# The Detection of the New Active Galactic Gamma-Sources NGC 1275, 3C454.3 and 1739+522 and Comparison With Early Known Metagalactic and Galactic Sources

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## Abstract

Cherenkov mirror telescope SHALON-1 created at Lebedev Physical Institute and stated at 1991-1992 at Tien-Shan mountains 3338 m high above the sea level with 11,2 $m^2$ mirror area and image matrix consisting of 144 photomultipliers with full angle of $8^o$ during 1992-2000 was used for observations of metagalactic sources: Markarian 421, Markarian 501, NGC 1275, 3C454.3, 1739+522 and galactic sources: Crab Nebula, Cygnus X-3, Geminga, Tycho Brage. A new metagalactic source of gamma-quanta with energies $> 0.8$ TeV with flux $(0.78 \pm 0.13) \bullet 10^{-12} cm^{-2} s^{-1}$ – Seyfert galaxy NGC 1275 was detected. Active galactic nuclei 3c454.3 and 1739+522 (z=0.859 and z= 1.375) with flux accordingly $(0.43 \pm 0.17) \bullet 10^{-12} cm^{-2} s^{-1}$ and $(0.47 \pm 0.18) \bullet 10^{-12} cm^{-2} s^{-1}$ were also detected. Taking into account the fact that nowadays the observable total gamma-quanta with energies $> 10^{12}$ eV flux from metagalactic sources is greater than the flux from nearest galactic source Crab Nebula, one may consider that the major part of cosmic rays with $E > 10^{13}$ eV observed in the near-earth space have the metagalactic origin. The SHALON-2 gamma-telescope established 260 m far from SHALON-1 telescope prepared for observations at the high-mountainous Tien-Shan observatory.

The investigation of extra-high energy gamma-quanta sources by any methods including mirror Cherenkov astronomy touches the problem of cosmic ray nature and correspondingly the role of Galaxy and Metagalaxy in their generation. An opinion widely distributed that the cosmic rays before the break in their spectrum have the galactic origin (energies $< 10^{15} - 10^{16}$ eV) and only from energies $> 10^{16}$ the Metagalaxy role probably increases. Still not numerous experimental extra-high energy gamma-astronomical data completely denies the predominantly

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galactic origin of cosmic rays. Presently detected metagalactic sources of gamma-quanta with energies $> 10^{12}$eV have in $10^6$ times high radiation intensity than the most powerful galactic gamma-quanta source Crab Nebula, that is connected with its closeness to the Solar System.

**Table 1.** The gamma-quanta sources with energy > 0.8 TeV

| Sources | Type | Distance | | Flux, $cm^{-2}sec^{-1}$ |
|---|---|---|---|---|
| ***Extragalactic*** | | ***mpc*** | ***z*** | |
| Markarian 421 | Blazar | 124 | 0.031 | $(0.63\pm0.14)10^{-12}$ |
| Markarian 501 | Blazar | 135 | 0.034 | $(0.86\pm0.13)10^{-12}$ |
| NGC 1275 | Seyfert galaxy | 71 | 0.013 | $(0.78\pm0.13)10^{-12}$ |
| 3c4543 | Quasar | 4685 | 0.859 | $(0.43\pm0.17)10^{-12}$ |
| 1739+522 | Quasar | 7500 | 1.375 | $(0.47\pm0.18)10^{-12}$ |
| ***Galactic*** | | ***kpc*** | | |
| Crab Nebula | Supernova remnant | 2.0 | | $(1.00\pm0.17)10^{-12}$ |
| Cygnus X-3 | Binary | 1.1 | | $(0.42\pm0.07)10^{-12}$ |
| Geminga | Radio-weak pulsar | 0.25 | | $(0.48\pm0.17)10^{-12}$ |
| Tycho' SNR | Supernova | 2.0-3.1 | | $(0.19\pm0.06)10^{-12}$ |

