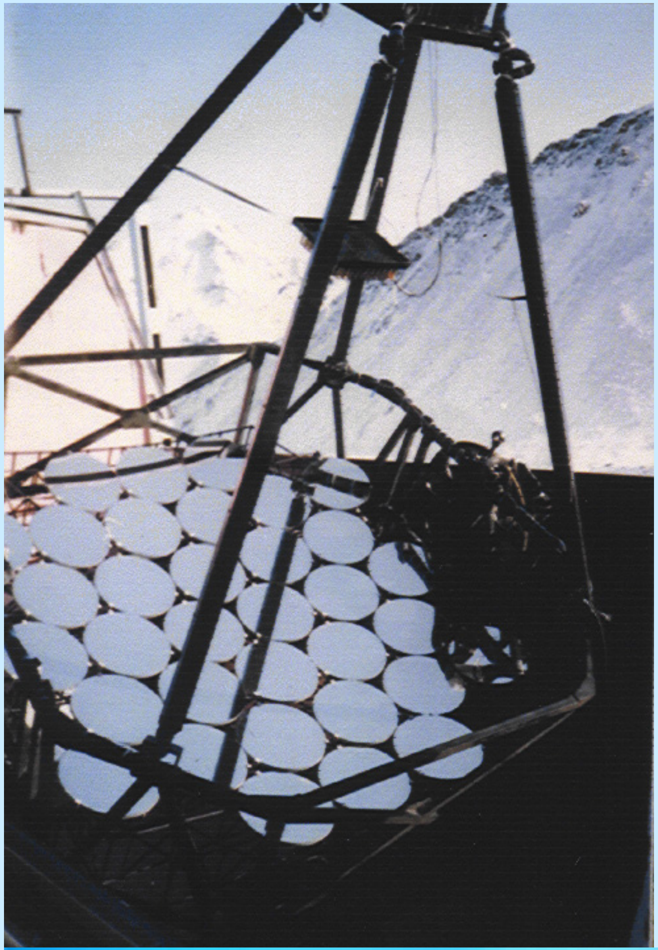
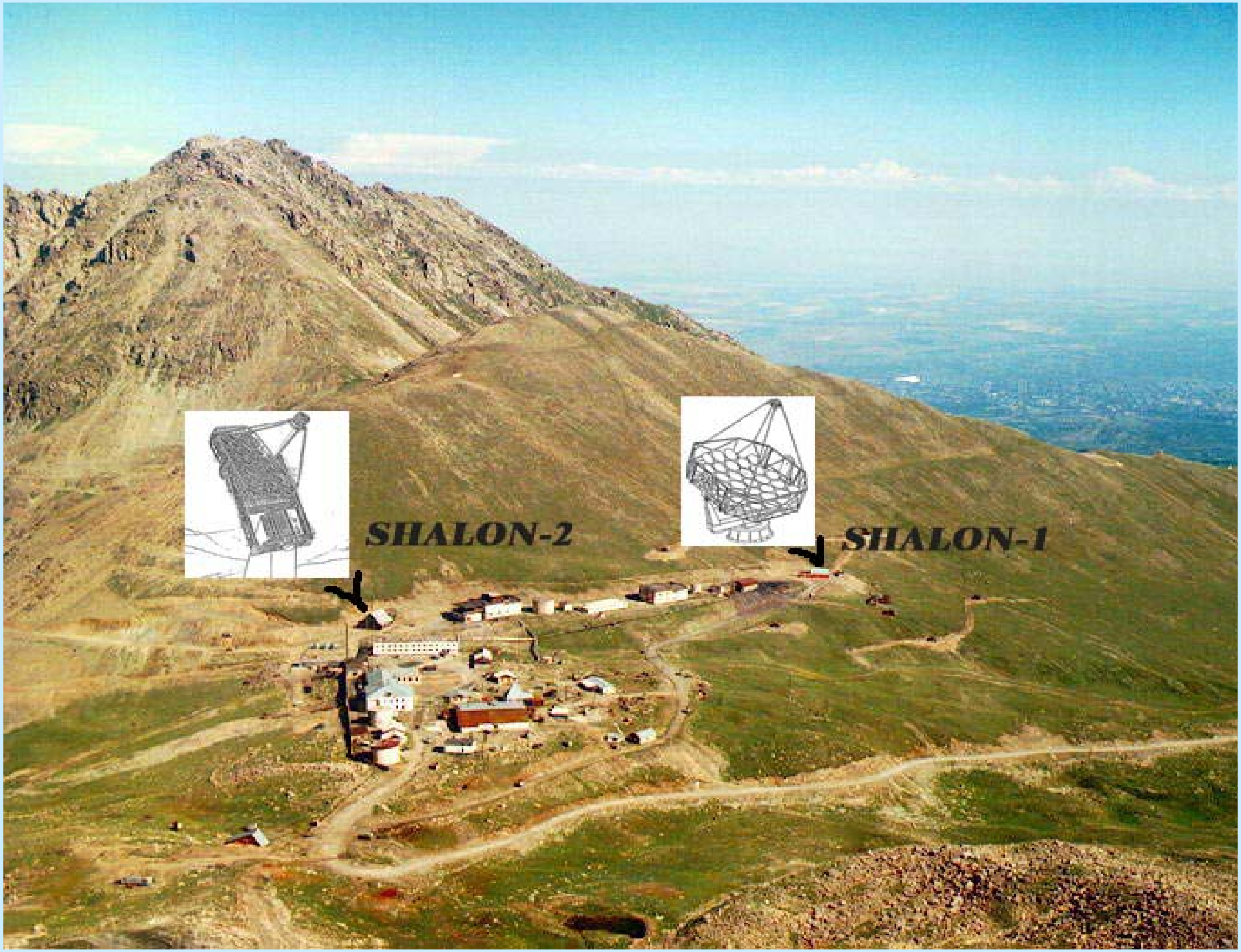


CYGNUS X-3 FLARING ACTIVITY DURING 10 YEARS OF OBSERVATION AND NEW GALACTIC BINARY 2129+47XR.

