The close metagalactic sources SN2006gy, NGC 1275, Mkn 421, Mkn 501 (z from 0.0179 to 0.034): spectral energy distributions and images

V.G. Sinitsyna, F.I. Musin, S.I. Nikolsky, V.Y. Sinitsyna
P.N. Lebedev Physical Institute,
Moscow, Russia
Email: sinits@sci.lebedev.ru

***Abstract*— Exploration of the galactic and metagalactic objects in which the acceleration of protons and nuclei is accompanying with generation of gamma-quanta and neutrinos is of great current interest for astroparticle physics. These gamma-astronomical researches are carrying out with SHALON mirror telescope at the Tien-Shan high-mountain observatory. The observation results of three type of metagalactic sources: BLLacs Mkn 421 (z = 0.031), Mkn 501 (z = 0.034), Seyfert galaxy NGC 1275 (z=0.0179) and extragalactic Supernova remnant SN2006 gy (z=0.019) are presented. NGC 1275 has been regularly observed by SHALON since 1996. NGC 1275 is being intensively studied and gamma-ray flux are found to be $(0.78 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$. The flux increase was detected from the region NGC 1275 in autumn 2006. The detailed analysis of gamma-shower direction turned out the detection of metagalactic object. This object was identified with the supernova SN 2006gy that is about 10 minutes away from NGC 1275. The integral -ray flux for SN 2006gy is found to be $(3.71 \pm 0.65) \times 10^{-12} cm^{-2}s^{-1}$ at energies of > 0.8 TeV. The integral average gamma-ray fluxes of Mkn 421 and Mkn 501 were estimated as $(0.63 \pm 0.14) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(0.86 \pm 0.13) \pm 10^{-12} cm^{-2}s^{-1}$ respectively. The increase of the flux over the average value was detected in 1997 and 2004 observations of Mkn 421 by SHALON and estimated to be $(1.01 \pm 0.25) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(0.96 \pm 0.2) \times 10^{-12}\ cm^{-2}s^{-1}$, respectively. The significant increase of Mkn 501 flux was detected in 1997 and 2006 with the VHE ground telescopes all over the world. The integral - ray flux by SHALON telescope was estimated as $(1.21 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(2.05 \pm 0.23) \times 10^{-12}\ cm^{-2}s^{-1}$, respectively that is comparable with flux of powerful galactic source Crab Nebula. The research of extragalactic and galactic sources of very-high energy gamma-quanta by methods, including ones using mirror Cherenkov telescopes concerns, rather than delicate problem of the cosmic ray nature and the role of our Galaxy and Extragalaxy in their generation.**

I. INTRODUCTION

A greater understanding of modern physics and astrophysics will be realized by investigating galactic and metagalactic objects, where the proton and nucleus acceleration processes, accompanied with the generation of gamma-quanta and neutrinos are not dissipated by the magnetic fields of the Universe. These gamma-astronomical researches are carrying out with SHALON mirror telescope at the Tien-Shan high-mountain observatory. During the period 1992 - 2007,

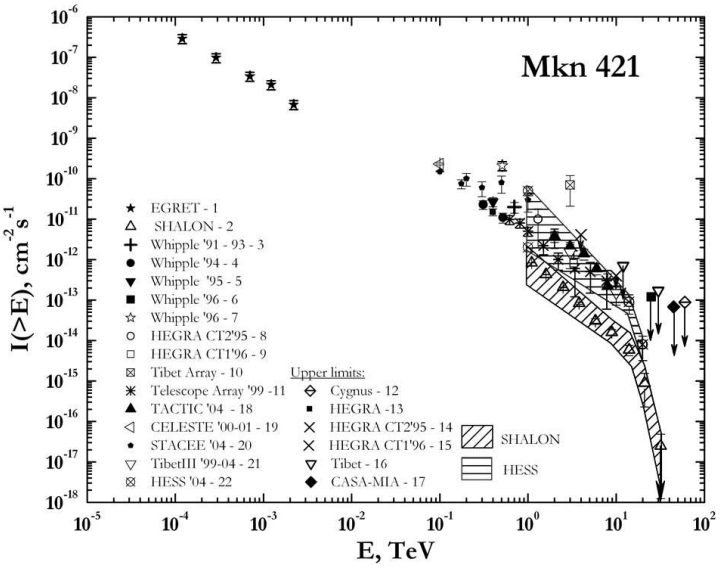

Fig. 1. The Mkn 421 gamma - quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with other experiments [1 - 25].

