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The TeV gamma emission of the far active galaxies 1739+522 (z=1.375), 3c454.3 (z=0.859) and Markarian 501 (z=0.034), Markarian 421 (z=0.031)

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The new far metagalactic sources 1739+522 (z=1.375) and 3c454.3 (z=0.857) are detected by SHALON at energy of > 0.8 TeV with fluxes $(0.53 \pm 0.10) \times 10^{-12}$ cm^{-2} s^{-1} and $(0.43 \pm 0.13) \times 10^{-12}$ cm^{-2} s^{-1} respectively. The spectra and fluxes of known blazars Markarian 421, Markarian 501 and far FSRQs 1739+522 and 3c454.3 are presented. Thus, the average energy spectrum of metagalactic sources Mkn 421, Mkn 501 at range of $10^{12} - 10^{13}$ eV differs from spectra of far quasars 1739+522 and 3c454.3 that does not contradict to united energy spectrum $F(> E_\gamma) \propto E_\gamma^{-1.2\pm0.1}$.

The greater place in modern physics and astrophysics is taken up by researches of galactic and metagalactic objects, where the proton and nucleus acceleration processes, accompanying with generation of not dissipated by magnetic fields of Universe gamma-quanta and neutrinos, are realized. These researches have been carried out by SHALON mirror telescope on Tien-Shan high mountainous station since 1992. During 1992–2005 SHALON have been used for observations of metagalactic sources: Mkn 501, Mkn 421, NGC 1275, 3c454.3, 1739+522 (Figs. 1 – 5) [1 – 14] and galactic sources: Crab Nebula, Cygnus X-3, Tycho's SNR, Geminga, 2129+47XR.

The SHALON observation results of known gamma-sources (Mkn 501, Mkn 421, Crab Nebula) are consistent with observation data of the best world telescopes (Fig. 1 and 5). The energy spectrum agrees with the extrapolation of spectra observed using EGRET at the energy region $10^2 - 10^3$ MeV. Crab Nebula and Mkn 421 and Mkn 501 galaxies observation results are compared with the other experiment's data including the data from space at energy region $10^8 - 10^{14}$ eV. The Mkn 421 and Mkn 501 with redshift of 0.031 and 0.034 can be classified as high frequency peak BLLacs. This sources are X-ray bright and radio-loud. The high redshift blazar sample was chosen from sources of FSRQ class which are generally more distant and more luminous and shows high radio polarization and radio intensity.

Table 1. The metagalactic gamma-quantum sources catalogue, observed by SHALON; at the column Relative intensity of source the Crab Nebula intensity is taken as a unit.

Sources	Observable flux (cm^{-2} sec^{-1})	Distance (Mpc)	Red shift z	Relative intensity of source (in Crab units)
Mkn 421	$(0.63 \pm 0.14) \times 10^{-12}$	124	0.031	3.8×10^9
Mkn 501	$(0.86 \pm 0.13) \times 10^{-12}$	135	0.034	4.6×10^9
NGC 1275	$(0.78 \pm 0.13) \times 10^{-12}$	71	0.013	1.2×10^9
OJ287	$< 0.24 \times 10^{-12}$	1290	0.306	$< 1 \times 10^{11}$
3c454.3	$(0.43 \pm 0.13) \times 10^{-12}$	4685	0.859	5.3×10^{12}
1739+522	$(0.53 \pm 0.10) \times 10^{-12}$	7500	1.375	1.4×10^{13}

