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A SEARCH FOR EVIDENCE OF POINT SOURCES IN THE CHERENKOV FLASH DATA FROM FLY'S EYE II

R.G. Cooper, S.C. Corbato, H.Y. Dai, B.R. Dawson, B.L. Emerson,
J.W. Elbert, D. Kieda, S. Ko, E.C. Loh, M.Z. Luo, M.H. Salamon,
J.D. Smith, P.V. Sokolsky, P. Sommers, J.K.K. Tang, S.B. Thomas
Department of Physics, University of Utah
Salt Lake City, UT 84112 USA

Abstract

A portion of the Fly's Eye II detector has been recording Cherenkov flashes since 1987 in the declination band 10° < ä < 50°. This band includes Cyg X-3, Her X-1, the Crab nebula, and Cyg X-1. The threshold energy is approximately 70 TeV. Observed and expected shower counts are available for all points in this declination band on a nightly basis. Searching for steady, transient, or sporadic point sources has yielded no positive detections. Flux upper limits are reported.

Detection and analysis methods

By triggering on a high amplitude pulse in any single phototube, the Fly's Eve II detector has been accumulating a large data base of air shower Cherenkov flashes. This has been analyzed in a search for ã-ray point sources. The cumulative results allow a search for an excess do flux from any point of the exposed sky. By examining results from the individual nights separately, we have searched for significant transient sources (bursts). To search for sporadic ã-ray sources, we have looked for sky locations exhibiting excesses of moderate significance on multiple nights.

Properties of Cherenkov flash detections at Fly's Eye II were reported in some detail at the Adelaide ICRC (1J. The operating conditions have not changed. The solid angle of Cherenkov flash sensitivity is 0.75 sr and provides exposure to declinations 10° < ä < 50°. The energy threshold is approximately 70 TeV, and the effective detection area is $\pi \times 10^6 \text{cm}^2$. The analyzed data include 393 nights from 11 November 1987 through 17 April 1991. The running time is 8.2×10^6 seconds, and the number of detected showers is 10.1×10^6.

The sky search employs a grid of 14400 points in the declination range 11°   ä 50° with   gridpoints separated by 1° in both declination and right ascension. For each gridpoint, the number of observed showers and the number of expected showers are determined for each night. The procedures are the same as for the candidate source study previously reported (1). A shower is counted as "observed" at a gridpoint if the gridpoint was separated from the phototube's central direction by less than 3.5° at the time of detection. The expected number of showers is computed for each gridpoint):y averaging the observed numbers of showers at that point from 30 simulation data sets. A simulation data set is derived from the night's actual data set by changing each shower's time of detection to another time randomly sampled from the other times of shower detections.

To search for persistent ã-ray sources, results from the various nights are combined by finding, for each gridpoint, the cumulative number of observed showers N and the cumulative number of expected showers X. Exposure is not uniform in right ascension or declination, but the numbers N and X are between 20000 and 40000 for the various gridpoints. The deviation ó = (N – X) / X can be used to measure the statistical significance of the excesses (ó > 0) and deficits (ó < 0).

Results

Figure 1 shows the distribution of ó-values for the 14400 gridpoints, together with the expected normal distribution. The distribution of measured ó-values has a width 1.4 instead of 1.0. This is not caused by non-gaussian statistics on individual nights. Those distributions have widths which differ very little from unity. Moreover, if the nightly results are combined using a random shift in declination and right ascension from night to night, the cumulative distribution has unit width. This means that the accumulation of a non-statistical excess or deficit is somehow due to a gridpoint's sky location. A check of bright star locations does not indicate that they cause excesses or deficits. Although the distribution is slightly broader than expected, its shape does not display any bump or tail at high positive values which would be necessary for a definitive point source detection.

