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A search for TeV photons from 4U0115 + 63

R. C. Rannot[1], C. L. Bhat[1], V. K. Senecha[2], M. L. Sapru[1], A. K. Tickoo[1], R. K. Kaul[3] and H. S. Rawat[2]

[1]*Bhabha Atomic Research Centre, Nuclear Research Laboratory, Bombay 400 085*
[2]*Centre for Advanced Technology, Rajendra Nagar, Indore 452 012*
[3]*Bhabha Atomic Research Centre, Nuclear Research Laboratory, Jammu 180 006*

Abstract. An analysis of 47 hours of data collected by the Gulmarg γ-ray telescope during the period 1989 September 27-October 30, indicates absence of a statistically significant steady, persistent-pulsed or episodic pulsed signal from the X-ray binary pulsar, 4U0115 + 63, at photons energies $\geq$ 4 TeV. An upper limit of 2.33×10^{-11} photons cm^{-2} sec^{-1} is placed at 99% confidence level on the steady γ-ray flux from this transient X-ray binary system.

Key words : gamma-rays—binary—4UO115 + 63

1. Introduction

This binary system was apparently first detected by Stepanian *et al.* (1972) as a VHE γ-ray source in 1971 at Crimea and was named by them as Cas gamma-1. The Crimean group did not, however, find any evidence for emission from the source in 1972-73, thereby indicating possibility of its transient nature. Subsequently, a more significant result was claimed by the Durham group (Chadwick *et al.* 1985), who reported detection of persistent-pulsed TeV gamma-ray emission from this source in 1984. The γ-ray period was found to be consistent with the corresponding X-ray pulsar period. They did not find evidence for any variability in the signal strength during the entire observation period, lasting for 9 nights. Identical results, particularly with regard to the constancy of the signal strength, were obtained in the course of repeat-observations made by this group during 11 nights in 1988 September-October (Brazier *et al.* 1990).

During 1985, the Haleakala group (Resvanis *et al.* 1987) found a weak evidence for episodic gamma-ray emission from the source. The Pachmarhi group (Acharya *et al.* 1990) have also reported detection of a 2-3 hour-long episode of VHE gamma-rays from 4UO115 + 63 in 1986 with a pulsation period of (3.62 ± 0.006)s, but they reported null results for the period 1987-88. Using the more sensitive Whipple imaging Cerenkov telescope, Macomb *et al.* (1991) did not find any evidence for a steady or pulsed gamma-ray signal from the source in their database, spanning the period 1985-1988. Similarly, our group too, did not record a statistically significant VHE signal (steady or pulsed) from the source direction during the period 1987-88 (Rannot *et al.* 1992).

2. Experiment details

Observations were made at Gulmarg (74.4°E, 34.1°N, 2740 m al) during the period 1989 September-November, using one 3-mirror bank of our gamma-ray telescope (see Koul *et al.* 1989 for details). The occurrence time of each 3-fold prompt- and delayed- (or chance) coincidence event (resolving time ~ 20 ns) was registered with a resolution of 1 μs and an absolute time accuracy of ±170 μs (Sapru *et al.* 1990). The genuine coincidence rate (GCR), due to the combined contribution of cosmic-ray and γ-ray primaries, is obtained by subtracting the delayed coincidence rate (DCR) from the prompt coincidence rate (PCR). This rate has an average value of 0.33 Hz, corresponding to an estimated gamma-ray primary threshold energy of 4 TeV.

3. Results and discussion

A total of 47 hours of data were obtained on this binary system in the on/off mode of observations. A search was conducted for a possible steady emission from the source by comparing, as such, the GCR counts recorded in a given on-source scan with the corresponding off-source counts. No significant excess was noted in the on-source counts in any of the individual data-sets, as is reflected by the overall GCR counts ratio of (1.2 ± 0.01). This yields an upper limit at 99% confidence level of 2.3×10^{-11} photons cm^{-2} s^{-1} on the steady gamma-ray signal from 4U0115 + 63 at photon energies $E\gamma \geq 4$ TeV.

A search for the episodic-pulsed emission was next conducted by subjecting, individually, all the 47 on- and off-source data segment pairs to the Rayleigh test. Rayleigh power (Q) was calculated for 14 independent periods (IP) covering the period range 3.56-3.66s. No significantly high Q was obtained for any of the data segments. In a related study, aimed at looking for shorter time-scale pulsed episodes, each 30 minute-long date segment was subdivided into contiguous intervals ranging in duration from 300-1800s. Each of the resulting subsets was also subjected to a period search in the above-referred range. Again, this search yielded a null result. These analyses indicate the absence of a significance pulsed-emission from the source in the form of a short-duration episode, spanning the time-scale range 300-1800s.