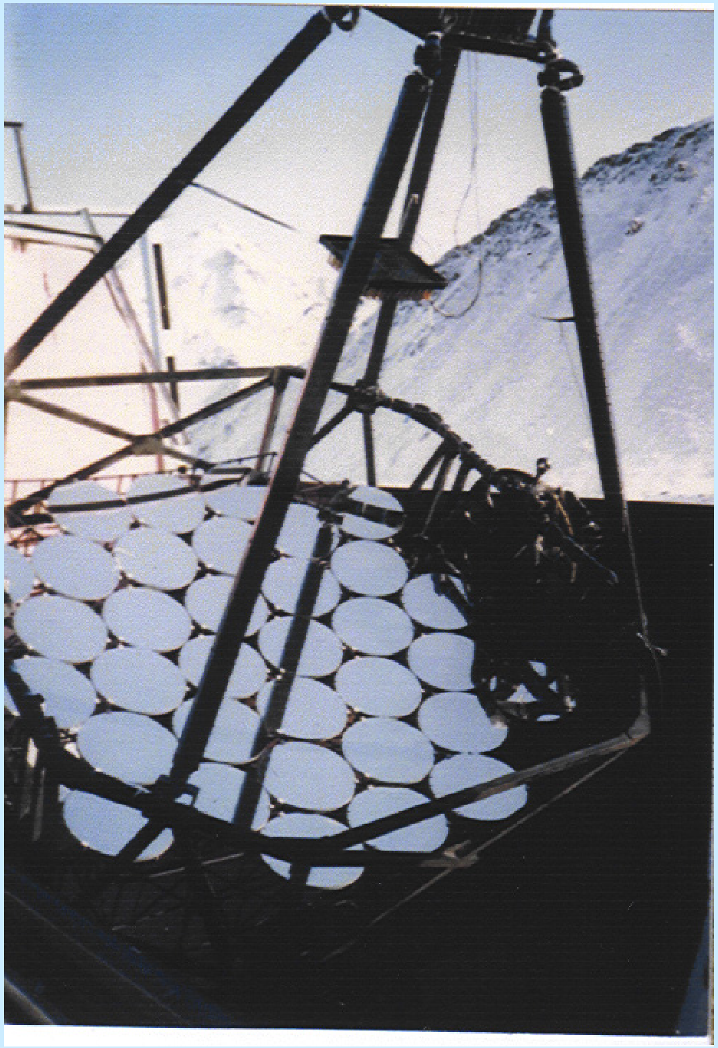
V. Y. SINITSYNA

P. N. Lebedev Physical Institute,
Leninsky prospect 53, Moscow, 119991 Russia


SHALON-2
SHALON-1

HIGH MOUNTAINOUS OBSERVATORY SHALON ALATOO

SHALON mirror Cherenkov telescope created at Lebedev Physical Institute and stated in 1991 - 1992

