Possible detection of a neutrino signal on 23 February 1987 at the Baksan underground scintillation telescope of the Institute of Nuclear Research

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(Submitted 6 April 1987)
Pis'ma Zh. Eksp. Teor. Fiz. **45**, No. 10, 461–464 (25 May 1987)

A signal was observed at 7:36:11 UT on 23 February 1987 at the Baksan underground scintillation telescope, at a time indicated by a Japanese water Čerenkov detector. This signal consisted of five pulses over 9 s; the first three pulses occurred in 2 s.

According to the present theoretical understanding, the collapse of massive stars should be accompanied by the emission of neutrinos, in bursts lasting from a few seconds to several tens of seconds. The average energies expected for the electron neutrinos, ν_e, $\tilde{\nu}_e$, are $E_\nu = 8$–12 MeV, and the total energy of the neutrino emission is expected to be[1] $\sim 10^{53}$–10^{54} erg.

In a search for such events, our galaxy has been under continuous observation since June 1980 at an underground scintillation telescope at the Baksan Neutrino Observatory of the Institute of Nuclear Research, Academy of Sciences of the USSR. The telescope[2] is in the North Caucasus Mountains, under Mt. Andyrchi, at a depth of 850 m water equivalent. The telescope consists of 3156 standard detectors combined in eight planes, four horizontal and four vertical (Fig. 1). Each detector, with dimensions of $70 \times 70 \times 30$ cm, is filled with a liquid organic scintillator based on "white spirit" ($C_nH_{2n+2}, n \sim 9$) and is viewed by one FÉU-49 photomultiplier.

The telescope is most sensitive to the detection of electron antineutrinos $\tilde{\nu}_e$ on the basis of the reaction in which they are absorbed by free protons of the scintillator, $\tilde{\nu}_e + p \rightarrow n + e^+$. However, there is also the possibility that electron neutrinos ν_e will be detected, if their energy exceeds ~ 30 MeV: $\nu_e + {}^{12}\mathrm{C} \rightarrow {}^{12}\mathrm{N} + e^-$. Since the energies of the $e^+ (e^-)$ which are produced are small, and their ranges are basically contained within the individual detectors, an expected event from the collapse of a star should be seen as a series of operations of single detectors during a burst. Consequently, the method for selecting signals at the telescope according to this program consists of selecting cases in which one and only one detector of the 3156 operates. This selection condition significantly reduces the role of the primary background source: cosmic-ray muons. Three inner planes of the telescope, having the lowest frequency of background pulses, are selected as the "sensitive" mass of the apparatus. The total target mass of the selected part of the apparatus is 130 metric tons; the count rate of single operations of detectors is 0.0127 s^{-1}. When an expected neutrino signal is detected, information can be obtained from the detectors of the outer planes of the telescope in order to analyze the event. In this case the total target mass can be increased to ~ 200

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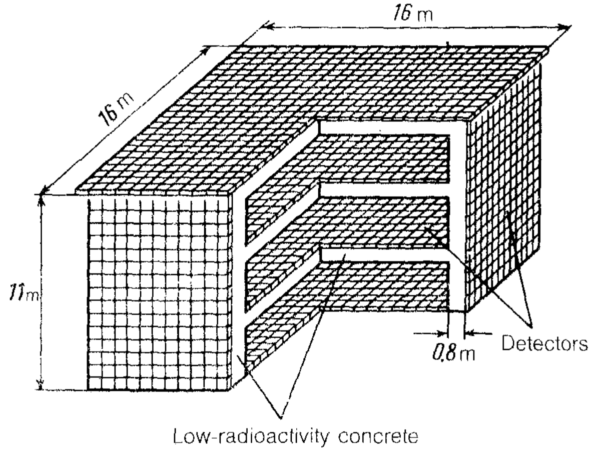

FIG. 1. The Baksan underground scintillation telescope.

metric tons, and the count rate of individual background pulses increases to ~ 0.033 s^{-1}.

The further analysis of the data consists of using a 20-s window, which slides from pulse to pulse, to select events with $\geqslant 4$ signals.

Over the time this telescope has operated ($T_{\rm life} = 5.5$ yr), no events with >7 operating detectors within an interval $\leqslant 20$ s have been detected. According to the model of Ref. 1, the expected event from the collapse of a star 10 kpc away would be ~ 35 signals from $\tilde{\nu}_e$ interactions in the inner part of the telescope, or ~ 54 signals in 200 metric tons of target.

Over the period from 1 to 23 February 1987 preceding the supernova SN1987A LMC,[3] no events exceeding Poisson background fluctuations were observed at the telescope. Reports[4-6] were subsequently received that neutrino signals had been obtained at Soviet-Italian (LSD), Japanese (KAMIOKANDE II), and American

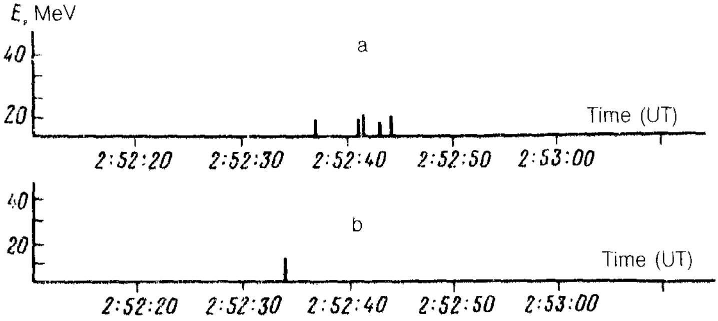

FIG. 2. Signals detected by two installations at 2:52:36 UT on 23 February 1987. a—The Soviet-Italian LSD installation; b—the Baksan telescope.

