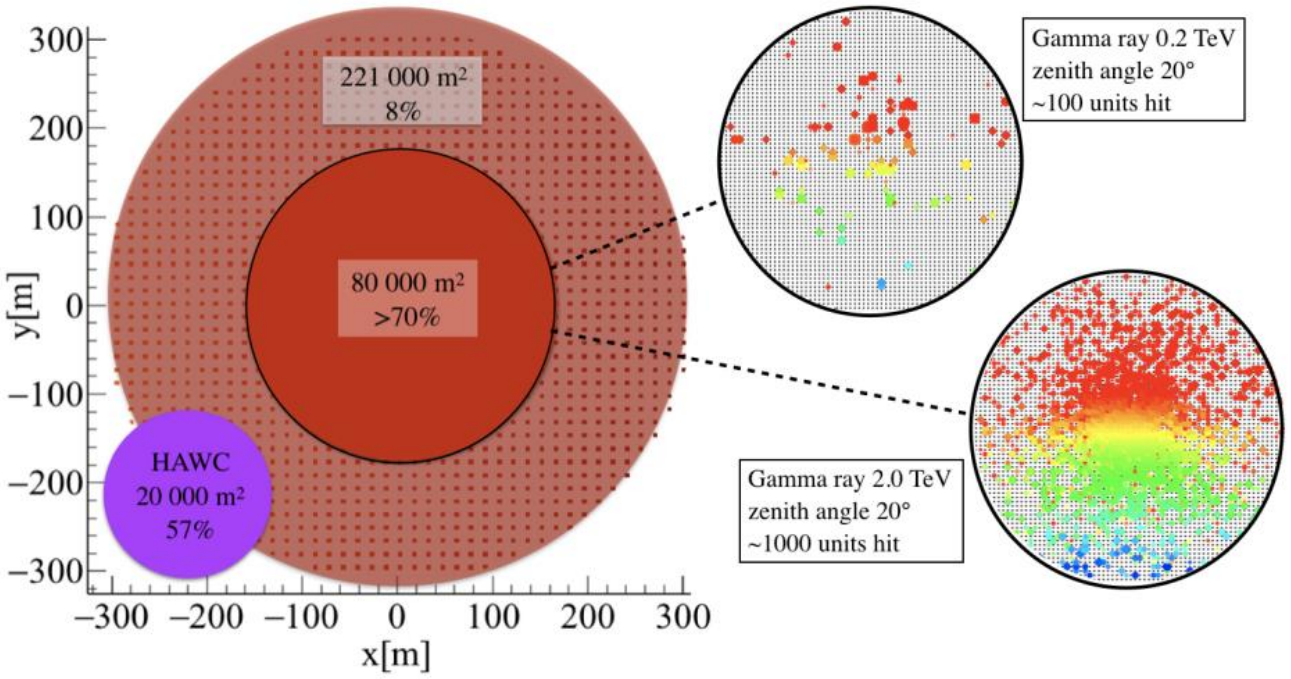


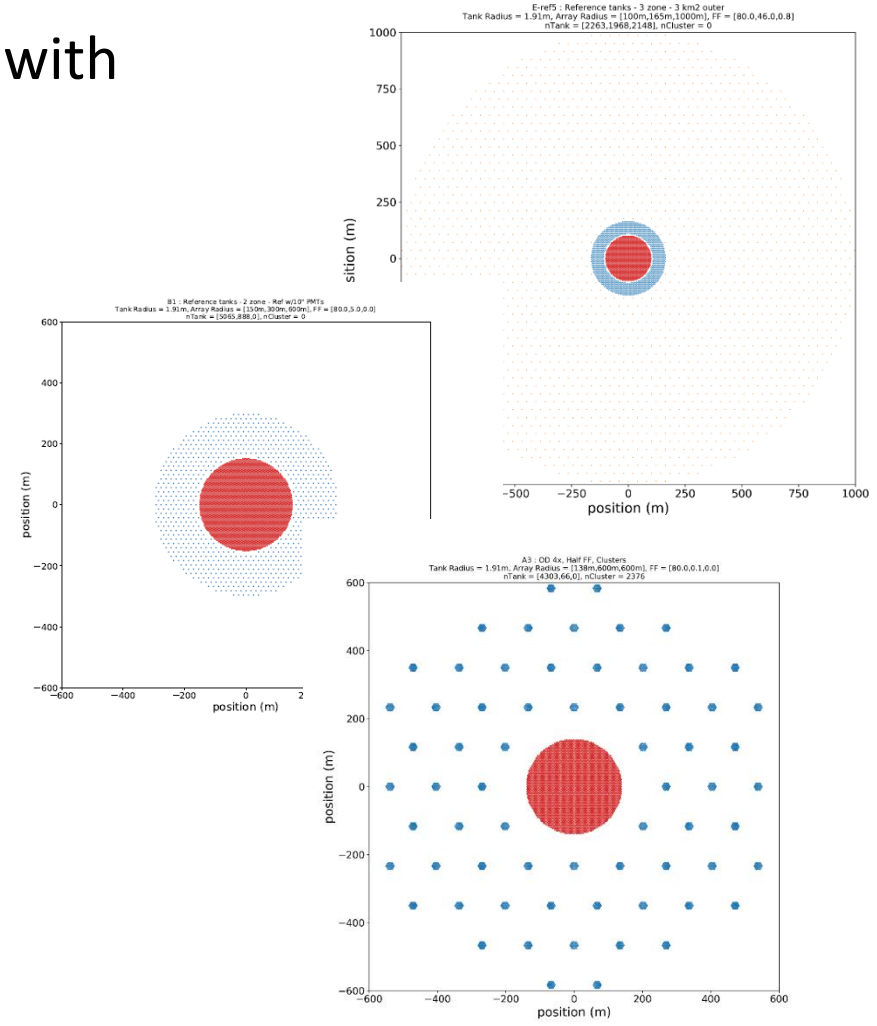




Towards the SWGO concept

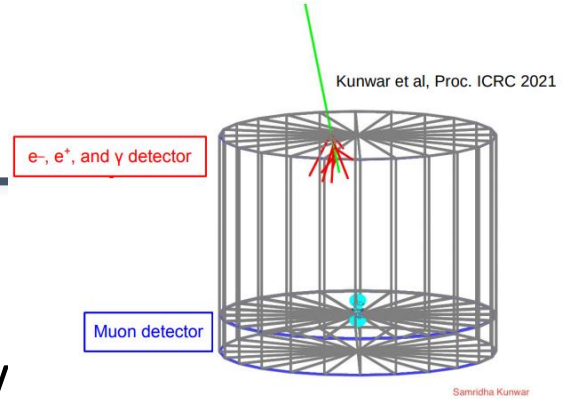
- Array of WCD units in multiple circular concentric zones with different fill factors



