Analysis of rare signals at the Baksan underground scintillation telescope

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Data accumulated since 1980 at the Baksan scintillation telescope in the course of a search for neutrinos from supernovae have been used to analyze the trajectories constructed from the individual counts of detectors over a time $\Delta t \leqslant 1$ s. An excess of signals amounting to $\sim 7\sigma$ has been found in the direction of the Sun. Difficulties in interpreting the effect are discussed.

The solar-neutrino problem ranks among the most important ones in astrophysics today. The deficiency of solar neutrinos which has been detected in three experiments[1–3] and the time variations of the flux of these particles which have been found at the Cl–Ar detector[1] have yet to be satisfactorily explained. Analysis of the data which have been accumulated in various underground experiments, particularly an analysis of rare events detected under low-background conditions, might provide additional information about the processes occurring on the Sun.

The Baksan underground telescope of the Institute of Nuclear Physics, Academy of Sciences of the USSR, is situated in northern Caucasia, at a depth of 850 meters water equivalent under Mt. Andyrcha. It consists of a closed parallelepiped with two inner layers. All eight planes of the parallelepiped (four horizontal and four vertical) are completely covered by standard counters ($70 \times 70 \times 30$ cm). The counters are filled with a liquid organic scintillator. Each counter is monitored by a separate photomultiplier with a photocathode 15 cm in diameter. There are a total of 3150 detectors; the total mass of scintillator is 330 metric tons. The energy threshold for a count is 10 MeV.

The data on which this letter is based were accumulated in the course of a search for neutrino bursts from the gravitational collapse of the cores of massive stars of the local galaxy. This search has been under way since 1980. In this search program, the events which are selected are those in which one and only one detector of the 3150 of the telescopes operates.[4] The data used for this analysis were taken from only three inner planes of the telescope (130 metric tons of scintillator) over the years 1985–1990. The average count rate of single pulses from the inner detectors is $\sim 0.012\ \mathrm{s}^{-1}$.

Signals consisting of single operations of detectors from any two of the three inner planes of the telescope, separated by a time interval $\leqslant 1$ s, were selected and examined. A trajectory was drawn through these two detectors, and the numbers of such signals from the closest astrophysical objects—the Sun and the Moon—were counted. Without any assumption about the nature of the pulses, the direction of the vector in each signal was determined from the detector which was the first to operate. The results of this analysis for data obtained in daytime are shown in Fig. 1. Plotted along the abscissa is the cosine of the angle (α) between the direction to the Sun and the trajectory of the signal (the value $\cos \alpha = 1$ means that the signal vector is directed toward the Sun). Plotted along the ordinate is the number of signals in each direction. The step of this distribution is $\Delta\cos \alpha = 0.005$.

It can be seen from this figure that there is a significant excess of signals in the direction of the Sun ($\Delta\alpha = 5.7°$). Figure 2a shows the distribution of the numbers of signals in the $\cos \alpha$ cells. We see from this figure that the experimental histogram can be described well by a Poisson distribution with a mean value of 7.5 (the smooth curve). The probability that the observed excess in the direction of the Sun (27 signals; Fig. 1) occurred purely by chance is $\sim 2 \times 10^{-8}$ or $\sim 7\sigma$.

Figure 2b shows the corresponding distribution for signals detected at night, i.e., when the Sun is on the opposite side of the Earth. We see that the histogram of the nocturnal signals coincides with the expected curve; there are no excesses. The same result, i.e., the absence of deviations from the expected distribution, was found in the direction of the Moon.

The flux of signals from the Sun in daytime at the telescope was thus found. The event vector was directed toward the Sun. The time interval between the events in the signals was $\leqslant 1$ s. The magnitude of the effect is $\sim 7\sigma$.