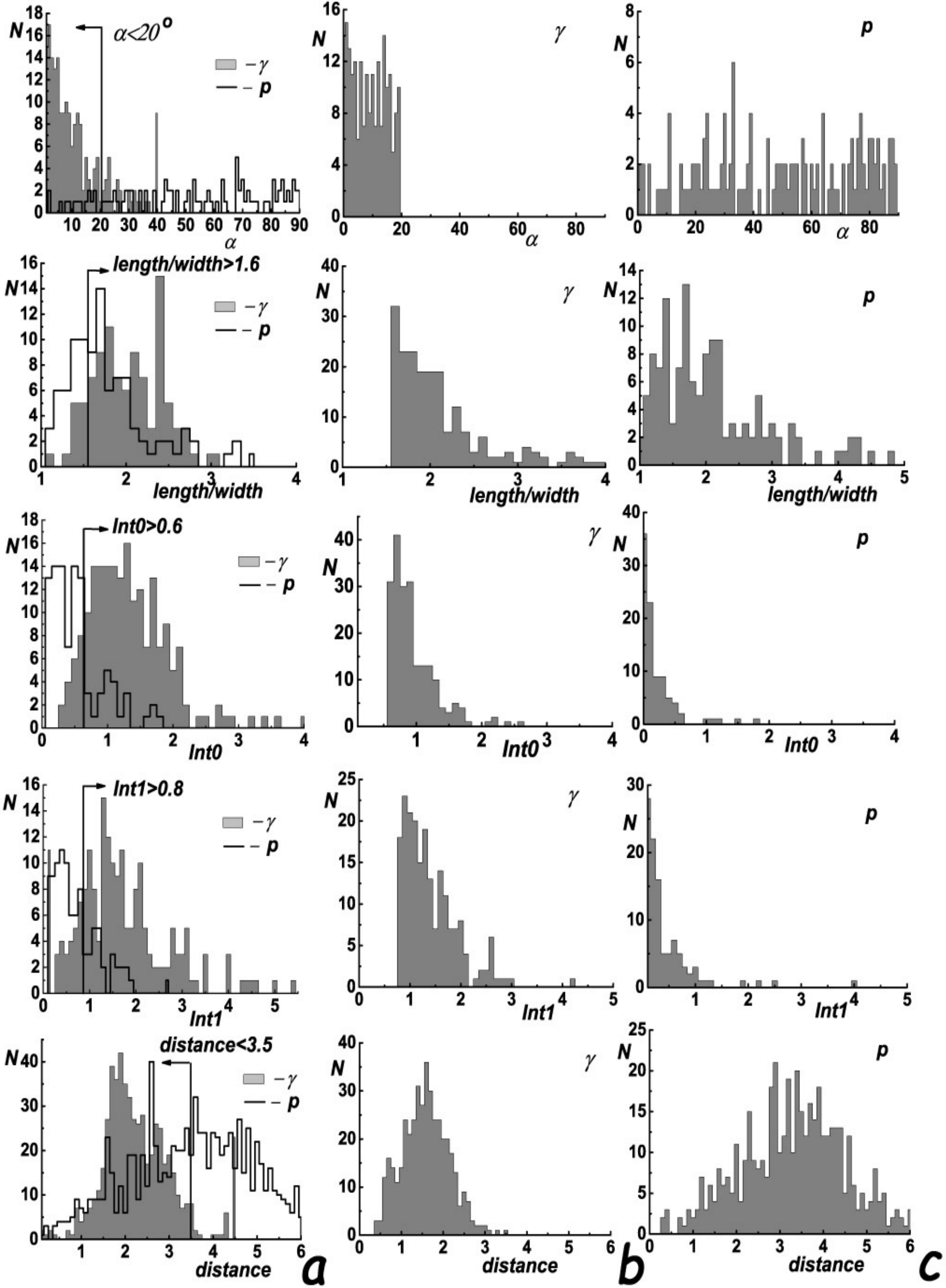


- Total area of spherical mirror — 11.2 m^2
- Radius of mirror curvature — 8.5 m
- The angle range of telescope turn:
  – azimuth — 0^o-360^o
  – zenith — 0^o-110^o
- The accuracy of telescopic axis pointing — $\leq 0.1^o$
- The photomultiplier tube camera (12x12) — 144 elements
- Field of view > 8^o
- Weigth 6 ton
- altazimuth mounting

It is essential that our telescope has a large matrix with full angle >8^o that allows us to perform observations of the supposed astronomical source (ON data) and background from extensive air showers (EAS) induced by cosmic ray (OFF data) simultaneously. Thus, the OFF data are collecting for exactly the same atmospheric thickness, transparency and other experimental conditions as the ON data.

SHALON-1

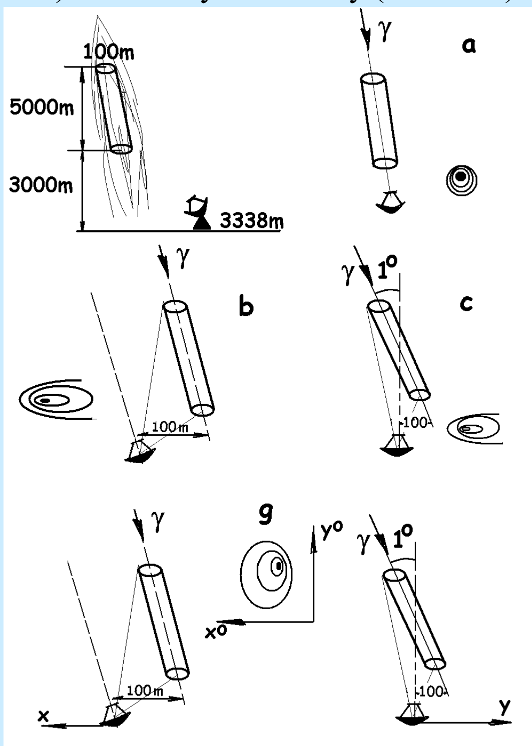
SHALON-2



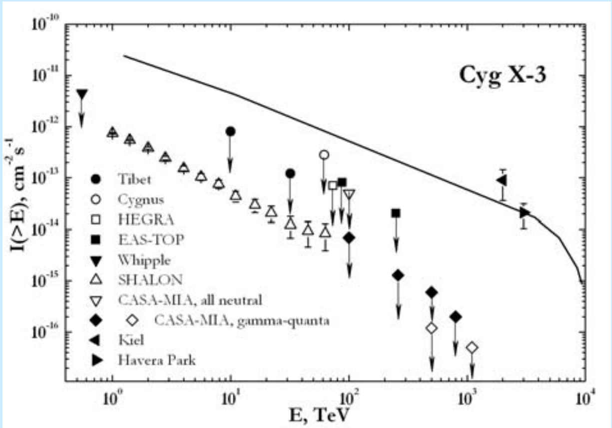
The selection of gamma-initiated showers from the background of proton showers is performed by applying the following criteria:

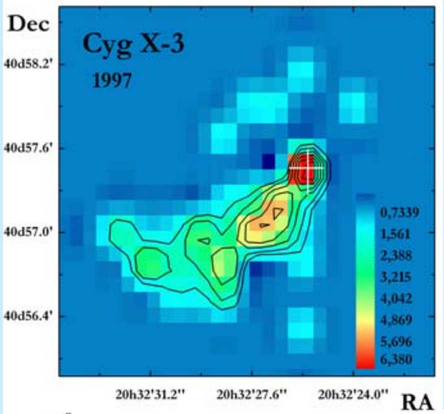
1) **α < 20°**;
2) **length/width > 1.6**;
3) the ratio **INT0** of Cherenkov light intensity in pixel with maximum pulse amplitude to the light intensity in the eight surrounding pixels exceeds **> 0.6**;
4) the ratio **INT1** of Cherenkov light intensity in pixel with maximum pulse amplitude to the light intensity in the in all the pixels except for the nine in the center of the matrix is exceeds **> 0.8**;
5) **distance** is less than **3.5** pixels.