Upper limits for point source fluxes are calculated for each gridpoint at the 90% confidence level, using the cumulative number of showers observed and number of showers expected together with the detection area and exposure time (cf. [1]). In units of *showers/cm*^{2} a, these flux upper limits range from $10^{-12.9}$ to $10^{-11.6}$. Figure 3 is a contour map indicating the variation of flux limits on the sky. The black regions are the highest flux limits. Since the exposure does not vary dramatically over the grid, black also indicates regions of higher ó-values.

Specific results for the *a priori* candidate sources are presented in the following table.

Candidate source	Number observed	Number expected	o	Flux Upper Limit (cm- 2s-1)
Crab	37997	37951	0.24	5.2 x 10- s
Her X-1	21082	21294	-1.4	3.9 x 10-13
Cyg X-3	35880	36031	-0.79	3.7 x 10'13
Cyg X-1	36563	36268	1.5	8.6 x 10-13

Table 1

The search for unusual bursts of showers consists of studying the nightly results for all gridpoints. For each night that a gridpoint had exposure, the Poisson probability P(n; x) is computed using the number n of observed showers and the number x of expected showers. Figure 2 displays the distribution of probabilities together with the uniform distribution on a log-log plot to detail the low probability end. The figure shows that there are no bursts of such low, probability as to stand out in this large set of trials.

To search for sporadic sources, we have used the distribution of nightly probabilities for each gridpoint. The product B of the nightly probabilities and the number of exposure nights *N* can be used to compute the probability *P* P (< *N*; -InII), using the Poisson distribution, For nightly probabilities sampled from a uniform distribution, the probabilities *P* should also be uniformly distributed [2,3]. (Since the nightly results come from discrete Poisson distributions of variable means, the expected distribution for *P* in the absence of point sources is biassed somewhat toward high *P*-values.) The distribution of measured *P*-values is in good agreement with the expected distribution. In particular, there is no special population of low *P*-values which could be used as evidence for sporadic ã-ray sources.

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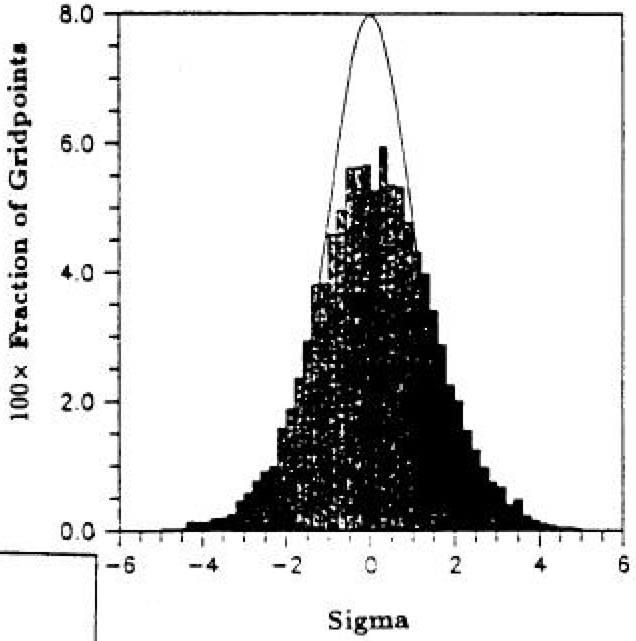

Fig. 1
The distribution of a-values for 14400 gridpoints. The solid curve is a normal distribution of width 1.