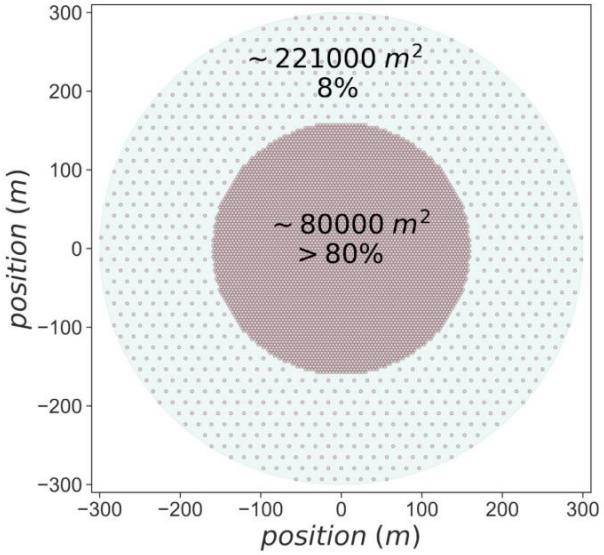


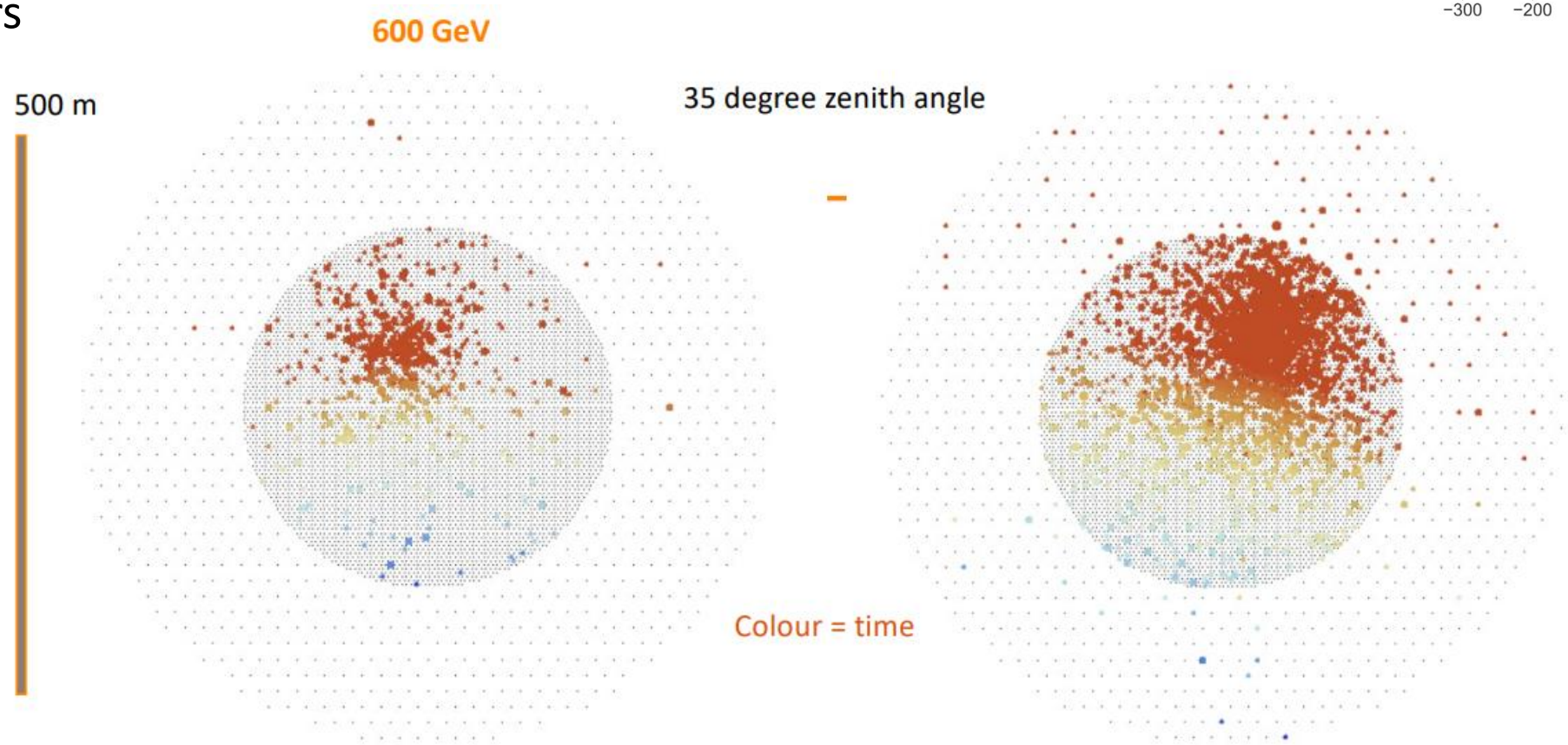
Reference configuration

- Larger detector array and increased altitude w.r.t. HAWC
- Precise measurements possible even below 1 TeV
- Increasing area → better sensitivity to PeV showers



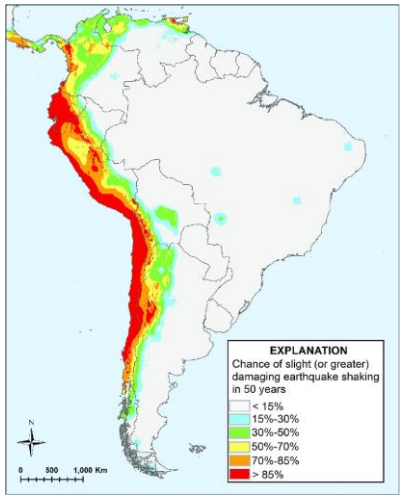
Muon identification a key element of background rejection





Choosing optimal location for SWGO

- Alto Tocomar (Argentina)
- Cerro Vecar (Argentina)
- Chacaltaya (Bolivia)
- AAP Pajonal (Chile)
- AAP Pampa La Bola (Chile)
- Lake Sibinacocha (Peru)
- Imata (Peru)
- Yanque (Peru)