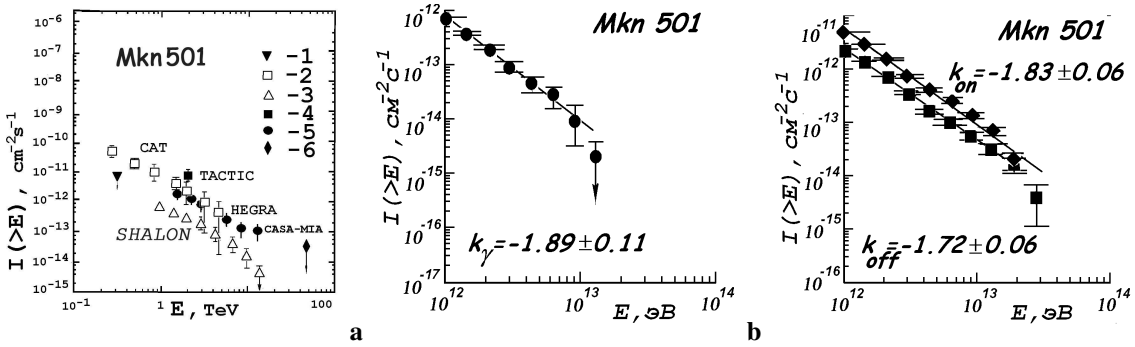

Figure 1. a – The Mkn 501 gamma-quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with other experiments: [3 – 14] 1 – Whipple; 2 – CAT; 3 – SHALON; 4 – TACTIC; 5 – HEGRA CT1; 6 – CASA-MIA; b – The gamma-quantum integral spectrum of Mkn 501 with power index of $k_\gamma = -1.89 \pm 0.11$; c - The spectrum of events coming from Mkn 501 with index of $k_{on} = -1.83 \pm 0.06$ and the spectrum of background events observed simultaneously with Mkn 501 with index of $k_{off} = -1.72 \pm 0.06$.

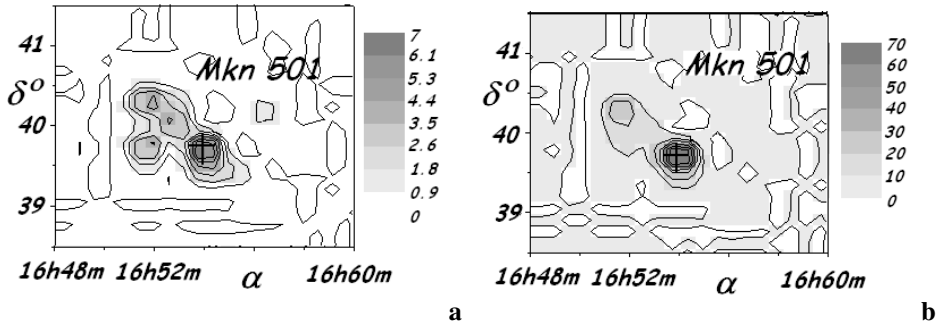

Figure 2. a – The Mkn 501 image at energy range of more then 0.8 TeV by SHALON; b – The energy image (in TeV) of Mkn 501 by SHALON.

In 1998 year a new metagalactic source 3c454.3 ($z = 0.875$) was detected by SHALON at TeV energies. The integral gamma-quantum flux above > 0.8 TeV is $(0.43 \pm 0.13) \times 10^{-12}$ cm^{-2} s^{-1} (Table 1, Fig. 3a). The observation of this source by Whipple telescope at energy more than 0.5 TeV, puts only upper limit of flux 0.84×10^{-11} cm^{-2} s^{-1} [9, 10]. Figure 3 also shows the observation results of 3c454.3 by EGRET at energy range $\sim$ 30 MeV – 50 GeV, with index of power spectrum ~ -1.2 (see Ref. [11]). Thus, as follows from the figure, the experimental data can be described by the uniform law $F(> E) \propto E^\gamma$ at energy range $10^8 - 10^{13}$ eV (see Refs. [3]–[14]).

The more far metagalactic source was detected by SHALON in 1999. This source coincides by its coordinates with the active galactic nucleus 1739+522. It has been intensively observed by SHALON since then. The integral gamma-quantum flux is $(0.53 \pm 0.10) \times 10^{-12}$ at energies of > 0.8 TeV. The most far metagalactic source 1739+522 with red shift of $z = 1.375$ is also most powerful (Table 1). Energy spectrum can be well described by a power low with integral flux following $I(> E_\gamma) \propto E_\gamma^{-1.10 \pm 0.06}$ at range of $0.8-7$ TeV (Fig. 3). The integral spectrum of events from source has power index of $k_{on} = -1.38 \pm 0.07$ and the power index of spectrum of background events, observed simultaneously with source is $k_{off} = -1.72 \pm 0.08$. At Fig. 4 the image of 1739+522 is also presented. The average gamma-quantum flux at range $\sim$ 30 MeV – 50 GeV