SHALON has been used for observations of the metagalactic sources Mkn421, Mkn501, NGC1275, 3c454.3, 1739+522 and galactic sources Crab Nebula, Cygnus X-3, Tycho's SNR, Geminga, 2129+47XR. The observation results of two type of metagalactic sources: BLLacs Mkn 421 (z = 0.031), Mkn 501 (z = 0.034) and Seyfert galaxy NGC 1275 (z=0.0179) are presented. The integral average gamma-ray fluxes of Mkn 421 and Mkn 501 were estimated as $(0.63 \pm 0.14) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(0.86 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$ respectively. NGC 1275 is being intensively studied by SHALON and gamma-ray flux are found to be $(0.78 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$. The integral spectra of events from source - k_{on} and background events, observing simultaneously with source's events - k_{off}, and source image are presented.

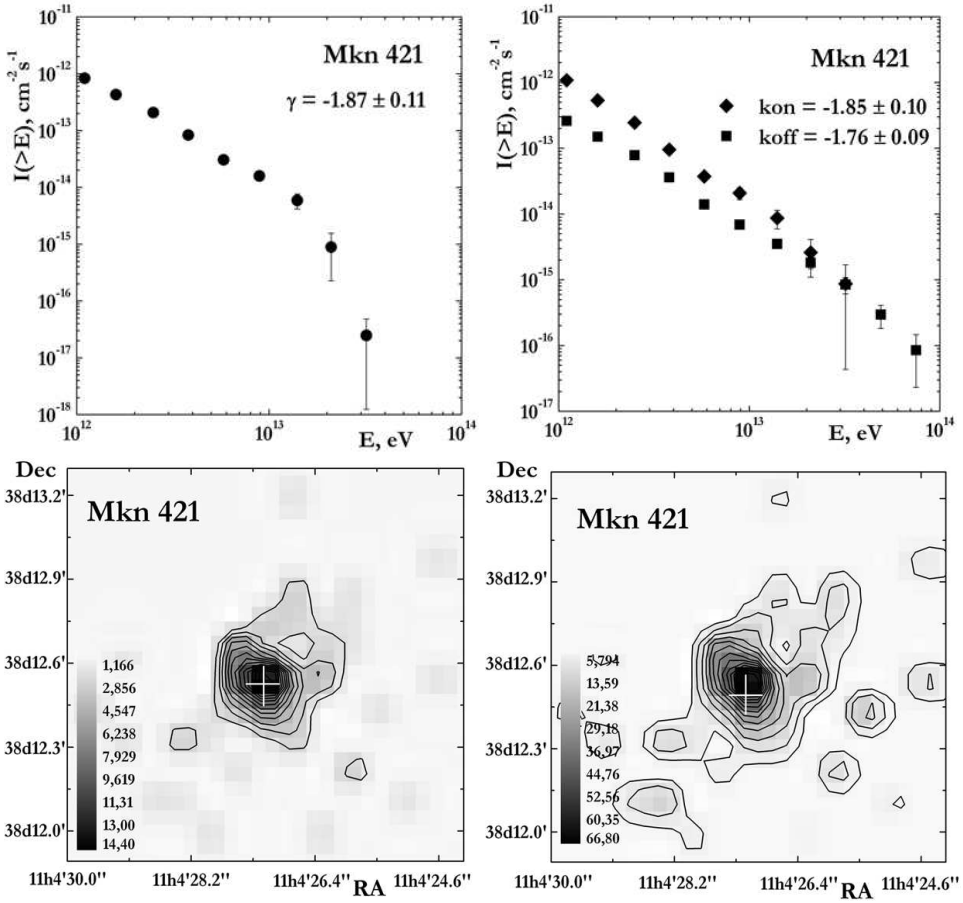

Fig. 2. **Top. left** – The Mkn 421 γ-quantum integral spectrum with power index of $k_\gamma = -1.87 \pm 0.11$; **right** – The event spectrum from Mkn 421 with background with index of $k_{ON} = -1.85 \pm 0.10$ and spectrum of background events observed simultaneously with Mkn 421 with index $k_{OFF} = -1.76 \pm 0.09$; **Bottom. left** – The Mkn 421 image at energy range of > 0.8 TeV; **right** – The energy image (in TeV units) of Mkn 421 by SHALON.