- Candidate sites in four countries

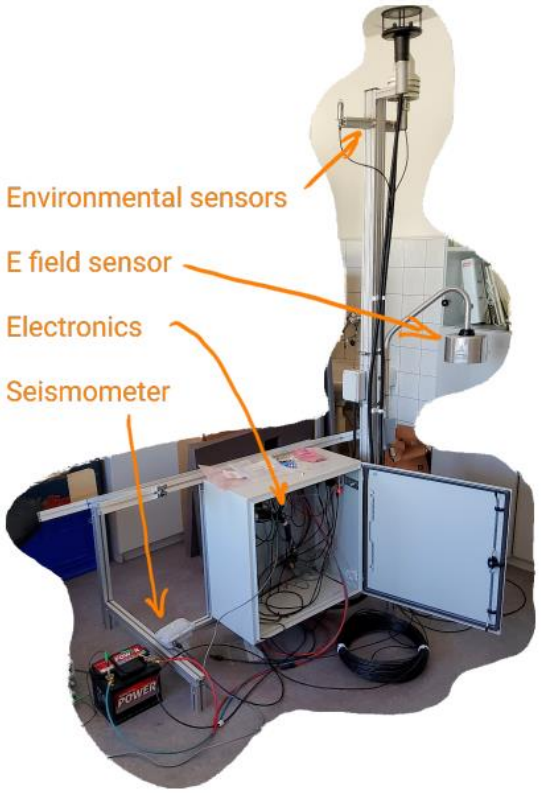
Requirements:

- Altitude above ~4500 m a.s.l.
- Flat region of area at least $1\ \mathrm{km}^2$
- Good weather conditions
- Stable subsoil, no strong earthquakes

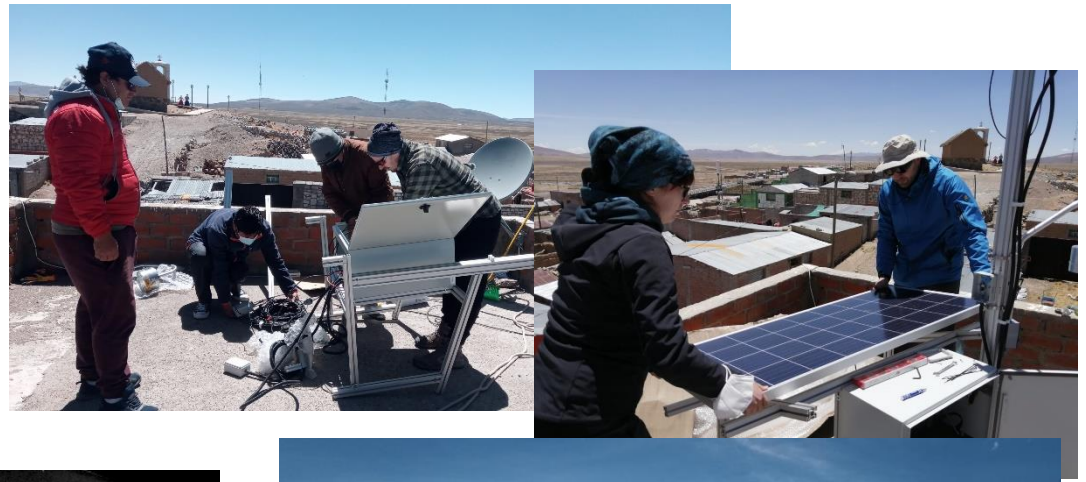

Bolivia 4.7k
Chile 4.8 k
Peru
Bolivia
Chile
Argentina 4.8 k
Peru 4.9 k

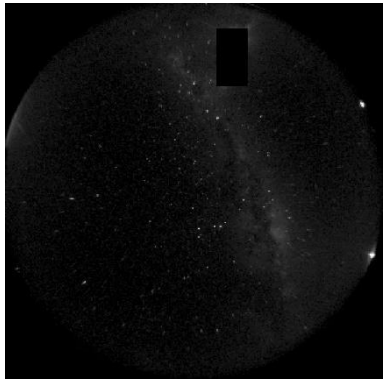
Atmospheric conditions

- Installation of AEROSITE (Autonomous Environmental and Scientific SWGO site Characterization Instrument) and all sky camera on candidate sites