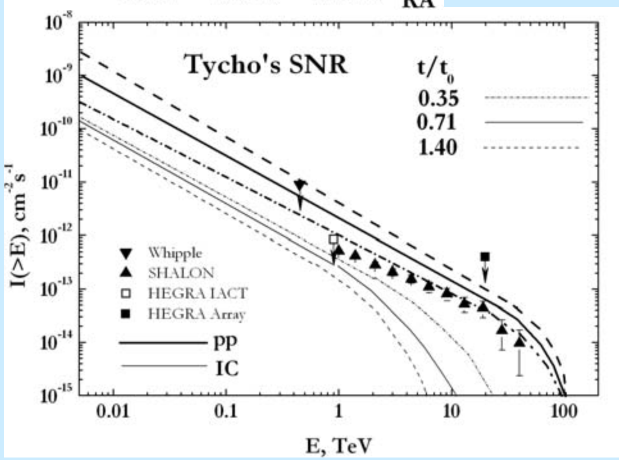
It is essential that our telescope has a large matrix with full angle >8° that allows us to perform observations of the supposed astronomical source (ON data) and background from extensive air showers (EAS) induced by cosmic ray (OFF data) simultaneously.



TeV gamma-rays from Galactic sources







During the period 1992 - 2008 12 metagalactic and galactic sources have been observed. Among them are galactic sources Crab Nebula (supernova remnant), Cygnus X-3 (binary), Tycho's SNR (supernova remnant), Geminga (radioweak pulsar) and 2129+47 (binary)

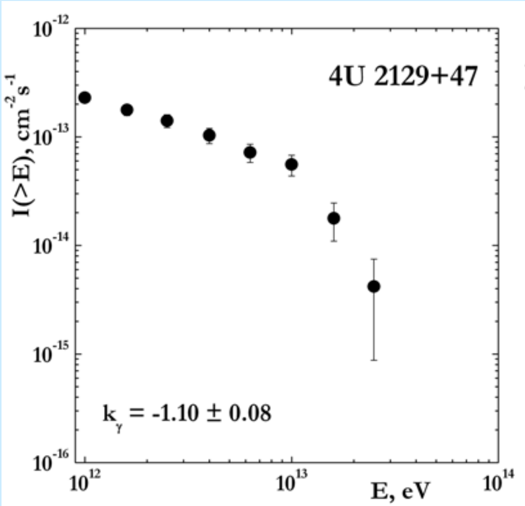
The energy spectrum of Cyg X-3 at 0.8-65 TeV can be approximated by the power law $F(>E0) \propto E^{k\gamma}$, with $k_\gamma=-1.21 \pm 0.05$. This flux, measured for the first time, is several times less than the upper limits established in the earlier observations.

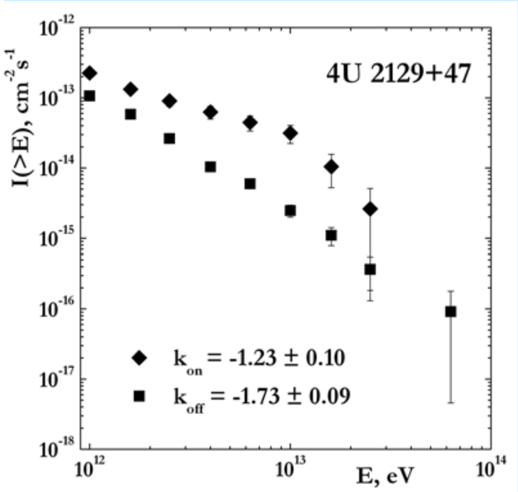
Tycho's SNR has long been considered as a candidate to cosmic ray hadrons source in Northern Hemisphere, although it seemed that the sensitivity of the present generation of Imaging Atmospheric Cherenkov System's too small for Tycho's detection. The expected π^O-decay gamma-quantum flux $F_\gamma \propto E_\gamma^{-1}$ extends up to ~ 30 TeV, whereas the Inverse Compton gamma-ray flux has a cutoff above the few TeV. So, the detection of gamma-rays at energies of ~ 10-40 TeV by SHALON telescope is the evidence of hadron origin.

SHALON catalogue of galactic gamma -quantum sources

Source	Observable flux, $cm^{-2}s^{-1}$	Distance, kpc
Crab Nebula	$(1.70\pm0.15)\times10^{-12}$	2.0
Cygnus X-3	$(0.68\pm0.07)\times10^{-12}$	10
Geminga	$(0.48\pm0.17)\times10^{-12}$	0.25
Tycho's SNR	$(0.52\pm0.09)\times10^{-12}$	2.3
2129+47XR	$(0.19\pm0.09)\times10^{-12}$	6.0

4U 2129+47





4U 2129+47 is a low-mass X-ray binary that undergo high-low transitions in its X-ray flux. It shows evidence of an extended X-ray emission region often called an accretion disk corona. The 4U 2129+47 is currently the only accretion disk corona source in a low state .

