Observed and Expected TeV Gamma-Ray Emission from Geminga and Tycho's Supernova Remnants

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Abstract

We discuss some results of the observation gamma-quanta sources Geminga and Tycho's SNR and the discrimination methods between gamma-rays and protons. $I_{Geminga} = (0.48 \pm 0.17) \bullet 10^{-12} cm^{-2}s^{-1}$ and $I_{Tycho} = (1.89 \pm 0.56) \bullet 10^{-13} cm^{-2}s^{-1}$. Selection of showers produced by gamma-quanta from background has made according the following criteria 1) $\alpha < 20^o$; 2) length/width$>$ 1.6; 3) int0$>$ 0.6; 4) int1$>$ 0.8; 5) distance is $<$ 3.5. The experimental distributions of image parameters on used criteria are presented. The time analysis of observation data on NGC 1275, Mkn 501, Crab Nebula, Cygnus X-3 has shown that the contribution of cosmic ray background into observable gamma-quanta does not exceed – 10 - 15%. The obtained Tycho's spectrum compares with theoretical predictions.

More than ten years ago the project of the mirror Cherenkov telescope SHALON (Sinitsyna, 1987) was suggested and the first observations were started in 1991 at the ALATOO mountain observatory at the height 3338m (Sinitsyna, 1992-2003)[1, 2]. A distinctive property of the telescope is a large full angle due to a relatively large size of photomultipliers matrix (144 pixels, full angle 8^o)(Fig. 1). This allows to detect extensive air showers coming at to the distance up to 120 m from an optical axis of the telescope, that increases the statistics from the sources of very high energy gamma-quanta. In addition such a large full angle of an image matrix allows to research an isotropic background of extensive air showers from charged particles of cosmic rays (OFF data) simultaneously with the observation of gamma-quanta local sources (ON data) at the same optical characteristics of atmosphere. It is particularly important because in our research of gamma-sources the extensive air showers generated by gamma-quanta are selected not only according to exceeding flux of showers in a small angle, but also according to the differences of the evaluation in the atmosphere depth of electron-photon cascades generated by protons and by nuclei of cosmic rays.

Such additional selection of electron-photon showers among extensive air

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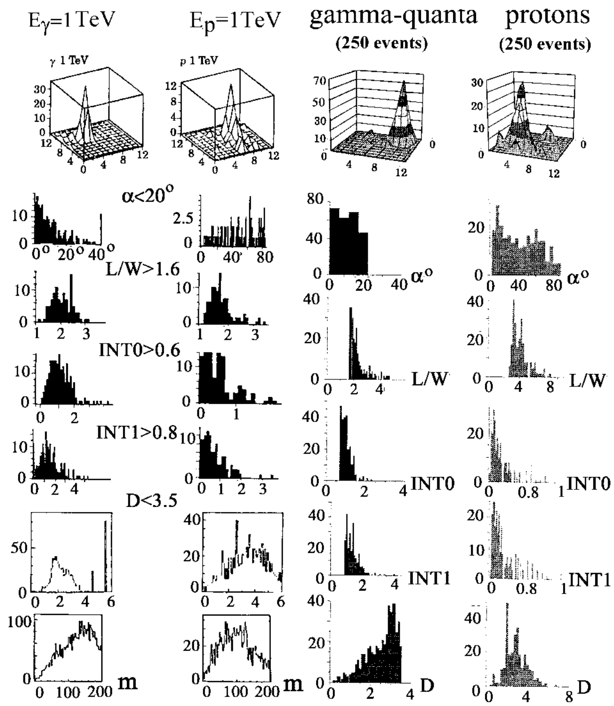

Fig. 1. The Monte Carlo and experimental distributions of the Image parameters for proton and gamma showers.

showers of cosmic rays can be carried out by the analysis of a light image (generally of an elliptic spot in a lightreciever matrix) in comparison with developed characteristic parameters of distributions for both showers from gamma - quanta and showers from protons and nuclei. Selection of gamma-quanta showers from a background of showers produced by protons (Fig. 1) is performed according to the following: 1) α <20; 2) length/width > 1.6; 3) relation of Cherenkov light intensity in pixel with max light to the light in eight pixels around it is int0 >0.6; 4) relation of Cherenkov light intensity in pixel with max light to light intensity in all pixels except nine in the center is for int1 >0.8; 5) distance is <3.5 in pixels.