MARKARIAN 421

The Bl Lac Mkn 421 was detected as the first and the nearest (z = 0.031) metagalactic source of blazar type of TeV energy gamma-quanta in 1992 year using Whipple telescope. Presently this source is systematic studied by different experiments: VERITAS, SHALON, TACTIC, HESS, MAGIC (fig. 1). Mkn 421 is being intensively studied since 1994 by SHALON. As is seen from fig. 1 the SHALON results for this known gamma-source are consistent with the data by best world telescopes. An image of gamma-ray emission from Mkn 421 is shown in Fig. 2. The integral averaged for the period 1994 to 2007 gamma-ray flux above 0.8 TeV was estimated as $(0.63 \pm 0.14) \times 10^{-12}\ cm^{-2}s^{-1}$. Within the range 1 - 10 TeV, the integral energy spectrum is well described by the power law $F(> E_O) \propto E^{k_\gamma}$, with $k_\gamma = -1.87 \pm 0.11$ (fig. 2). Extreme variability in different wavelengths including VHE gamma rays on the time-scales from minutes to years is the most distinctive feature of BL Lac objects. The increase of the flux over the average value was detected in 1997 and 2004 observations of Mkn 421 by SHALON and estimated to be $(1.01 \pm 0.25) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(0.96 \pm 0.2) \times 10^{-12}\ cm^{-2}s^{-1}$, respectively. The similar

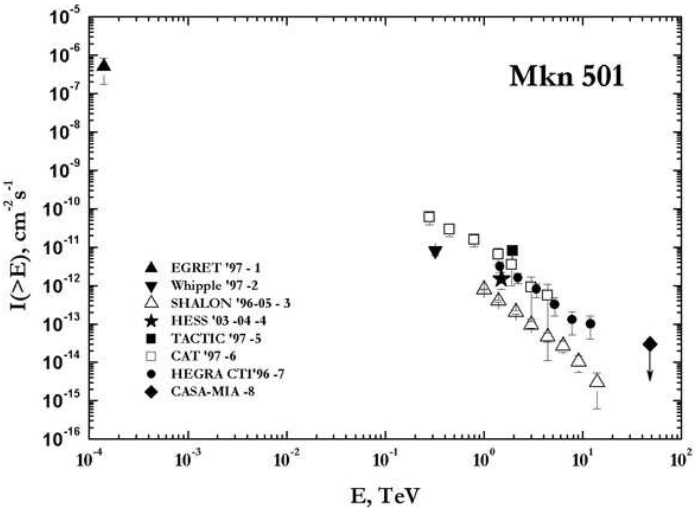

Fig. 3. The Mkn 501 gamma - quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with other experiments [1, 21 - 31];

