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SEARCH FOR UHE EMISSION FROM 4U0115+63

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ABSTRACT

We report here the preliminary results of our observations of the sporadic X-ray binary system 4U0115+63. The CYGNUS air shower array has been collecting data since April 1986. No significant excess is seen from the direction of this source, nor any correlation with its 24-day orbital period. A 90% confidence-level upper limit on the flux from 4U0115+63 is 2.8×10^{-13} cm^{-2} s^{-1} above 50 TeV. This flux limit is considerably lower than those reported by other UHE experiments. Search for periodicity at the neutron star frequency is in progress.

THE CYGNUS EXPERIMENT AT LAMPF

The CYGNUS experiment[1] consists of an Extensive Air Shower array and muon detectors located in Los Alamos, NM, (106.3° W, 35.9° N) at an altitude of 2130 m corresponding to an atmospheric overburden of about 800 g cm^{-2}. The results presented here are based on the data collected between April 1986 and August 1990 by the part of the array described below.

The first part of the CYGNUS array consists of 108 counters covering 20,000 m^2. The spacing between counters ranges from 10 m in the center to about 20 m near the edges of the array. In each counter a 2″ photomultiplier tube views a scintillator of area 0.83 m^2 and thickness 0.1 m. The event triggering requirement is 20 counters each registering a hit above the 0.1 minimum ionizing particle level within 300 ns of each other. A layer of lead, about 1 radiation length thick, has been placed above each detector, resulting in a lower trigger threshold and a larger effective area. The event rate is 5 sec^{-1}.

With an average of 18 counters (each registering ≥ 1 minimum ionizing particles) in each reconstructed event, the uncertainty in the arrival direction is about 0.75°. The maximum systematic pointing error is less than 0.3°. All events are accepted independent of their core being inside or outside of the array. Event arrival times are recorded with a 0.5 ms accuracy. Simulations show that for gamma-ray-initiated showers with cores within the array, the detection efficiency is 70% for primary energies of 100 TeV.

PAST OBSERVATIONS

The UHURU satellite was the first to observe an (X-ray) outburst from a source located at right ascension $01^h15^m13.8^s$, declination $+63°28'38''$, hence called 4U0115+63. Months later the Crimean Astrophysical Observatory discovered a variable discrete source above 2 TeV, which they called Cas Gamma-1. Because of the positional coincidence and temporal behavior of this source in X-rays and VHE gamma rays, it has been suggested that 4U0115+63 is identical to Cas Gamma-1.[2] During subsequent X-ray outbursts from 4U0115+63, pulsations with a period of 3.61 s were detected, and an orbital period of 24.31 days with large eccentricity (0.34) was deduced.

Group	Observation	Threshold	Duration	Integral Flux
Crimea [3]	'71 - '73	2 TeV	two months	$3.0\ 10^{-10}$
Dugway [4]	Sep '84	1 TeV	continuous	$7.0\ 10^{-11}$
Haleakala[5]	Aug - Dec '85	0.2 TeV	$3 \times 1000s$	$2.0\ 10^{-9}$
Whipple [6]	Sep '85 - Jan '86	0.6 TeV	3 days	$1.5\ 10^{-10}$
Pachmarhi[7]	Winter '86	1.5 TeV	.2-3 hrs	$2.7\ 10^{-11}$
Gulmarg [8]	'87 - '88	2 TeV	1950 s	$1.8\ 10^{-10}$
Pachmarhi[9]	Oct - Nov '87	1.5 TeV		$< 6.0\ 10^{-12}$
La Palma [10]	Sep - Oct '88	0.4 TeV	continuous	$4.4\ 10^{-10}$
Plateau Rossa[11]	Feb 82 - Dec 87	30 TeV		$< 4.1\ 10^{-12}$
EAS Top [12]	88 - 89	150 TeV		$< 1.9\ 10^{-13}$

Table 1: Summary of past observations.

Table 1 summarizes most of the past VHE-UHE observations of the source. All observatories are Cherenkov telescopes except the last two which are air shower arrays. For positive detections, the duration of the emission is given. For the rest, the integral flux is an upper limit in photons cm^{-2} s^{-1}. Detections have been made only by Cherenkov telescopes and only by searching for the neutron star spin period. No enhancement of the on-source counting rate over the background has ever been observed.

ANALYSIS AND RESULTS

Given the angular resolution of our array, 71% of the signal from a point source should be contained in a bin of 2.3° width in declination and 5.2° width in right ascension. The background is estimated with eight bins at the same declination as the on-source bin, four on each side of it in right ascension. Thus, on a given day all nine bins traverse the same part of the sky; daily variations due to local air pressure etc. are also accounted for by this method. An hour angle cut ensures that all bins get equal exposure.

