RESULTS FROM THE CYGNUS EXTENSIVE AIR SHOWER ARRAY

David A. Williams
Santa Cruz Institute for Particle Physics
University of California
Santa Cruz, California 95064

Representing the CYGNUS* Collaboration

Abstract

Recent results from the CYGNUS cosmic ray experiment on objects studied by the Compton Observatory are presented. Studies of Geminga and several active galactic nuclei which have recently been detected by the Compton Observatory are discussed. Preliminary results of a search for ultrahigh-energy gamma rays coincident with gamma-ray bursts are also shown.

INTRODUCTION

The CYGNUS extensive air-shower experiment began operation in April 1986 with 50 scintillation counters, located around the Los Alamos Meson Physics Facility beam stop (106.3°W, 35.9°N, altitude 2130 m). One of its primary goals is the search for point sources of cosmic rays. The array has been expanded substantially since 1986. This paper describes data taken with the CYGNUS-I array, which presently has 108 counters, including the original 50, covering an area of 22,000 m². The median primary energy for detected gamma-ray initiated events is about 80 TeV in the present configuration; for protons, the median is about 100 TeV. Studies of the cosmic-ray shadows of the sun and the moon1,2 have shown that the CYGNUS array has a resolution for the projected angle of 0.66° ± 0.07°. The CYGNUS-I event rate is presently about 3.5 events/s. A more detailed description of the the CYGNUS experiment can be found elsewhere.3

The CYGNUS data set from April 1986 to May 1991 has been used to survey the whole sky from declination 0° to 80° for continuously emitting point sources.4 No evidence is found for emission from a source. Flux upper limits (90% confidence


Presented at The Compton Symposium, St. Louis, MO, October 15–17, 1992
<table>
<thead>
<tr>
<th>Source</th>
<th>Flux limit above 40 TeV</th>
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</thead>
<tbody>
<tr>
<td>Crab</td>
<td>&lt; $4.4 \times 10^{-13}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>Cyg X-3</td>
<td>&lt; $1.9 \times 10^{-13}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
<tr>
<td>Her X-1</td>
<td>&lt; $1.6 \times 10^{-13}$ cm$^{-2}$ s$^{-1}$</td>
</tr>
</tbody>
</table>

Table 1: Flux limits for continuous emission from some candidate sources.

level) for the three objects widely considered to be the most likely sources in the CYGNUS energy region are given in Table 1.

We have also conducted a search for emission lasting several hours (one day of observation) from many candidate sources. There is no evidence for any excess beyond what is expected from statistical fluctuations of the background. Typical flux upper limits (given in Ref. 2) are generally of order $10^{-12}$ cm$^{-2}$ s$^{-1}$.

We turn now to results from some specific Compton Observatory sources.

GAMMA RAY BURSTS

We have made a preliminary analysis of ten strong gamma ray bursts detected by BATSE for coincidences with the CYGNUS experiment. We search for events within a square bin 14° on each side (to account for the uncertainty in reconstruction of the burst direction by BATSE), centered on the burst position determined by BATSE, and arriving during the burst. We compare the number of events found for each burst to the number of background events expected. The number of expected background events depends very steeply on the zenith angle. The results are summarized in Table 2. The number of events found is consistent with background alone and the absence of a signal. For each burst, we calculate a preliminary flux upper limit (at the 90% confidence level), assuming that the photon spectrum is the same as the spectrum of background cosmic rays. The limits are shown in Table 2. They are given as the integral of the flux above a particular energy; for each burst, we choose the energy corresponding to our estimate of the median energy for gamma rays we would observe from that burst.

MARKARIAN 421 and OTHER AGN’S

Recently, the EGRET experiment and the Whipple experiment have detected gamma rays from the distant active galactic nucleus Markarian 421. These measurements indicate a differential energy spectrum of roughly $E^{-2}$ from this object. Because of its distance (about 125 Mpc), photons with energy above about 100 TeV are expected to be absorbed by $e^+e^-$ pair production off the 2.7 K microwave background. Our data from April 1986 through September 1992 show a small but insignificant (one standard deviation) excess from the direction of Markarian 421. We have made a preliminary calculation of our sensitivity to a

Note that the 1986 Hercules burst previously published (Ref. 5) is significant primarily because of the observed periodicity in addition to the excess of events.
Table 2: Summary of preliminary upper limits for the photon flux from ten gamma ray bursts detected by BATSE.

