Detection of a rare event on 23 February 1987 by the neutrino radiation detector under Mont Blanc

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A rare event which was detected at $2^h32^m36^s$ UT on 23 February 1987 by a liquid scintillation detector in a tunnel under Mont Blanc, at a depth of 5200 m water equivalent, is discussed. The active mass of the detector is about 90 metric tons. Over a time interval of 7 s, five pulses with amplitudes ranging from 7 to 11 MeV were detected. An upper limit of 0.7 yr^{-1} is estimated for the frequency at which such events would result from random fluctuations of the background. The possibility that this event is correlated with the supernova SN1987A in the Large Magellanic Cloud, which was observed at 9^h UT on 23 February 1987, is not ruled out. Such a correlation would occur at random once in ~ 1000 yr.

This liquid scintillation detector (LSD),[1] intended for research in neutrino astrophysics and elementary particle physics, was brought into operation in October 1984. It was constructed jointly by the Institute of Nuclear Research, Academy of Sciences of the USSR, and the Institute of Cosmogeophysics of the National Research Counsel of Italy in a tunnel under Mont Blanc, at a depth of 5200 m water equivalent. The LSD consists of 72 liquid scintillation modules (each $1.0 \times 1.5 \times 1.0$ m in size), arranged in three rows in a parallelepiped with an area of 6×7 m^2 and a height of 4.5 m. The detector is shielded by steel plates with a total weight of about 200 metric tons to reduce the background of natural radioactivity from the surrounding rock. The molecular composition of the scintillator is C_nH_{2n+2}, with $\bar{n} \cong 10$. Each module is monitored by three FÉU-49B photomultipliers (with a photocathode diameter of 15 cm). An energy evolution of 1 MeV in a module corresponds to an overall signal with an amplitude ~ 15 photoelectrons from the three photomultipliers. The amplitude of the energy evolution in a module is analyzed only upon a coincidence of the signals from the three photomultipliers with a time resolution of 200 ns. The pulse from the coincidence circuit of any of the 72 modules serves as a trigger for the overall detector. In this case, the amplitude and time of the energy evolution in each of the 72 modules of the detector are recorded. The information is fed to a computer.

In this letter we report some results which were obtained in the LSD experiment as part of a program of searching for neutrino emission from collapsing stars. It is

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predicted theoretically that stars with massive cores will terminate their evolution by undergoing a gravitational collapse, which should be accompanied by a powerful neutrino burst.[2–6] The total energy carried off by the neutrinos would be ~ 0.1 of the value of Mc^2 of the core of the star. A calculation shows that a neutrino burst could be detected under favorable conditions by a detector with a mass[7–9] $\gtrsim 100$ metric tons. The following reaction is used to search for such bursts:

$$(\tilde{\nu}_e p) \rightarrow (ne^+), \ \sigma = 6.2\times 10^{-42} \ \text{cm}^2 \ \text{at} \ E = 10 \,\text{MeV},$$

$$(np) \rightarrow (d\gamma), \ E_\gamma = 2.2 \ \text{MeV}. \tag{1}$$

The high sensitivity of the detector and the low background make it possible to detect both of the particles, e^+ and n, in reaction (1). The neutrons are moderated in the scintillator, and they are captured by hydrogen in 170 μs, forming deuterium and a γ ray. Scintillations from γ rays with $E = 2.2$ MeV are detected in a high-sensitivity channel (the threshold is 0.8 MeV) which is opened for a time of 500 μs by the pulse from the positron. The neutron detection efficiency in the same counter in which the positron is detected is 40–50%. A neutrino burst is identified on the basis of the appearance of a series of scintillations with amplitudes above the threshold for the detection of scintillations from positrons, over a time $\tau \lesssim 20$ s. The number of pulses in a series is (under otherwise equal conditions) proportional to the mass of the detector and to the positron detection efficiency. The background may simulate a genuine event. The expected frequency of collapses in our galaxy is once per 5–50 yr, and the frequency of false events should be lower than this figure. The frequency of false events is

$$m \frac{(m\tau)^{k-1}}{(k-1)\,!} e^{-m\tau}, \tag{2}$$

where m is the frequency of the background pulses, τ is the length of the packet of pulses, and k is the number of pulses in the packet. Electrical interference is a dangerous source of false events. Reducing the background and shielding against electrical interference—over many years of operation—are the basis difficulties of an experiment to search for neutrino bursts from collapses. Over the observation time ~ 2 yr, the frequency of all detected events is consistent with their simulation by the background.[10]

On 23 February 1987, the LSD experiment detected a series of five pulses in 7 s. The times at which the pulses appeared and their amplitudes[1)] are given in Table I.

