

THE CAPABILITY OF THE EXISTING NETWORK OF INSTALLATIONS FOR DETECTING THE ANTINEUTRINO BURST FROM COLLAPSING STARS

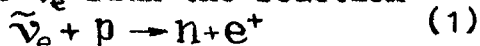
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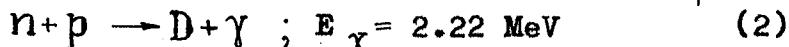
1. Introduction. As the neutrino fluxes can bring information from the internal layers of the collapsing star, the problem of the neutrino burst detection is of importance for both the direct registering of the collapse itself and the investigation of its dynamics. The main characteristics of the neutrino fluxes have been obtained by simulations /1-7/. The total neutrino flux energy is estimated as $2.5 \cdot 10^{53} - 1.4 \cdot 10^{54}$ erg, the energy of $\tilde{\nu}_e$ -flux being 10^{53} erg. Predictions on neutrino energy spectra are quite different. We will use two models of the collapse: the model by Bowers and Wilson /2/, hereafter "BW", and the model by Nadyozhin and Otroschenko ("NO"). The $\tilde{\nu}_e$ -spectrum in the BW-model reaches the maximum at $E_{\tilde{\nu}_e}^{\max} = 8$ MeV. Average energy of $\tilde{\nu}_e$ $\bar{E}_{\tilde{\nu}_e} = 10$ MeV. The NO-model /1/ gives $E_{\tilde{\nu}_e}^{\max} = 10.5$ MeV and $\bar{E}_{\tilde{\nu}_e} = 12.6$ MeV. The $\tilde{\nu}_e$ -burst duration is $\Delta\tau_{\nu} = 20$ s for the NO-model. As the black hole formation is the result of the star collapse in the BW-model, $\Delta\tau_{\nu}$ is taken to be 5s according to /7/. In the NO-model the emission of $\nu_{\tau}\tilde{\nu}_{\tau}$ during star collapse is not taken into account. So in our estimates we correct the intensity of $\tilde{\nu}_e$ -burst with the factor of 2/3, the latter resulting from the hypothesis about the equal energy release in various types of neutrinos.

2. $\tilde{\nu}_e$ -burst detection efficiency of various scintillation installations

To detect the $\tilde{\nu}_e$ -flux the reaction



will be used. The neutrons will slow down during $5\mu\text{s}$ and then will be captures by scintillator protons ($\tau_{\text{capt}} = 170\mu\text{s}$):



The $\tilde{\nu}_e$ -burst detection has the following features /8/: 1) the counting rate increase in the energy range of 5-45 MeV during 5-20S; 2) the time correlation between the pulses due to reactions (1) and (2); 3) the homogeneous spatial distribution of the interactions (1) in a detector; 4) simultaneous events in various detectors.

We have considered /8/ the $\bar{\nu}_e$ -burst detection capability of four installations: Artyomovsk scintillation detector (ASD), Baksan scintillation telescope (BST), the USSR-Italy liquid scintillation detector (LSD) and the scintillation telescope in the Homestake Gold Mine (HST). The main characteristics of the installations are presented in Table 1.

ASD /9,10/ is a steel cylinder ($h = 5.6$ m, $\phi = 5.6$ m) containing 105 tons of C_nH_{2n+2} ($\bar{n} \approx 10$) with a scintillator. The pulses in the energy ranges of 5-50 MeV (the 'positron' range) and of 1.5 - 4.5 MeV (the 'neutron' range) are analyzed. The 'neutron' channel is opened during 10- 510 μs after the 'positron' pulse arrival. The 97% of positrons and 80% neutrons from the reaction (1) can be detected. The background counting rates are $0.4 s^{-1}$ in the 'positron' range and $1.2 \cdot 10^3 s^{-1}$ in the 'neutron' one. The events are selected from background provided that at least 15 pulses in 20 appears in the 'positron' range, ≥ 10 of them being accompanied by 'neutron' pulses. At the next step the events are selected if each of ≥ 13 'positron' pulses is accompanied by 1-3 'neutron' pulses. The same liquid scintillator is used for BST and LSD.

BST consists of 3136 standard modules $0.7 \times 0.7 \times 0.3 m^3$. The pulses in the energy range of $E \geq 12.5$ MeV are analyzed. Three step criterion is used for the event selection. At the first step an event is selected provided that ≥ 5 pulses in 20 s appear in the detection range. The spatial and time distributions are analyzed at the second and the third steps. The background counting rate is $0.034 S^{-1}/12, 13./$

LSD /14/ consists of 72 modules $1.5 \times 1.0 \times 1.0 m^3$. The neutrons from the reaction (1) can be detected. The threshold is adjusted to 6 MeV, resulting in the background counting rate less than $0.01 S^{-1}$. The selection criterion: ≥ 4 pulses in 20 s in 6- 50 MeV energy range.

HST /15/ is under construction now. The telescope will employ 200 modules $8 \times 0.3 \times 0.3 m^3$ filled with a liquid scintillator. The threshold is expected to be of 5-10 MeV. The background counting rate and the selection criteria have not been published.

We have calculated the energy spectra of e^+ produced by $\bar{\nu}_e$ -burst in various detectors. The spectra are calculated assuming the distance to collapsing star to be $R = 10$ kpc and the scintillator mass $M = 100$ tons (Fig.1). The $\bar{\nu}_e$ -spectra from /1,2/ were used for the calculations. While simulating, the module design and light collection conditions for various detectors were taken into account.