<table>
<thead>
<tr>
<th>Burst Number</th>
<th>Zenith Angle</th>
<th>Expected Background</th>
<th>Events Observed</th>
<th>Median Energy $E_m$ (GeV)</th>
<th>Flux Limit above $E_m$ (cm$^{-2}$ s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>13°</td>
<td>2.4</td>
<td>3</td>
<td>60.</td>
<td>$&lt; 6.7 \times 10^{-10}$</td>
</tr>
<tr>
<td>451</td>
<td>55°</td>
<td>0.058</td>
<td>0</td>
<td>1000.</td>
<td>$&lt; 2.3 \times 10^{-10}$</td>
</tr>
<tr>
<td>467</td>
<td>58°</td>
<td>0.025</td>
<td>0</td>
<td>1000.</td>
<td>$&lt; 9.2 \times 10^{-10}$</td>
</tr>
<tr>
<td>999</td>
<td>38°</td>
<td>0.41</td>
<td>2</td>
<td>150.</td>
<td>$&lt; 9.7 \times 10^{-10}$</td>
</tr>
<tr>
<td>1088</td>
<td>31°</td>
<td>0.039</td>
<td>0</td>
<td>100.</td>
<td>$&lt; 8.7 \times 10^{-9}$</td>
</tr>
<tr>
<td>1121</td>
<td>34°</td>
<td>7.0</td>
<td>7</td>
<td>110.</td>
<td>$&lt; 1.1 \times 10^{-10}$</td>
</tr>
<tr>
<td>1425</td>
<td>18°</td>
<td>3.0</td>
<td>3</td>
<td>60.</td>
<td>$&lt; 5.0 \times 10^{-10}$</td>
</tr>
<tr>
<td>1519</td>
<td>25°</td>
<td>4.2</td>
<td>3</td>
<td>90.</td>
<td>$&lt; 1.6 \times 10^{-10}$</td>
</tr>
<tr>
<td>1538</td>
<td>32°</td>
<td>0.62</td>
<td>0</td>
<td>140.</td>
<td>$&lt; 3.0 \times 10^{-10}$</td>
</tr>
<tr>
<td>1609</td>
<td>56°</td>
<td>0.019</td>
<td>0</td>
<td>1000.</td>
<td>$&lt; 8.5 \times 10^{-10}$</td>
</tr>
</tbody>
</table>

source at the declination of Mkn 421 with an $E^{-2}$ spectrum, cut off by the effect of the microwave background.\(^1\) We obtain a preliminary upper limit for the flux from Mkn 421 above 50 TeV of $1.5 \times 10^{-13}$ cm$^{-2}$ s$^{-1}$ (90% c.l.). This upper limit is compared to the extrapolation of the EGRET and Whipple measurements in Figure 1.

In the day-by-day search for emission (described above), we find no evidence for a "hot" day from Markarian 421.

We have also searched for continuous emission from eleven other active galactic nuclei which have been detected by EGRET and are in the CYGNUS field of view. They are 3C273, 3C279, 3C454.3, 4C+11.69, 4C+38.41, 4C+71.07, PKS0235, PKS0420, PKS0528, 0202+149, and 0716+714. We do not find evidence for a signal from these AGN’s. Calculations of our sensitivity to these sources are still in progress.

**GEMINGA**

We have searched the complete CYGNUS data set for continuous emission from Geminga. A 2.1 standard deviation excess is found over the expected background. Considering the number of sources that we have studied for continuous emission, as well as for emission on shorter time scales, this is not a significant excess. Thus, we calculate an upper limit for the flux from Geminga, which is $8.2 \times 10^{-14}$ cm$^{-2}$ s$^{-1}$

\(^1\)Several authors (see Ref. 10) have argued that the field of infrared radiation is sufficient to produce significant absorption at energies above about 1 TeV. Because of the uncertainties in the amount of infrared radiation present, we have not attempted to take it into account.
CONCLUSIONS

The CYGNUS experiment has looked for emission from several Compton Observatory sources, including gamma ray bursts, AGN's, and Geminga. At the present sensitivity of the experiment, emission above about 40 TeV has not been detected from these sources.

ACKNOWLEDGMENTS

We thank the BATSE Collaboration for sharing preliminary data on gamma ray bursts. We are indebted to C. Kouveliotou of the BATSE Collaboration for selection and transmission of the burst data and for extended communications concerning the operation of BATSE and interpretation of the data. The author wishes to thank the MP Division of Los Alamos National Laboratory for its hos-
Figure 2: Phase distribution for events from the direction of Geminga.

pitality. This work is supported in part by the National Science Foundation, Los Alamos National Laboratory, the U.S. Department of Energy, and the Institute of Geophysics and Planetary Physics of the University of California.

REFERENCES