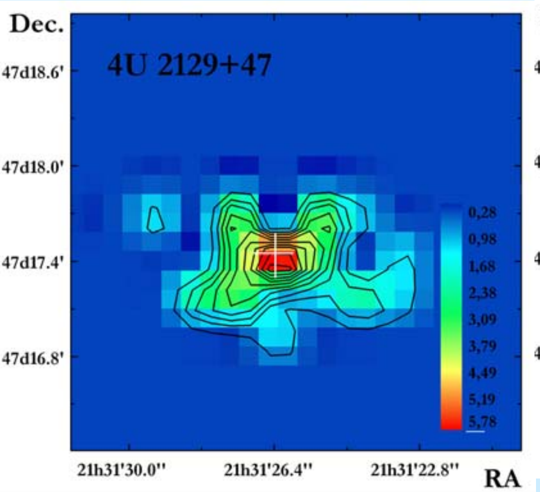
The **4U2129+47** as a new galactic gamma-source is detected at energy >0.8 TeV with flux

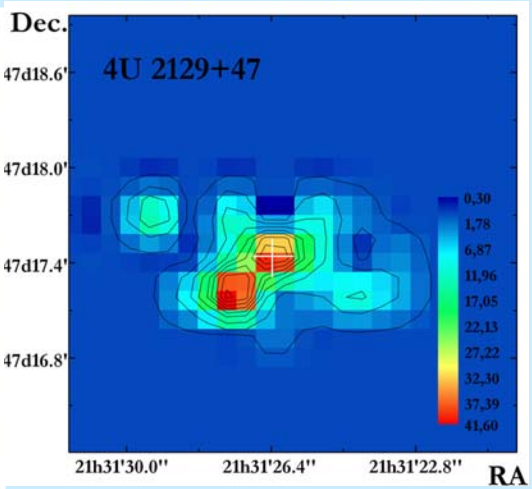
(0.19±0.05)×10^{-12}cm^{-2}s^{-1} and indices of the integral spectra are

k_γ =-1.10± 0.08,

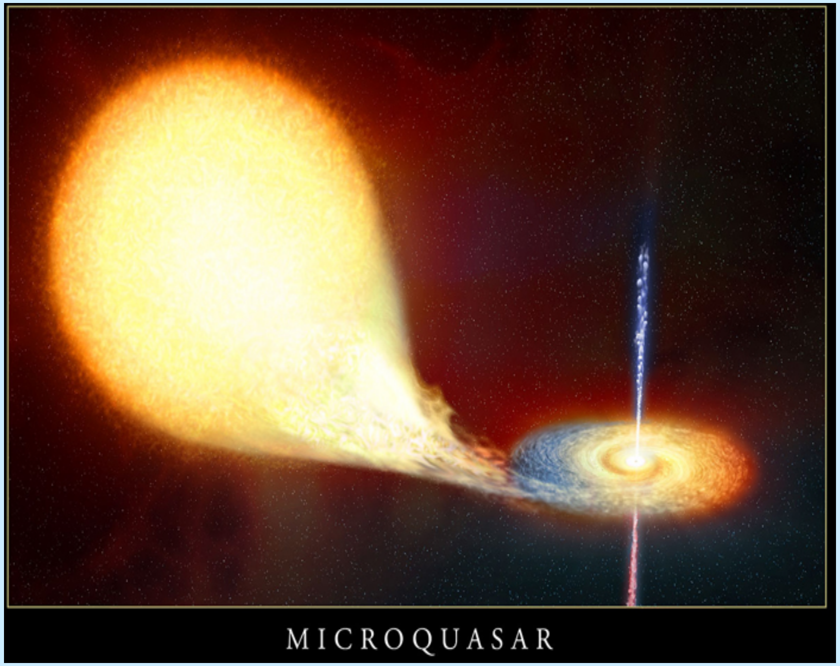
k_{ON}=-1.23 ± 0.10

k_{OFF}=-1.73 ± 0.09.





Cygnus X-3



Cygnus X-3 is peculiar X-ray binary system discovered about 40 years ago. The system has been observed throughout wide range of the electromagnetic spectrum. It is one of the brightest Galactic X-ray sources, displaying high and low states and rapid variability in X-rays. It is also the strongest radio source among X-ray binaries and shows both huge radio outbursts and relativistic jets. The radioactivity is closely linked with the X-ray emission and the different X-ray states. Based on the detections of ultra high energy gamma-rays, Cygnus X-3 has been proposed to be one of the most powerful sources of charged cosmic ray particles in the Galaxy.

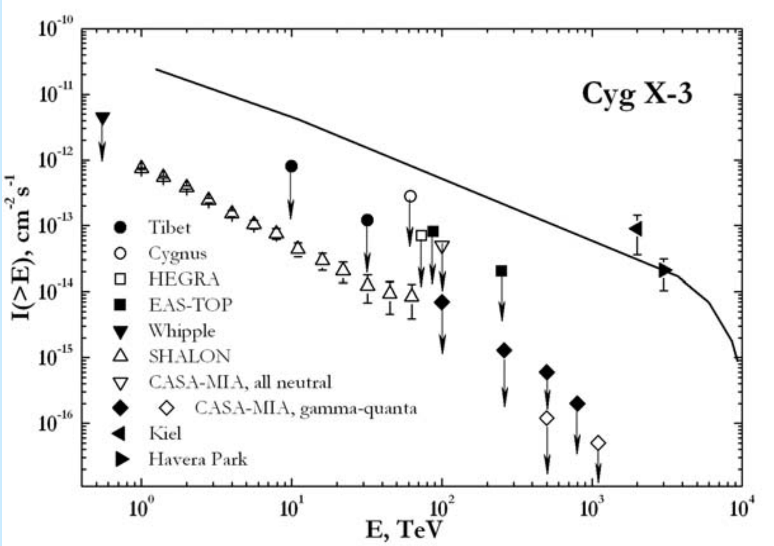
The attempts of detection of TeV emission from Cygnus X-3 were first made in the mid of 1970s and continued through the mid 1980s. Two observations were particularly important: the Kiel results and contemporaneous observation at Haverah Park. These results indicated a very large UHE flux from Cygnus X-3. So, these results stimulated the construction of many of new detectors. The upper limits of the Cygnus X-3 flux are over an order of magnitude lower than the detected in the 1980s levels. Figure shows upper limits on the steady flux from Cygnus X-3 reported between 1990 and 1995 compared with earlier observations. The Cygnus X-3 flux obtained by SHALON is one order of magnitude lower than upper limits published before.

