Correlation between background events detected on 23 February 1987 by the LSD apparatus and the Baksan telescope

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(Submitted 23 March 1989)
Pis'ma Zh. Eksp. Teor. Fiz. **49**, No. 9, 480–483 (10 May 1989)

A joint analysis of the data recorded over the time interval 1:45–3:45 UT on 23 February 1987 by the LSD apparatus and the Baksan telescope reveals a correlation between natural radioactivity and high-energy cosmic-ray muons.

After the results of an analysis of temporal correlations found between the events at the LSD apparatus and two gravitational antennas in the time interval 1:45–3:45 UT on 23 February 1987 were published,[1] there was an exchange of experimental data between the LSD and Baksan-telescope groups.[2] The first of these groups has already published its studies.[3] In the present letter we are reporting the first results of a comparison of the LSD events with all of the data recorded over this time interval at the Baksan telescope.

 0021-3640/89/090548-05$01.00

The Baksan underground scintillation telescope, which has been described in several places in the literature,[2] is an installation for studying cosmic-ray muons and neutrinos of atmospheric and galactic origin, including neutrinos from gravitational collapses of massive stars, in a search for heavy magnetic monopoles. This installation is in an underground room at a depth of 850 meters water equivalent and consists of a closed parallelepiped with two interior layers. All eight planes are covered with standard counters (whose total number is 3150; the total mass of scintillator is ~ 330 metric tons). Each of the counters is monitored by a single photomultiplier with a photocathode 15 cm in diameter. The energy threshold for detection is ~ 10 MeV.

The stiff requirements on the background in the program of searching for "collapse" neutrinos led to the use of a special condition for selecting events for this problem: The only pulses which are recorded are those in which only a single counter in the entire telescope operates. The effective mass of the target during the subsequent processing is ~ 200 metric tons, since readings of a relatively low-background part of the apparatus are selected. The average count rate of single pulses with a restriction $\lesssim 50$ MeV on the energy release is $\sim 0.0345\ \mathrm{s}^{-1}$. Unfortunately, the uncertainty in the synchronization of the telescope clock with absolute time on 23 February 1987 was $(-54$ s, $+2$ s), there was a precision of 1 ms in relative time.[2] The LSD clock was synchronized within ~ 2 ms (Ref. 1). This circumstance ruled out a direct comparison of the data from the different installations and demands an analysis of the results with various shifts of the telescope data backward in time.

Figure 1a shows the count rates from the two installations over 15 min, normalized to the corresponding average values, observed over the time interval 0:0–10:0 UT on 23 February 1987. It can be seen from this figure that there are no significant correlations in the data. Figure 1b shows the number of coincidences of events at these installations in a 1-s window over 2 h (1:45–3:45 UT), plotted as a function of the time shift of the Baksan telescope, ΔT_{Bak}. The maximum number of coincidences is formed at $\Delta T_{\mathrm{Bak}} \sim -29.5$ s. The length of the time window in which one pulse from each installation falls influences the number of coincidences at the maximum but does not change the position of this maximum along the ΔT_{Bak} axis within $-(29.5 \pm 2)$ s. We accordingly examined a window of ± 1 s in this case. The probability for a random spurious signal is $\sim 5 \times 10^{-3}$. The significance of this correlation is increased by the circumstance that this value of ΔT_{Bak} agrees with that which has been suggested for bringing into synchronization the neutrino signals from SN 1987A in the Large Magellanic Cloud which were detected at 7:35 UT by the IMB installation, Kamiokande II, and the Baksan telescope.[4] Over the rest of the time between 0:0 and 10:0 UT, the number of coincidences agreed with the expected value.

In addition to analyzing the data of the collapse-neutrino program, we used a corresponding procedure to analyze the data obtained from the other physics projects being carried out at the telescope. Figure 2 shows the ΔT_{Bak} dependence of the number of coincidences between LSD events and cosmic-ray muons which arrived at the telescope at large angles $\theta \sim 70$–$80°$ with energies $E_\mu \sim 4$ TeV (Fig. 2a) and muons traveling approximately in the vertical direction with $E_\mu \sim 300$–400 GeV which were formed in the shower apparatus (Fig. 2b) We see from these figures that in both cases there is an increase above the average background at the same value of ΔT_{Bak}. The

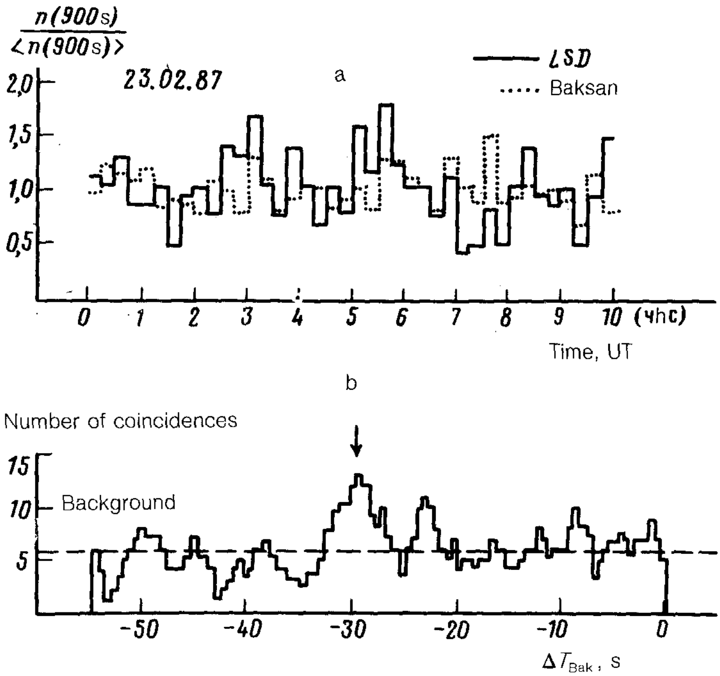

FIG. 1. a—Count rates at the LSD and the Baksan installations over 15 min, normalized to the average value for each installation; b—number of coincidences over 2 h (1:45–3:45 UT) of events in the LSD and Baksan installations versus the magnitude of the backward time shift of the clock at the Baksan telescope, $\Delta T_{\rm Bak}$. The coincidence time window is ± 1 s.