Figure 1 shows the total number of counts in the source and background

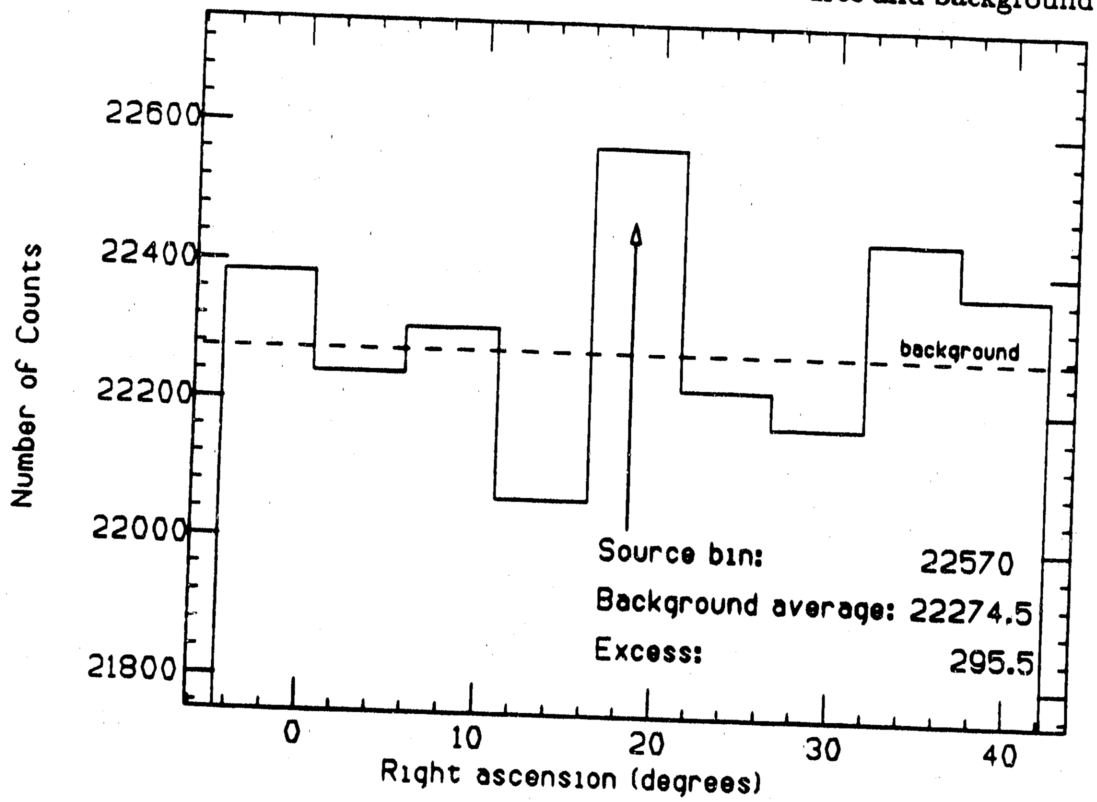

Figure 1: Right ascension scan around 4U0115+63

bins for the entire data set. For a signal spectrum with integral flux energy dependence E^{-1}, the 295.5 event excess (corresponding to 1.9 σ) from the source direction implies a 90% confidence-level upper limit on the flux from 4U0115+63 (assuming no signal) of 2.8×10^{-13} cm^{-2} s^{-1} above 50 TeV. This value is lower than any other published so far by UHE experiments (see previous table). On a day-to-day basis, the source excess count is calculated from the average background counts and histogrammed in Figure 2. In a total