Cygnus X-3

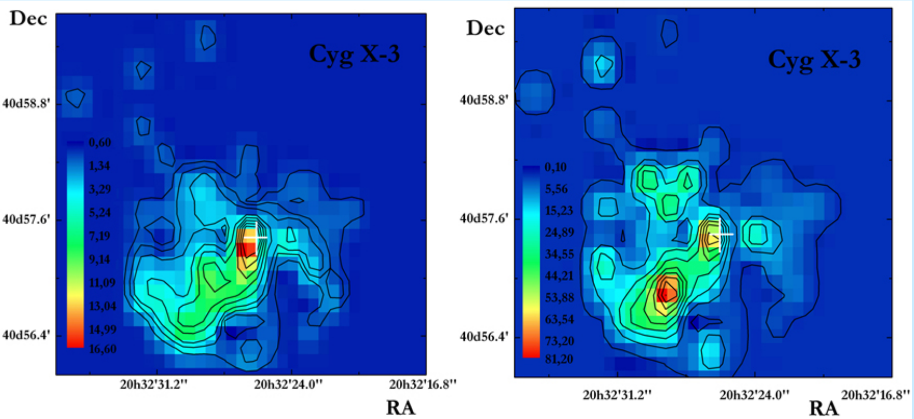
Figures collect observational data obtained with SHALON mirror Cherenkov telescope for the Cygnus X-3 point source. This galactic binary system regularly observed since a 1995 is known as a source with variable intensity (from 5×10^{-12} to 10^{-11} $cm^{-2}s^{-1}$); the average gamma-quantum flux from Cygnus X-3 for E >0.8 TeV is estimated as

$$\mathbf{F(E_O>0,8\ TэB)=(6.8\pm0.7)\bullet10^{-13}\ cm^{-2}s^{-1}}.$$

The standard output of the SHALON data processing consists of the integral spectrum of events coming from a source under investigation; spectrum of the background events coming simultaneously, during the observation of the source; temporal analysis of the source and background events; and the source image. The energy spectrum of Cygnus X-3 at 0.8 - 65 TeV can be approximated by the power law $F(>E_O) \propto E^{k\gamma}$, with k_γ=-1.21± 0.05. This flux, measured for the first time, is several times less than the upper limits established in the earlier observations.

