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Observations of Cygnus X-3 at energies above 1000 GeV

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The Crimean Observatory Group have reported, in several publications, the detection of high energy γ-rays from the X-ray source Cygnus X-3 (Vladimirsky *et al.* 1973; Vladimirsky *et al.* 1975, Stepanian *et al.* 1977, Neshpor *et al.* 1979, Mukanov *et al.* 1979). The energy was in the region of 1000 GeV, and observations were made by means of the atmospheric Cherenkov technique. Measurements at lower energies have shown conflicting results. Satellite observations in the 10^8 eV region have shown positive effects from Cygnus X-3 in the case of SAS-2 (Lamb *et al.* 1977), but not in COS-B (Bennett *et al.* 1977). Similarly, γ-rays have been seen in some balloon flights (Galper *et al.* 1977), but not in others (McKechnie *et al.* 1976, White *et al.* 1980). A Cherenkov study at 300 GeV (Helmken & Weekes 1979) showed no effect, but this has been shown by Neshpor *et al.* (1979) to be compatible with the Crimean results.

The Crimean group found a periodic signal with the same 4.8 hour period as the X-rays. Two γ-ray peaks have been observed: a narrow main one at 0.18 periods after the X-ray minimum, and a broader interpulse at 0.7–0.8 periods after the X-ray minimum. In recent measurements (Stepanian, private communication) the interpulse has been dominant over the main peak. A sporadic non-periodic effect has also been observed.

We report here on observations taken at Mount Hopkins Observatory, Arizona (altitude 2.3 km) in April, May and June 1980. The system was made as similar as possible to one unit of the Crimean experiment. Two mirrors of diameter 1.5 m were used, with a 5 cm photomultiplier and aperture stop at the focus of each, giving a full-field of view of 2.0°. Coincidences were taken between the two detectors with a resolving time of 7 ns, and were recorded on digital magnetic tape together with pulses from the single detectors and random coincidences. Current-controlled servolamps were used to keep the background light constant. Observations were made in drift scans lasting thirty minutes each: ten minutes before the source entered the field (off), ten minutes in the field (on), and a final ten minutes outside the field (off). A scan was rejected if: (*a*) the off parts of the scan, divided into 120 ten second intervals, failed a Poisson homogeneity test at the 1% level; (*b*) the two off observations differed by more than two Poisson standard deviations; or (*c*) if in any ten second interval the count rate was sufficiently high to give a 4σ departure from the mean. Of 139 scans on Cygnus X-3, 95 were acceptable. These were taken at various phases on the 4.8 hour period.

Figure 1 shows the ratio of on/off rates plotted in ten bins corresponding to the particular phases of X-ray emission. Standard errors have been calculated experimentally for each phase bin, and are approximately 14% higher than the Poisson values. This is consistent with previous experience with the atmospheric Cherenkov technique (Long *et al.* 1965). Phases have been calculated by using Stepanian's period, period derivative and base-date. It will be seen that the ratios are close to one except for the interval 0.7–0.8, which has a $+3.5\sigma$

departure from unity. The numbers of counts involved are: on, 799; off, 662 before and 668 after transit. Three drift scans are available. Random coincidences and single rates were normal during the scans. The apparent flux corresponding to the effect at the interpulse is approximately 1.5×10^{-10} ph cm^{-2} s^{-1}, in good agreement with the value of 9×10^{-11} ph cm^{-2} s^{-1} quoted by Neshpor *et al.* (1979), and the threshold energy is approximately 2×10^{12} eV, similar to that of the Crimean group. Although there is some slight uncertainty in the period and period derivative for Cygnus X-3 (Mason & Sanford 1979, Elsner *et al.* 1980), our phases are directly comparable with the Crimean results, since we have used the same constants. We appear, therefore, to have confirmed, at least qualitatively, their observations. We note that the phase of the peak in our results corresponds to maximum emission for lower energy γ-rays (Lamb *et al.* 1977) and for X-rays (Bonnet-Bidaud *et al.* 1978).

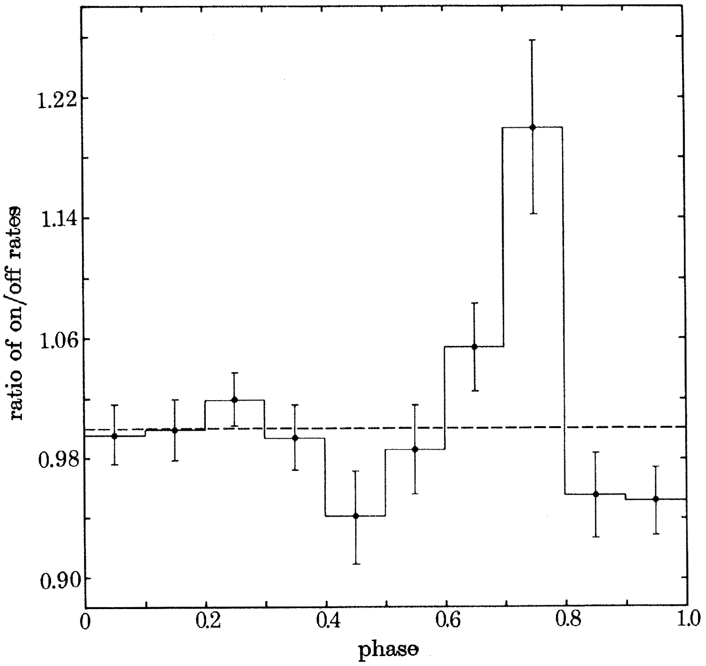

FIGURE 1. Phase histogram of γ-ray emission from Cygnus X-3.

If the Cherenkov measurements are accepted as indicating a flux of high energy γ-rays, they favour models that require a young pulsar (Bignami *et al.* 1977). Cygnus X-3, although usually classified as an X-ray binary, then becomes an unusual type of source, in which very high energy processes are dominant, while the X-ray and lower energy emissions are secondary. To explain the conflicting results for low energy γ-rays, it may be necessary to assume an emission declining slowly from a high value at the time of the radio outburst in 1972. Some variability is implied by the high energy γ-ray results alone. If the source is indeed a young pulsar, a periodic analysis of the high energy data may reveal the predicted 4–20 ms rotation period.

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