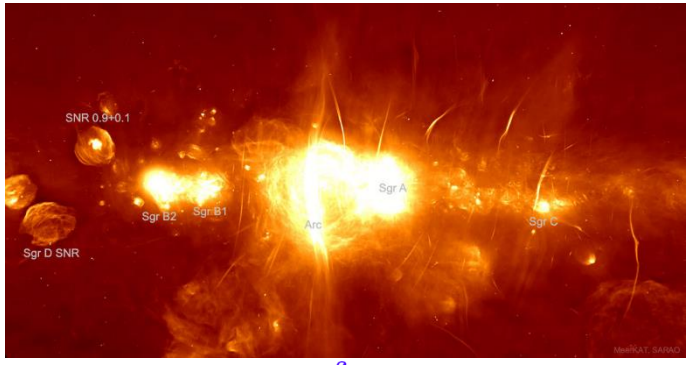
- Pressure
- Humidity
- Temperature
- Wind speed
- Solar irradiation
- Electric field
- Seismic activity

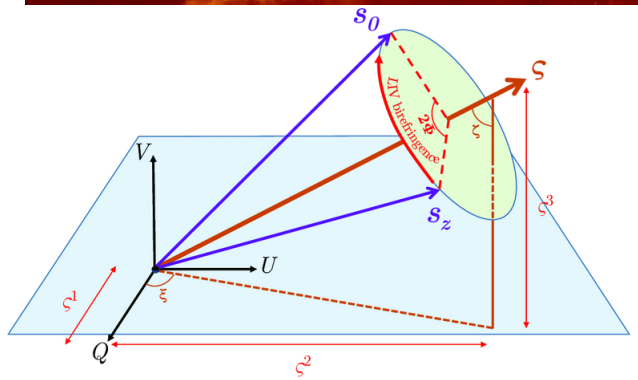


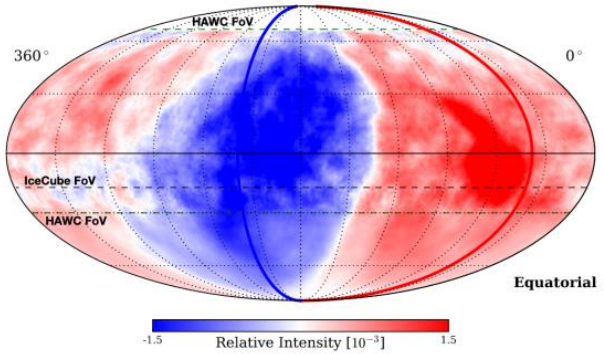


Science with SWGO

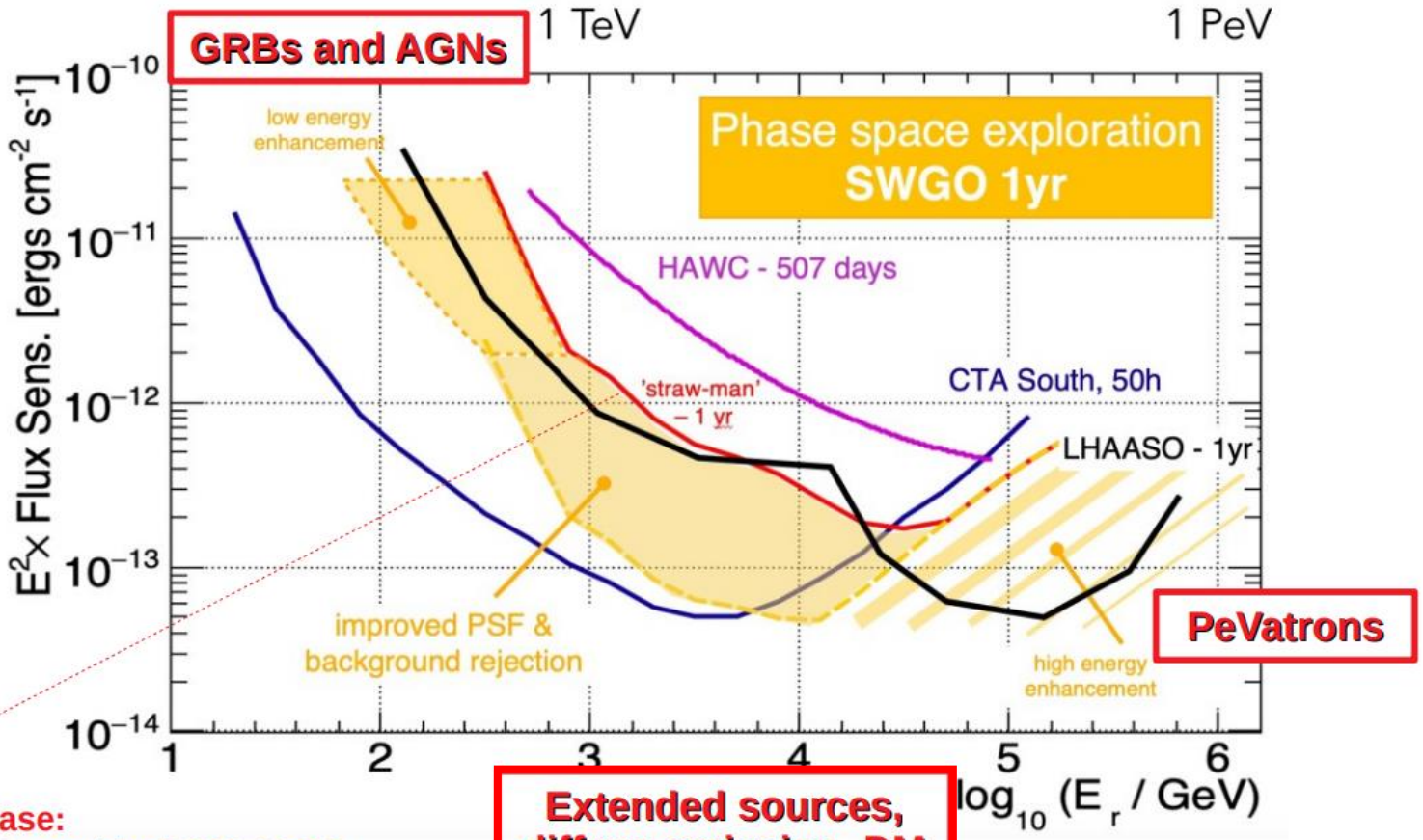
- Galactic sources
  - Milky way PeVatrons, pulsar halos, Galactic Diffuse Emission, Fermi Bubbles, Galactic center
- Extragalactic and Transients
- Fundamental physics
  - Dark matter, primordial black holes, Lorentz Invariance violations, Axions
- Cosmic rays
  - Spectrum, anisotropies, composition, electrons, heliospheric studies





