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The Southern Wide-field Gamma-ray Observatory

SWGO: Gamma-Astronomy at the Highest Energies

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Content

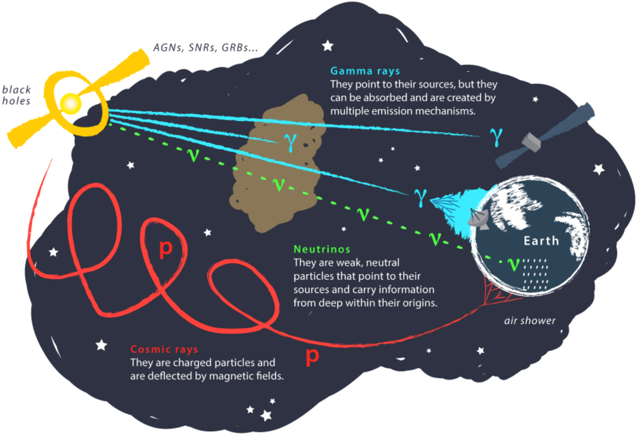

Figure: Sources and messenger particles in multi-messenger astronomy.[1]

[1] J. A. Aguilar and J. Yang. Cosmic messengers. 'eme-universe/. [Visited

IACTs vs. Ground Particle Detectors

- Imaging Air Cherenkov Telescopes (IACTs)
  - Telescope that measures Cherenkov radiation produced in the atmospere by extensive air shower (EAS)
  - Benefits: Great for energy resolution, whole view of shower in atmosphere, background rejection
  - Disadvantages: Poor field-of-view (FOV) and duty cycle
- Ground-particle detectors
  - Array of water filled tanks with photodetectors that measure Cherenkov light produced when shower particle passes through the tank
  - Benefits: 90° FOV, almost 100% duty cycle
  - Disadvantages: Lack energy and angular resolution, only recently acceptable sensitivity and background rejection at lower energies

	IACT Arrays	Ground-particle Arrays
Field of view	3°–10°	90°
Duty cycle	10%–30%	>95%
Energy range	30 GeV – >100 TeV	∼500 GeV – >100 TeV
Angular resolution	0.05°–0.02°	0.4°–0.1°
Energy resolution	∼7%	60%–20%
Background rejection	>95%	90%–99.8%

Figure: Typical performances of IACT arrays and ground-particle arrays.[2]

[2] A. Albert et al. Science Case for a Wide Field-of-View Very-High-Energy Gamma-Ray Observatory in the Southern Hemisphere. 2019. DOI: 10.48550/ARXIV.1902.08429. URL: https://arxiv.org/abs/1902.08429, p. 8.

About SWGO

- SWGO collaboration founded in 2019, first planned ground-particle array in the southern hemisphere
- 80 research institutions, from 14 countries

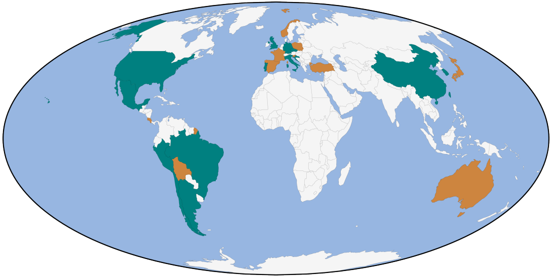

Figure: Collaborating countries for SWGO. Partner countries in green, countries with supporting scientists in orange.[3]

[3] SWGO collaboration homepage. https://www.swgo.org/. [Visited on 14.02.2023].

About SWGO

- Planned between 10 - 30° latitude in South America
- > 4.4 km altitude
- Prospective energy range 100s of GeV - 100s of TeV
- High fill factor (80%) core (larger and higher sensitivity than HAWC), low density (8%) outer array

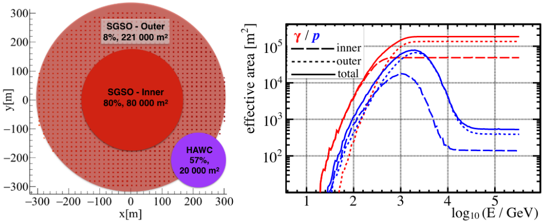

Figure: Left: Straw man design of SWGOs instrumented area and fill factors. Right: Effective area as function of primariy particle energy.[4]

[4] Albert et al., Science Case for a Wide Field-of-View Very-High-Energy Gamma-Ray Observatory in the Southern Hemisphere, p. 10.

About SWGO

- Galactic center observation possible
- Currently still in its R&D phase, which is expected to complete by end of 2023

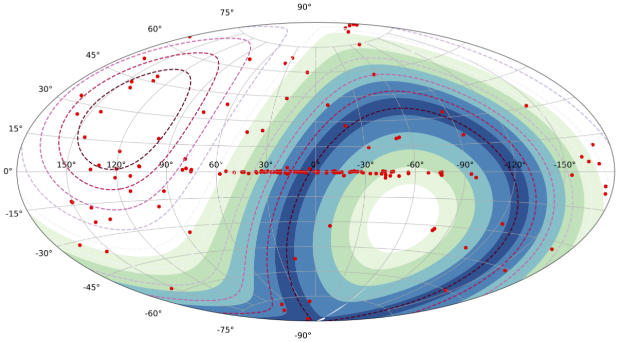

Figure: Skymap with contours showing both SWGO at an example 25° latitude and HAWC FOV. Color bands are 10° steps of SWGO FOV, dashed contours for HAWC. [5]

[5]Albert et al., Science Case for a Wide Field-of-View Very-High-Energy Gamma-Ray Observatory in the Southern Hemisphere, p. 14.

