1000 GeV GAMMA RAYS FROM CYGNUS X-3 - AN UPDATE.

Chadwick, P.M., Dowthwaite, J.C., Kirkman, I.W., McComb, T.J.L., Orford, K.J. and Turver, K.E.
Department of Physics, University of Durham, Durham DH1 3LE, U.K.

ABSTRACT

Measurements of 1000 GeV γ-rays from Cygnus X-3 made with the University of Durham facility at Dugway, Utah in 1981/82 are reviewed. The light curve of the 4.8 hour modulated emission is updated and shows evidence significant at the 4.4 σ level for strong emission (9% of the cosmic ray rate) at phase 0.625 and less significant (1.4 σ level) indications of weaker emission (3% of the cosmic ray rate) at phase 0.125. The effect constituting the excess on the few nights showing the strongest emission appears to arise from the smallest Cerenkov light signals suggesting a steep γ-ray spectrum. The 1982 data have been searched unsuccessfully for evidence of emission at phase 0.2, in coincidence with the results from the ultra-high energy EAS measurements in 1979-1982.

A systematic investigation of a long term variation in the strength of the peak of the 4.8 hr modulated 1000 GeV γ-ray emission has been made. We find that in addition to the approximately 34 d variation reported by us previously, a stronger effect exists at around 19d.

The results of an unsuccessful search for a pulsar period or pseudo-regular variations in γ-ray emission are reported.

1. INTRODUCTION.

Cygnus X-3 was observed for 350 hrs in 1981/82 using the Dugway γ-ray facility. The initial results on the emission of the 1000 Gev γ-rays have already been reported [1]. We here update the analysis in the light of our further understanding of our equipment and the considerable interest in Cyg X-3 since that time. Most of the data in 1981 were taken with the telescopes in the drift scanning mode, a reliable but inefficient mode of operation. In contrast to other VHE γ-ray observations, we made our drift scans of Cyg X-3 at predetermined phases in the 4.8 hr orbital period using the X-ray ephemeris [2]. Observations on the other experiments are made with no preconsideration of the orbital phase and the results from many drift scans, in a typical 10 % phase range, are combined and presented as a phase histogram. In our case the ON/OFF ratio of counts, being the basic data of the driftscan, represent the flux of VHE γ-rays in a 10 min time slot (0.035 in phase) at fixed orbital phases. We chose to make most of our observations at spot phases, separated by 0.125 steps from 0 to 1.0. A small number were made in 0.125 steps from 0.03 to 1.03. The observations in 1982 were made using the telescopes to track the object with the intention of investigating the duration of any activity detected using the driftscan data and to search for a pulsar periodicity.

2. RESULTS.

We show in Figure 1 the light curve for 1000 GeV Υ-rays based on all the data recorded on clear nights. The data are similar to those reported earlier [1] but allowance has been made for what we now know to be the non-uniform background in the Cygnus region [3] which causes the effective background for point source detection to be different in the region of Cygnus X-3. Figure 1 shows at phase 0.64 $\pm$ 0.03 an excess of 9.4 % of the cosmic ray rate for our telescopes (a flux of $3\times10^{-10} cm^{-2} s^{-1}$). The excess is significant at the 4.4 σ level if we assume, in the light of earlier Υ-ray observations and a knowledge of the phase of the X-ray maximum, that this was the expected phase. The measurements around phases 0.5 and 0.75 show no excess indicating a duty cycle of < 20%. Consideration of the tracking data [1] suggests that the activity lasts for only 5 - 10 min. At phase 0.14 $\pm$ 0.03 we note a 3.4 % excess significant at the 1.4 σ level.

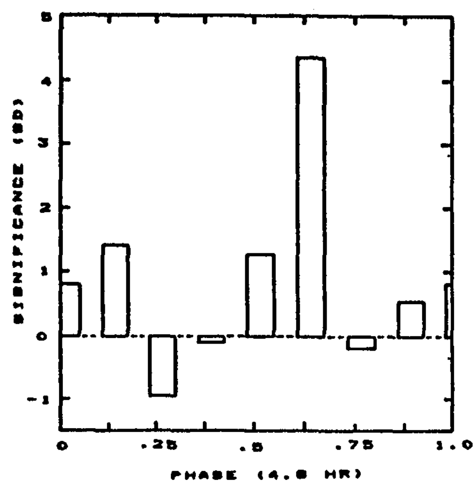

Figure 1. The 4.8 hr light curve.

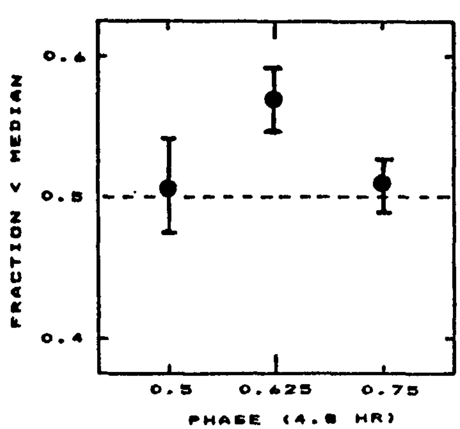

Figure 2. The fraction of recorded light flashes smaller than the median value.