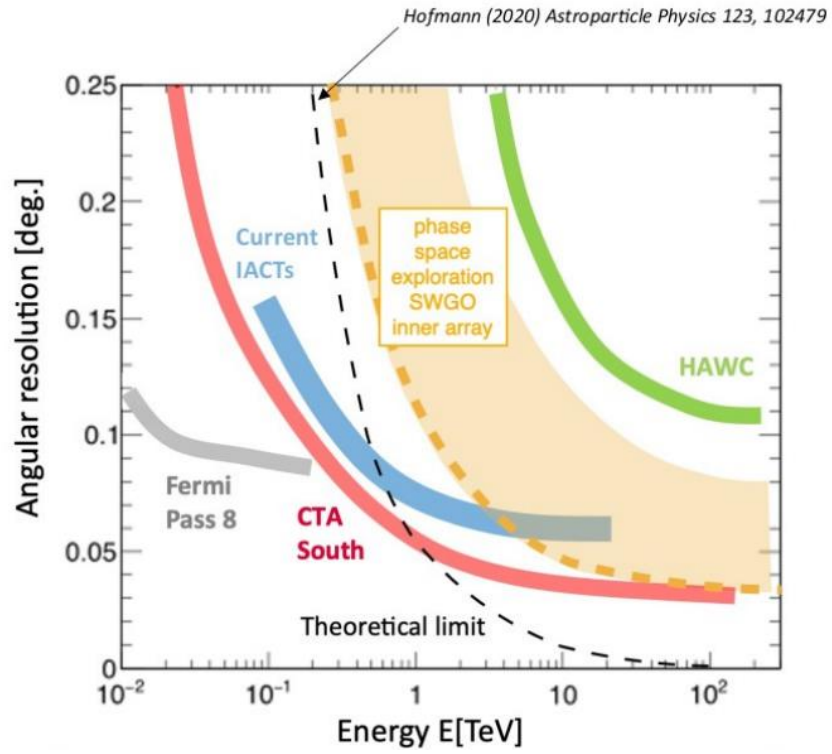


Sensitivity range and resolution



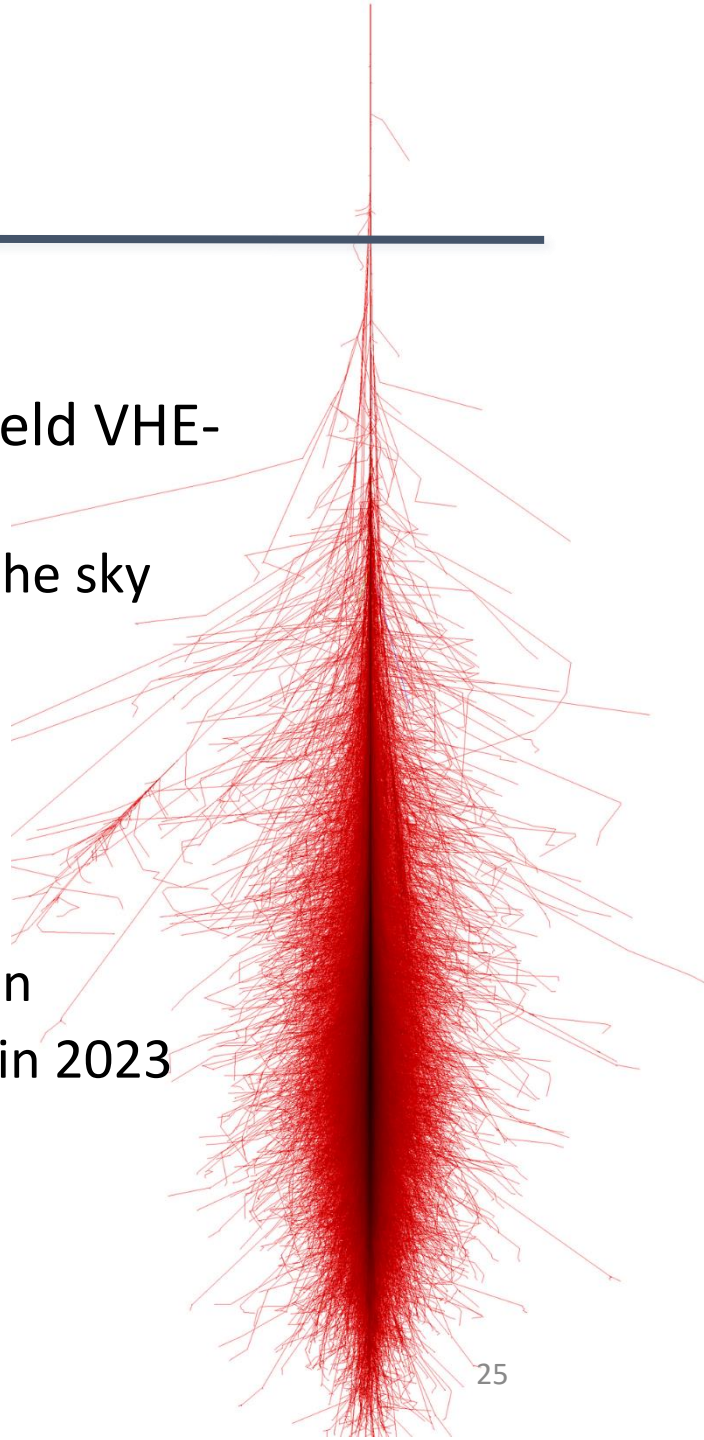
Science Case:
https://arxiv.org/abs/1902.08429

Extended sources, diffuse emission, DM



Conclusions

- There is a clear need and large scientific potential for a wide-field VHE-UHE instrument in the Southern hemisphere
  - Complementarity with LHAASO to provide full TeV-PeV view of the sky
  - Strong synergies with CTA in the Southern Sky
  - A key player in the multi-messenger arena
- SWGO if halfway in its R&D phase
  - Site shortlisting done – each country defined one best fit location
  - Final site choice and detector/array configuration to be defined in 2023
- Engineering array 2024-2027, Full construction phase 2027+



Thank you for your attention!

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