HAWC`s Eye a novel imaging atmospheric detector

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Outline

• Why measure cosmic Gamma Rays?
• Indirect Gamma Ray R&D detection techniques
• Surface Arrays, HAWC
• Imaging Atmospheric Cherenkov Telescopes
• HAWC’s Eye
• Test at Sierra Negra, Mexico.
• Simultaneous observations with HAWC
• Summary and Future Plans.
Why High Energy cosmic Gamma Rays

✧ We can observe the sources.

✧ No thermal origin

✧ The most extreme and violent phenomena

✧ What is the highest energy?
Indirect Detection

- Brief history: 66 year R&D

Fig. 2.3, Left: The first design of an air Čerenkov counter in a garage can used by B. Galbreith and J. V. Jeffley in

Fig. 4.3, Photo of the Whipple 10-m telescope at Mount Hopkins. Courtesy Brian Hemensky.
Different Detectors

Wide Field of View, Continuous Operations

Space Based

- Fermi
- AGILE
- EGRET

30 MeV – 300 GeV

TeV Sensitivity

Extensive Air Shower (EAS) Arrays

- HAWC
- ARGO
- Milagro
- Tibet ASγ
- LHAASO

500 GeV – 100 TeV

Imaging Atmospheric Cherenkov Telescopes (IACTs)

- VERITAS
- HESS
- MAGIC
- CTA

50 GeV – 20 TeV

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Indirect Gamma Ray detection techniques
EAS and IACT

Simulation (CORSIKA)

<table>
<thead>
<tr>
<th></th>
<th>EAS Array</th>
<th>IACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View (FOV)</td>
<td>~90° (~2 sr)</td>
<td>~5° (~4 msr)</td>
</tr>
<tr>
<td>Duty Factor</td>
<td>~100%</td>
<td>~10%</td>
</tr>
<tr>
<td>Angular Resolution</td>
<td>1° - 0.2°</td>
<td>0.1° - 0.06°</td>
</tr>
<tr>
<td>Energy Range</td>
<td>500 GeV - 100 TeV</td>
<td>50 GeV – 50 TeV</td>
</tr>
<tr>
<td>Energy Resolution</td>
<td>50% - 30%</td>
<td>20% - 8%</td>
</tr>
</tbody>
</table>

EAS – Altitude Matters
Higher = Lower Energy

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HAWC in a nut shell

HAWC Observatory

HAWC operates day and night, providing a large field of view for the observation of the highest energy gamma rays.

HAWC is located at 4,100 m above sea level, covering an area of 20,000 m².

Mapping the Northern Sky in High-Energy Gamma Rays

Water Cherenkov tank

HAWC comprises an array of 300 tanks that record the particles created in gamma-ray and cosmic-ray showers.

Particles inside the shower produce Cherenkov radiation that is detected by the PMTs.

Gamma rays vs cosmic rays

HAWC selects gamma rays from among a much more abundant background of cosmic rays.

“hot” spots concentrate around the core

“hot” spots are more dispersed

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2HWC catalog ApJ 2017 was 507 days and contained 39 sources of which 10 were new
IACTs

How a IACT look like?

Traditionally PMTs are used as photodetectors, In 2011 SiPMs were used on an IACT, First Avalanche-

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Ideal situation: Hybrid observatory

It will be nice to have a compact and affordable IACT,
HAWC’s Eye idea

Characterization

It will be nice to have a compact and affordable IACT, Could be an option a refractive device?

Calibration

Can we improve: Energy resolution? pointing and sensitivity?

Combined

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HAWC’Eye instrumentation
HAWC’s Eye Electronics

DAQ : same as FACT telescope

FACT Boards:

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Slow control and calibration

By Monitoring the temperature, the gain is controlled by the auto-adjustable DC power supply.

A average of 3 Pe from Noise
At the HAWC site
One of the water storage E16C-B. PMTs are marked as bad in software so it will not interfere on HAWC reconstruction.
Very well correlated Showers
Very well correlated showers

![Graph showing number of detected showers vs tank hits for coincident and random events. The graph indicates a clear distinction between coincident and random events, with coincident events showing a more concentrated distribution in the lower tank hits range.](image)
Very well correlated Showers

The core distribution of the coincident events has a peak around HAWC’s Eye position. And no events beyond the angular aperture.
Now we are on track.
Summary and Future Plans.

✧ HAWC’s Eye is a low cost, portable, refractive cosmic ray detector.

✧ We started the process of characterization by comparing with HAWC data.

✧ While HAWC’s Eye is not a replacement for a traditional IACT, the first results shown that it is a complement for surface array observatories.

✧ As future work, we will take data with a second telescope (it is ready at the HAWC site) therefore we will start to work with stereo observations.
Thanks

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Fig. 2.2. Simulations of air showers, from left to right: (a) secondaries of a 50 GeV $\gamma$-ray primary particle, (b) same, but only those secondaries that produce Cherenkov light are plotted. (c) Secondaries of a 200 GeV proton primary particle, (d) same, but only those secondaries that produce Cherenkov light are plotted. In all figures, the particle type of the secondaries is encoded in their track color: red = electrons, positrons, gammas; green = muons; blue = hadrons. Figures courtesy Dario Hrupec (Institut Ruder Bošković, Zagreb), produced using code done by Fabian Schmidt (Leeds University), using CORSIKA.
Summary

• Could be part of SWGO

Southern Wide FOV Gamma-ray Observatory (SWGO)

H. Schoorlemmer, PoS(ICRC2019)785

• Formed new collaboration on July 1, 2019 to pursue R&D for SWGO

• Looking at 5 South American sites all >4.5 km up to 5km

• See www.SWGO.org for more info.