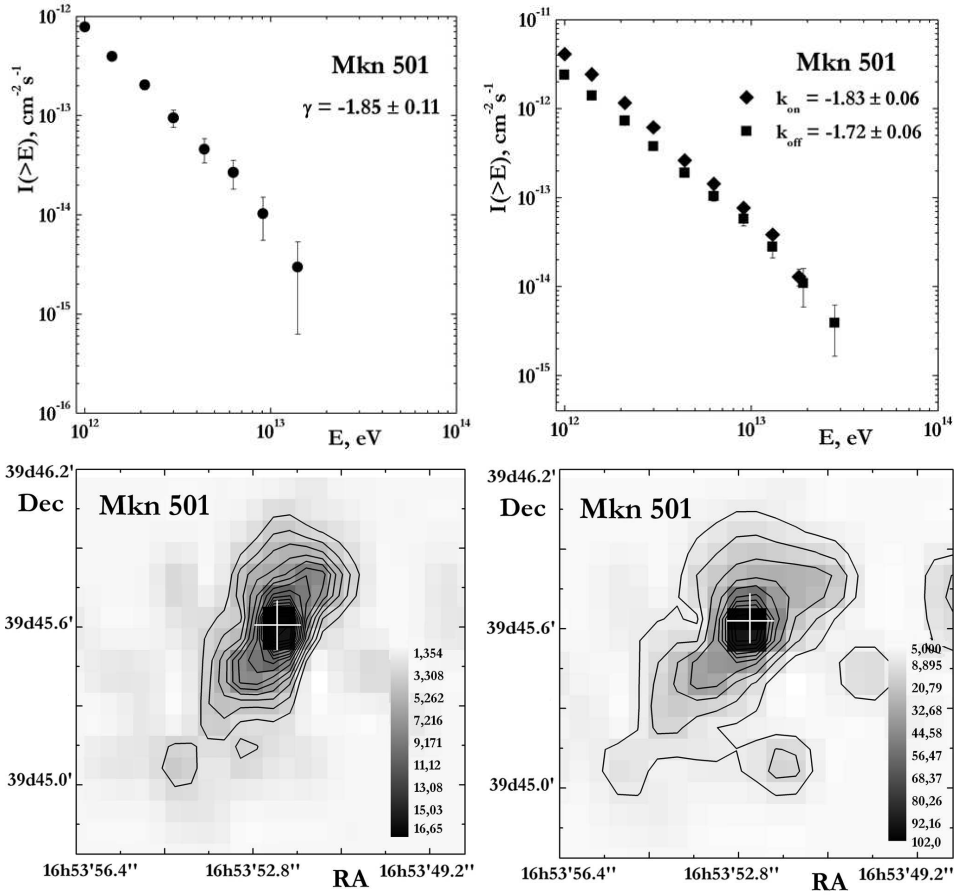

Fig. 4. **Top. left** – The Mkn 501 γ-quantum integral spectrum with power index of $k_\gamma = -1.85 \pm 0.11$; **right** – the event spectrum from Mkn 501 with background with index of $k_{ON} = -1.83 \pm 0.06$ and spectrum of background events observed simultaneously with Mkn 501 with index $k_{OFF} = -1.72 \pm 0.06$; **Bottom. left** – The Mkn 501 image at energy range of > 0.8 TeV; **right** – The energy image (in TeV units) of Mkn 501 by SHALON.

variations of the flux over the average value was also observed with the telescopes of Whipple, HEGRA, TACTIC, HESS $(60^o - 67^o)$, MAGIC (45^o).

MARKARIAN 501

The detection of Mkn 421 as metagalactic VHE gamma-ray source initiated a search for VHE emission from several other active galactic nuclear of blazar type. This led to the detection of BL Lac object Mkn 501 (z = 0.034) by Whipple in 1995. In contrast to Mkn 421, EGRET had not detected this source, as significant source of gamma rays. So Mkn 501 was the first object to be discovered by as gamma-ray source from the ground. As is seen from fig. 3 the SHALON results for this gamma-source are consistent with the data telescopes of Whipple, TACTIC, HESS, MAGIC. An image of gamma-ray emission from Mkn 501 by SHALON telescope is shown in Fig. 4. The integral average gamma-ray flux above 0.8 TeV was estimated as $(0.86 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$ and the power index of the integral spectrum is $k_\gamma = -1.85 \pm 0.11$. The significant increase of Mkn 501 flux was detected in 1997 and 2006 with the VHE ground telescopes all over the world. The integral gamma-ray flux in 1997 and 2006 by SHALON telescope was estimated as $(1.21 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(2.05 \pm 0.23) \times 10^{-12}\ cm^{-2}s^{-1}$, respectively that is comparable with flux of powerful galactic source Crab Nebula.

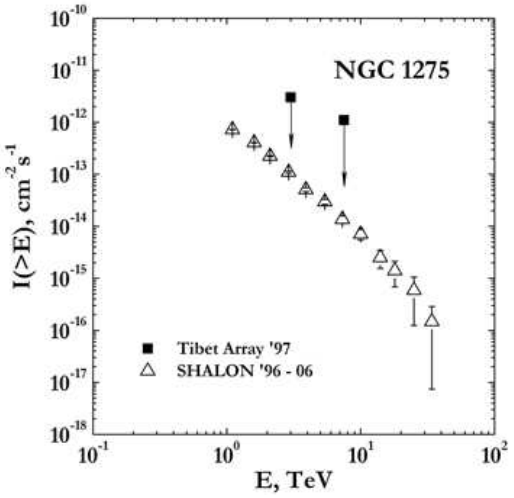

Fig. 5. The NGC 1275 gamma - quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with Tibet Array data [12];