An out-of-astronomy has detected amount of various by nature gamma-quanta with energies $10^8 - 10^9$ eV sources, and in EAS with primary particles energies $10^{14} - 10^{15}$ eV investigations was estimated the "no muons" or "no hadrons" showers flux ($10^{-3} - 10^{-4}$ of EAS formed by primary protons and cosmic rays nucleus flux) which allows to assume that such showers are generated by primary gamma-quanta. Now it's not known whether the observing gamma-quanta flux ($10^{-3} - 10^{-4}$ of protons and cosmic rays nucleus flux) is a diffuse gamma-quanta flux or a sum of local sources flux, because the experimental accuracy of coming gamma-quanta direction distinction does not allow to link them with possible sources coordinates. Using the directivity of Cherenkov radiation predetermines a good angular resolution and reliable conjunction of telescope coordinate system to the star coordinates of the observing part of the sky.

Created at the Lebedev Physical Institute and stated at the Alatoo mountains 3338 m high above the sea level SHALON-1 mirror telescope with mirrors square 11.2 $m^2$ and image-matrix consisting of 144 photomultipliers with the full angle of $> 8^o$ was used for observations of galactic and metagalactic very-high energy gamma-quanta at the energy range 1-50 TeV sources. Selection of showers produced by gamma-quanta from a background of showers produced by protons is made according to the following point (see fig. 1 a, b in these Proceedings). From fig.1a of used in SHALON experiment gamma-quanta and proton with en-

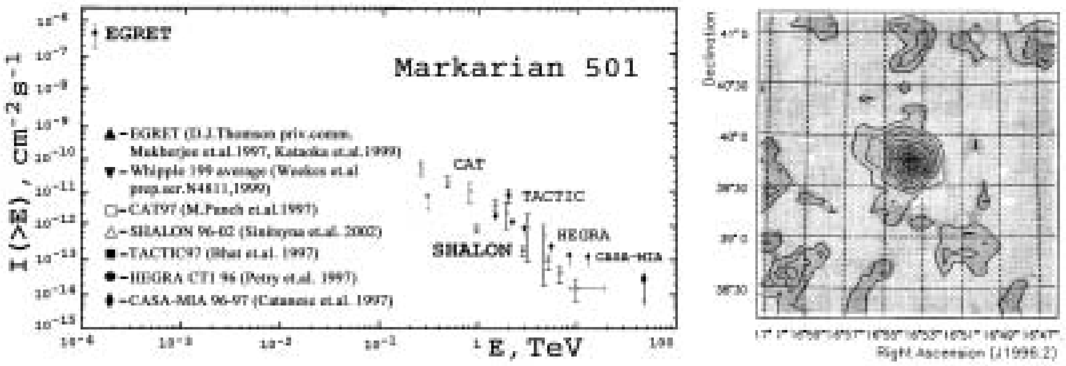


**Fig. 1.** Gamma-quanta integral spectra by SHALON-1 of: left - Markarian 501 ; right - Markarian 501 Image by Whipple

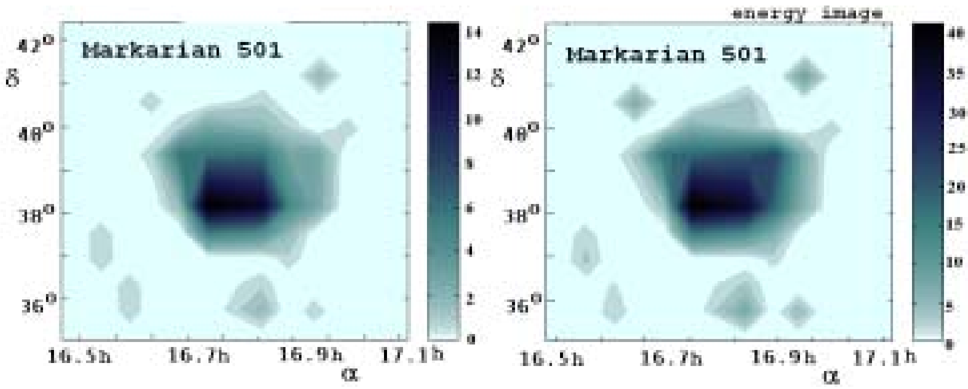


**Fig. 2.** Image at energy range of more than 0.8 TeV and energy image (in TeV) of Markarian 501 by SHALON-1

ergy 1 TeV image-parameters Monte-Carlo simulations and fig.1b of experimental gamma-quanta from local sources and cosmic rays protons image-parameters distributions observed by SHALON telescope one can see that selection criteria used in SHALON-1 experiment extracts gamma-quanta from the proton background which confirms correctness of chosen in SHALON experiment gamma-quanta selection criteria.

