# TeV emission from NGC1275 viewed by SHALON 15 year observations

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The Perseus cluster of galaxies is one of the best studied clusters due to its proximity and its brightness. It have also been considered as sources of TeV gamma-rays. The new extragalactic source was detected at TeV energies in 1996 using the SHALON telescopic system. This object was identified with NGC 1275, a giant elliptical galaxy lying at the center of the Perseus cluster of galaxies; its image is presented. The maxima of the TeV gamma-ray, X-ray and radio emission coincide with the active nucleus of NGC 1275. But, 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. The integral gamma-ray flux of NGC1275 is found to be $(0.78 \pm 0.13) \times 10^{-12} cm^{-2} s^{-1}$ at energies $> 0.8$ TeV. Its energy spectrum from 0.8 to 40 TeV can be approximated by the power law with index $k = -2.25 \pm 0.10$. NGC1275 has been also observed by other experiments: Tibet Array (5TeV) and then with Veritas telescope at energies about 300 GeV in 2009. The recent detection by the Fermi LAT of gamma-rays from the NGC1275 makes the observation of the energy $E > 100$ GeV part of its broadband spectrum particularly interesting.

## 1. Introduction

The gamma-astronomical researches are carrying out with the SHALON [1–5] mirror Cherenkov telescope at the Tien-Shan high-mountain observatory (3340 m a.s.l.). The mirror telescopic system of SHALON consists of a composed mirror with an area of $11.2m^2$. It is equipped with a 144-photomultiplier light-receiver that has a field of view $> 8°$ (the largest in the world). It enables one to continuously control the background of cosmic-ray particle emission and the atmosphere transparency, thus increasing the observation efficiency. The results of observation data analysis for each source are integral spectra of events coming from source - $k_{ON}$, and background events, coming simultaneously with source observation - $k_{OFF}$, temporal analysis of these two kind events and the source images. During the period 1992 - 2010, SHALON has been used for observations of galactic and metagalactic sources; among them are the known blazars Mkn421 (z=0.031), Mkn501 (z=0.034) and Seyfert galaxy NGC1275 (z=0.0179).

The observation results of two type of metagalactic sources: Seyfert galaxy NGC1275 [1–4] and SN 2006gy are presented. The explosion of SN2006gy extragalactic supernova (z = 0.019) was detected at TeV energies with the SHALON telescope during the observations of NGC1275.

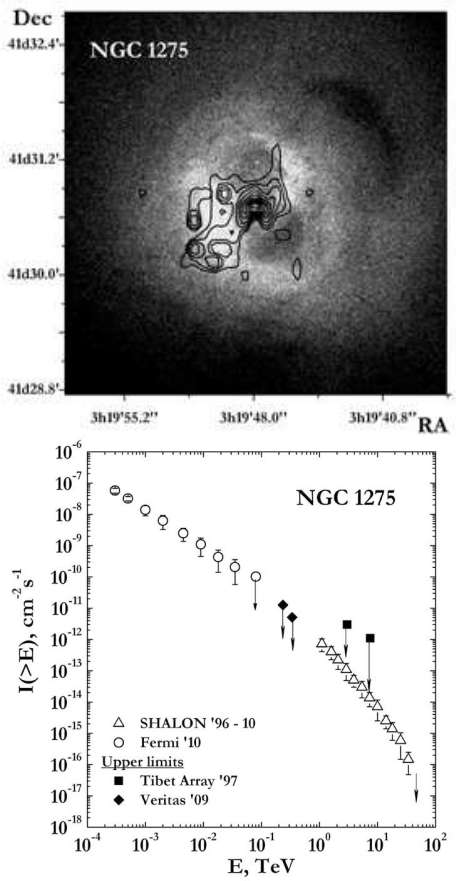


Figure 1: Chandra X-ray image of NGC 1275 together with SHALON data. The contour lines show the TeV - structure by SHALON observations. The TeV energy spectrum of NGC 1275 from SHALON, 15 year observations in comparison with other experiments: Fermi LAT [11] and upper limits: Veritas [12], Tibet Array [10];

## 2. NGC 1275

Galaxy clusters have been considered 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 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 a powerful X-ray and radio source. Many studies explored correlations

