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Very high energy gamma-ray emission of close metagalactic sources Mkn 421, Mkn 501 and NGC 1275.

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Abstract: Gamma-astronomical researches are carrying out with SHALON mirror telescope at the Tien-Shan high-mountain observatory. During the period 1992 - 2007, 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. 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 with the VHE ground telescopes all over the world. The integral gamma- ray flux by SHALON telescope was estimated as $(1.21 \pm 0.13) \times 10^{-12} cm^{-2}s^{-1}$ that is comparable with flux of powerful galactic source Crab Nebula. 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 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.

Introduction

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 because the gammas and neutrinos do not dissipate energy after propagation through the magnetic fields of the Universe providing a unique probe into these cosmic accelerators. These gamma-astronomical researches are carrying out with SHALON mirror telescope at the Tien-Shan high-mountain observatory. During the period 1992 - 2007, 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:

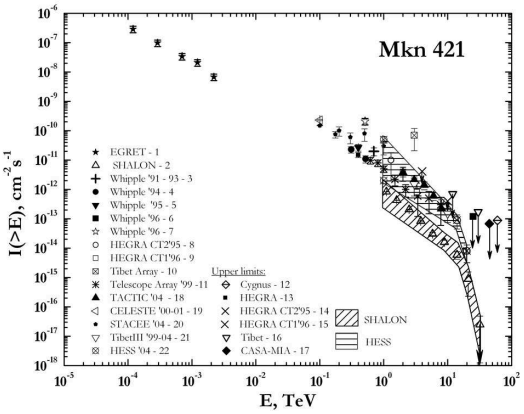

Figure 1: The Mkn 421 gamma - quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with other experiments [1 - 20].

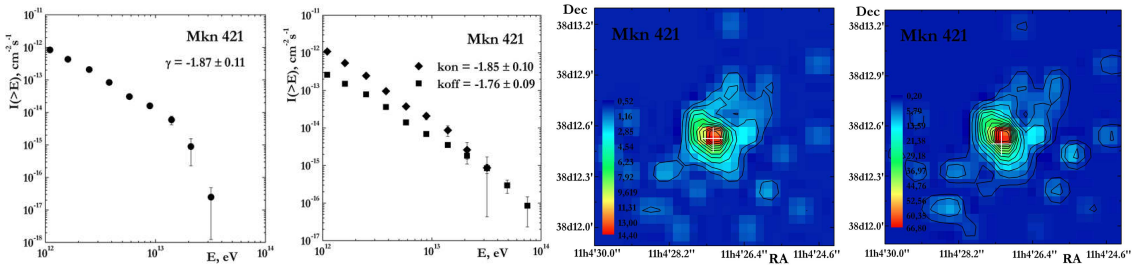

Figure 2: left – The Mkn 421 γ-quantum integral spectrum with power index of $k_\gamma = -1.87 \pm 0.11$; The event spectrum from Mkn 421 with background with index of $k_{ON} = -1.85 \pm 0.10$ and spectrum of background events observed simultaneously with Mkn 421 with index $k_{OFF} = -1.76 \pm 0.09$;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

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.

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 2006 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 timescales from minutes to years is the most distinctive

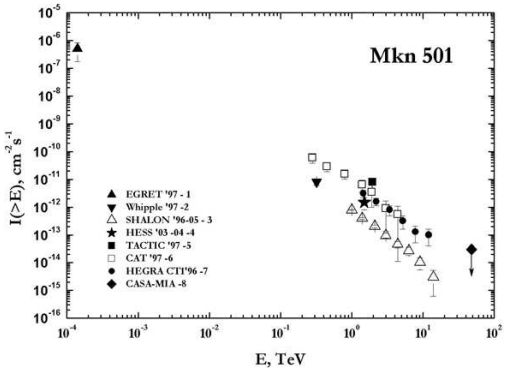

Figure 3: The Mkn 501 gamma - quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with other experiments [1, 21 - 31];

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 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 de-