On Fig. 1 experimental distribution of image parameters for proton and gamma showers data obtained with the SHALON telescope is shown. At the left is Monte Carlo distributions of particles both gammas and protons on selection criteria. And on the right the gamma-quanta (250 events) from point sources observed by SHALON and selected by criteria and far the cosmic ray protons (250 events) from zenith SHALON observations are represented. As the analysis of this particle distributions on five criteria of selection used in experiment SHALON has shown that the contribution of background proton events into gamma events is not more than 10%, i.e. 90% of a background is cut, whereas the separation of gamma - quanta according to carried out estimations is not more than 6% (Fig.

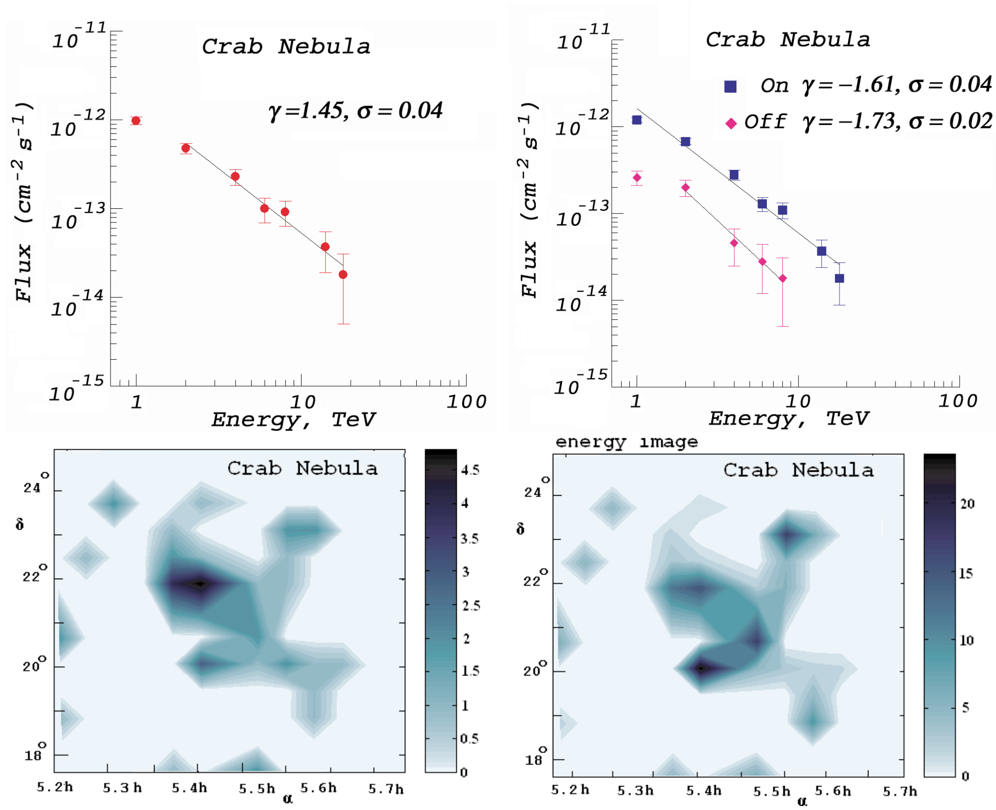

Fig. 2. **Above:** left–Crab Nebula spectrum by SHALON-1; right –observed spectrum (ON) with 10%-15% contribution of the proton showers and cosmic rays spectrum (Off); **Below:** left–Crab images at energy range of more than 0.8 TeV and energy image (in TeV);

1). The results of the time analysis on Crab Nebula and on Markarian 501, NGC 1275 and Cygnus X-3 are in these Proc. and [1 - 4]). The time analysis shows number of event (gamma or background), coming with the certain time interval (delta days). At ON data in all sources groups of peaks with common average 5-10 days width were detected with the period to multiple 24-26 days. These peaks can be interpreted as periods connected with the fact that observations are being carried out only by moonless nights. As one can see from presented at [1 -4] the contribution of cosmic rays background (dashed line) into observable gamma-quanta with energies > 0.8 TeV doesn't exceed 10% - 15%. The observable energy distribution of gamma-quanta from Crab Nebula $dF/dE_\gamma \sim E_\gamma^{-2.45\pm0.04}$. The observed spectra of the gamma-quanta including the 10%-15% contribution of the proton showers is $dF/dE \sim E^{-2.61\pm0.04}$. It also differs from observed energy spectrum for cosmic rays $dF/dE \sim E^{-2.73\pm0.02}$ (Table 1, [5]).