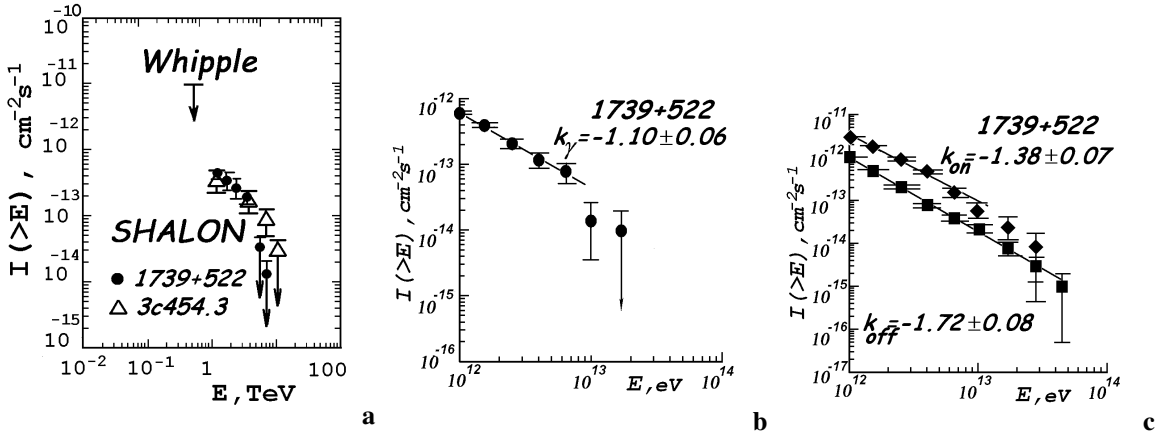

Figure 3. a – The 3c454.3 and 1739+522 gamma-quantum ($E > 0.8TeV$) integral spectrum by SHALON in comparison with Whipple data; b – The 1739+522 gamma-quantum integral spectrum with power index of $k_\gamma = -1.10 \pm 0.06$; b – The event spectrum from 1739+522 with background with index of $k_{on} = -1.38 \pm 0.07$ and spectrum of background events observed simultaneously with 1739+522 with index of $k_{off} = -1.72 \pm 0.08$;

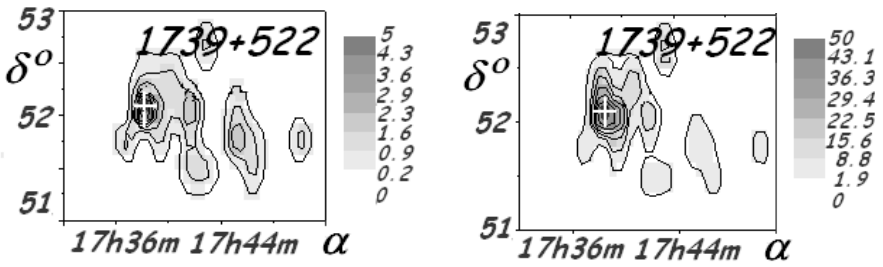

Figure 4. a – The 1739+522 image at energy range of more then 0.8 TeV by SHALON; b – The energy image (in TeV) of 1739+522 by SHALON.

on observation data of telescope EGRET of Compton observatory (CGRO) is $\sim 2 \times 10^{-8}$ cm^{-2} s^{-1} with integral spectrum index ~ -1.2 (see Ref. [11]). But the spectral energy distributions of far quasars 3c454.3 and 1739+522 differ from average ones of other known distant sources – blazars Mkn 421 ($z = 0.031$) and Mkn 501 ($z = 0.034$) that are $F(> E_\gamma) \propto E_\gamma^{-1.53\pm0.21}$ and $F(> E_\gamma) \propto E_\gamma^{-1.89\pm0.11}$ respectively. The integral spectra of events from Mkn 421 and Mkn 501 have power indexes of $k_{on} = -1.46 \pm 0.06$ and $k_{on} = -1.83 \pm 0.06$ and the power indexes of spectra of background events are $k_{off} = -1.75 \pm 0.06$ and $k_{off} = -1.72 \pm 0.06$. Thus, the average energy spectrum of metagalactic sources - quasars Mkn 421, Mkn 501 at range $10^{12} - 10^{13}$ eV, differs from spectra of far quasars 1739+522 and 3c454.3 that does not contradict to united energy spectrum $F(> E_\gamma) \propto E_\gamma^{-1.2\pm0.1}$. The new problem arose in comparing the power of Galactic gamma-quantum sources and metagalactic sources. The power of metagalactic sources exceeds the power gamma-sources in our galaxy by 10^8 (Table 1). The most distant currently known source 1739+522 is 10^{11} times more powerful than the total gamma-radiation of all known gamma-sources in our Galaxy. So the development of gamma-astronomy raises two questions: what mechanisms give the presently observed gamma-quantum fluxes of far metagalactic sources; what processes form the cosmic ray spectrum as a uniform

