



## A Search for Diffuse Sources of Ultra High Energy Gamma-Rays

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We describe a search for diffuse emission from several candidate sources of gamma-rays with energies  $\gtrsim 100$  TeV, using the Chicago Air Shower Array / Michigan Muon Array (CASA-MIA) experiment. Since March 1990, CASA-MIA has recorded over  $2.0 \times 10^9$  air shower events. Searches for diffuse emission are based upon the muon content of air showers. Candidate source regions include molecular clouds in the galaxy and the galactic plane. Results from CASA-MIA are compared to predicted diffuse emission.

### 1. INTRODUCTION

Gamma ray emission from diffuse gas clouds is an important tracer of cosmic rays in the galaxy, and can be used to probe the origins of cosmic rays of energies ranging from 100 MeV to 500 TeV or more [1–3]. We expect a diffuse flux of gamma rays from regions of concentrated hydrogen gas density, such as the galactic plane and giant molecular clouds. In these regions, the permeating flux of high energy cosmic rays will interact with the gas to produce new hadronic particles, including neutral pions, which subsequently decay into gamma rays.

### 2. THE CASA-MIA AIR SHOWER EXPERIMENT

The combination of the Chicago Air Shower Array (CASA) and the Michigan Muon Array (MIA) is the world's most sensitive detector of gamma-rays with energies above 100 TeV [4]. CASA consists of 1089 scintillation detectors laid out on a square grid of 15 m spacing. The total collection area of the experiment is roughly 230,000 m<sup>2</sup>. MIA consists of 1024 scintillation counters buried 3 meters below ground level. The counters are grouped into sixteen "patches" and have a total scintillator area of 2500 m<sup>2</sup>.

### 3. EXPERIMENTAL TECHNIQUE

To search for diffuse concentrations of cosmic gamma rays, we employ the technique developed by Matthews *et al.* [5]. Extensive simulations predict that the number of muons in 100 TeV gamma-ray showers is twenty to fifty times less than the number in cosmic ray showers of the same energy [6]. We search for gamma ray emission by looking for a localized excess of cosmic rays which are muon-poor with respect to the number of muons expected from hadron-initiated showers. We parameterize the muon content by the quantity:

$$r_\mu \equiv \log_{10} \frac{(n_{\mu\text{-obs}})}{(n_{\mu\text{-exp}})}, \quad (1)$$

where  $n_{\mu\text{-obs}}$  represent the number of muons actually *observed* for a shower and  $n_{\mu\text{-exp}}$  represents the number of muons *expected* for hadronic showers based upon the surface array measurement.

To determine if there is evidence for gamma ray emission from a localized candidate source region of the sky, we examine the distribution of  $r_\mu$  for showers within some "on-source" region and we search for an excess of muon-poor events. The excess is determined relative to some comparison "off-source" region which presumably contains a background of uniformly hadronic show-

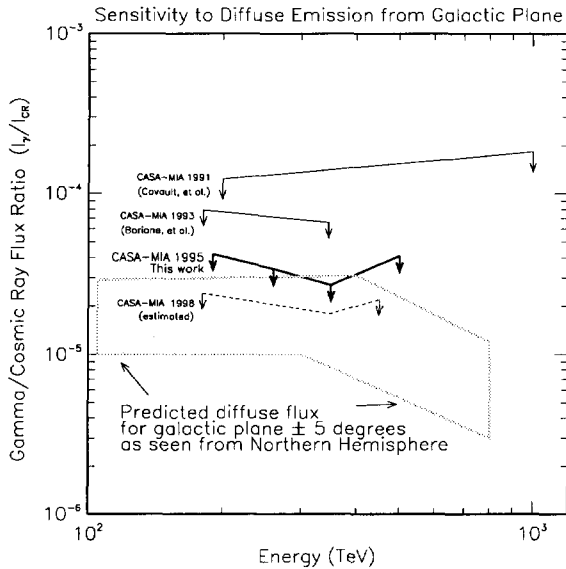


Figure 1. CASA-MIA sensitivity to diffuse gamma ray emission from the central plane of the galaxy ( $b_{II} = \pm 5^\circ$ ,  $50^\circ < \ell_{II} < 200^\circ$ ). Sensitivities are given in terms of the fraction of gamma rays relative to the detected all-particle flux of cosmic rays at the earth. Predicted flux from Aharonian [1].

ers. To compare the  $r_\mu$  distributions from source and background regions, we normalize the background so as to match the total number of events with  $r_\mu > 0.0$  from the source, assuming that all such events are purely hadronic. Events with  $r_\mu < -0.7$  are considered to be possible gamma ray primaries.

#### 4. CASA-MIA SENSITIVITY TO DIFFUSE EMISSION

Figure 1 shows the current CASA-MIA upper limits to diffuse flux from molecular clouds in the plane of the galaxy. This analysis is based on over  $1.8 \times 10^9$  events collected through Noveme-

ber, 1994. Table 1 shows the current flux limits obtained for galactic plane regions. These flux limits represent the most sensitive search to date for diffuse emission above 100 TeV in the plane of the galaxy.

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Galactic Plane Region ( $50^\circ < \ell_{II} < 200^\circ$ )	Median Energy (TeV)	Significance (Li-Ma $\sigma$ )	$I_\gamma/I_{CR}$ 90% C.L. ( $10^{-4}$ )
$-5^\circ < b_{II} < 5^\circ$	190	+1.7	< 0.42
	260	+0.9	< 0.34
	350	+1.4	< 0.27
	500	+0.4	< 0.41
$-10^\circ < b_{II} < 10^\circ$	190	+1.3	< 0.36
	260	+0.8	< 0.24
	350	+1.8	< 0.20
	500	+0.2	< 0.28

Table 1

Current results from a search for diffuse emission from galactic plane region as seen from northern sky.

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