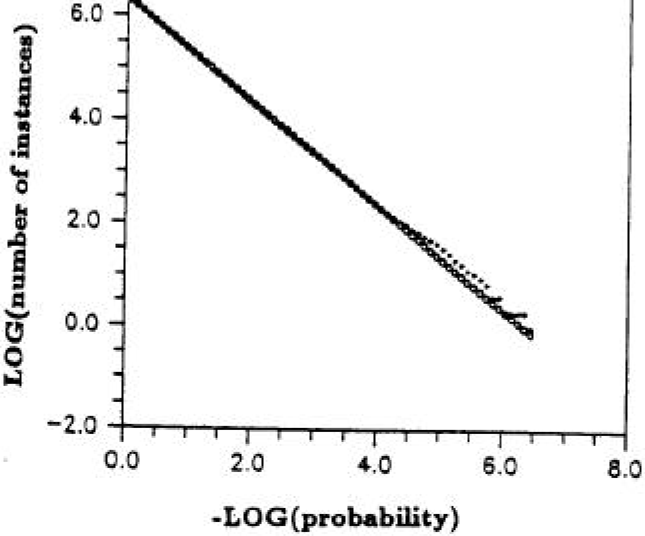

Fig.2
Log-Log plot of the distribution of probabilities (+). Each probability is for a particular gridpoint on a particular night. There are a total of 2,476,312 probabilities is the distribution. The open circles indicate a uniform distribution with equal number of trials.

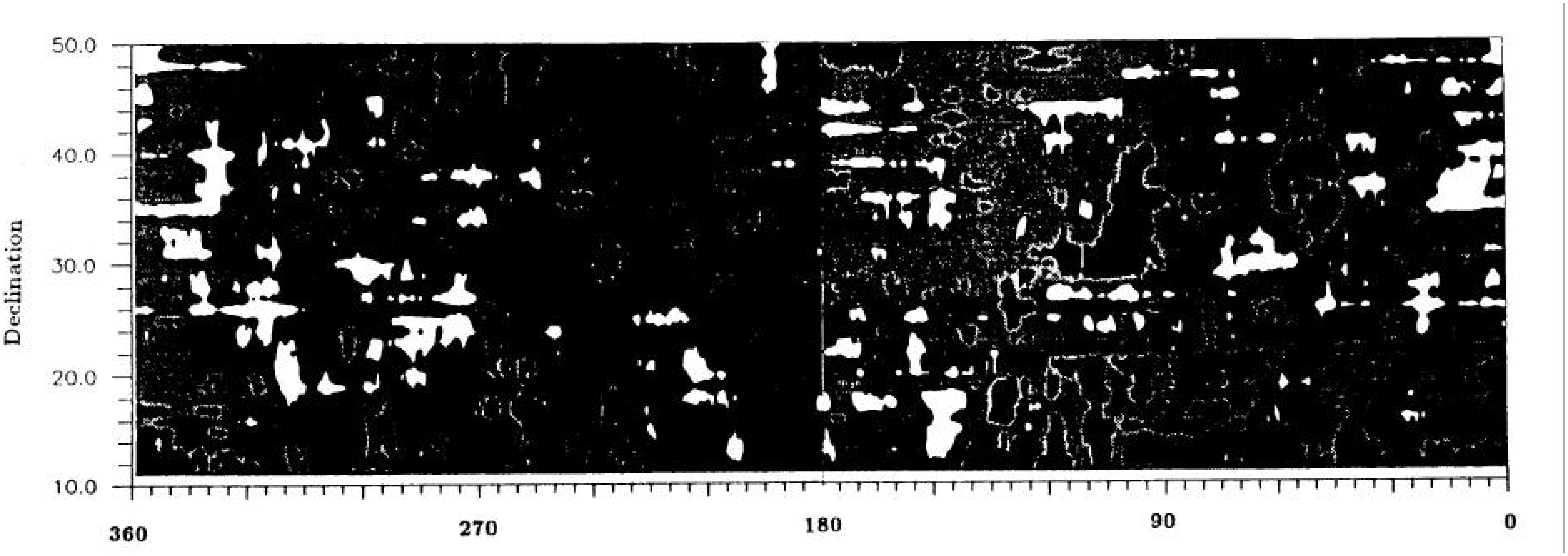

Fig. 3

Flux upper limits (90% C.L.)
All gridpoints have limits in the range $10^{-12.9}$ to $10^{-11.6}$ cm^{-2}s^{-1}
White: $10^{-12.9} < U.L. < 10^{-12.5}$
Gray: $10^{-12.5} < U.L. < 10^{-12.0}$
Black: $10^{-12.0} < U.L. < 10^{-11.6}$