probability for random spurious events is $\sim 1.4\times 10^{-2}$ for horizontal muons and $\sim 2\times 10^{-3}$ in the second case. Shown in the same figure (2c and 2d) are the numbers of coincidences of events of both muon programs, on the one hand, with the data of the collapse program, on the other, plotted as a function of the temporal separation of events. Since we are dealing with the pulses from different programs being carried out on a common apparatus here, these pulses conform to a common time scale, and the effect—if it exists—should be manifested at $\Delta t\ \sim 0$ s. We see from Fig. 2c and 2d that at $\Delta t\ \sim 0$ s there is an increase above the average background, with probabilities $\sim 8\times 10^{-3}$ and $\sim 2\times 10^{-2}$, respectively, for spurious events.

As we have already mentioned, the collapse program of the telescope makes use of information which arrives from detectors with a fairly low intrinsic noise level. As a test we studied coincidences of counts from "noisy" counters with the LSD data. In comparison with the expected 4.6 random coincidences we found 5 ($\Delta T_{\rm Bak}\ \sim -29.5$ s); in other words, the effect observed above is not related to the intrinsic noise of the installation.

The count rate of single operations was different for the detectors of the inner and outer planes. The background of the latter was ~ 2 times that of the former, since the

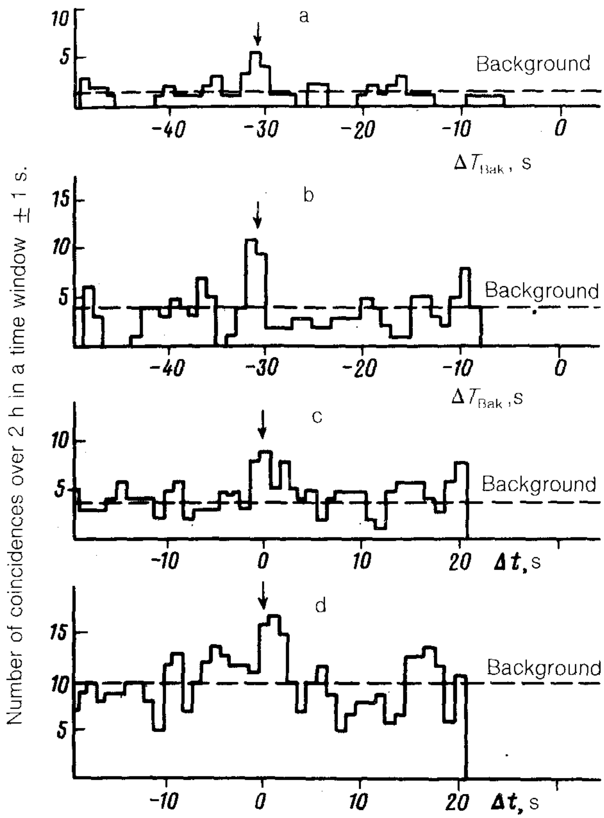

FIG. 2. Number of coincidences over 2 h (1:45–3:45 UT). a—Between the LSD data and the data on horizontal ($\theta \sim 70$–$80°$) muons at the telescope; b–between the LSD data and the data on muons at the telescope which interacted vertically; c—between horizontal muons and collapse events at the telescope; d—between muons which interacted vertically and collapse events at the telescope.

selection conditions (one detector out of the 3150) meant that they were not protected as well against passing muons and their accompaniment. The coincidences of events in the collapse program of the telescope with the LSD data (Fig. 1b) come primarily from the detectors of the outer planes.

Summarizing the information in Figs. 1b and 2, we conclude that a significant fraction of the telescope events which caused coincidences with the LSD data was caused by cosmic-ray muons which arrived from the upper hemisphere of the earth. In the behavior of the intrinsic events of the installations we observed no significant changes in terms of either the count rate or the distribution of time intervals between counts. Furthermore, while most of the background in the telescope was caused by muons, the primary source of background at the LSD installation was natural radioactivity.[5] We can thus conclude that a joint analysis of the data of these two detectors reveals a correlation between high-energy cosmic-ray muons and the natural radioactivity which prevailed during the time interval 1:45–3:45 UT on 23 February 1987.

In an effort to explain this fact one might suggest that over these two hours there were synchronized changes in the background at these installations, manifested by an increase in the number of coincidences between events differing so greatly in origin. It is totally obvious that a test of this suggestion will require an analysis of the data of all of the corresponding experiments which were carried out at this time. This work is continuing.

The phenomenon which we have been discussing here occurred several hours (seven or eight) before the optical observation of SN 1987A in the Large Magellanic Cloud, and it is reasonable to suggest that this phenomenon is linked with it.

We wish to thank Academician G. T. Zatsepin for useful discussions of this study.

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Translated by Dave Parsons