Two basic features of the signals require careful scrutiny if they are to be interpreted on the basis of elementary particle physics. First, there is the long time between

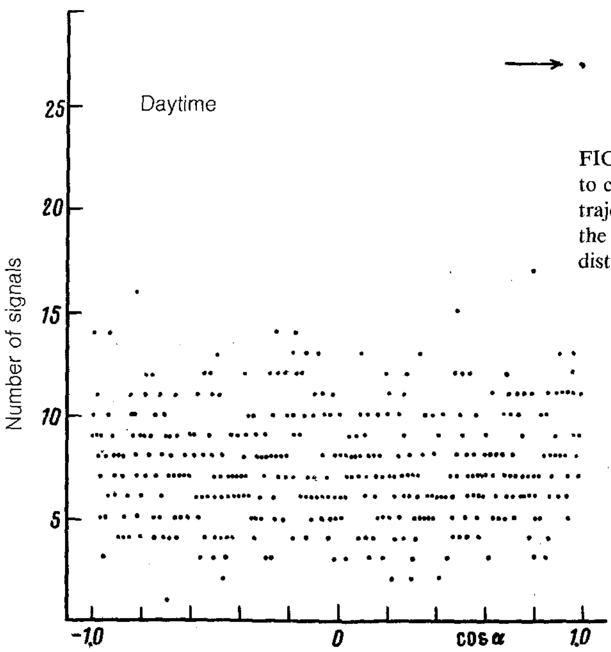

FIG. 1. Distribution of signals with respect to $\cos \alpha$, where α is the angle between the trajectory of the signal and the direction of the Sun. Here $\Delta\alpha = 5.7°$. The step of the distribution is $\Delta\cos \alpha = 0.005$.

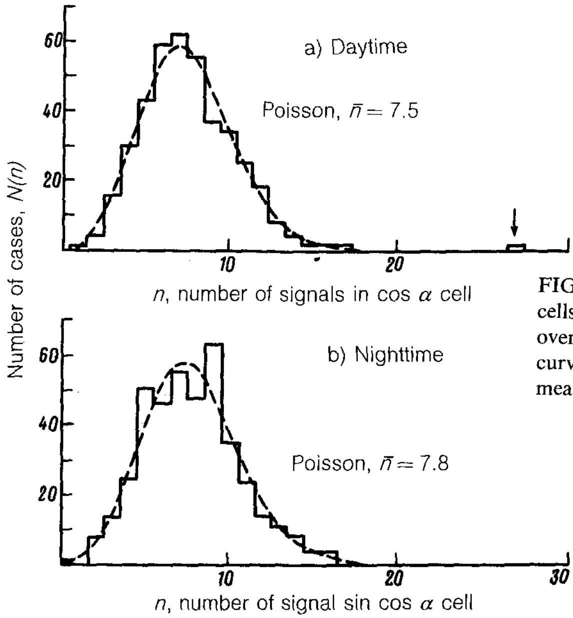

FIG. 2. Distribution of signals in the cos α cells detected (a) in daytime and (b) at night over the years 1985–1990. The smooth dashed curves are expected Poisson distributions with mean values (a) $n = 7.5$ and (b) $n = 7.8$.

the events in the signals, $\leqslant 1$ s (the transit time of relativistic particle between neighboring planes would be ~ 12 ns). Second, there is the fact that the event vector is directed toward the Sun. In other words, the detector in the lower plane is always the first to operate.

The appearance of pulses in a gate ~ 1 s in the detectors might be expected after passage through the telescope of a high-energy particle (e.g., a muon) or a cascade of particles, if delayed decays of newly formed nuclei are observed as the result of interactions of these particles with the scintillator. This possibility was tested for the cascades of particles at the telescope. An excess over the average background number of single pulses was found after the passage of cascades. This excess can be described well by an exponential function with a constant ~ 0.03 s, which corresponds to the decay half-life of $^{12}B_5$ (0.0203 s). This nuclide forms in nuclear interactions involving $^{12}C_6$.

However, it would be difficult to explain the observed effect as a consequence of an interaction of muons intersecting the telescope, since (Fig. 3a) the distribution of "solar" signals with respect to the time $\Delta t = t_2 - t_1$ (curve 1) differs from the corresponding distribution for events caused by muons (curve 2).