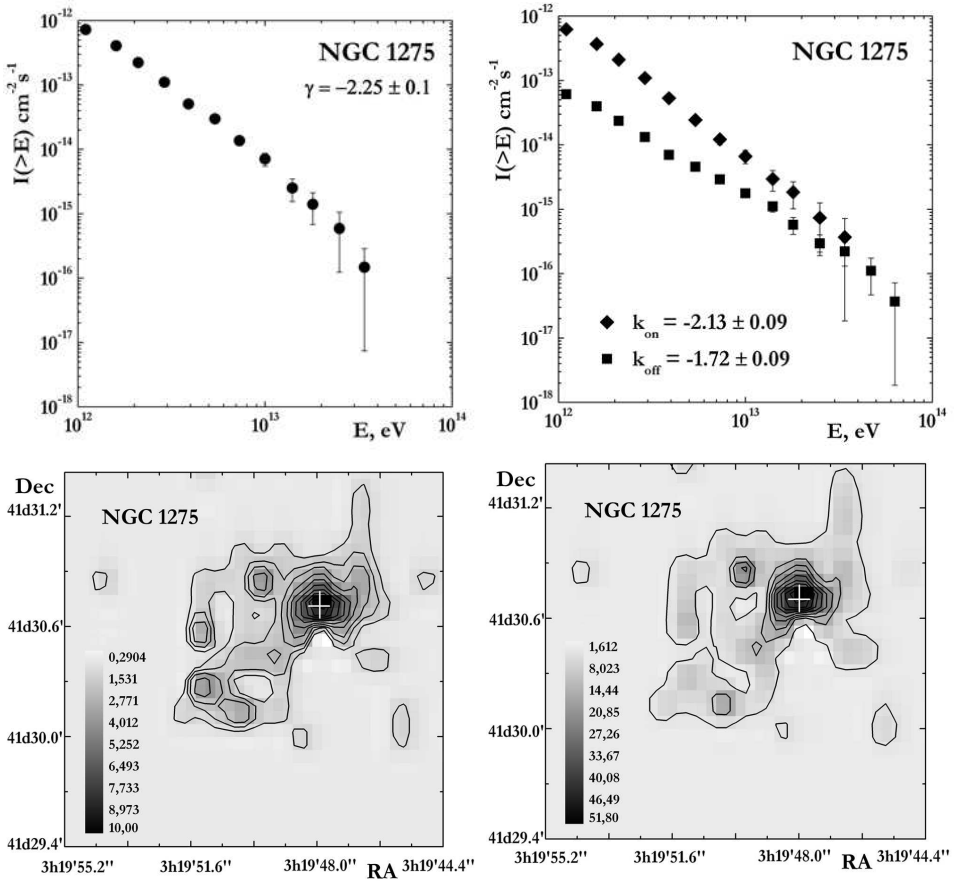

Fig. 6. **Top. left** – The NGC 1275 γ-quantum integral spectrum with power index of $k_\gamma = -2.25 \pm 0.10$; **right** – The event spectrum from NGC 1275 with background with index of $k_{ON} = -2.13 \pm 0.09$ and spectrum of background events observed simultaneously with NGC 1275 with index $k_{OFF} = -1.72 \pm 0.09$; **Bottom. left** – The NGC 1275 image at energy range of > 0.8 TeV; **right** – The energy image (in TeV units) of NGC 1275 by SHALON.

NGC 1275

Galaxy clusters have been consider as sources of TeV gamma rays emitted by high-energy protons and electrons accelerated by large scale structure formation shocks, galactic winds, or active galactic nuclei. The Perseus cluster of galaxies is one of the best studied clusters due to its proximity (116Mpc or z= 0.0018 1' corresponds to 30 kpc for $H_0 = 50 kms^{-1}Mpc^{-1}$) and its brightness. Galaxy NGC 1275 is the central dominant galaxy of the Perseus Cluster of Galaxies and is of Seyfert galaxy class. NGC 1275 is known as powerful X-ray and radio source. Many studies explored correlations of X-ray radio optical and ultraviolet emission (see e.g. [33]).