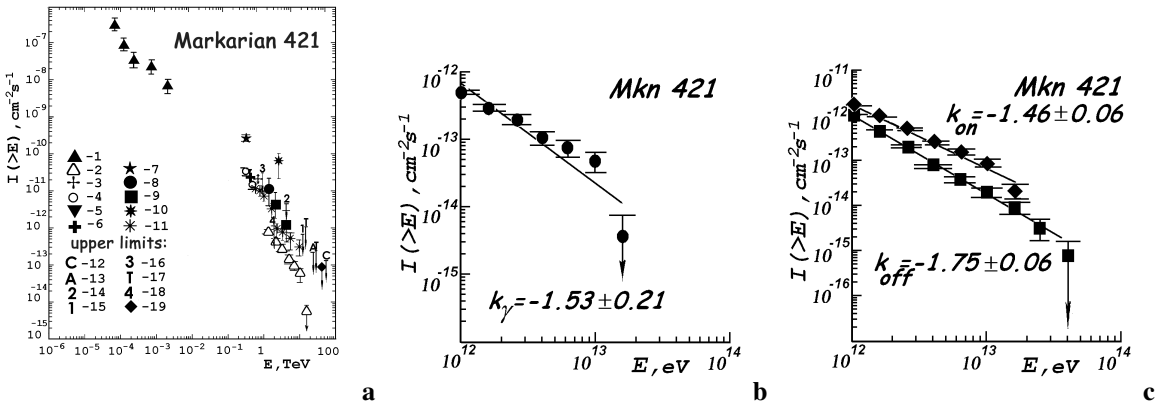

Figure 5. a – The Mkn 421 integral gamma-quantum ($E > 0.8$ TeV) spectrum by SHALON in comparison with other experiments [2 - 14]: 1- Egret; 2 - SHALON; 3, 4, 5, 6, 7- Whipple; 8, 14 - HEGRA CT2; 9, 15 - HEGRA CT1; 10, 11 - Telescope Array; 12 - CYGNUS; 13 - HEGRA; 16, 19 - TACTIC; 17 - Tibet; 18 - CASA-MIA; b – The gamma-quantum integral spectrum of Mkn 421 with power index of $k_\gamma = -1.53 \pm 0.21$; c - The spectrum of events coming from Mkn 421 with index of $k_{on} = -1.46 \pm 0.06$ and the spectrum of background events observed simultaneously with Mkn 421 with index of $k_{off} = -1.75 \pm 0.06$.

spectrum $dF/dE \propto E^{-2.72\pm0.01}$ over a wide energy range of $10^{11} - 10^{19}$ eV, but differing from the harder energy spectrum of powerful metagalactic sources.

References

[1] Nikolsky S. I., Sinitsyna V. G., VANT Ser. TFE. (1987) 1331 30.
[2] Sinitsyna V. G., Nuovo Cimento 19C(6) (1996) 965.
[3] Nikolsky S. I. and Sinitsyna V. G., Physics of Atomic Nuclei 67(10) (2004) 1900.
[4] Sinitsyna V.G., Nikolsky S.I., et.al., Nucl. Phys. B. 122 (2003) 247, 409; 97 (2001) 215, 219.
[5] Sinitsyna V.G., AIP 515 (1999) 293, 205.
[6] Sinitsyna V. G., Toward a Major Atmospheric Cherenkov Detector-I, ed. Fleury P., Vacanti G. (Frontieres) (1992) 299; Detector -II, ed. Lamb R. C. (Iowa State University) (1993) 91; Detector-IV, ed. Cresty M. (PapergrafPD) (1995) 133; Detector-V, ed. O.C. de Jager (WESPRINT, Pocherfstroom) (1997) 136, 190.
[7] Nikolsky S.I., Sinitsyna V.G., et.al., Izv. RAN., ser. fiz. 66(11) (2002)1667, 1660; 63(3) (1999) 608; 61(3) (1997) 603.
[8] Sinitsyna V.G., Nikolsky S.I., et.al., The Universe viewed in Gamma Rays, ed. R. Enomoto, M.Mori, S. Yanagita, (Universal Academy Press, Inc, 2003) 503, 211, 235, 383.
[9] Kerrick A.D., et al., ApJ, L59 (1995) 438.
[10] Buckley J.H., Astropart. Phys. 11 (1999) 119.
[11] Mukherjee R., Astrophys. J. 490 (1997) 116.
[12] Krennrich F., Weekes T.C., et. al., Universal Academy Press. Inc. (2003) 157.
[13] Catanese M., Weekes T.C., et al., Preprint Series 4811, (1999); 4450, (1996).
[14] Petry D., et. al., Astr. Astrophys. Lett. 13 (1996) 311; Proc. 25th ICRC, 3 (1997) 241.