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Cygnus X-3: TeV observations during 1995 – 2003

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The results of almost ten-year observation of Cygnus X-3 point source by SHALON mirror Cherenkov telescope are presented. The galactic source Cygnus X-3, known for more than 10 years as a source with variable intensity $< 10^{-11} - 5 \times 10^{-12}$ cm^{-2} s^{-1}, was regularly observed since a 1995 with average gamma-quantum flux of $F(E_O > 0.8TeV) = (6.8 \pm 0.7) \times 10^{-13}$ cm^{-2} s^{-1}. The flux at 2003 year is $(1.79 \pm 0.33) \times 10^{-12}$ cm^{-2} s^{-1}. Earlier, in 1997, the increase of the flux was also observed $(1.2 \pm 0.5) \times 10^{-12}$ cm^{-2} s^{-1}. The limits on gamma-rays from Cygnus X-3, the source that results stimulated the construction of many of new detectors are presented. These upper limits and SHALON fluxes are now more than a factor 100 less than the fluxes originally reported.

The Cherenkov gamma-telescope SHALON [1, 2, 3] at high-mountain observatory of Lebedev Physical Institute at Tien Shan, located at 3338m a.s.l., is destined for gamma - astronomical observation in the energy range $1 - 65$ TeV Refs. [4]–[26]. The SHALON mirror telescopic system consists of composed mirror with area of 11.2 m^2. It is equipped with 144 photomultipliers receiver with the pixel of $0.6°$ and the angular resolution of