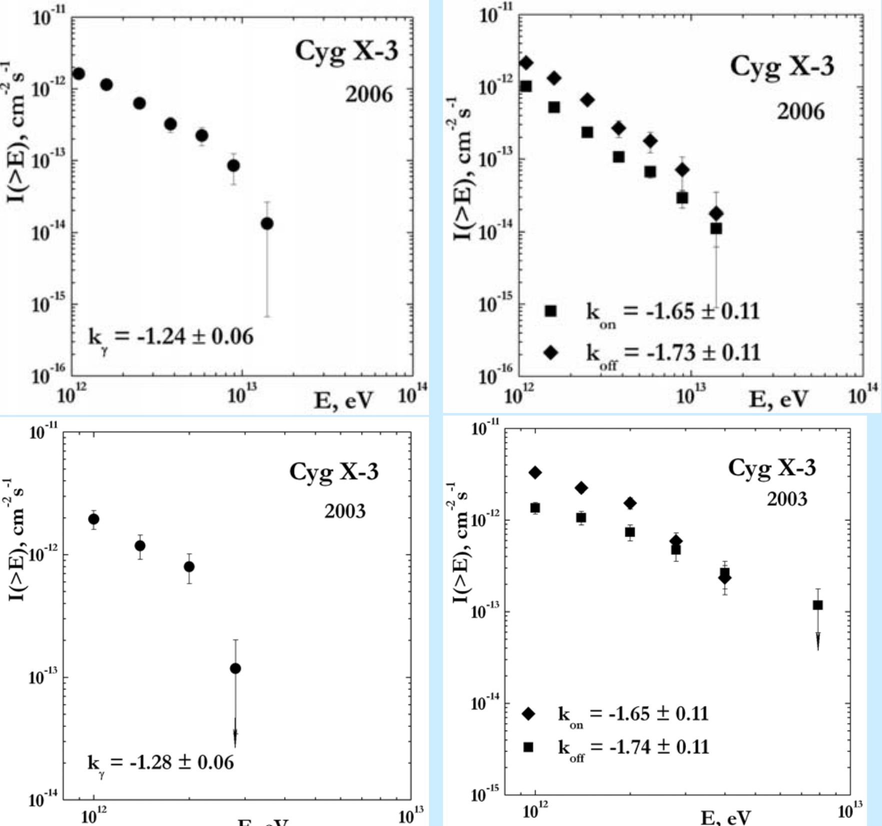


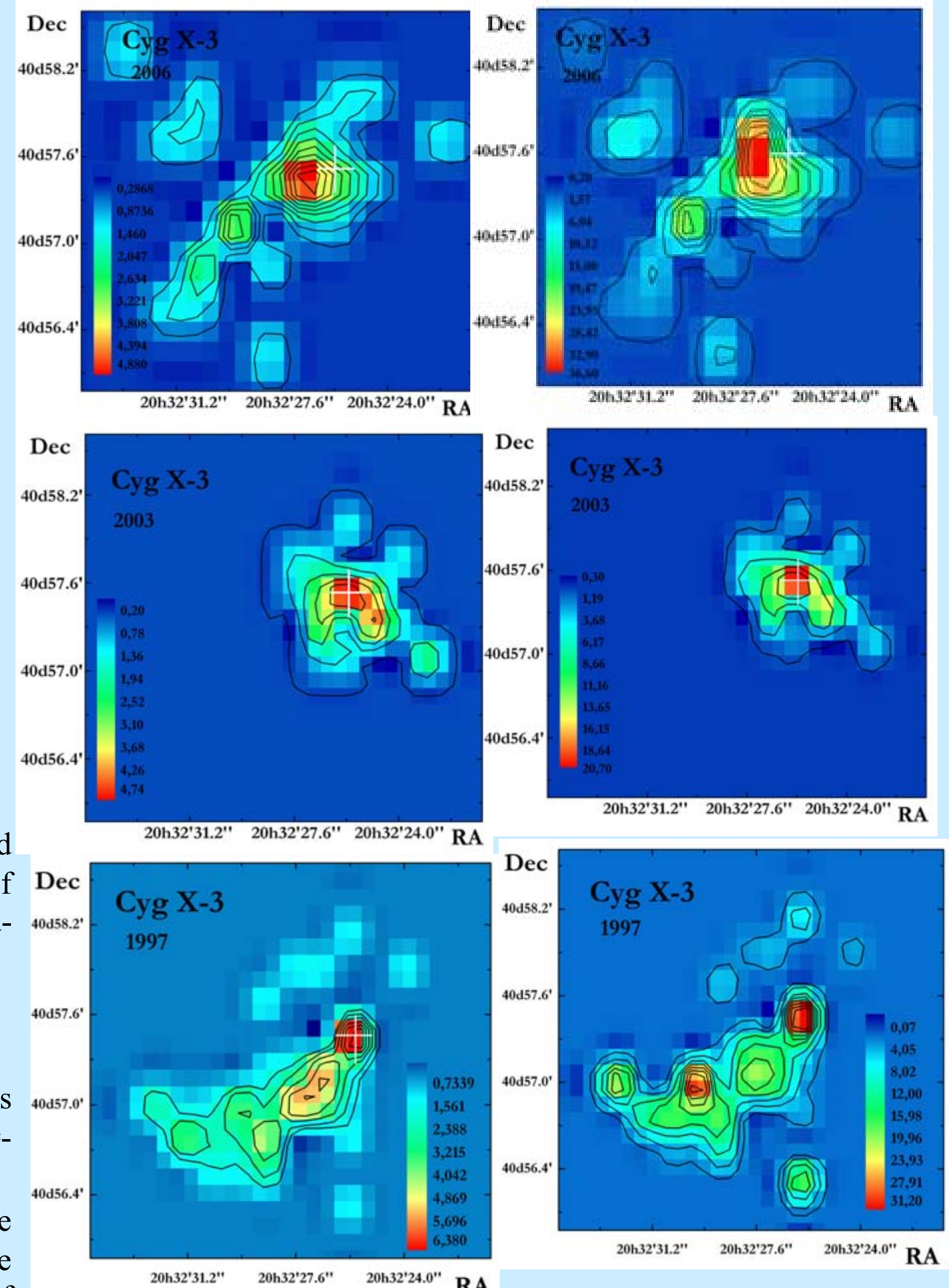
The Cygnus X-3 gamma-quantum (*E* > 0.8 TeV) integral spectrum by SHALON in comparison with other experiments: TIBET, [7]; 2 - CYGNUS, [8, 9]; 3 - HEGRA, [10]; 4 - EAS-TOP, [11, 12]; 5 - Whipple, [13, 14]; 6 - SHALON, [16, 17]; diamonds - CASA-MIA, [15]; the solid line is the theoretical calculation (Hillas) [4, 5]. The Cygnus X-3 gamma-quantum spectrum with power index of k_γ=-1.21± 0.05.



The spectra of events satisfying the selection criteria (spectral index k_{ON}=-1.33±0.05) and of the background events observed simultaneously with the source (spectral index k_{OFF}=-1.74±0.05) are both shown in Figure for comparison.

The image of gamma-ray emission from Cygnus X-3;
The energy image of Cygnus X-3 by SHALON.





The binary Cyg X-3 came to new period of flaring activity at radio- and X-ray energies in 2006. In May and July 2006 the significant increase of Cyg X-3 flux have detected with SHALON at TeV energy. The gamma-ray flux detected by SHALON in 2006 was estimated as

$\mathbf{(1.47 \pm 0.24) \times 10^{-12} cm^{-2} s^{-1}}$ with the indices of integral spectra are

$k_\gamma = -1.21 \pm 0.06$, $k_{ON} = -1.65 \pm 0.11$ and $k_{OFF} = -1.73 \pm 0.11$.

The gamma-ray flux detected by SHALON in 2003 was estimated as $\mathbf{(1.79 \pm 0.33) \times 10^{-12} cm^{-2} s^{-1}}$ with the indices of integral spectra are $k_\gamma = -1.28 \pm 0.06$, $k_{ON} = -1.65 \pm 0.11$ and $k_{OFF} = -1.74 \pm 0.11$.

