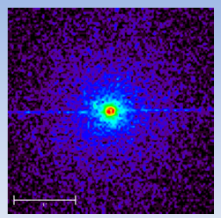

Two Bursts of Ultra High Energy Gamma Rays Detected by the Baksan Air Shower Array

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Abstract

During a Cygnus X-3 campaign many years ago the Carpet air shower array of the Baksan Neutrino Observatory had recorded two bursts from two different sources: from the Crab Nebula on February 23, 1989 and from Cygnus X-3 on October 14-16, 1985. The characteristics of the bursts were quite different, as well as types of the source objects. The first of these bursts was discussed in some detail after registration of regular flares of gamma rays with energies of several hundred MeV by satellite gamma ray telescopes FermiLAT and AGILE. The second burst was not discussed in recent time, and in this paper attention is attracted to it in connection with plans to start new observations in the Carpet X-3 project, now in progress.

Introduction

Recently [1] the Tibet ASγ Collaboration reported about detection of 100 TeV photons from the Crab Nebula. However, their statement "This is the first detection of photons with $E > 100$ *TeV* from an astrophysical source" (see abstract in [1]) is not fully true. Some people pretended to detect positive signals from different sources in this or even higher energy range. Among them are the two bursts recorded by the Carpet air shower array of the Baksan Neutrino Observatory from two different sources: from Crab Nebula on February 23, 1989 and from Cygnus X-3 on October 14-16, 1985. In 1980s the gamma ray astronomy of ultra-high energies ($E\gamma > 10^{14}$ *eV*) was at a peak of activity in connection with sensational data of Kiel University group that reported about a signal detected from the X-ray source Cygnus X-3 in this energy range. Later it became clear that this result was obviously wrong, but it stimulated many experimental and theoretical works on the problem. A lot of experimental efforts (including specially constructed EAS array called Cygnus) were made and witty hypotheses put forward (like hypothetical new elementary particle cygnet and quark confinement violation). Among other results obtained in the course of the campaign for Cygnus X-3 observations there were two which are discussed here. First was a three-day excess of count rate in the source's angular cell detected by the Baksan air shower array (BASA) on October 14-16, 1985 [2, 3]. This event had occurred several days after a most powerful radio outburst in Cygnus X-3 (in fact the strongest for all previous history of observations). Another burst-like event was detected by the BASA three and a half years later from the Crab Nebula [7, 9]. Both these events are discussed below in some detail.

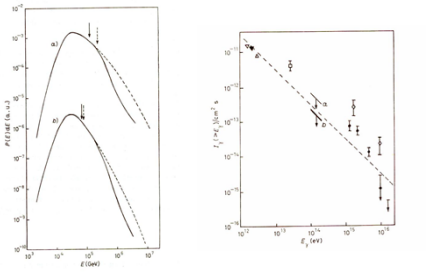

Fig. 1. Summary of Cyg X-3 observation in the DC mode. Energy distribution and median energies (left) and the upper limits of flux (right) obtained for two variants of primary gamma ray spectra with absorption by microwave background taken into account.

Cyg X-3 Observations and a Recorded Burst

Fig. 1 summarizes the general yield of Cygnus X-3 observations in DC mode for several years. Since no energy reconstruction was made for individual events, calculated energy distributions were used for flux estimations. Power-law distribution was postulated for gamma rays with two spectral indices: either 2.1 as presumed for the spectrum in the source or 2.7 coinciding with background cosmic ray spectrum. In both cases cosmic MWB absorption was taken into account, and one can see its effect in Fig. 1 (distributions without absorption are shown by dashed lines): two arrows demonstrate the median energy in each spectrum. The upper limits a) and b) derived from the BASA data in Fig. 1 right panel correspond to spectra a) and b) of Fig. 1 left panel. One can see in the right plot that the Kiel group was not alone in recording positive signal from Cyg X-3. In addition to the Kiel data mentioned above Fig. 1 shows definite fluxes measured by Plateau Rosa and Haverah Park experiments. However, the BASA results are in obvious contradiction with their measurements; only upper limits were obtained by us for steady flux from the source. However, for three days in October 1985 the signal from the Cyg X-3 angular cell exceeded the background value significantly. This event was interpreted as a burst of high-energy gamma ray emission [3], especially when it was found that a powerful outburst of radio emission had been detected from Cyg X-3 several days before.

Of great importance could be the fact that this radio burst was the strongest over the entire history of observations. Soon after it the Gulmarg gamma ray telescope in India detected significant signals from Cyg X-3 on October 10 and 12 [4]. In [5] an attempt was made to construct a model explaining a considerable delay between the radio signal and VHE and UHE gamma ray signals in this event. In recent times coordinated observations of ground-based radio telescopes and satellite gamma ray telescopes [6] proved that "the γ -ray activity is related to the level of radio flux".