For three of the five modules (Nos. 14, 33, and 35), the threshold is $E = 5$ MeV, since these modules are in the inner part of the LSD and are additionally shielded from the background by the outer modules. For the two outer modules, Nos. 25 and 31, the threshold is $E = 7$ MeV. The interaction in module No. 25 was accompanied by a low-energy pulse (1.2 MeV), which was detected 278 μs after the main pulse. The probability that the neutron and the γ ray will move out of the module in which interaction (1) is detected and will be detected in surrounding modules is estimated to be 40%. Identifying the neutrons is complicated by the presence of background pulses in the channel with the low threshold; the situation with regard to the neutron accompani-

TABLE I.

$2^h\, 52^m\, 36^s\, 792$	7 MeV	Module N⁰ 31
40^s, 649	8	N⁰ 14
41^s, 007	11 (1,2 MeV)	N⁰ 25
42^s, 696	7	N⁰ 35
43^s, 800	9	N⁰ 33

ment of the packet of five pulses requires further analysis and Monte Carlo calculations. A preliminary on-line analysis sets an upper limit $\leqslant 0.7\ \text{yr}^{-1}$ on the frequency of the random appearance of a packet of five pulses in 7 s in our experiment.

According to data from the ESO observatory in Chile, a supernova, SN1987A, was detected in the Large Magellanic Cloud at about 9^{h} UT on 23 February 1987. According to the present understanding, the flareup of a supernova should be preceded by a gravitational collapse with a powerful pulse of neutrino emission. The advance time would be several hours or, according to certain arguments, several days. The packet of pulses detected by the LSD falls in this time interval. If this was a random coincidence, and if the packet itself was the result of background fluctuations, then we have witnessed a realization of a situation which would be expected to occur once in ~ 1000 yr. The effect resulting from a collapse in the Large Magellanic Cloud would be two or three pulses for the LSD, according to the model of Ref. 6. This value does not contradict the packet of five pulses which we detected.

[a] If the e^+ is detected, the amplitude will be equal to the sum of the kinetic energy of the positron and the energy of the annihilation γ rays (~ 1 MeV). These amplitudes will be refined after further calibrations.

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[1] G. Badino *et al.*, Nuovo Cim. **7C**, 573 (1984).

[2] Ya. B. Zel'dovich and O. Kh. Guseĭnov, Dokl. Akad. Nauk SSSR **162**, 791 (1965) [Sov. Phys. Dokl. **10**, 524 (1965)].

[3] W. D. Arnett, Can. J. Phys. **44**, 2553 (1966).

[4] L. N. Ivanova *et al.*, in Trudy Mezhdunarodnogo seminara po fizike neĭtrino i neĭtrinnoĭ astrofizike (Proceedings of an International Seminar on Neutrino Physics and Neutrino Astrophysics), Vol. 2, FIAN, Moscow, 1969, p. 180.

[5] V. S. Imshennik and D. K. Nadezhdin, Itogi nauki i tekhniki, Moscow **21**, 63 (1982).

[6] J. R. Wilson *et al.*, Ann. NY Acad. Sci. **470**, 267 (1986).

[7] G. V. Domogatsky and G. T. Zatsepin, in Proc. 9th ICCR, Vol. 2, 1965, p. 1030.

[8] G. T. Zatsepin *et al.*, Preprint P-0388, Institute of Cosmic Studies, Academy of Sciences of the USSR, Moscow, 1985.

[9] F. F. Khalchukov *et al.*, Proc. 19th ICCR, Vol. 8, 1985, p. 140.

[10] V. L. Dadykin *et al.*, in Proceedings of the Twelfth International Conference on Neutrino Physics and Astrophysics, Neutrino 86, p. 285.

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