# CYGNUS X-3 RESULTS FROM THE UTAH CHERENKOV ARRAY

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## Abstract

Observations of Cygnus X-3 during June-November 1988 and June-July 1989 are discussed. The 1989 data were taken during the interval between the June and July radio outbursts from Cyg X-3. Searches were performed for periodic signals from Cyg X-3. Upper limits far periodic fluxes were found. The upper limits are lower than those expected assuming a 1/E integral spectrum normalized to previous observations.

Introduction An array of four tracking Cherenkov telescopes has been constructed and operated at Dugway, Utah, U.S.A. The array is described in OG 10.3-2 of these proceedings. The array is centered on the common center of the components of the Utah-Michigan-Chicago extensive air shower experiment. It is able to operate together with the large buried muon detector (Sinclair, 1989) so that showers can be selected which have a low muon content. There are a number of scientific and instrumental goals of the work reported here. This paper deals with an attempt to observe periodic emission from Cygnus X-3. Another goal is to demonstrate the usefulness of a fast-timing Cherenkov array.

The data were obtained at night, when the moon was below the horizon. The 1988 data were taken during 6 monthly Fly's Eye runs from June to November. The 1989 data were taken on 10 nights during the U.T. interval June 26 to July 8. These data were taken between (not during) the times of the intense radio outbursts. Since reconstructed core positions are required to be within 120 m of the array center, the maximum effective area of the array is 45,000 m2. The array had a triggering efficiency of 50% within this area at 55 TeV in 1988 and 30 TeV in 1989. (Some minor changes in the equipment were made between 1988 and 1989.) Showers below 70 TeV and 40 TeV, respectively, were rejected during 1988 and 1989.

The number of hours of operation during the six monthly runs in 1988 were 5,32,40,21,22, and 10, giving a total of 130 hours at zenith angles less than 40°. The 1989 run duration was 34 hours. The rates of successfully reconstructed showers above the optimal energy thresholds during 1988 and 1989 were 1.0 and 2.3 per minute, respectively.

Periodic Signal Analysis The cubic Cyg X-3 ephemeris of van der Klis and Bonnet-Bidaud (1988) was used for this analysis. Foreground and background rates of showers were measured simultaneously by the following method. Showers whose reconstructed directions were within 1.0° of Cyg X-3 were accepted as foreground. Showers with directions between 1.5° and 2.5° of Cyg X-3 were counted as background showers.

For each monthly data set, the ratio, á, of the total number of foreground to the .total number of background showers was determined. Then for each phase bin, the expected foreground was estimated as the observed background multiplied by á. In searching for a signal in a phase bin, á was calculated excluding the phase bin being tested. In this way, a signal in a phase bin being tested would not cause the calculated expected number to be overestimated.

The data were analyzed in 5 phase bins. The phase bins 0.2-0.4 and 0.6-0.8 were examined for an excess. In addition, bin boundaries were E shifted to search for excesses in the phase interval 0.15-0.35 and 0.55 0.75. These intervals contain the periodic effects seen in most previous experiments.

The data from 1988 and 1989 were tested separately. There were 8 tests, from 4 phase intervals and 2 years. The results are shown in the following table. The significance is given in standard deviations according to Equation 9 of Li and Ha (1983), modified by the effect of the uncertainty in á. No evidence of a signal was obtained. Upper flux limits (Berkeley Particle Data Group,1988) were obtained in each phase interval at the 90% confidence level. As is usual, the flux is averaged over all phases. Some previous experiments have supported an integral spectrum of F-a$E^{-1}$, with a equal to about 40 eV $cm^{-2}$ $s^{-}$1. For the thresholds used in analyzing the 1988 and 1989 data, this would predict fluxes of $5.7\times10^{-13}$ and $10^{-12}$ $cm^{-2}$ $s^{-1}$ respectively. Our limits for periodic fluxes are substantially below these values.

| Year | Phase Interval | #á | # Observed | # Expected | Flux Limit ($cm^{-2}$ $s^{-1}$) |
|---|---|---|---|---|---|
| 1988 | 0.15-0.35 | -0.8 | 362 | 383.9 | $9.3\times10^{-14}$ |
| | 0.20-0.40 | -1.1 | 391 | 422.4 | $8.5\times10^{-14}$ |
| | 0.55-0.75 | -0.7 | 239 | 253.4 | $1.3\times10^{-13}$ |
| | 0.60-0.80 | 0.5 | 261 | 251.2 | $2.2\times10^{-13}$ |
| 1989 | 0.15-0.35 | -1.9 | 17 | 29.3 | $3.1\times10^{-13}$ |
| | 0.20-0.40 | -2.1 | 38 | 57.9 | $2.3\times10^{-13}$ |
| | 0.55-0.75 | 0.6 | 189 | 176.6 | $4.3\times10^{-13}$ |
| | 0.60-0.80 | 1.2 | 183 | 160.0 | $5.7\times10^{-13}$ |

Discussion. The , results set significant limits on fluxes during the operating times in 1988 and 1989. In the phase bins considered, the highest flux limits correspond to 15 $E^{-1}$ eV $cm^{-2}$ $s^{-1}$ and 23 $E^{-1}$ eV $cm^{-2}$ $s^{-1}$ in out 1988 and 1989 data, respectively. The 1989 data, analyzed without a cut on muon-poor showers, do not indicate a large periodic flux during the time between the two radio outbursts of 1989. Recent significant upper limits on Cyg X-3 fluxes are also reported from the Fly's Eye (Paper OG4.2-14) and from the Utah-Michigan Array (Paper OG 4.1-12).

Analysis is in progress to interpret the results of the muon array in order to select muon-poor showers. By selecting showers with less than 10% of the average number of muons for an observed shower energy and zenith angle the number of background showers can be greatly reduced. Because of Th energy threshold of the Cherenkov array, the factor by which the background can be reduced is smaller than for surface air shower arrays. Nevertheless, the preliminary results indicate that the background can be reduced by a factor of 20, increasing the sensitivity of the Cherenkov array to muon-poor gamma ray fluxes.

The present result supports the conclusion that a Cherenkov telescope array can be a very sensitive detector of air shower point sources in the energy range near and below $10^{14}$ eV. Additional data, especially muon-poor showers obtained by the Chicago Air Shower Array operating together with the Michigan Muon Array, can be expected to yield more definitive results on the existence and character of signals from Cygnus X-3.

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