In another exercise, the overall 14-day data were reorganized into 7 pairs of mutually exclusive, nearest-neighbour days. The purpose behind this clubbing is to search, with a comparatively better sensitivity, for persistent-pulsed emission from the source on a time-scale of up to a few days. Rayleigh power (Q) was calculated this time for the 136 independent periods covering the search-window (3.61 ± 0.05)s. Figure 1 shows the resulting differential distribution of Rayleigh power values. The largest $Q = 11.25$ is obtained for the trial-period of 3.59289s for the composite data-set belonging to 1989 September 27 and 28. The chance occurrence probability for this value is 3.4% when all the trials are taken into account. This chance origin probability, will further increase by a factor of 2-3 when we consider the effect of search-induced phase-alignments resulting from combining non-contiguous data-segments. Therefore the alternative hypothesis (presence of a signal) is not favoured. In order to detect a weak persistent γ-ray signal, Rayleigh powers were summed over all the 47 data segments. No significant enhancement of average power at any trial period was found, indicating the absence of a persistent-pulsed gamma-ray signal in the present database. Following Macomb *et al.* (1991), we have also used the average value of the incoherently summed power at the expected X-ray period to give an upper limit on the persistent-pulsed flux of TeV gamma-rays from 4U0115 + 63. It turns out to be 2.4×10^{-11} photons cm^{-2} s^{-1} at 99% confidence level.

The new results discussed here are compared in figure 2 with upper limits and flux values reported earlier by other groups for 4U0115 + 63 in the VHE range. The disparity

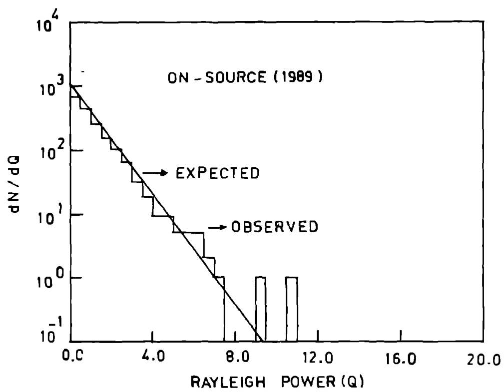

Figure 1a. Rayleigh power distribution for the on-source data groups obtained during 47 h of observations in 1989. Each group comprises data belonging to two neighbouring days. The distribution expected for random data is also shown for comparison.

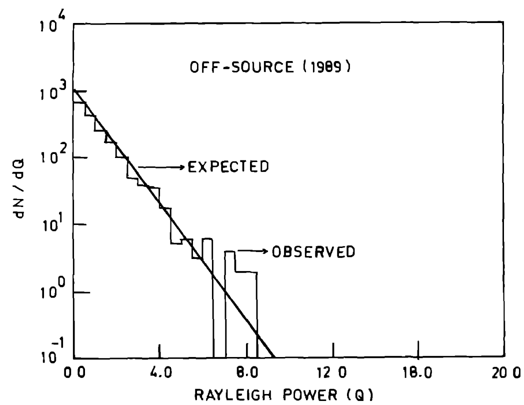

Figure 1b. Same as figure 1a, except that the corresponding off-source data are used.

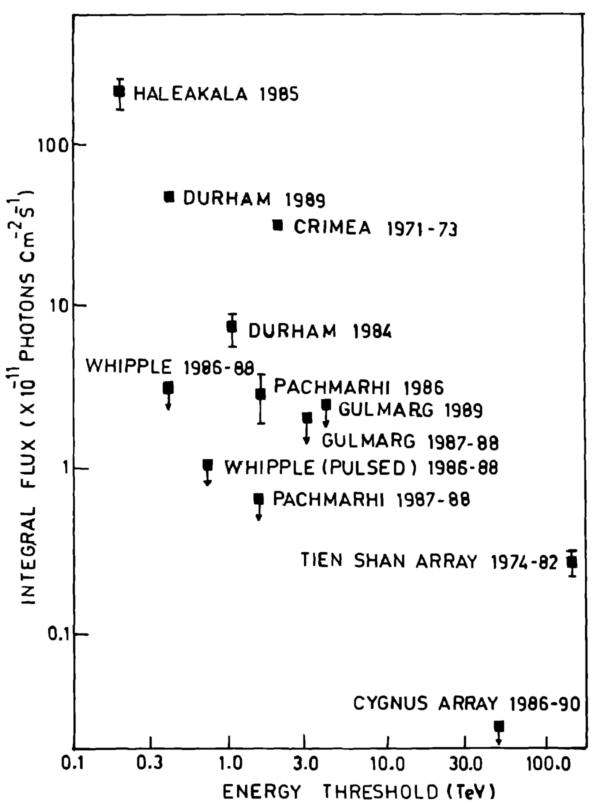

Figure 2. A summary of important results obtained on 4U0115 + 63 by various groups. The reported upper limits (points with arrow) and flux values for d.c. and pulsed emission are plotted against corresponding threshold energy.

of the recent results, including those from the Whipple group, with detections reported by the Crimean and Durham groups, is clearly evident from the figure. One possible explanation for this apparent disparity can be in terms of a time-variability of the VHE source in 4U0115 + 63.

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