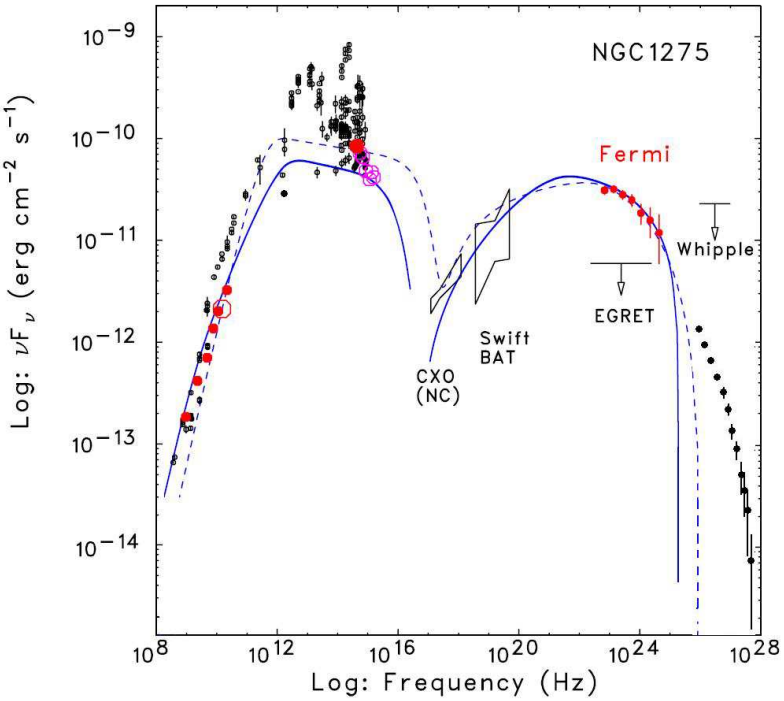


Figure 2: Overall spectral energy distribution (SED) of NGC 1275. The low energy data from [11]. The SED is fitted with a one-zone synchrotron/SSC model (blue dashed curve) and a decelerating flow model (blue solid curves) [14].

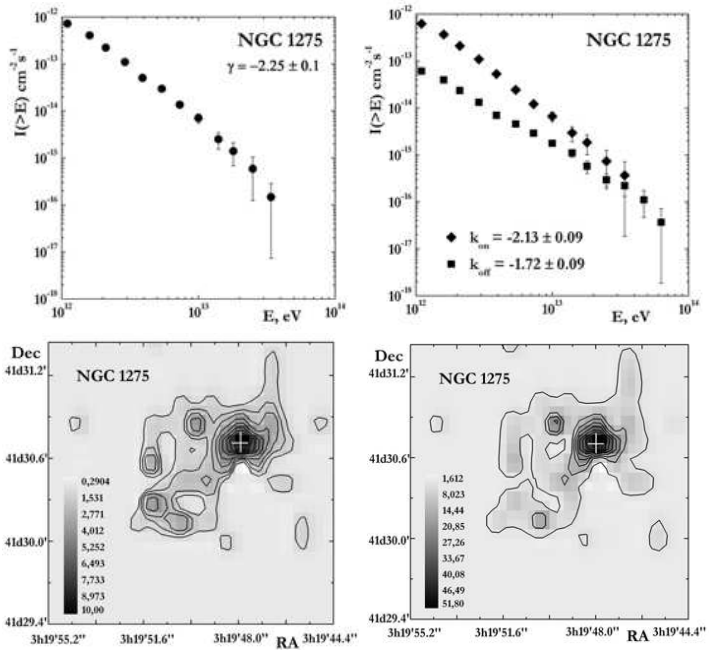


Figure 3: **From left to right** The NGC 1275 observational data by SHALON: the $\gamma$-quantum integral spectrum; The NGC 1275 image at energy range of $> 0.8$ TeV; The event spectrum from the source with background with index of $k_{ON}$ and spectrum of background events observed simultaneously with the object with index $k_{OFF}$; The NGC 1275 image at TeV energy range; The energy image (in TeV units) of NGC 1275.

of X-ray, radio,(fig. 1) optical and ultraviolet emission (see e.g. [6]).

