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RESULTS FROM THE CYGNUS EXTENSIVE AIR SHOWER ARRAY

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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 m^2. 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 moon[1,2] have shown that the CYGNUS array has a resolution for the projected angle of $0.66° \pm 0.07°$. 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

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Source	Flux limit above 40 TeV
Crab	$< 4.4 \times 10^{-13}$ cm^{-2} s^{-1}
Cyg X-3	$< 1.9 \times 10^{-13}$ cm^{-2} s^{-1}
Her X-1	$< 1.6 \times 10^{-13}$ cm^{-2} s^{-1}

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.[2] 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[6] 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[7] and the Whipple experiment[8] 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.[9] 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.

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

Table 2: Summary of preliminary upper limits for the photon flux from ten gamma ray bursts detected by BATSE.

source at the declination of Mkn 421 with an E^{-2} spectrum, cut off by the effect of the microwave background.[‡] We obtain a preliminary upper limit for the flux from Mkn 421 above 50 TeV of 1.5×10^{-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 8.2×10^{-14} cm^{-2} s^{-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.

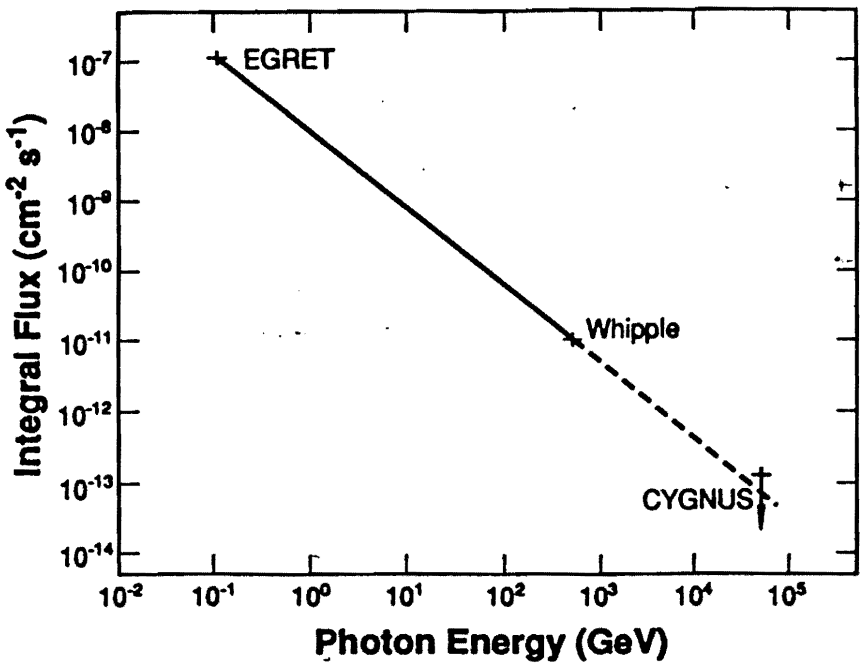

Figure 1: Comparison of the preliminary upper limit flux from Markarian 421 measured by CYGNUS experiment to the extrapolated fluxes from the EGRET and Whipple experiments.

(90% c.l.) above 80 TeV.

As for Markarian 421, the search for emission lasting about a day from Geminga fails to reveal a signal.

The subset of data from 6 July 1989 to 17 August 1992 has been analyzed using the ephemeris measured by the EGRET team[11] to search for periodic emission from Geminga. The phase distribution of events is shown in Figure 2. As can be seen in the figure, we find no evidence for continuous periodic emission from Geminga.

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 the experiment, emission above about 40 TeV has not been detected from these sources.

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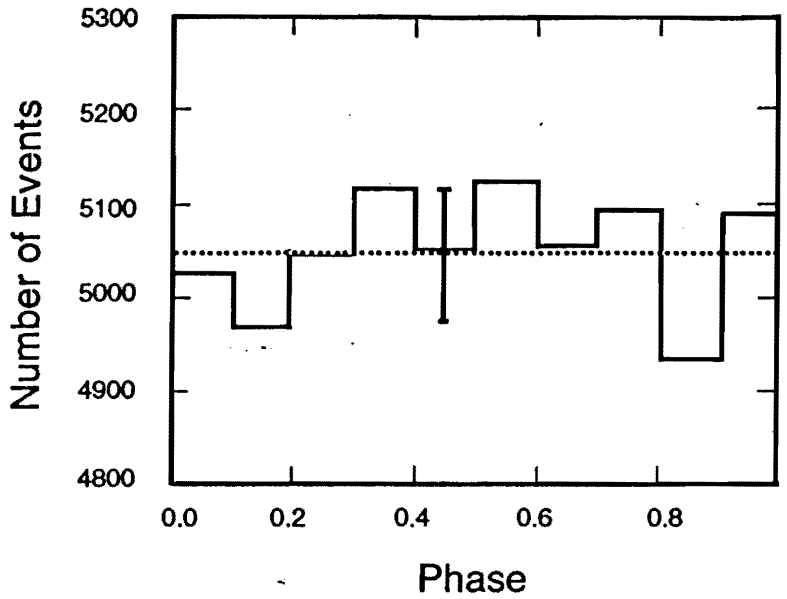

Figure 2: Phase distribution for events from the direction of Geminga.

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