Earlier, in 1997, a comparable increase of the flux over the average value was also observed and estimated to be $\mathbf{(1.2 \pm 0.5) \times 10^{-12} cm^{-2} s^{-1}}$. These results provide an evidence for a variability of the flux. Confirmation of the variability (and, perhaps, periodicity) of very high-energy gamma-radiation from Cygnus X-3 by the future observations would be important for understanding the nature of this astrophysical object.

Cygnus x-3 flaring activity during 10 years of observation and new galactic binary 2129+47XR.

Cygnus X-3 is peculiar X-ray binary system discovered about 40 years ago. The system has been observed throughout wide range of the electromagnetic spectrum. It is one of the brightest Galactic X-ray sources, displaying high and low states and rapid variability in X-rays. It is also the strongest radio source among X-ray binaries and shows both huge radio outbursts and relativistic jets. The radio activity is closely linked with the X-ray emission and the different X-ray states. Based on the detections of ultra high energy gamma-rays, Cygnus X-3 has been proposed to be one of the most powerful sources of charged cosmic ray particles in the Galaxy. The binary Cyg X-3 came to new period of flaring activity at radio- and X-ray energies in 2006. In May and July 2006 the significant increase of Cyg X-3 flux have detected with SHALON at TeV energy. The gamma-ray flux detected by SHALON in 2006 was estimated as $(1.47\pm0.24)\times10^{-12}$ $cm^{-2}s^{-1}$ with the indices of integral spectra are $k_{\gamma} = -1.21\pm0.06$, $k_{ON} = -1.65\pm0.11$ and $k_{OFF} = -1.73\pm0.11$. The gamma-ray flux detected by SHALON in 2003 was estimated as $(1.79\pm0.33)\times10^{-12}$ $cm^{-2}s^{-1}$ with the indices of integral spectra are $k\gamma = -1.28\pm0.06$, $k_{ON} = -1.65\pm0.11$ and $k_{OFF} = -1.74\pm0.11$. Earlier, in 1997, a comparable increase of the flux over the average value was also observed and estimated to be $(1.2\pm0.5)\times10^{-12}$ $cm^{-2}s^{-1}$. These results provide an evidence for a variability of the flux. Confirmation of the variability (and, perhaps, periodicity) of very high-energy gamma radiation from Cygnus X-3 by the future observations would be important for understanding the nature of this astrophysical object. The new galactic gamma-source neutron star 2129+47XR is detected at energy >0.8TeV with flux $(0.19\pm0.9)\times10^{-12}cm^{-2}s^{-1}$ and indices of the integral spectra are $k_{\gamma} = -1.05\pm0.10$, $k_{on} = -1.23\pm0.10$ and $k_{off} = -1.73\pm0.09$.

Cygnus X-3 flaring activity during 10 years of observation and new galactic binary 2129+47XR.

Unlike a spectrum of cosmic protons and nuclei, the energy spectrum of gamma-quanta is hard, $F_\gamma(E_\gamma)dE_\gamma \propto E_\gamma^{-2.2}\, dE\gamma$. This lead to a rather small contribution of gamma-quanta to the total flux of cosmic ray with energies ¸ 6×10^5 GeV. But in the energy range of GZK cutoff, the contribution of gamma-quanta grows up to 20% of the total cosmic-ray flux. It is possible that the gamma-spectrum is not changed up to super-high energies and thus it carries a unique information on super-high-energy processes in the Metagalaxy. All the above-mentioned put a further development in experimental gamma-astronomical researches and in observational methods for gamma-quanta of energies 10^3 -10^9 GeV to the list of the most important physical problems.

References

[1] J.Cocconi, in Proc VIth Int. Cosmic Ray Conf., Moscow, 2, (1960) 309
[2] S.I. Nikolsky and V. G. Sinitsyna, VANT, Ser. TFE 1331, (1987) 30.
[3] V.G. Sinitsyna, Nuovo Cim., 19C, (1996) 965.
[4] A.M. Hillas, Nuovo Cim. 19C, (1996) 701; Nature 312, (1984) 50.
[5] J.W. Cronin, Nuovo Cim. 19C, (1996) 847.
[6] C.M. Hofman, C. Sinnis, P. Fleury, et al., Rev. Mod. Phys. 71, (1999) 897.
[7] M. Amenomori et al., in Proc. 23rd Int. Cosmic Ray Conf., Calgary 1, (1993) 342.
[8] D.E. Alexandreas et al.,Astrophys. J. 418, (1993) 832.
[9] D.E. Alexandreas et al.,in Proc. 23rd Int. Cosmic Ray Conf., Calgary 1, (1993) 373.
[10] A.D.Karle et al.,Astropart. Phys. 4, (1995) 1.
[11] P.L. Ghia et al., Proc. 24th Int. Cosmic Ray Conf., Rome 2, (1995) 421.
[12] M.Aglietta et al.,Astropart.Phys. 3, (1995) 1.
[13] T.C. Weekes Proc. 25th Int. Cosmic Ray Conf., Durban 5, (1997) 251.
[14] M. Catanese and T. C. Weekes, Preprint Series No. 4811, (1999); No 4450, (1996).
[15] A. Borione et al., Phys Rev. 55, (1997) 1714.
[16] V.G. Sinitsyna et al., Nucl. Phys. B (Proc.Suppl.) 122, (2003) 247.
[17] V.G. Sinitsyna, S. I. Nikolsky, et al., Izv. Ross. Akad. Nauk Ser. Fiz. 69(3), (2005) 422.
[18] M.R. Garcia, P. J. Callanan, Astron. J., 118, (1999) 1390