R&D considerations

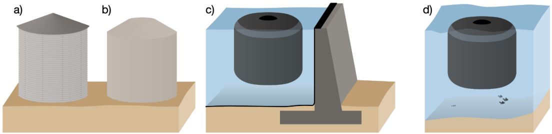

Figure: Possible detector concepts. Cylindrical tanks (a) made of corrugated steel or (b) roto-moulded HDPE. Floating bladders in (c) open ponds or (d) a natural lake. [6]

Detector options

- On-Ground tanks
- Artificial pond with floating bladder
- Natural lake with floating bladder

Site selection

- High altitude necessary for detector design
- Andes in South America
- Multiple excellent candidate sites across Argentina, Bolivia, Chile, Peru
- Two sites in Peru with natural lake access

[6] J. Hinton. “The Southern Wide-field Gamma-ray Observatory: Status and Prospects”. In: (2021). DOI: 10.48550/ARXIV.2111.13158. URL: https://arxiv.org/abs/2111.13158, p. 4.

The science cases

The different topics of interest that SWGO sets out to reaseach in depth are the following

- Galactic Particle Accelerators, e.g. PeVatron sources, Pulsar Wind Nebulae (PWNe)
- Transient Phenomena, e.g. Active Galactic Nuclei (AGN), Gamma Ray Bursts (GRB)
- BSM physics, e.g. Dark matter searches, Primordial Black Holes (PBH)
- Cosmic-ray observations, e.g. cosmic-ray spectrum, anisotropy

Reasons for SWGO

Improvements in these areas of study can be achieved due to different parts of SWGOs prospective design

- Galactic Particle Accelerators
  - High duty cycle + large FOV great for measurements of diffuse gamma-ray background, extended emission regions
  - Complementary coverage to Northern Hemisphere experiments (e.g. HAWC) for almost full sky coverage
- Transient Phenomena
  - Mainly high uptime and large FOV mean near constant monitoring of transient sources possible, more unbiased observations help with not fully understood phenomena
  - Limited very high energy (VHE) gamma-rays from extragalactic sources due to pair production: higher sensitivity of SWGO at low energies is important
- BSM physics
  - WIMP (Weakly Interacting Massive Particle) searches benefit from high duty cycle and large FOV
  - Higher sensitivity allows improved measurements of different theories (PBHs, Axion-Like Particles [ALPs], Lorentz Invariance Violation [LIV])

Reasons for SWGO

- Cosmic-ray observations
  - Energy range of SWGO makes it key for measurements regarding the "knee" (steepening of spectral index) in the gamma-ray spectrum
  - Southern hemisphere sky coverage can improve measurements of gamma-ray arrival direction anisotropy
  - High uptime and FOV allow spectral measurements of VHE electron to higher energies than before, as well as possible search for arrival direction anisotropy
  - Expanded observation of interplanetary magnetic field (IMF) influence on cosmic rays due to high low-energy sensitivity

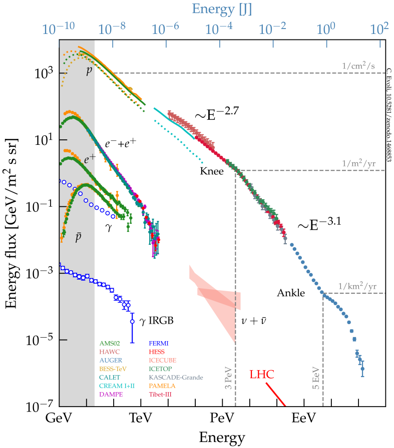

Figure: The Cosmic-Ray Energy Spectrum.[7]

[7] C. Evoli. The Cosmic-Ray Energy Spectrum. Oct. 2018. DOI: 10.5281/zenodo.2360277. URL: https://doi.org/10.5281/zenodo.2360277.

Conclusion and Outlook

To summarize: Promising project, especially because first of its kind the southern hemisphere

- Lots of opportunity for observation that's not possible in the northern hemisphere
- Ample collaboration opportunities with other gamma-ray observatories (e.g. CTA, LHAASO, HAWC)
- Proposed capabilities match/exceed existing ground-particle arrays, allows better measurements of both understood and not fully understood phenomena

However important to note:

- Project still in development
  - Design/capabilities subject to change
  - No specific site/detector type chosen yet
- Clearer picture when R&D phase is over (end of 2023)

Thank you for listening!

Sources

Aguilar, J. A. and J. Yang. Cosmic messengers. https://icecube.wisc.edu/news/research/2016/10/neutrinos-and-gamma-rays-partnership-to-explore-extreme-universe/. [Visited on 13.02.2023]. Oct. 2016.

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