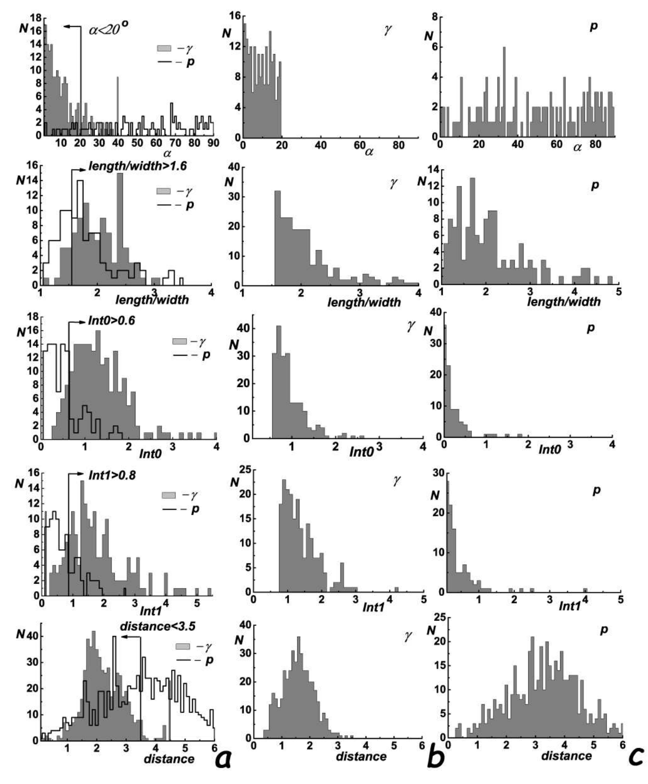

Figure 1. The distributions of image parameters

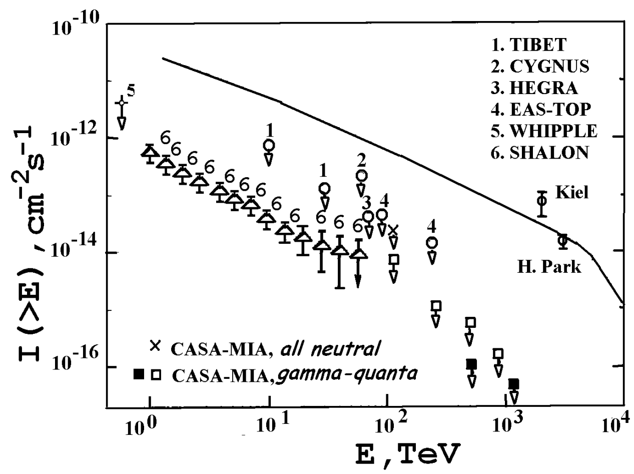

Figure 2. The Cygnus X-3 gamma-quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with other experiments: 1 – TIBET [7], 2 – CYGNUS [8, 9], 3 – HEGRA [10], 4 – EAS-TOP [11, 12], 5 – Whipple [13, 14], 6 – SHALON [18 – 26], squares – CASA-MIA [15], circles – Kiel [16] and H. Park [17]; the solid line is the theoretical calculation (Hillas) [4, 5].

the experimental method of $0.1° - 0.2°$. It is necessary to note, that our telescope has the large matrix with full angle $> 8°$, that allows to made the observation of the supposed source (ON data) and background of cosmic ray EAS (OFF data) simultaneously. So OFF data are taken in the same atmosphere thickness, transparency and other experimental conditions as the ON data. An additional selection of electron-photon showers among extensive air showers of cosmic rays is done by the analysis of a light image (that is generally an elliptic spot in light receiver matrix). The selection of gamma-quantum initiated showers from a background of proton showers is done using the criteria: 1) $\alpha < 20°$; 2) $\mathrm{length/width} > 1.6$; 3) ratio of Cherenkov light intensity in pixel with max light to the light in the eight pixels around is $INT0 > 0.6$; 4) ratio of Cherenkov light intensity in pixel with max light to the light in all the pixels except for the nine in the center is for $INT1 > 0.8$; 5) distance is < 3.5 pixels. In Figure 1a the Monte Carlo distributions of image parameters for gamma-quantum and proton showers are shown. In Figure 1b the distributions of image parameters of gamma-quantum showers obtained in SHALON observations of point sources are presented, while in Figure 1c the distributions of parameters of cosmic ray protons from zenith SHALON observations are shown. The analysis of these distributions shows that the background was rejected with 99.8% efficiency.

The galactic source Cygnus X-3, known more than 10 years as a source with variable intensity $< 10^{-11} - 5 \times 10^{-12}$ cm^{-2} s^{-1}, have been regularly observed since a 1995 with average gamma-quantum flux $F(E_0 > 0.8\,TeV) = (6.8 \pm 0.7) \times 10^{-13}$ cm^{-2} s^{-1}. In Figs. 2, 3, 4 the observation results of Cygnus X-3 point source by SHALON mirror Cherenkov telescope are presented.

The results of observation data processing are integral spectra, time analysis of the events, coming from source and background events, obtained simultaneously with observation of source, and source image. The energy spectrum of Cygnus X-3 at $0.8 - 65$ TeV $F(> E_0) \propto E^{k_\gamma}$, where $k_\gamma = -1.21 \pm 0.05$ is obtained for the first time and the source flux is less by the order than the upper limits published before. The spectrum of events passing through distinguishing criteria with background with index of $k_{on} = -1.33 \pm 0.05$ and the spectrum of background events observed simultaneously with source with index of $k_{off} = -1.74 \pm 0.05$ are shown in