In 1996 a new metagalactic source was detected by SHALON at TeV energies (figs. 1, 2, 3). This ob-

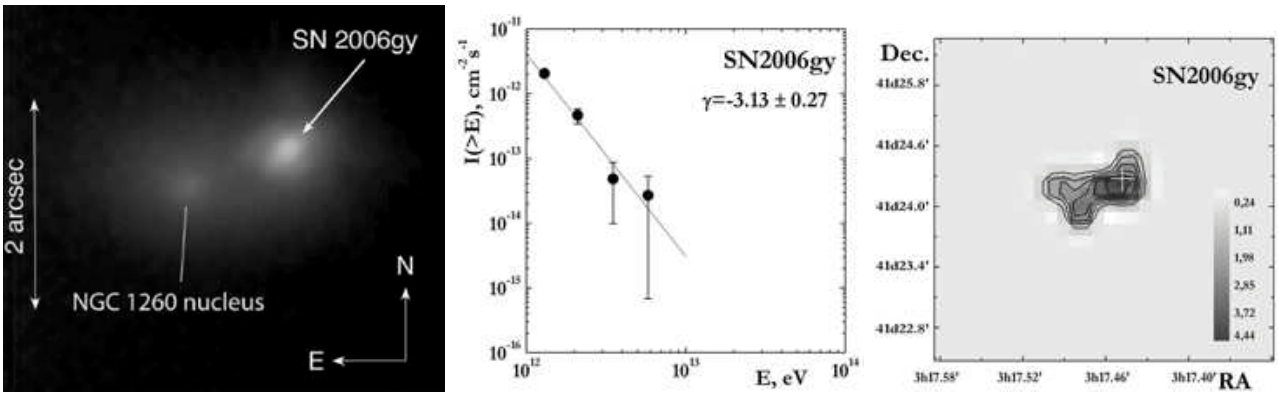


Figure 4: The image of SN 2006gy (Chandra) and the nucleus of NGC 1260 at three wavebands: J band(1.25 m), H band (1.65 m), and Ks band (2.2 m).; The SN2006gy by SHALON: the $\gamma$-quantum integral spectrum; **right:** The SN2006gy image at TeV energy range.

ject was identified with the Seyfert galaxy NGC 1275 [1–4] (with redshift z=0.0179); its image is shown in fig. 1, 3. The maxima of the TeV gamma-ray, X-ray [7] 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. 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 $> 0.8$ 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 increase of very high energy $\gamma$-quantum flux over the average value was detected in October 2009: $(1.81 \pm 0.31) \times 10^{-12} cm^{-2} s^{-1}$. In general, the variations of the gamma-ray flux on the year scale are no more than 25% of average value.

## 3. SN 2006gy

The flux increase was detected from the region NGC 1275 in autumn 2006. The detailed analysis of the gamma-shower direction turned out to be the detection of a metagalactic object. This object was identified with the supernova SN 2006gy (see fig. 4) [8] that is about 10 minutes of arc away from NGC 1275.

Observations were made on cloudless nights during moonless periods in 2006 September, October, November, December and then during the winter of 2007. No flux increase was found in the September observations. In the flare, observed on October 22, the flux increased 6 times from NGC 1275 and stayed at this level throughout the October 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 $> 0.8$ TeV. The energy spectrum of SN 2006gy at 0.8 to 7 TeV can be approximated by the power law $F(> E_O) \propto E^{k_\gamma}$, with $k_\gamma = -3.13 \pm 0.27$ (fig. 4). An image of gamma-ray emission from SN 2006gy by SHALON telescope is shown in Fig. 4. Follow-up observations at the end of November showed that the flux of SN 2006gy had dropped to a flux level of about $(0.69 \pm 0.17) \times 10^{-12} cm^{-2} s^{-1}$ and was constant during the November, December period. The results of the observation analysis of 2007 have not revealed any TeV gamma-ray emission from the region of SN 2006gy. So, the explosion of an extragalactic supernova was observed at TeV energies for the first time with the SHALON Cherenkov telescope.

No other significant variations of the gamma-quantum flux during the observations of NGC1275 were found during the whole observation period.