The SHALON-1 observations at Tien-Shan high-mountainous station were carried out since 1992 during this period 12 metagalactic and galactic sources were observed. Among them are galactic sources Crab Nebula (the supernova remnant), Cygnus X-3 (binar), Tycho Brage (supernova remnant), Geminga (radioweak pulsar) and metagalactic ones Markarian 501 (blazar), Markarian 421(blazar), NGC1275 (Seyfert galaxy), 3c454.3 (quasar) and 1739+522 (quasar) (see table 1). For the each source the observation data results analysis are integral spectrum,

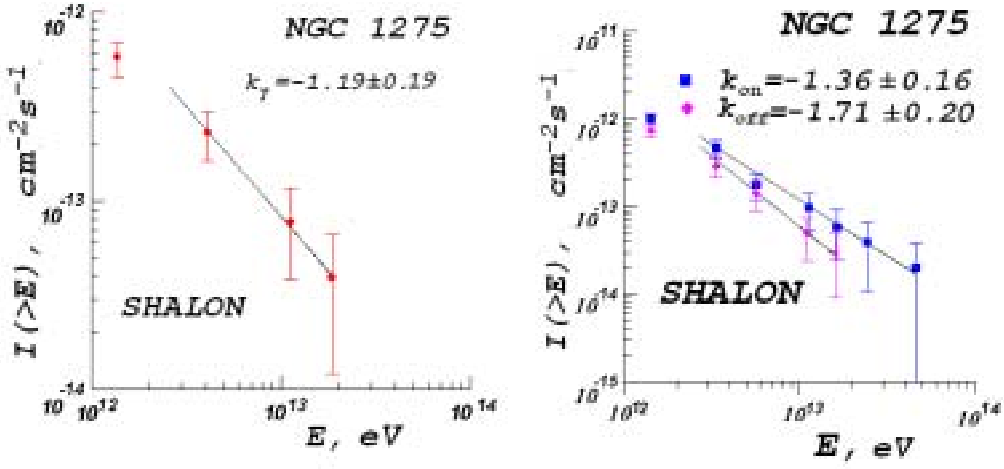


**Fig. 3.** Gamma-spectra of the gamma radiation from NGC 1275. The observable energy distribution of gamma quanta from local sources NGC 1275 $dF/dE_\gamma \sim E_\gamma^{-2.19\pm0.19}$. The observed spectra of the gamma-quanta including the 10%-15% contribution of the proton showers is $dF/dE \sim E^{-2.36\pm0.16}$. It also differs from observed energy spectrum for cosmic rays $dF/dE \sim E^{-2.71\pm0.19}$

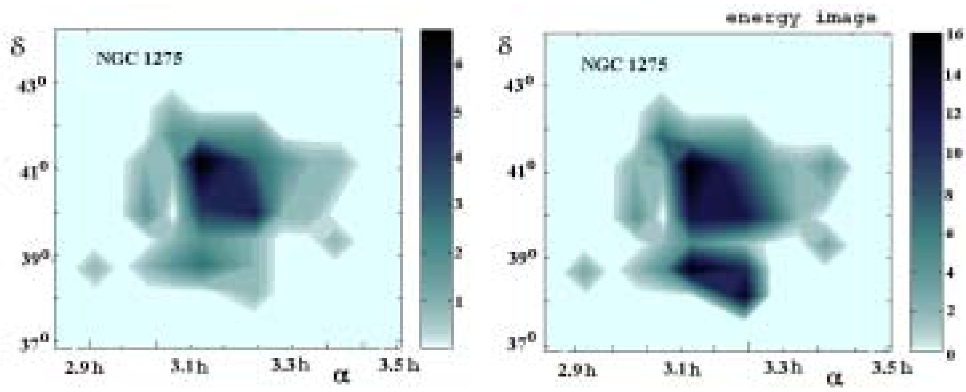


**Fig. 4.** Image at energy range of more than 0.8 TeV and energy image (in TeV) of NGC 1275 by SHALON-1

time analysis of events from the source and background ones observed simultaneously and the sources images (fig. 2, 4, 6). The observation data of previously known gamma-quanta sources (Markarian 421, Markarian 501 and Crab Nebula) observed by both SHALON and other experiments are approximately equal (see fig.1 and these Proc.).