The efficiency of selection gamma-quanta from cosmic ray background in

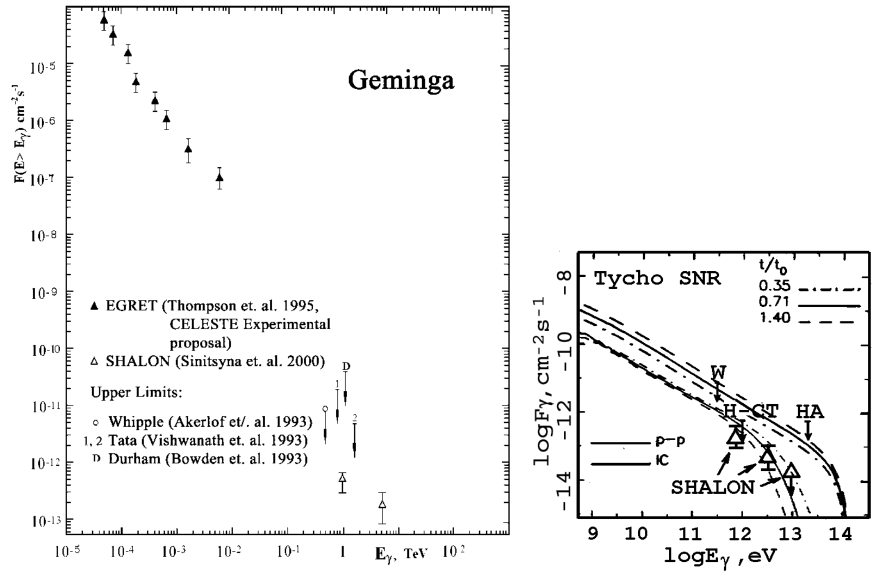

Fig. 3. left–gamma-quanta integral spectra of Geminga by SHALON-1 and other experiments; right – gamma-quanta integral spectra of Tycho Brage by SHALON-1 with experimental upper limits W – Whipple, H-CT – HEGRA IACT- system, HA – HEGRA AIROBICC and theoretical calculations from [6];

Table 1. Flux from Crab Nebula

Group	VHE Spectrum (10^{-11} photons $cm^{-2}s^{-1}TeV^{-1}$)	E_{th} TeV
Whipple (1991)	$(25(E/0.4TeV))^{-2.4\pm0.3}$	0.4
Whipple (1998)	$(3.2\pm0.7)(E/TeV)^{-2.49\pm0.06_{stat}\pm0.04_{syst}}$	0.3
SHALON (2003)	$(1.7\pm0.26)\bullet10^{-1}(E/TeV)^{-2.45\pm0.04}$	0.8
CANGAROO (1998)	$(2.01\pm0.36)\bullet10^{-2}(E/7TeV)^{-2.53\pm0.18}$	7
CAT (1999)	$(2.7\pm0.17\pm0.40)(E/TeV)^{-2.57\pm0.14_{stat}\pm0.08_{syst}}$	0.25
HEGRA (1999)	$(2.7\pm0.2\pm0.8)(E/TeV)^{-2.60\pm0.05_{stat}\pm0.05_{syst}}$	0.5
Tibet HD (1999)	$(4.61\pm0.90\bullet10^{-1})(E/3TeV)^{-2.62\pm0.17}$	3

experiment SHALON has allowed to observe the gamma-sources like Tycho Brage, Geminga (Fig. 3) and Cygnus X-3 (these Proc.). The obtained Tycho's spectrum compares with theoretical predictions [6] .

1. Sinitsyna V.G. 1999, AIP. 515, 293, 205.
2. Nikolsky S.I., Sinitsyna V.G. 2002, Izv. RAN ser. fiz. 66(11), 1667 and 1660.
3. Sinitsyna V.G., Arsov T.P., Nikolsky S.I. et.al. 2001, Proc. 27th ICRC 3, 2665.
4. Sinitsyna V.G., Arsov T.P., Nikolsky S.I. et.al. 2001, Nucl.Phys. B. 97, 215.
5. Weekes T.C. 1999, AIP. 515, 3.
6. Volk H.J., Berezhko E.G. et. al 2001, 27th ICRC, 2469.