The origin of a strong excess (~20%) in counts at phase 0.625 in 4 observations has been investigated. The median value of the Cerenkov light amplitudes has been evaluated for each detector in each observation. This has been done on the basis of the events in 20 min OFF SOURCE measurement in each scan. The number of flashes in the ON SOURCE interval for each detector in each scan below this predicted median value has been evaluated and summed over all 4 observations. We show in Figure 2 the number of events below the predicted median, expressed as a fraction of the total, for observations in the phase range 0.5 - 0.75. If the light amplitudes from Υ-rays and protons were similar we would expect a ratio of 0.5. There is clear evidence that the events constituting the count rate excess at phase 0.625 are amongst the smaller Cerenkov signals. A complicated behaviour of the proportion of 0.625 phase ON SOURCE signals within the first octile and quartile (again calculated on the basis of the OFF SOURCE data) which correlates with the individual detector energy thresholds is noted. The detectors with the highest threshold energy show the strongest concentration of γ-ray candidates in near-threshold events. This supports the idea of a γ-ray spectrum which is steeper than the proton spectrum.

A search has been made of the data taken in 1982 with the telescopes in the tracking mode for emission at phase near to 0.2, the phase at which 10^{15} eV emission has been noted [4,5]. This has been unsuccessful with only a flux limit (at the 3 σ level) of 2×10^{-11} cm^{-2} s^{-1} being derived.

X-ray observations of Cyg X-3 have suggested variations in the amplitude of the 4.8 hr modulation [6] on a time scale of 34 d. In addition, the magnitude and sign of the phase shift in the time of occurrence of the peak X-ray emission on a time scale of 19 d [7]has been noted.

We previously reported the result of folding the values of the amplitude of the 4.8 hr VHE γ-ray peak at phase 0.625 in individual scans modulo 34.1 d [6]. Recently we have investigated the long term variation in this peak strength in a more general way.

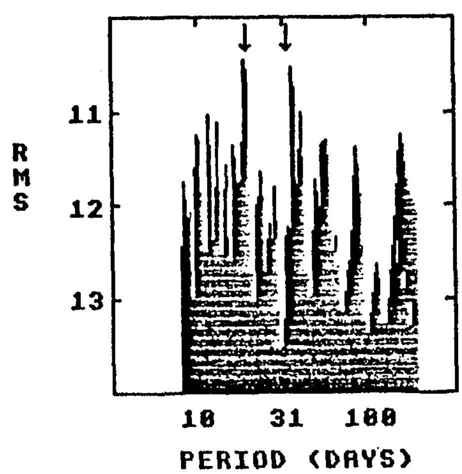

Figure 3. The long term variation of the 4.8 hr peak.

We have fitted a sine wave to the excess shown in all the individual scans at 0.625 phase with the fit constrained to have the observed strength averaged over all scans and to have a peak-to-peak amplitude ranging from zero to twice the average. The rms deviation from such a sine wave fit for independent periods in the range 8 to 500 d is shown in Figure 3. There are two periods with small deviations - the best fit - and these are 19.2 ± 0.4 and 36.8 ± 1.5 d.

The sine wave with period 19 d has its maximum (i.e. maximum 1000 Gev γ-ray emission at phase 0.625 in the 4.8 hr orbital period) at JD 2445163 ± 0.5. The X-ray phase effect reported [7] has a maximum phase lead, interpreted as due to apsidal motion, at JD 2444389 ± 1. These two possible effects cannot be reliably linked in phase due to the combined uncertainties in period and epoch.

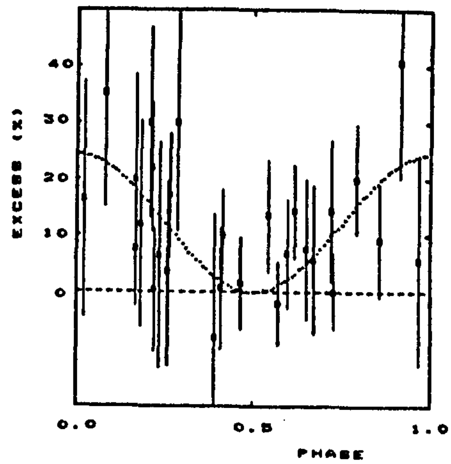

Figure 4. The peak strength at phase 0.64 folded modulo 19.2 d.

We have searched a small subset of Cerenkov light data selected to be rich in γ-ray candidates, those recorded at the times of maximum VHE γ-ray emission (phase 0.625), for periodicity on the time scales of 1 ms - 100 s. Having tested the 6×10^5 independent periods using the Rayleigh test, we find no evidence for periodicity involving a light curve with a large duty cycle. Indeed on the basis of the count rate of the present generation of telescopes, we would not expect to obtain sufficient counts in the short time (mins) during the observed excess at phase 0.625 and which is the maximum allowable if we are to avoid the effects of the (unknown) Doppler shift due to a typical orbit. For example, a γ-ray signal of 10% of the cosmic ray background would require a data rate in excess of 3 Hz to produce, in a time of 10 min, a probability of periodicity of 10^{-7} on the Rayleigh test which would stand clear of chance expectation.

The Rayleigh test applied to the 1982 tracking data has provided no evidence for any pseudo-periodic emission in the range 500 ms to 100s (1200 independent periods tested) of the type reported for the X-ray emission [8].

REFERENCES.

(1) Dowthwaite J.C., et al:1983, Astron. Astrophys,126,1.
(2) Van der Klis,M., et al : 1981, Astron.Astrophys,95,L5.
(3) Dowthwaite J.C., et al:1985,Astron.Astrophys,142,55.
(4) Samoski,M. and Stamm,W.:1983,Ap.J.Lett,268,L17.
(5) Lloyd-Evans, J. et al :1984, Nature,305,784.
(6) Molteni,D., et al: 1980, Astron. Astrophys.,87,88.
(7) Bonnet-Bidaud, M., et al:1981, Astro. Astrophys.,101,299.
(8) Van der Klis: 1984 Proc 17th ESLAB Symposium.