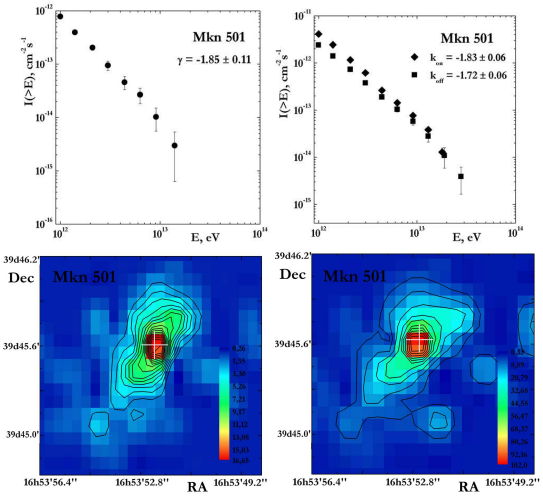

Figure 4: **top:** left – The Mkn 501 γ-quantum integral spectrum with power index of $k_\gamma = -1.85 \pm 0.11$; right – the event spectrum from Mkn 501 with background with index of $k_{ON} = -1.83 \pm 0.06$ and spectrum of background events observed simultaneously with Mkn 501 with index $k_{OFF}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

tected 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 with the VHE ground telescopes all over the world. The integral gamma-ray flux by SHALON telescope was estimated as $(1.21 \pm 0.13) \times 10^{-12}\ cm^{-2}s^{-1}$ that is comparable with flux of powerful galactic source Crab Nebula.

NGC 1275

In 1996 year a new metagalactic source are detected by SHALON at TeV energies (fig. 5). This object was identified with Seyfert galaxy NGC

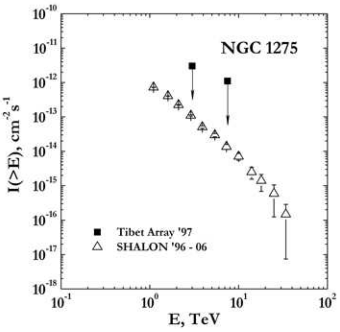

Figure 5: The NGC 1275 gamma - quantum ($E > 0.8$ TeV) integral spectrum by SHALON in comparison with Tibet Array data [12];

1275 (with redshift z=0.0179); its image is shown in fig. 6. The integral gamma-ray flux for this source is found to be $(0.78 \pm 0.13) \times 10^{-12}$ at energies of > 0.8 TeV. The energy spectrum of NGC 1275 at 0.8 to 20 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). 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 $(1.71 \pm 0.20) \times 10^{-12}$ at energies of > 0.8 TeV.

Conclusion

According to our analysis, the energy spectra of distant quasars 3c454.3 and 1739+522 differ from those of the known blazars Mkn 421 (z=0.031) and Mkn 501 (z=0.034): $F_{Mkn\ 421}(> E_\gamma) \propto E_\gamma^{-1.87 \pm 0.11}$ and $F_{Mkn\ 501}(> E_\gamma) \propto E_\gamma^{-1.85 \pm 0.11}$. The indices of integral spectra of events from Mkn 421 and Mkn 501 are respectively, $k_{ON} = -1.85 \pm 0.10$ and $k_{ON} = -1.83 \pm 0.06$ and the spectral indices of background events are $k_{OFF} = -1.76 \pm 0.09$ and $k_{OFF} = -1.72 \pm 0.06$. Hence, the average energy spectrum of

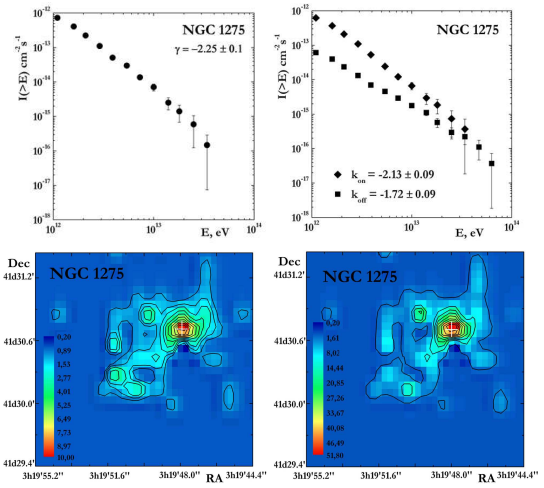

Figure 6: **top:** left – The NGC 1275 γ-quantum integral spectrum with power index of $k_\gamma = -2.25 \pm 0.10$; right – The event spectrum from NGC 1275 with background with index of $k_{ON} = -2.13 \pm 0.09$ and spectrum of background events observed simultaneously with NGC 1275 with index $k_{OFF}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

these two metagalactic sources differs from spectra of remote objects 1739+522 and 3c454.3 within the energy range $10^{12} - 10^{13}$ eV. This observation does not contradict to unified energy spectrum $F(> E_\gamma) \propto E_\gamma^{-1.2\pm0.1}$.

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