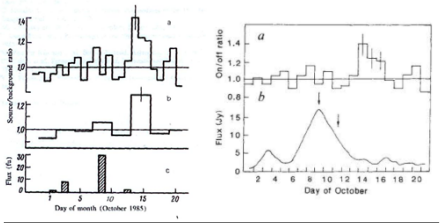

Fig. 2. On the left is the ratio of the count rate in the Cyg X-3 cell to the average control count rate (one-day (a) and three-day (b) averaged values). The bottom panel (c) presents spectral power density in the radio outburst of the source. The plot is taken from [3]. The arrows in the right figure taken from [4] show the maximum of radio flare and the time of detection of a signal by the Gulmarg gamma-ray telescope (energy threshold is 6 TeV).

The Crab Nebula burst on Feb 23, 1989

First announcement about this burst was made during the International Workshop on Gamma-Ray Astronomy in Crimea in 1989 [7]. An increase of intensity of extensive air showers (EAS) was detected by the Carpet air shower array of the Baksan Neutrino Observatory on February 23, 1989. After this communication the group at Kolar Gold Fields (KGF) in India confirmed this result of Baksan and published a paper [8] on simultaneous detection of a gamma-ray burst in the Crab Nebula at ultra high-energies independently by two EAS arrays. Final publication [9] by the Baksan and Durham University teams summarized the data of all arrays that could observe the source on this day. It was demonstrated that with different significance the burst was detected by all air shower arrays located in the longitude range from India to Italy (KGF, Tien Shan, Baksan and EAS TOP). Thus, the total duration of the observed effect was no longer than about 7 hours. One can speak also about a possible decay of intensity whose maximum probably fell on observations with the KGF array. It is quite important that both KGF and BASA observed a clear connection with the pulsar periodicity. In case of BASA almost all excess of events can be produced by a single decimal bin of the phase curve (see Fig. 4). In addition, the events from this bin form a sort of quasi-periodic groups with duration of about one hour. When satellite gamma ray telescopes FermiLAT and AGILE discovered regular flares of high energy (several hundred *MeV*) gammas in the Crab Nebula, in [11] it was demonstrated that the temporal structure of the old UHE event is very similar (with a constant scale factor of about 20) to one of AGILE flares. While the energies in events of Figs. 4 and 5 differ by a factor of 10^6, the time parameters have lesser difference (hours in one case and days in another).

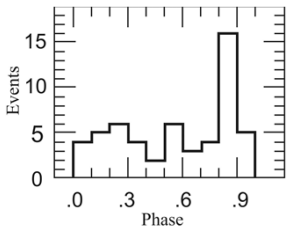

Fig 3. The relative phase distribution of the 55 events within the Crab cell after barycentring the arrival times and applying the values of the pulsar period and its derivative according to the Jodrell Bank Crab ephemeris.

Discussion and Conclusion

The Tibet ASγ collaboration observed 24 photon-like events with $E > 100$ *TeV* against 5.5 background events, which corresponds to 5.6σ statistical significance [1]. This seems to be well established result, though some probability of being a rare fluctuation still remains for it. It is instructive to see Fig. 1 where at least three experimental groups presented more or less established results of their observations of another astrophysical object. None of them has any credit at the moment. Moreover, even the new result of Tibet ASγ could be not so reliable, as its authors believe. Strange to say, but two burst-like events observed by the BASA during the Cyg X-3 campaign in 1980s have better chances to be true. In case of the October 1985 burst the probability for such an event to occur at random was estimated as 10^{-5} (see [3]), and its significance is psychologically supported by preceding radio flare, VHE signal, and a reasonable model that reproduced the observed delays. As for the Crab February 23, 1989 event, it is much better established in comparison with permanent flux detection of [1]. Calculated probability of simultaneous count rate excesses was equal to 1.07×10^{-5}. Formal inclusion of two phase non-uniformities gave a combined probability as low as 1.25×10^{-7} [9], which is several orders of magnitude better than chance probability in [1].

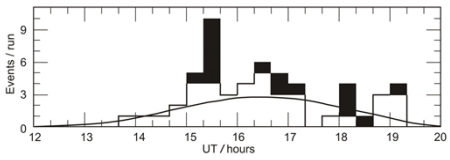

Fig. 4. The number of events within the Crab cell per 20 min run for 23 February 1989. Smooth curve represents expected background. Blacked events are from the 9th bin in Fig. 3.

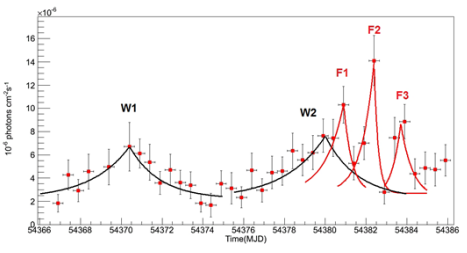

Fig. 5. The difference between flares and waves in the Crab Nebula gamma-ray emission according to Striani et al. [10] (the September 2007 event). Three-flare structure of the event is similar to three bunches of narrow-phase emission constituting almost all excess counts in Fig. 4.

Acknowledgments

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