The energy spectrum agrees with the extrapolation of spectra observed using EGRET at the energy region $10^2 - 10^3$ MeV. Crab Nebula and galaxies Markarian 421 and Markarian 501 observation results are compared with the

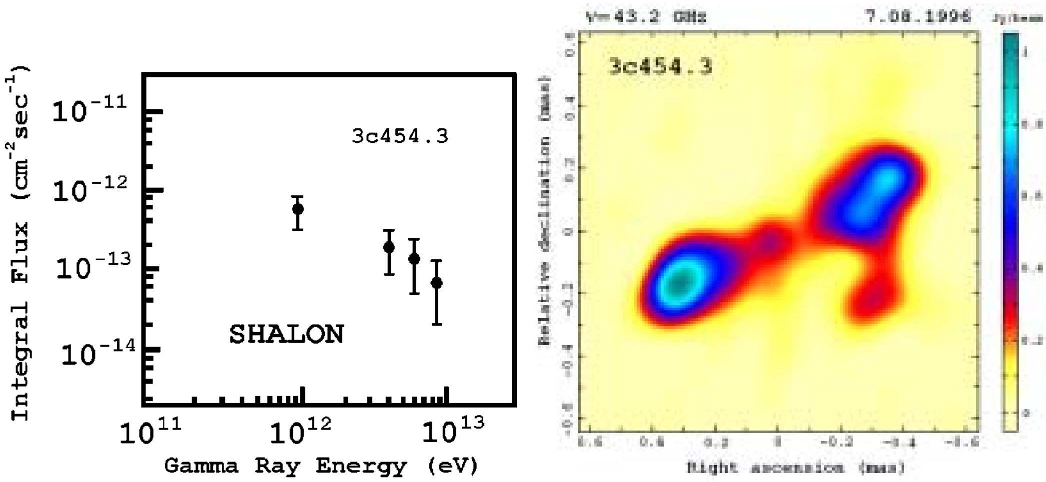


**Fig. 5.** Gamma-quanta integral spectra by SHALON-1 of: left - 3c454.3; right - 3c454.3 Image by group from Boston University