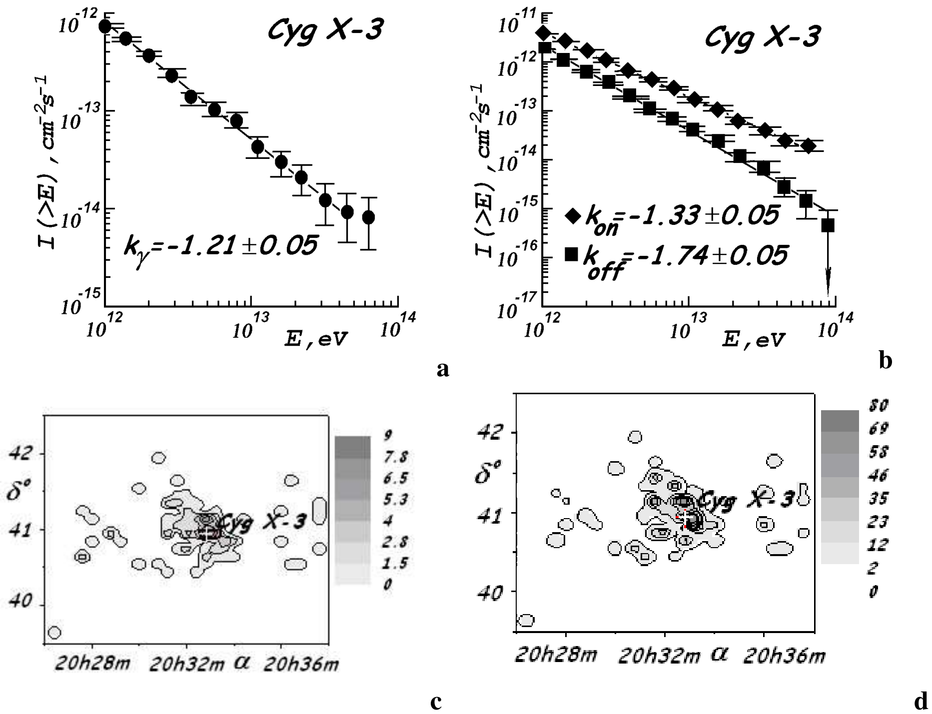

Figure 3. a – The Cygnus X-3 gamma-quantum spectrum with power index of $k_\gamma = -1.21 \pm 0.05$; b – The event spectrum from Cygnus X-3 with background has power index of $k_{on} = -1.33 \pm 0.05$ and spectrum of background events observed simultaneously with Cygnus X-3 has index of $k_{off} = -1.74 \pm 0.05$; c – The image at energy range of more then 0.8 TeV; d –The energy image (in TeV) of Cygnus X-3 by SHALON.

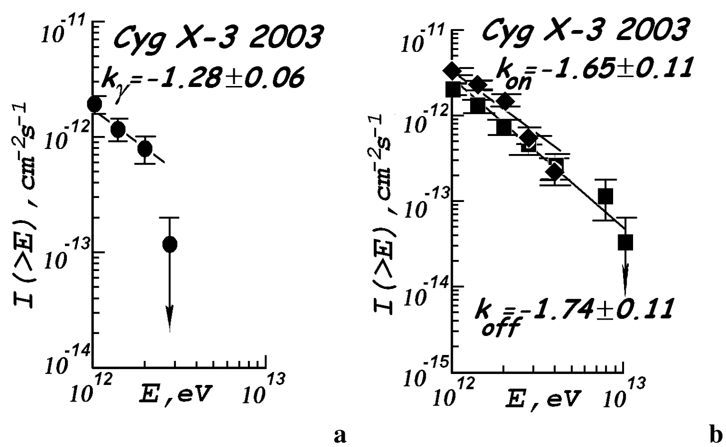

Figure 4. a – The gamma-quantum spectrum of Cygnus X-3 in 2003 year $dF/dE_\gamma \propto E_\gamma^{-2.28\pm0.06}$; b – The event spectrum from Cygnus X-3 with background $dF/dE \propto E^{-2.65\pm0.11}$ and spectrum of background events observed simultaneously with Cygnus X-3 $dF/dE \propto E^{-2.74\pm0.11}$.

comparison. The flux in 2003 year was $(1.79 \pm 0.33) \times 10^{-12}$ cm^{-2} s^{-1}. The indexes of integral spectra are $k_\gamma = -1.28 \pm 0.06$, $k_{on} = -1.65 \pm 0.11$, $k_{off} = -1.74 \pm 0.11$, respectively. Earlier, in 1997, the increase of flux was also observed $(1.2 \pm 0.5) \times 10^{-12}$ cm^{-2} s^{-1}. Thus, among ten observable gamma-quantum objects, there is Cygnus X-3 galactic source, with periodic change of intensity. The variability of radiation can give the essential information about a source nature.

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