VARIABILITY IN THE HIGH ENERGY GAMMA RAY EMISSION FROM CYG X-3 OVER A TWO-YEAR PERIOD (1983-1984) AT E > 4 x 10^{11}eV.

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1. The Data Base. The data base on Cygnus X-3 has been accumulated during the period between April 1983 and September 1984 using the Cherenkov camera described in a companion paper (Cawley et al 1985, paper OG9.5-4). The source was observed for almost 100 hours using both ON/ OFF tracking scans and long tracking runs (with no comparison "OFF" observations). The quality of the data was determined using standard statistical tests (see, for example, Danaher et al 1981); observations deemed acceptable for inclusion in the final data base are summarised in table 1. As the camera system evolved somewhat over the observational interval, the data base does not represent a homogeneous set of observations and the data categories in table 1 were analysed individually. Calibration procedures applied to the data prior to analysis are described elsewhere (paper OG9.5-4 this conference).

TABLE 1

Category	Observational Interval		Observation Mode	hours on source	coincidence requirement*	camera status
1	April-May	1983	ON/OFF	13.17	3/7	19-pixel
2	June	1983	ON/OFF	10.88	3/7	19 "
3	Oct-Nov	1983	ON/OFF	9.22	1/7	37 "
4	Nov-Dec	1983	ON/OFF	4.47	1/7	37 "
5	April-May-June	1984	ON/OFF	4.58	1/7	37 "
6	April-May-June	1983	Tracking	9.48	3/7	19 "
7	April-May-June	1984	"	10.17	1/7	37 "
8	August-Sept	1984	"	21.82	2/19	37 "
9	June	1984	Tracking	16.87	4/7	7 "
			TOTAL	100.66		

* Coincidence requirement: n-fold out of N pixels

2. Data Analysis. In accordance with the data reduction procedure outlined in the companion paper (Cawley et al. 1985), each category in table 1 was initially subjected to simple software trigger and threshold cuts (to eliminate very small fluctuation-dominated events)

and to a variety of total brightness (shower energy) cuts. These data categories were then folded modulo the 4.8h X-ray period using the ephemeris of van der Klis and Bonnet-Bidaud (1981). Light curves for each category are displayed in Fig. 1; categories 1 to 8 have been subjected to a 2/7 software trigger (demanding 45 $\pm$ 15 photoelectrons in at least 2 of the inner 7 tubes) while category 9 has had no software cut applied to it and simply represents the raw data as obtained with a four out of seven hardware threshold. Only the category 3 data shows a significant effect (4.5 σ at phase 0.6) while the remainder of the data is compatible with zero emission from the source at all phases. The data was then subjected to a variety of selection criteria based upon (i) Monte Carlo simulations of the Cherenkov images produced by gamma rays and protons and (ii) empirical optimization of the effect observed in the category 3 data. These tests were applied with two aims in mind: firstly, to see if the effect observed in the category 3 raw data set might be enhanced by application of a selective algorithm designed to isolate gamma ray type events and secondly, to see if any other effects might become apparent in any of the other categories. Referring to the imaging criteria outlined in Cawley et al (1985) the following tests were applied to each Cherenkov image with a view to enhancing the gamma ray signal:

(1) test for size and shape: some simulations indicate that the gamma ray images are more compact than their proton counterparts,

(2) test for orientation: some simulations indicate that gamma ray images show preferential orientation towards the centre of the field of view,

(3) tests based upon combination of both 1 and 2.

An improvement in the effect (over the complete lightcurve) was obtained for the Oct/Nov 1983 data by selecting compact showers irrespective of orientation; the net effect was increased from 3.7 to 5.2 σ and the peak at phase 0.6 was seen to broaden considerably (Fig. 2). It should be noted however that while this selection method was based on Monte Carlo predictions, it was optimized on this particular data. The same selection criteria applied to the rest of the data did not reveal any hidden effects. Similarly, cuts based upon shower orientation were not seen to improve the effect or reveal new effects.

The category 9 tracking data, taken in June 1984, was unique in that the data was acquired during the period of the full moon. The observation formed part of a collaborative effort to simultaneously monitor Cygnus X-3 over a wide range of the electromagnetic spectrum. Measurements were made in the infrared, radio, X-ray and VHE gamma ray bands and also with air shower arrays at energies $E > 10^{15}$ eV. Due to the lack of UV sensitivity in the 37 pixel camera a cluster of 7 one-inch photomultiplier tubes were used in conjunction with a UV filter to observe Cyg X-3 under full moon conditions, at a threshold energy of 2×10^{13} eV. The raw data was subjected to five different software thresholds based upon selection of showers with progressively larger light content and therefore greater energy. A significant effect was found for one of these selections which rejected 95.6% of the raw data giving an event rate after thresholding of 0.23 m^{-1} in comparison with a projected average zenith rate in the raw data of 6 events m^{-1}. A phase-optimised 10-bin plot is presented in Fig.(3) showing a 4.6 σ effect at phase 0.6. The significance diminishes for smaller total intensities, in contrast with trends observed in the Oct/Nov 1983 data. Also data taken using the conventional 37 element camera in the weeks immediately prior to this June 84 observation fail to show any effect.

