G. T. Zatsepin and O. G. Ryazhskaya. *Program for the search for star collapse in the Galaxy.* Theory predicts that stars with massive cores experience gravitational collapse at the end of the their evolution. According to modern concepts the process must be accompanied by a powerful neutrino flareup.[1] The total energy carried away by the neutrinos amounts to 0.1 Mc^2 of the stellar core. A measurement of the energy and time distribution of neutrinos in a flare would enable one to obtain information on the dynamics of the collapse of the nuclear core of a star. The most detailed investigation of collapses is given in Refs. 2–6. The results of the calculations of the parameters of a neutrino burst accompanying a collapse are shown in Table I.

W_1 is the total energy of the flare communicated to neutrinos of all kinds, W_2, W_3 is the total energy carried away by ν_e and $\bar{\nu}_e$ respectively, W_4 is the energy of ν_e at the stage of neutronization of a star during a time $\leqslant 3\cdot 10^{-3}$ s, $\bar{E}_\nu$ is the energy $\bar{\nu}_e$ averaged over the spectrum, T is the duration of the neutrino flare. Observation of collapses using neutrino emission would be an important confirmation of our astrophysical concepts.[7]

At the present time in experiments searching for neutrino flares the following reaction is used

$$\bar{\nu}_e + p \to n + e^+, \qquad \sigma = 6{,}2\cdot 10^{-42}\ \mathrm{cm}^2 \text{ at } \quad E_{\bar{\nu}_e} = 10\,\mathrm{MeV}. \tag{1}$$

A scintillation or a Cherenkov detector is filled with hydrogen-containing material; the scintillation from e^+ is recorded by photoelectric multipliers (PEM). A neutrino flare is identified by the appearance of a series of scintillations with amplitudes in the range (E_n — 50) MeV during a time $\leqslant 20$ s, E_n is the threshold energy above which scintillations are recorded. The number of pulses in a series with everything else being equal is proportional to the mass of the detector and the efficiency of recording positrons η_{e^+}. The background can simulate an actual event. The expected frequen-

TABLE I.

Model	W_1, erg	W_2, erg	W_3, erg	W_4, erg	$\bar{E}_{\bar{\nu}}$, MeV	T, sec
2	$(2{,}5-14)\cdot 10^{53}$	$(1-3)\cdot 10^{53}$	$(1-3)\cdot 10^{53}$	10^{52}	12,6	20
3					10	5

cy of collapses in the Galaxy is once every 5–50 years, and the frequency of simulations must be less than this quantity. In order to reduce the background the detectors are placed deep underground and anticoincidence screening is used. But simulations are possible also under conditions of minimum background, not to mention simulations due to electrical noise. In order to ensure that the recording of a collapse is genuine it is very important to have several independent detectors in operation.

Table II gives characteristics of ten detectors. The first four lines refer to detectors which are either presently operating, which have operated, or which have begun to operate in a program of recording collapses. The others are either in existence, but so far have been used to search for nucleon decay, or are in the stage of design or construction.

The Baksan scintillation telescope (BST) consists of 3130 modules. Each module is rectangular in shape ($0.7\times 0.7\times 0.3$ m^3) and is observed by a single PEM. The BST is a unique multipurpose detector, and the search for collapses is only one of the problems of its extensive work program. In order to decrease the background its external modules are utilized as an anticoincidence screen. The cellular structure enables one to decrease the background, by using an anticoincidence method in selecting events within the working volume, down to a very small value.

The Artemov scintillation detector (ASD) is a single 105-ton counter observed by 128 PEM's. Due to the small depth and low threshold the background conditions are not favorable. But the high sensitivity of the detector made it possible to propose and realize the idea of lowering the background by the method of recording both particles e^+ and n in (1). The neutron is slowed down in the scintillator with $\tau = 170\ \mu$s and is captured by hydrogen:

$$n + p \rightarrow d + \gamma. \qquad (2)$$

The scintillations from $E_\gamma = 2.2$ MeV are recorded in a highly sensitive channel which is opened for a time interval of 500 μs by a pulse from a positron. This enables one to reduce the background by a factor of 2.5. The liquid scintillation detector (LSD) is situated in a tunnel under Mont Blanc and consists of 72 modules of rectangular shape ($1\times 1\times 1.5$ m^3). A module is observed by 3 PEM's. As in the case of ASD the method of recording neutrons is employed here.