In 1996 year a new metagalactic source are detected by SHALON at TeV energies (fig. 5). This object was identified with Seyfert galaxy NGC 1275 (with redshift z=0.0179); its image is shown in figs. 7, 6. The maxima of the TeV gamma-ray, X-ray [32] and radio emission coincide with the active nucleus of NGC 1275. In contrast, the X-ray and TeV emission disappears almost completely in the vicinity of the radio lobes. The correlation TeV with X-ray emitting regions was found whereas The integral gamma-ray flux for this source is found to be $(0.78 \pm 0.13) \times 10^{-12} cm^{-2} s^{-1}$ at energies of > 0.8

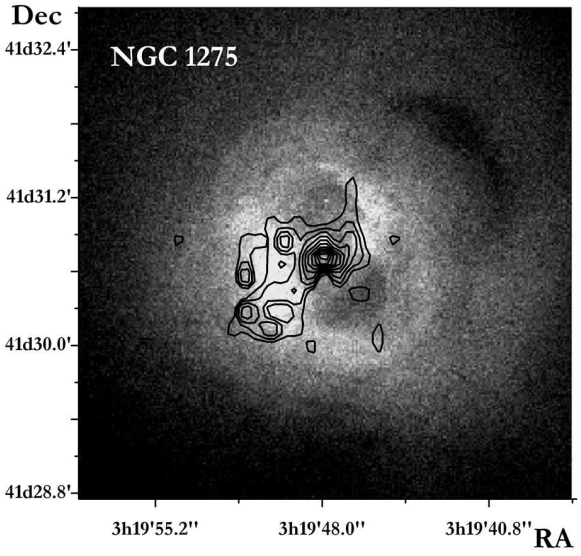

Fig. 7. A Chandra X-ray image of NGC 1275 at the centre of the Perseus galaxy cluster. The contour lines show the TeV - structure by SHALON observations.

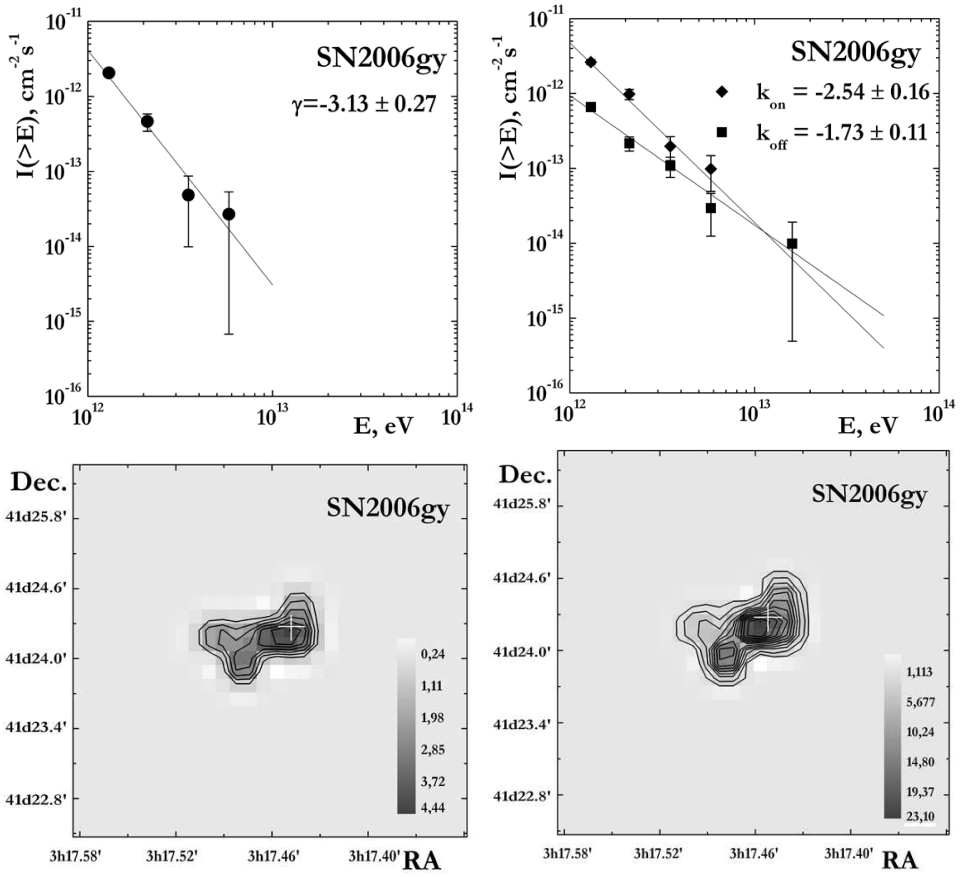

Fig. 8. **Top. left** – The SN 2006gy γ-quantum integral spectrum with power index of $k_\gamma = -3.13 \pm 0.27$; **right** – the event spectrum from SN 2006gy with background with index of $k_{ON} = -2.54 \pm 0.16$ and spectrum of background events observed simultaneously with SN 2006gy with index $k_{OFF} = -1.73 \pm 0.11$; **Bottom. left** – The SN 2006gy image at energy range of > 0.8 TeV; **right** – The energy image (in TeV units) of SN 2006gy by SHALON.