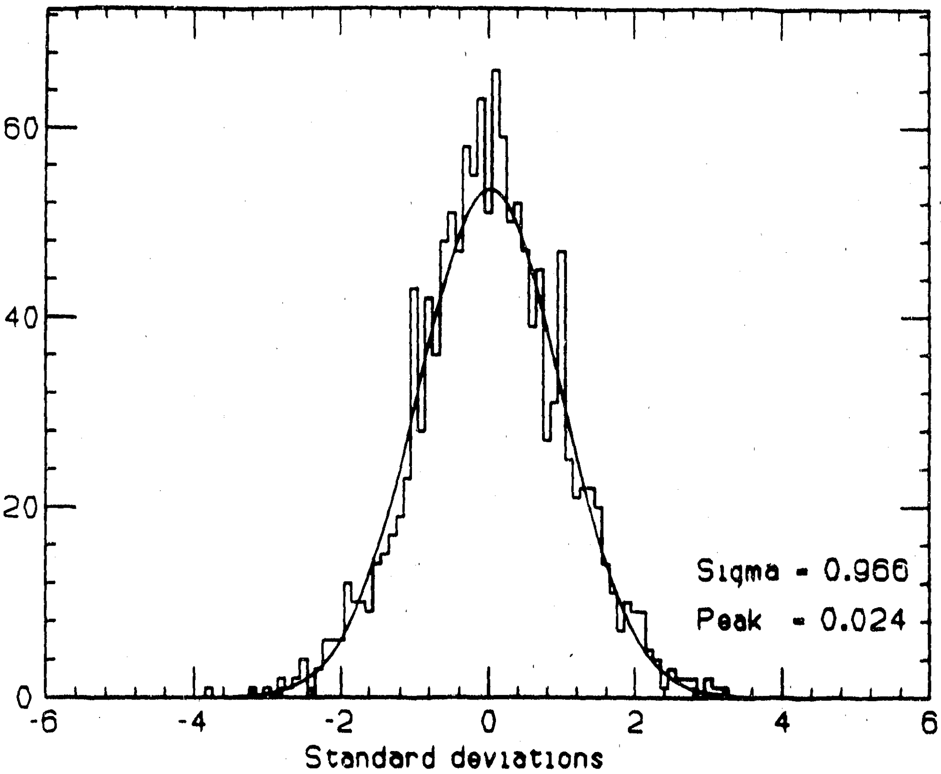

Figure 2: Distribution of daily excesses

of 1340 days, no large deviation from the expected Gaussian distribution, no "hot day," is observed.

Because of its long and continuous operation, this experiment has the possibility of observing emission correlated with the long orbital period of this binary system. Figure 3 shows the 10 bin phasogram which results when the event arrival times are folded with the 24.3154-day orbital period of 4U0115+63; it does not exhibit any such correlation. For this phasogram $\chi^2 = 12.6$ with 10 degrees of freedom.

We are currently working on the search for pulsed emission at the neutron star spin period of 3.61 s.

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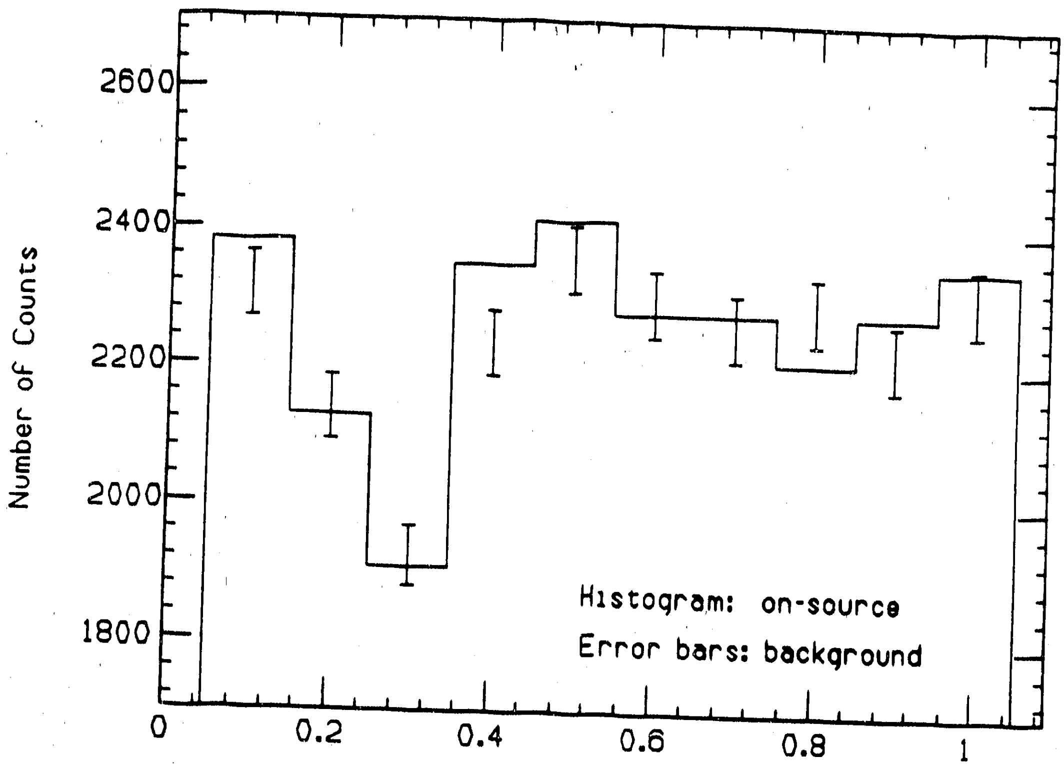

Figure 3: Orbital Phase

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