TABLE II.

Detector	Depth m.w.e.	Type of detecting material	Total mass, t	Working mass, t	Threshold for detection, MeV	Efficiency of detection, η_{e^+}[a]	Expected number of pulses in a series $\bar{n}(R = 10$ kpc$)$[b]	Frequency of background pulses, s^{-1}	R, kpc[c]	Exposure time, years
BST, USSR [8]	850	Scintillation C_nH_{2n+2}	330	130	12.5	0.45	27	0.031	21.2	3.8
ASD, USSR [9]	570	The same	105	105	5	0.97	47	0.18	20.2	3.5
LSD, USSR Italy [10]	5200	The same	90	90	6	0.89	36	0.003	34.1	0.1 since 1985
HĈD, USA [11]	4200	Cherenkov, H_2O	300	150	10	0.50	24	0.3		2.0 up to 1982
HSD, USA [12]	4200	Scintillation C_nH_{2n}	140	140	10	~0.65	41			Assembly
IMB, USA [13]	1570	Cherenkov, H_2O	7000	3300	30	~0.02	21			
Kamiokande, Japan [14]	2700	The same	3000	880	10	~0.65	190			
JACK, Japan [15]	2700	The same	50 000	22 000	6	~0.9	6300			Design project
HT, USA [16]	4200	Scintillation C_nH_{2n}	1406	1406	10	~0.65	410			Design project
LVD, Italy [17]	4200	Scintillation C_nH_{2n+2}	> 1000	> 1000	6	0.89	>400			Design project

[a] The efficiency of detection η_{e^+} depends on the threshold and construction details of the detector.

[b] The expected number of pulses in a series has been calculated according to the model of Ref. 2; according to the model of Ref. 3 it is lower by a factor of two.[18]

[c] R is the distance to a star for which the effect in the detector corresponds to a frequency of simulations of 10^2 per year for a typical collapse. This quantity characterizes the capabilities of different detectors taking the signal-to-noise ratio into account.

TABLE III.

K	2	3	4	5
$t(\geqslant 2, \mathrm{K})$,%	64	90	97	99

The Homestake Cherenkov Detector (HCD) operated up to 1982. At present it is in the stage of having its Cherenkov modules being replaced by scintillation modules ($0.3\times0.3\times8$ m^3). According to plan the reconstructed detector (HSD) should begin operation in 1985. Of the other detectors one should mention JACK—a Cherenkov counter of cylindrical shape, the height and diameter of the cylinder is 40 m, 40% of the surface is occupied by photocathodes of 11 000 PEM. This is the only detector capable of recording radiation during the phase of stellar neutronization utilizing the reaction

$$\nu_e + e^- \to \nu_e + e^-. \qquad (3)$$

This detector, and also the Homestake track spectrometer (HT) and the LVD can record a collapse not only in our Galaxy, but also in the Magellanic Clouds.

In the case of recording the fact of a collapse it is important to measure the amplitude and the time distribution of $\bar{\nu}$ in the flare, which would yield information on the dynamics of the collapse of the nuclear core of a star. Here detectors with a minimal threshold and a maximal η_{e^+} have the advantage. Cherenkov detectors can indicate the direction to the collapsing star.[19] The program for searching for stellar collapses must include several detectors operating simultaneously. Two detectors already give a reliable recording of a collapse even at the level of background simulations at the rate of 100 per annum. Practically the entire Galaxy is being covered by the detectors at present in operation. The "active" time of operation of a single detector can hardly be made greater than 80% of the total time. Table III shows the fraction of time during which not less than two detectors out of a total of K are in operation, $t(\geqslant 2, \mathrm{K})$ for $t_a = 80\%$. It can be seen from Table III that for an effective search for collapses in the Galaxy not less than three independent detectors are required. During the time that the above installations have been in operation of more than 3.5 years the frequency of simulations corresponds to the calculated one, i.e., no collapses have been recorded.

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