Extended TeV Sources

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HESS Observations of Galactic Sources

- Most HESS detections in the Galactic Plane are extended sources
- Largest Source is Vela Jr with diameter of 2 degrees
Extended Source Sensitivity

ACT’s rely on angular resolution for excellent background rejection.

When the source size is large compared to PSF, sensitivity is reduced by a factor of

\[ \sim \frac{\sigma_{\text{detector}}}{\sigma_{\text{source}}} \]

When the source size is large compared to the FOV, sensitivity is reduced much more.
Milagro TeV Observatory for Extended Sources

- Detect Particles in Extensive Air Showers from Cherenkov light created in 60m x 80 m x 6m pond containing filtered water.
- Reconstruct shower direction to ~ 0.5 degrees from the time different photodetectors are hit.
- 1700 Hz trigger rate mostly due to Extensive Air Showers created by cosmic rays
- Field of view is ~2 sr (± 45 degrees) and the average duty factor is >90%
Point Source Search - Weighted Analysis

Event Weighting: Bin Size = 2.1° (Optimal for Point Sources)

Crab significance: 10.0σ.
Mrk421 significance: 5.4σ.
Point in Cygnus Region at: 5.9σ.
Extended Source Search Weighted Analysis

Event Weighting: Bin Size = 5.9°
(Optimal for ~5° source)

Cygnus Region Significance: 9.1σ
Post-trials probability: >7σ

Cygnus Region is the most luminous source of VHE γ-rays in the northern sky.
A Closer Look at the Galactic Plane

- GP diffuse excess clearly visible from $l=25^\circ$ to $l=90^\circ$.
- Cygnus Region shows extended excess $\sim 5^\circ-10^\circ$.
- $F_{\text{Cygnus}} \sim 2 \times F_{\text{Crab}}$
Galactic Plane Excess:
( -2°<b<2° )

Consider Region l = 20°-100°
Weighted Map: 7.5σ

Exclude the Cygnus Region: l=20°-75°
Weighted Map: 5.8σ

Galactic longitude 20-75 excludes Cygnus region

Galactic longitude 20-100 includes Cygnus region

σ=1.42 +/- .26
Integral Flux: Milagro & EGRET

R1 (Gal. Long. 40 to 100 deg)
- Based on 3ys of data, $4.5\sigma$
- Flux($>3.5$ TeV)
  \[ = (6.8 \pm 1.5 \pm 2.2) \times 10^{-11} \text{ cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1} \]
- Spectral Index to connect with EGRET = $-2.61 \pm 0.03 \pm 0.05$
- With outriggers we can measure the spectrum at TeV energies
- 2 more years of data needed for $\pm 0.1$ on spectral index at TeV energies

R2 (Gal. Long. 140 to 200 deg)
- Flux($>3.5$ TeV)
  \[ < 4 \times 10^{-11} \text{ cm}^{-2} \text{ sec}^{-1} \text{ sr}^{-1} \text{ (99\% c.l.)} \]
- Spectral index to connect with EGRET $< -2.66$ (99\% c.l.)
- Not yet a crisis but spectrum may be softer in outer Galaxy
- Additional data will tell

Submitted to PRL
Cygnus Region Morphology

- Convolve Cygnus region excess with Milagro PSF(0.75°).
- Region shows resolvable structure.

HEGRA detected TeV Source:  TEV J2032_4130.
### 3rd EGRET Catalog sources shown with 95% position error circle.

<table>
<thead>
<tr>
<th>Source</th>
<th>Flux ($\Phi &gt; 100$ MeV/cm$^2$s)</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 3EG J2016+3657</td>
<td>$(34.7 \pm 5.7) \times 10^{-8}$</td>
<td>2.09</td>
</tr>
<tr>
<td>2 3EG J2020+4017</td>
<td>$(123. \pm 6.7) \times 10^{-8}$</td>
<td>2.08</td>
</tr>
<tr>
<td>3 3EG J2021+3716</td>
<td>$(59.1 \pm 6.2) \times 10^{-8}$</td>
<td>1.86</td>
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<td>4 3EG J2022+4317</td>
<td>$(24.7 \pm 5.2) \times 10^{-8}$</td>
<td>2.31</td>
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<tr>
<td>5 3EG J2027+3429</td>
<td>$(25.9 \pm 4.7) \times 10^{-8}$</td>
<td>2.28</td>
</tr>
<tr>
<td>6 3EG J2033+4118</td>
<td>$(73.0 \pm 6.7) \times 10^{-8}$</td>
<td>1.96</td>
</tr>
<tr>
<td>7 3EG J2035+4441</td>
<td>$(29.2 \pm 5.5) \times 10^{-8}$</td>
<td>2.08</td>
</tr>
</tbody>
</table>

Flux of maximum point: 500mCrab (May be extended)
Both EGRET sources have hard spectrum of 1.86 and 2.09

Milagro flux is ~ 1 σ below extrapolation of combined 2 source EGRET spectrum

Neither EGRET source is variable

Proposed Counterparts of the 2 EGRET sources
  - Blazar 2Jy@ 5GHz (Mukherjee et al. 2000, Halpern et al. 2001)
  - Young Pulsar with Nebula (Roberts et al. 2002)
Smooth EGRET >1 GeV $\gamma$-rays by EGRET's energy dependent psf
Slice of EGRET Data

- Cut on the Dec. band around Milagro’s bright spot
- 2 point sources or 1 extended source?
- EGRET catalog sources were fit as point sources ONLY
- How close together can GLAST resolve 2 sources of this signal strength?
What’s Next?
miniHAWC (High Altitude Water Cherenkov)

- Reuse Milagro’s 900 PMTs and DAQ system
- Build pond at extreme altitude (Tibet 4300m or Mexico 4200m)
- Incorporate new design
  - Optical isolation between PMTs
  - Larger PMT spacing (5 m vs 3 m in Milagro)
  - Deeper PMT depth (in only one layer)

$\sim$2-3 M for complete detector construction
$\sim$15x sensitivity of Milagro
  Crab Nebula at 4 $\sigma$ in 1 day
  60 mCrab at 5 $\sigma$ in 1 year on entire sky
NSF proposal to be submitted in 2006 to begin operation in 2008
One Year Survey Sensitivity

Assume 50 hr observations of 18 regions (10% duty factor)
The Diffuse Galactic Plane in miniHAWC and HAWC

Use Neutral H map to trace out VHE Gamma-Ray flux. Normalize to Milagro observed TeV diffuse Galactic plane.
Summary

- Work this next year includes
  - Milagro Run Manager
  - Publication of the Cygnus Region Morphology
  - Development of Energy Resolution for Milagro
  - Search of Milagro data for GRBs coincident with SWIFT
  - Monte Carlo and Budget preparation for miniHAWC proposal
  - GLAST DC2 and calculations of relevant GLAST sensitivities to GRBs and steady