## 4. NGC 1275 broadband spectrum

Experimental limits on the very high energy gamma-ray emission from the Perseus cluster and its central galaxy NGC1275 have been obtained by other experiments [9–13]. The Seyfert galaxy NGC 1275 has been also observed with the Tibet Array [10] (about 5 TeV) and then with Veritas [12] telescope at energies about 300 GeV in 2009. The radio-galaxy NGC 1275 has recently been detected by Fermi [11] as a source of high-energy gamma rays with an average flux and power-law photon index of $F(> 100 MeV) = (2.31 \pm 0.13) \times 10^{-7} cm^{-2} s^{-1}$ and $\gamma = 2.13 \pm 0.02$, respectively. The recent detection by the Fermi LAT of high-energy gamma-rays from the radio galaxy NGC 1275 makes the observation of the very high energy ($E > 100$ GeV) part of its broadband spectrum particularly interesting. The overall spectral energy distribution of NGC 1275 from low energies to TeV energies is presented (fig. 2, 5). The spectrum of NGC 1275 from the SHALON 15 year observations is also shown.

The Perseus cluster, as many other galaxy clusters, is expected to be a source of gamma-ray emission due to various emission mechanisms [15]. In the model

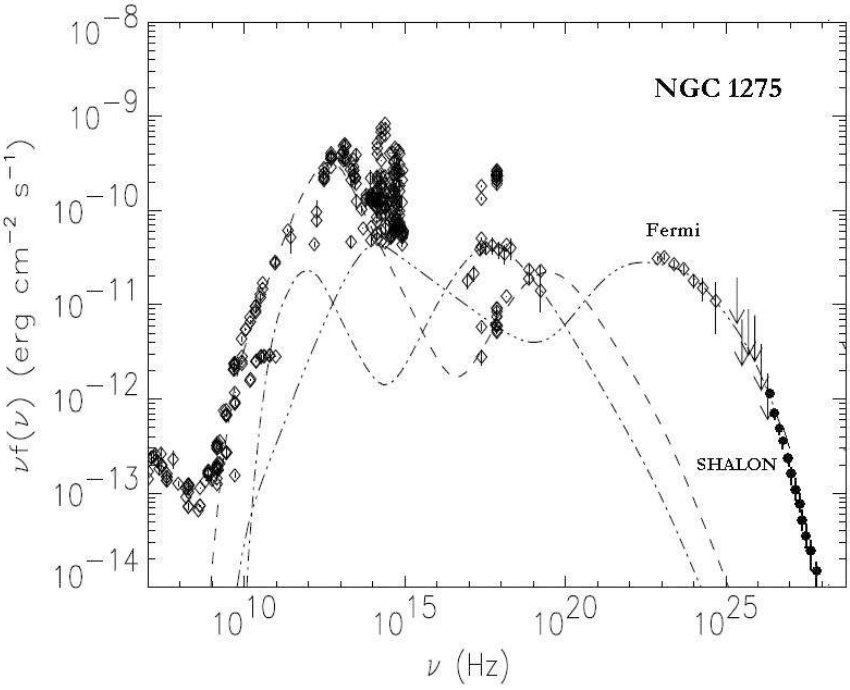


Figure 5: Overall spectral energy distribution (SED) of NGC 1275. The TeV energy spectrum of NGC 1275 from SHALON, 15 year observations in comparison with other experiments: Fermi LAT [11], and upper limits: Veritas [12], MAGIC [13];

[15] the photon emission over the wide energy range is produced by three components with a specific jet-blob structure that is able to reproduce the observed multi-frequency spectral energy distribution (fig. 5). The first blob of intermediate energy and larger radius produces SSC emission that recovers the low-frequency radio emission: the synchrotron peak and also, in its inverse Compton scattering branch, the historical X-ray data with lower flux. The second most energetic and smaller blob produces SSC emission that is systematically displaced towards high frequencies and fits the high energy data while remaining subdominant at all other frequencies. The third less energetic blob produces SSC emission that is able to fit the X-ray data of higher flux with its inverse Compton peak emission but remains subdominant at all other frequencies. The available high and very high energy data for NGC 1275 are well fitted in this model with three components, in which the second, most energetic and smaller blob produces SSC emission observed at gamma-ray energies [15] (fig. 5).

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