3. Conclusions. Cygnus X-3 has been observed to be emitting gamma rays with energies in excess of 4×10^{11} eV during two out of 9 observational categories over an 18 month time span. The emissions are observed at the 0.6 phase of the characteristic 4.8hr light curve for this binary system. We estimate a peak flux at phase 0.6 of 5×10^{-10} photons cm^{-2} s^{-1} at a software threshold of 8×10^{11} eV for Oct/Nov 1983. A flux for the June 84 effect cannot be reliably calculated at present due to lack of Monte Carlo simulations for the energy range and spectral region. For the other 7 observational categories the observations are consistent with zero source emission. The light curve would appear to be variable on a time scale of a couple of weeks at these energies. Attempts at optimising the gamma-ray light curve through the selective application of imaging routines have been moderately successful. Selection of compact images in accordance with recent Monte Carlo simulations (Turver 1983, Hillas 1985) combined with empirical optimization techniques have led to an enriched gamma ray light curve for the Oct/Nov 1983 data. Selection on the basis of shower orientation, however, has not led to any notable enhancement of the gamma ray content. It may well be that the fixed spacing in our camera (0.5^{0}) is too coarse to fully exploit the predictions of the Hillas simulations (1985). With a significantly smaller spacing the simulations predict that individual Cherenkov images can be reliably sorted on an event by event basis into either proton-induced or photon-induced showers. The observations reported preliminarily by Clear et al (1983) for May 1983 showed marginal significance (3.1 σ) and efforts to enhance this signal on the basis of recent simulations have not been successful.

The successful observation of Cygnus X-3 during a period of full moon using UV sensitive phototubes in conjunction with selective optical filters represents an encouraging advancement of the Cherenkov technique. This offers the potential of extended observations on suspected time variable sources.

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K.E. Turver. private communication (1983).

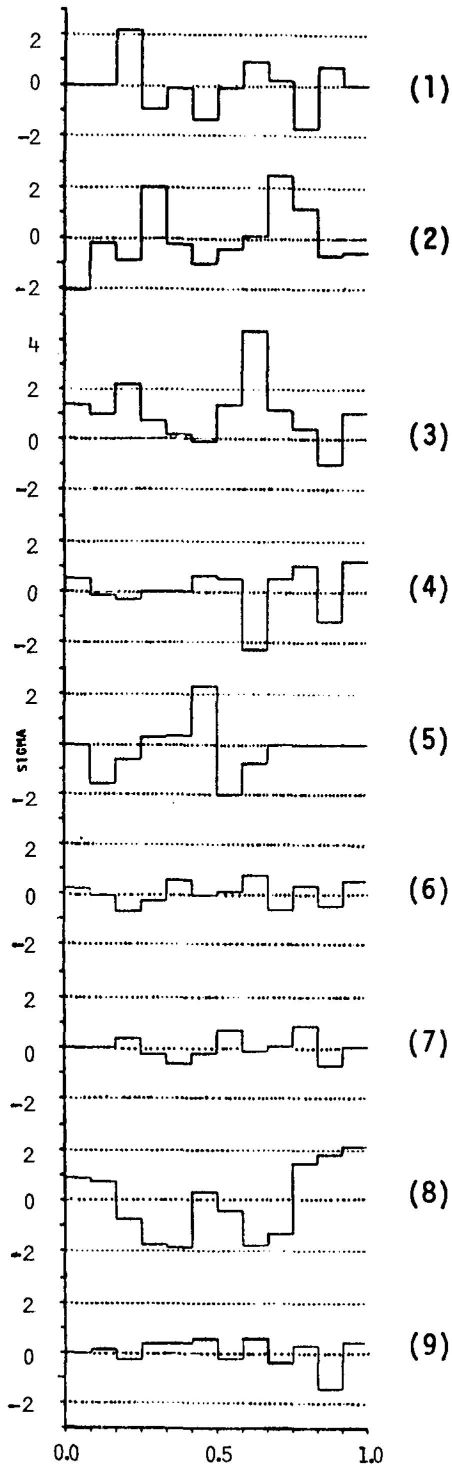

Fig. 1

4.8hr light curves for the corresponding data categories listed in table 1. The dashed lines indicate 0 and ±2 sigma levels. 12 phase bins per plot.

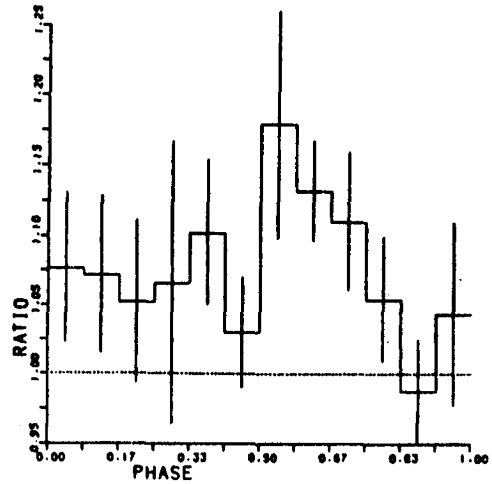

Fig. 2

Light curve for Oct/Nov 1983 data after selection of compact showers. 12 phase bins.

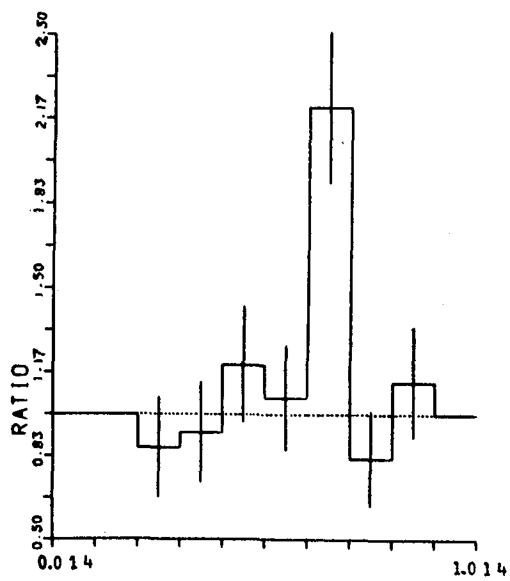

Fig. 3

Light curve for June 1984 data. The events have been subjected to a software threshold described in the text. The phase bins have been shifted by 0.014 phase to optimise the effect around phase 0.6. 10 phase bins are used.