TeV. The energy spectrum of NGC 1275 at 0.8 to 30 TeV can be approximated by the power law $F(> E_O) \propto E^{k_\gamma}$, with $k_\gamma = -2.25 \pm 0.10$. The spectra of events satisfying the selection criteria (spectral index $k_{ON} = -2.13 \pm 0.09$) and of the background events observed simultaneously with the source (spectral index $k_{OFF} = -1.72 \pm 0.09$) are both shown in Fig. 6 for comparison. The Seyfert galaxy NGC 1275 has been also observed with the Tibet Array (fig. 5).

SN 2006GY

The flux increase was detected from the region NGC 1275 in autumn 2006. The detailed analysis of gamma-shower direction turned out the detection of metagalactic object. This object was identified with the supernova SN 2006gy [34] that is about 10 minutes away from NGC 1275.

Observations had been done in cloudless nights of moonless periods of 2006 Sep., Oct., Nov. Dec. and then during the winter of 2007. No flux increase was found in September observations. In the flare, observed on Oct. 22, the flux increased 6 times from the NGC 1275 and stayed on this level all Oct. moonless period. The integral gamma-ray flux for SN 2006gy is found to be $(3.71 \pm 0.65) \times 10^{-12} cm^{-2} s^{-1}$ at energies of > 0.8 TeV. The energy spectrum of SN2006 gy at 0.8 to 7 TeV can be approximated by the power law $F(> E_O) \propto E^{k_\gamma}$, with $k_\gamma = -3.13 \pm 0.27$. An image of gamma-ray emission from SN2006 gy by SHALON telescope is shown in Fig. 8. Follow-up observations on end of Nov. showed that the flux of SN2006 gy had dropped to a flux level of about $(0.69 \pm 0.17) \times 10^{-12}$ and was constant during the Nov. Dec. period. The results of observation analysis of 2007 have no revealed TeV gamma-ray emission from region of SN 2006gy. So, the explosion of extragalactic supernova was observed at TeV energies for the first time with SHALON Cherenkov telescope.

CONCLUSION

The explosion of extragalactic hipernova was detected at TeV energies for the first time with SHALON Cherenkov telescope. The flux increase was detected from the region NGC 1275 in autumn 2006. The detailed analysis of gamma-shower direction turned out the detection of metagalactic object. This object was identified with the supernova SN 2006gy that is about 10 minutes away from NGC 1275. The integral gamma-ray flux for SN 2006gy is found to be $(3.71 \pm 0.65) \times 10^{-12} cm^{-2} s^{-1}$ at energies of > 0.8 TeV. The integral average gamma-ray fluxes of Mkn 421 and Mkn

501 were estimated as $(0.63 \pm 0.14) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(0.86 \pm 0.13) \pm 10^{-12} cm^{-2}s^{-1}$ respectively. The increase of the flux over the average value was detected in 1997 and 2004 observations of Mkn 421 by SHALON and estimated to be $(1.01 \pm 0.25) \times 10^{-12}\ cm^{-2}s^{-1}$ and $(0.96 \pm 0.2) \times 10^{-12}\ cm^{-2}s^{-1}$, respectively. The significant increase of Mkn 501 flux was detected in 1997 and 2006 with the VHE ground telescopes all over the world. The integral - ray flux by SHALON telescope was estimated as $(1.21 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$. For the increase of 2006 the flux value is $(2.05 \pm 0.23) \times 10^{-12}\ cm^{-2}s^{-1}$ that is comparable with flux of powerful galactic source Crab Nebula. The research of extragalactic and galactic sources of very-high energy gamma-quanta by methods, including ones using mirror Cherenkov telescopes concerns, rather than delicate problem of the cosmic ray nature and the role of our Galaxy and Extragalaxy in their generation.

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