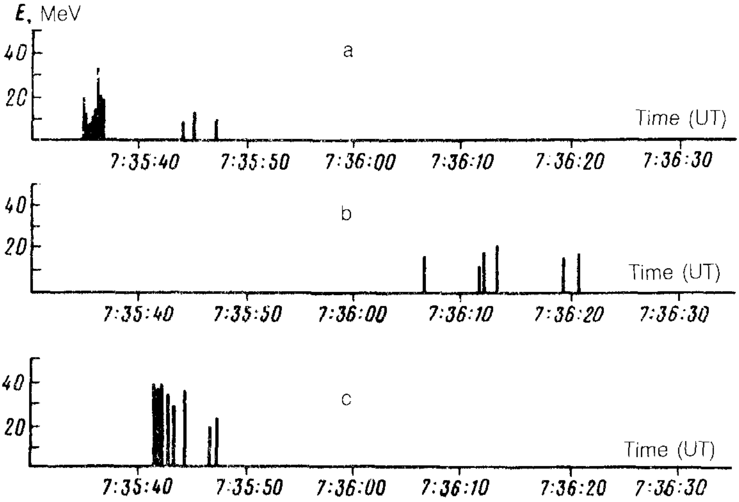

FIG. 3. Signals detected at 7:35 UT on 23 February 1987. a—At the Japanese detector; b—at the Baksan telescope; c—at the American detector.

(IMB) underground installations, at the times 2:52:36 UT, 7:35:35 UT, and 7:35:41 UT, respectively. If these events are reliable, the telescope should have observed packets of signals corresponding to interactions of $\tilde{\nu}_e$ in the scintillator. The simultaneous detection of an event by several installations adds considerably to its credibility.

Figure 2 shows the series of signals detected by the LSD, for which the frequency of false events simulated by the background is 1/1.5 yr, along with telescope signals detected at the same time in 130 metric tons of target. It can be seen from Fig. 2 that no packets of signals of any sort were observed at the telescope at this time. However, the data from the two installations are not mutually contradictory if it is assumed that the average neutrino energy was <10 MeV. The error in the synchronization of the telescope data with absolute time is ± 2 s; the energy threshold of the detection is ~ 10 MeV.

Figure 3 shows series of signals detected by the KAMIOKANDE and IMB water Čerenkov detectors, along with the telescope signals at the same time. The mass of the scintillation target was increased to 200 metric tons. To reduce the background from muons, we selected signals with an energy evolution $E \lesssim 50$ MeV in individual detectors. It can be seen from Fig. 3 that the telescope observes a series of signals starting at 7:36:06 UT, which is shifted ~ 30 s with respect to the series of pulses at the Japanese installation and ~ 25 s with respect to the event at the American installation. Obviously, the joint detection of a neutrino burst by the installations can be regarded as an established fact only if the events coincide within a few seconds. Since the error of the temporal synchronization of the IMB signals is ± 50 ms, that of the KAMIOKANDE installation is ± 1 min, and that of the Baksan telescope is ± 2 s, it does not appear possible to bring the data from the three installations into coincidence. Let us estimate the probability for a random coincidence of events and examine the compati-

TABLE I. Characteristics of the event detected at the Baksan telescope on 23 February 1987.

N°	Time (UT)	Energy (MeV)
	7 : 36 : 06 : 571	17.5 ± 3.5
1	7 : 36 : 11 : 818	12 ± 2.4
2	7 : 36 : 12 : 253	18 ± 3.6
3	7 : 36 : 13 : 528	23.3 ± 4.7
4	7 : 36 : 19 : 505	17 ± 3
5	7 : 36 : 20 : 917	20.1 ± 4.0

bility of the telescope data with the data from the Japanese detector, which has the highest reliability for the detected event: The frequency of false events simulated by the background is ~ 1 over 7×10^7 yr.

If the frequency of background pulses at the telescope is ~ 0.033 s^{-1}, one of the signals in the event under discussion here, on the average, should be background. On the basis of theoretical predictions of the neutrino luminosity function, which decays steeply over time, it is reasonable to suggest that the first of these signals is a background pulse. Since the frequency of false events simulating the five remaining signals over 9 s would be ~ 0.7 day^{-1}, the probability for random coincidence of such an event with the event at the Japanese installation within a time interval ~ 1 min would be $\sim 5 \times 10^{-4}$. Table I shows the characteristics of the event detected at the Baksan telescope at 7:36:06 UT on 23 February.

An estimate puts the energy carried off from the star by electron antineutrinos with $E_\nu \gtrsim 10$ MeV at $\sim 9 \times 10^{52}$ erg for the Baksan telescope or $\sim 4.1 \times 10^{52}$ erg for the Japanese installation. The discrepancy between these energy estimates can be reduced by assuming that only the narrow groups of pulses of each of the detectors are associated with $\tilde{\nu}_e$ signals: eight during 2 s (of which six have $E_\nu > 10$ MeV) for the KAMIOKANDE installation and three during 1.7 s for the Baksan telescope.

A final resolution of the question of the possible detection of a neutrino burst will apparently require a more careful analysis of the data from all the installations during the period preceding the optical burst.

It is a pleasure to express our gratitude to A. E. Chudakov and G. T. Zatsepin for useful discussions of this study.

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[2] E. N. Alexeyev *et al.*, in Proceedings of the Sixteenth International Cosmic Ray Conference, Kyoto, Japan, 1979, Vol. 10, p. 282; in Proceedings of the Twelfth International Conference Neutrino-86, Sendai, Japan, 1986, p. 270.

[3] IAU Circular No. 4316.

[4] IAU Circular No. 4323.

[5] K. Hirata *et al.*, Phys. Rev. Lett. **58**, 1490 (1987).

[6] R. M. Bionta *et al.*, Phys. Rev. Lett. **58**, 1494 (1987).

Translated by Dave Parsons