We have used the e^+ -spectra obtained for to determine the $\bar{\nu}_e$ -burst detection efficiency. The e^+ -spectra were not supposed to change with the time. When calculating, the positron and neutron pulses were generated at random and added to background pulses. Then the total pulse array was processed in search of $\bar{\nu}_e$ -burst events and the depen-

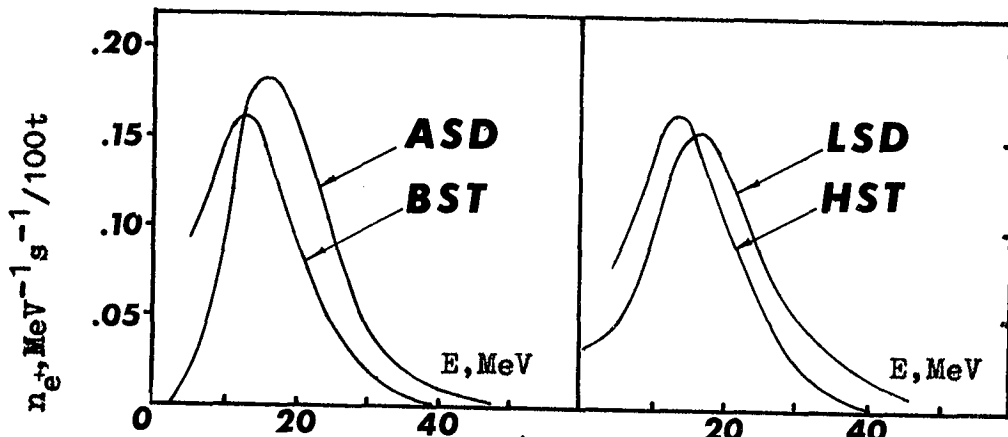


Fig. 1. The energy spectra of e^+ produced by $\tilde{\nu}_e$ -burst in various detectors (NO-model). The dashed lines - the electronic thresholds.

dence of the burst detection efficiency on the distance to collapsing star ($W(R)$) was determined for various installations.

The dependence $W(R)$ and the Galaxy star distribution $16\%, q(R)$, were used to calculate the probability of collapse $\tilde{\nu}_e$ -burst detection. The functions $W(R \leq R_0)$ are shown in Fig. 2.

3. The creation of the network of installations.

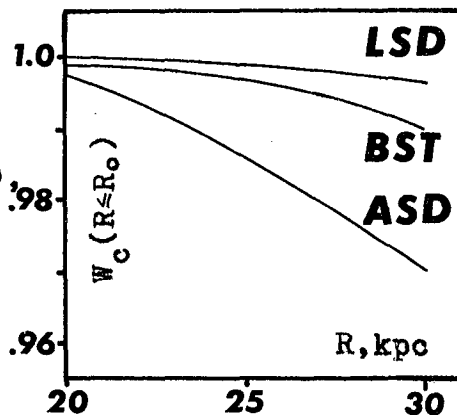
As one can see in Table 1 the $\tilde{\nu}_e$ -burst detection efficiency is rather great: $Q = W(R \leq 30 \text{ kpc}) \approx 95\%$ for every installation. It's to be noted, however, that the burst seems to be detected only by coincidence of signals from several installations. Let us estimate the possible imitation counting rate for every installation (n) supposing that coincidence counting rate has to be $< 1/100$ years. Provided the time resolution is $t \leq 10 \text{ S}$, we'll obtain for two installations :

$$n_{2c} = 2tn^2 \leq 1/100 \text{ years} \Rightarrow n \leq 1/3 \text{ days};$$

and for three ones:

$$n_{3c} = 3t^2n^3 \leq 1/100 \text{ years} \Rightarrow n \leq 1/2.7 \text{ hours}.$$

Certainly the network of installations allows more 'soft' selection criteria to be used, which increases the $\tilde{\nu}_e$ -burst detection efficiency up to 99% for every installation. So the installation 'living' time (w_1) is of importance. If w_1 were 85% for every installation,



$$W_c(R \leq R_0) = \frac{\int_0^{R_0} W(R) q(R) dR}{\int_0^{R_0} q(R) dR}$$

Fig. 2. The integral probability of collapse $\tilde{\nu}_e$ -burst detection.

the detection efficiency of the network should be $\geq 90\%$.

It should be emphasized that the creation of the network requires the close cooperation between various research groups. The cooperation could start with the joint time planning of runs, as well as the prompt and continuous exchange of the information

Table 1. The main characteristics of installations k_{NO} - the average number of $\bar{\nu}_e$ -interactions in a detector (NO-model); n_b -the background counting rate; Q -the Galaxy star part being observed by installation ($Q = W_c (R \leq 30 \text{ kpc})$); $I_{\bar{\nu}_e}^{\min}$ - the minimum $\bar{\nu}_e$ -flux which may be detected with probability $\omega \geq 0.9$.

Instal- lation	Mass (t)	Depth (mwe.)	Thre- shold (MeV)	\bar{k}_{NO}	n_b (s^{-1})	Q		$I_{\bar{\nu}_e}^{\min}$, cm $\Delta\tau_p = 20s$
						NO	BW	
ASD	105	570	5	47	0.40 (0.18)*	0.97	0.94	$9 \cdot 10^{10}$
BST	130	850	12.5	27	0.034	0.99	0.95	$8 \cdot 10^{10}$
LSD	90	5200	6	35	≤ 0.01 (0.001)*	1.00	1.00	$\leq 5 \cdot 10^{10}$
HST	140	4200	5-10	52-41	?	?	?	?

*) - the effective background counting rate with accounting the neutron detection.

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