A second important feature of the events which have been selected is that the vector is directed toward the Sun, as shown schematically in Fig. 3b. This result can be interpreted in the following way. We assume that the chronological first of the two events of a signal, which is lower in terms of position on the inner planes, results from the passage of the primary particle which causes this signal. The second and later

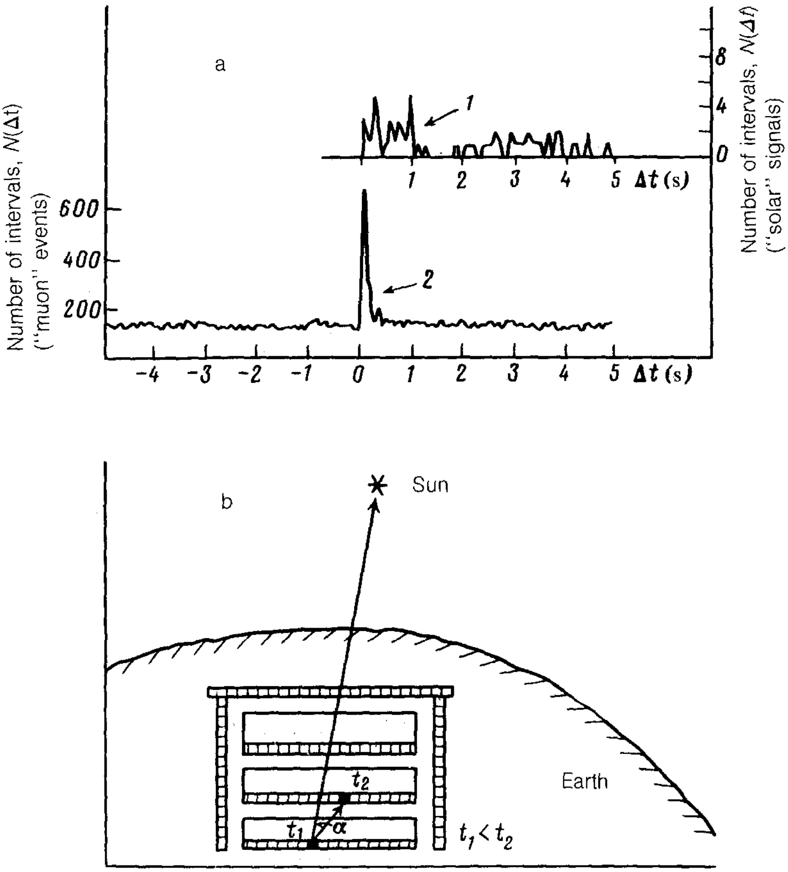

FIG. 3. a) Distributions of the time intervals $\Delta t = t_2 - t_1$ between the events in "solar" signals (curve 1) and between the muon cascade and the appearance of an isolated event ("muon" events; curve 2). Negative values of Δt represent cases in which single pulses appear before the muon cascade. The step of the distributions is 80 ms. b) Schematic diagram of Baksan-telescope signals directed toward the Sun. The detectors which operated, at times t_1 and t_2 ($t_1 < t_2$), are shown in black. Here α is the angle between the signal vector and the direction to the Sun.

event could then occur as a result of a nuclear transition in the scintillator.

The event selection logic at the telescope allows one to interpret the observed signals as resulting from the passage of a particle both from bottom to top and from top to bottom through the apparatus. The information presently available is not sufficient to make a clear choice between these two alternatives.

In summary, this preliminary analysis of 1985–1990 data reveals an excess of signals in the direction toward the Sun. The probability that this excess occurred purely by chance is $\sim 2\times 10^{-8}$. Telescope data generated in the course of other physics programs are presently being analyzed in order to carry out a more comprehensive study of the observed effect.

[1] J. K. Rowley, B. T. Cleveland, and R. Davis, in *Solar Neutrinos and Solar Astronomy* (ed. M. L. Cherry *et al.*) American Institute of Physics, New York, 1985.
[2] K. S. Hirata *et al.*, Phys. Rev. Lett. **65**, 1297 (1990).
[3] V. N. Gavrin, in *Proceedings of the International Conference "Neutrino-90,"* Geneva, Switzerland, 1990.
[4] E. N. Alexeyev *et al.*, Phys. Lett. B **205**, 209 (1988).

Translated by D. Parsons