G. T. Zatsepin. *Problems of Neutrino Astrophysics.* 1. *The sun.* The experiments performed by R. Davis to observe neutrinos from the sun on the basis of the reaction $Cl^{37} + \nu \rightarrow Ar^{37} + e^-$ ($Q = -0.814$ MeV) produced negative results in a long series of exposures extending over many years. This gave rise to numerous hypotheses and speculations. The last three exposures introduced another surprise: a high Ar^{37} yield, approaching predictions based on the standard model of the sun. Doubt was cast on the stability of the neutrino flux. Solution of the problems posed requires coordinated studies of the sun, and experiments to register the neutrino flux from the basic reaction $p + p \rightarrow D + e^+ + \nu$, which is practically model-independent, are especially important tant. This can be done with a detector based on gallium, which has a low energy threshold: $Ga^{71} + \nu \rightarrow Ga^{71} + e^-$ ($Q = -0.233$ MeV). A method for detection of neutrinos with the aid of gallium has recently been brought to the operational level in the laboratories of the USSR Academy of Sciences and Moscow State University. Twenty tons of gallium are required to conduct a full-scale experiment. The use of lithium as a target is also of interest. The yield on lithium is proportional to the density of the matter at the center of the sun and therefore would yield new information.

2. *Collapsing stars.* At the Artemovsk salt mines, the first large installation designed to detect pulses from antineutrino streams emitted on collapse of stars in our Galaxy is now near completion. A worldwide network of such detectors is planned and will make it possible to determine the direction to the collapsing star. Study of neutrino bursts will yield information on the dynamics of star collapse.

3. *Evolution of galaxies.* The space of the Universe is opaque to all high-energy particles except neutrinos. Therefore an American proposal calling for the creation of a gigantic detector at a depth of 5 km in the ocean to register events caused by neutrinos (Project DUMAND) is highly promising. It has been shown by Soviet physicists that this device will probably have sufficient grasp to register neutrinos with energies of $10^{15}-10^{17}$ eV that date from the violent formation of galaxies.

Neutrino astrophysics is still in its infancy. In the near future it will become a powerful new tool for understanding of the interiors of the stars and the evolution of the Universe.

B. M. Pontecorvo. *The Problem of Oscillations in Neutrino Beams.* Neutrino oscillations[1] may occur if there is a certain (very weak) interaction that disturbs conservation of the leptonic charges, which distinguish ν_e from $\tilde{\nu}_e$, ν_μ from $\tilde{\nu}_\mu, \ldots$ or mixes unlike neutrinos ($\nu_e, \nu_\mu, \ldots$) with one another. Neutrino oscillations are analogous to $K^0 \rightleftarrows \bar{K}^0$ oscillations. Like K^0 and $\bar{K}^0$, $\nu_{e,\mu}$ and $\tilde{\nu}_{e,\mu}$ are not described by stationary states, so that it is necessary to introduce neutrinos ν_1, ν_2 with definite masses (m_1, m_2) the superposition of whose fields describes $\nu_{e,\mu}$ and $\tilde{\nu}_{e,\mu}$. Experimental exploration for neutrino oscillations is a powerful tool for the study of possible violations of conservation laws, since it enables us to measure the amplitudes of the processes (rather than their squares). The neutrinos with defined masses may be either Majorana particles[2] or Dirac particles.[3]

The oscillation length L equals $4\pi p/|m_1 - m_2|(m_1 + m_2)$, where p is the momentum of the neutrino. In the case of the maximum oscillation amplitude, the intensity I_{ν_e} of electronic neutrinos at a distance R from the source ν_e is given by the expression

$$I_{\nu_e} = \frac{1}{2} I^0_{\nu_e} \left(1 + \cos 2\pi \frac{R}{L}\right),$$

where $I^0_{\nu_e}$ is the intensity of ν_e expected in the absence of oscillations.

In principle, oscillations of the type $\nu_e \rightleftarrows \nu_\mu$ can be observed on accelerators by measuring the ratio $r = I_{\nu_e}/I_{\nu_\mu}$ of the intensities of the electronic and muonic neutrinos at a given distance R between the neutrino detector and the neutrino source as a function of the neutrino momentum p. The ratio r is given by the expression

$$r(p) = \frac{1-\cos(a/p)}{1+\cos(a/p)},$$

where $a = R|m_1 - m_2|(m_1 + m_2)$ is a constant. Oscillations can be observed on the accelerator if $M = \sqrt{|m_1 - m_2|(m_1 + m_2)} \geq 0.2$ eV.

For solar neutrinos, the oscillations can be detected by comparing the average intensity $\bar{I}_{\nu_e}$ with the intensity $I^0_{\nu_e}$ expected in the absence of oscillations. In the simplest case,[1-3] in which there are two types of neutrinos, $\bar{I}_{\nu_e}/I^0_{\nu_e} \geq 1/2$, and when there are N types of neutrinos,[4,5] we have $\bar{I}_{\nu_e}/I^0_{\nu_e} \geq 1/N$ or even[6] $\bar{I}_{\nu_e}/I^0_{\nu_e} \geq 1/2N$. In principle, the oscillations can be detected if $M \geq 5 \cdot 10^{-7}$ eV.

Despite the "low" measured signal, the experiments of Davis *et al.*[7] do not yet justify the conclusion that oscillations exist, since the expected intensity is not known with any accuracy and the accuracy of the measurements themselves is still inadequate. Registration of solar neutrinos would appear highly promising for detection of Ga–Ge oscillations.

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