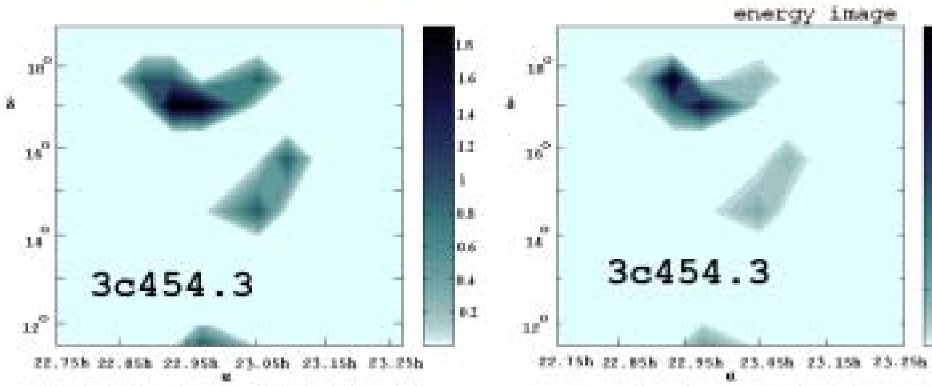


**Fig. 6.** Image at energy range of more than 0.8 TeV and energy image (in TeV) of 3c454.3 by SHALON-1

other experiment's data including the data from space at energy region $10^8 - 10^9$ eV. As it's follows from the picture the experimental data can be described by the unified law $F(>E) \sim E^{-\gamma}$ at the energy region of $10^8 - 10^{13}$ eV. At 1998 at SHALON observation there was a new metagalactic gamma-quanta with energies >0.8 TeV source with flux $(0.78 \pm 0.13) \bullet 10^{-12}$ detected. This source coincides by its coordinates with the active nucleus galaxy NGC 1275. The energy spectrum of active galactic nuclei NGC 1275 was measured at energy interval of 0.8 to 30 TeV, $k_\gamma = -1.19 \pm 0.19$ (fig. 3), time analysis was performed and the source image is presented at fig. 4. The observable energy distribution of gamma-quanta from local sources of NGC 1275 is $dF/dE_\gamma \sim E^{-2.19 \pm 0.19}$. The observed spectrum of the gamma-quanta including the 10%-15% contribution of the proton showers is for NGC 1275 $dF/dE_{on} \sim E^{-2.36\pm0.16}$. It is differs from observed simultaneously spectrum for cosmic rays $dF/dE \sim E^{-2.71\pm0.19}$. Firstly detected by SHALON telescope extragalactic source NGC1275 also was observed at Tibet installation. At the energy region from 0.8 to 10 TeV there were detected new metagalactic sources 1739+522, z=1.375 and 3c454.3, z=0.859 with fluxes $(0.43 \pm 0.17) \bullet 10^{-12}$ and $(0.47 \pm 0.18) \bullet 10^{-12}$ accordingly. The energy spectra at energy region from 0.8 to 10 TeV were measured (fig. 5, 6 and these Proc.). The galactic source Cygnus X-3 known more than for 10 years as a variable intensity $\leq 10^{-11} - 5 \bullet 10^{-12} cm^{-2}s^{-1}$ source was observed with gamma-quanta flux $F(E_o > 0,8TeV) = (4,2 \pm 0,8) \bullet 10^{-13} cm^{-2}s^{-1}$. For Cygnus X-3 the integral spectrum indexes are accordingly: $k_\gamma = -1.20 \pm 0.14$, $k_{on} = -1.51 \pm 0.22$, $k_{off} = -1.77 \pm 0.21$. Time analysis showed that the cosmic rays protons contribution into the observed gamma-quanta from Cygnus X-3 is no more than 10%-15%[1] (these Proc.).

The observed energy gamma-quanta spectrum from 4 sources in our Galaxy and 5 Metagalaxy sources do not contradict with the averaged energy gamma-quanta spectrum of all this sources at energy region 0.8-50 TeV $f(E_o)dE_o \sim E_o^{-2.35\pm0.16}dE_o$. The differential spectrum of protons and nucleus of cosmic radiation $f(E)dE \sim E^{-2.72\pm0.1}dE$ at energy interval of 1 - $3 \bullet 10^7$ TeV. So the energy spectrum at interval $10^{12} - 10^{14}$ eV of almost all detected gamma-sources in the power plot $\sim 0.5$ times harder the protons and nuclei of cosmic rays one. This intensifies the problem - what are the processes in Universe forming the unified cosmic rays spectrum on many orders of energy magnitude. The new problem arose in comparing the power of sources of gamma-quanta generated in our Galaxy (the supernova remnants) and power of metagalactic sources (active galactic nuclei, quasars). The powers of metagalactic sources in $10^6$ times exceeds the power of gamma-sources in our galaxy, and the most far from our Galaxy currently known source 1739+522 is in $10^{11}$ times more powerful than the total gamma-radiation of all known gamma-sources of our Galaxy. Among the ten observed by different researchers studying gamma-radiating objects there are some sources from with sporadical or periodical changes of gamma-radiation intensity (Markarian 421, Markarian 501, Crab Nebula). Radiation variability can be a helpful information about the object's nature, if it's not connected with the equipment instability or conditions of Cherenkov radiation observation in atmosphere. It is undoubt, that the synchronous gamma-quanta flux intensity changing observations by two spaced far one from another gamma-telescopes SHALON-1 and SHALON-2 is the best provement of radiation variability of gamma-quanta source itself.

1. Sinitsyna V.G., Arsov T.P., Nikolsky S.I. et.al. 2001, Nucl.Phys. B. 97, 215.