a later stage of its development. This indicates that at fields close to $(1 - n)H_c$ there is produced at the edges of the sample an n-phase layer, from which normal regions begin to break away in strong fields; motion of these normal regions under the influence of the transport current is the reason for the observed losses.

The minimal effective resistance of these losses lies in the interval $6 \times 10^{-9} - 1 \times 10^{-7}$ ohm for the plates and $4 \times 10^{-9} - 1 \times 10^{-8}$ ohm for the foil samples; this is much less than the values obtained under our conditions when a layered intermediate-state structure perpendicular to the current is produced.

Our experimental data, as well as experiments on the induced motion of magnetic-flux tubes in tin plates [1], allow us to assume that in the case of a plate (see Fig. 3) we are dealing with resistive losses, but the parameter α_c is in this case much smaller than for the foil or for the alloy ($\alpha_c \lesssim 10^{-1}$ G-A/cm^2). This difference is natural for two reasons. First, a cold-deformed foil is an object having many structural defects, and this makes the pinning appreciable. Second, an important role is played by the characteristic dimensions a_n of the normal regions themselves, which increase with increasing sample thickness, thereby decreasing the efficiency of the pinning in thicker samples. (An estimate under our conditions yields $a_n \lesssim 10^{-3}$ cm for the foil and $a_n \lesssim 10^{-2}$ cm for tin plates.)

We note that the resistive state in all tin samples was observed up to external field values $H \simeq 0.7H_c$; the field values did not vary noticeably with either the sample thickness or the temperature.

[1] P.R. Solomon, Phys. Rev. Lett. 16, 50 (1966).
[2] P.R. Solomon and F.A. Otter, Phys. Rev. 164, 608 (1967).
[3] G.J. Van Gurp, Phys. Lett. 24A, 528 (1967).
[4] H. Trauble and U. Essmann, Phys. Status Solidi 18, 813 (1966).
[5] C.J. Groter, Physica 23, 45 (1957).
[6] Yu.V. Sharvin, ZhETF Pis. Red. 2, 287 (1965) [JETP Lett. 2, 183 (1965)].

HEAVY LEPTONS AND NEUTRINO ASTRONOMY

B. Pontecorvo
Joint Institute for Nuclear Research

Submitted 8 February 1971
ZhETF Pis. Red. 13, No. 6, 281 - 283 (20 March 1971)

The possible existence of heavy leptons, i.e., of charged leptons heavier than $e^{\pm}$ and $\mu^{\pm}$, has been discussed recently a number of times [1 - 6], as well as the question of realizability of experiments intended for their observation [4 - 6]. Searches for a "heavy charged electron e'" in the reaction $ep \to e'p$ were made [7 - 9] with electron accelerators, and the negative results say nothing concerning the existence of different charged leptons that might not be produced only via electromagnetic interactions. In analogy with the known laws, it can be assumed that these heavy charged leptons, if they exist, take part together with the neutrino in weak interactions. Through a gracious communication from Yu.D. Prokoshkin and I.V. Chuvilo, I learned that experiments aimed at observing the formation of heavy leptons by high-energy electrons had been initiated by Schwartz's group with the SLAC, using a method proposed independently by Schwartz [4] and by myself [10], consisting of finding events produced in a neutrino detector by neutrinolike decay products of short-lived particles (heavy leptons), when the flux of "ordinary" neutrinos from the decay of long-lived particles (pions, kaons) is purposely suppressed.

I shall assume henceforth that the heavy leptons exist, and shall discuss certain consequences of this hypothesis in the field of neutrino astronomy.

Attention has already been called [11] to the possible existence of oscillations between different neutrino states. The oscillations might arise under certain conditions if the neutrino mass is not equal to zero and the lepton charge is not exactly conserved. The existence of oscillations would have far reaching consequences, on the one hand, for observational neutrino astronomy, and on the other hand for an experimental determination of important neutrino properties [10]. For the case when only four independent neutrino states exist in nature, the conditions necessary for the existence of neutrino oscillations, and the equations describing them, are contained in [12]. The diagonal states are two Majorana neutrinos with different masses (altogether four states if the spin direction is taken into account).

I confine myself below to certain remarks concerning the problem of neutrino oscillations for the case when heavy leptons exist. Let us consider three cases.

1. Each "new" charged lepton has its own corresponding neutrino ν_Λ, and all the neutrinos are strictly longitudinal [13].

Each neutrino has two states, and obviously there will be no oscillations.

2. In spite of the existence of a large number of charged leptons, there are only the two already-known types of neutrinos (altogether four states). The neutrinos are not strictly longitudinal, their mass is not equal to zero, and we are dealing with the theory of the four-component neutrino with parity violation [14 - 15]. This scheme is particularly attractive and simple if there exist many charged leptons. If the lepton charge conservation is also violated, then the $\nu_e \rightleftarrows \nu_\mu$ oscillations discussed in [12] arise. We have used here the ordinary notation for the "phenomenological" particles (ν_e and ν_μ). The average flux of neutrinos from the sun, which can be registered sufficiently far from the sun, will have the flux of detectable neutrinos under conditions of lepton charge conservation [11 - 12] (I shall not discuss here the subtle experiments on the observation [10, 12, 16, 17] of the cosinusoidal term connected with the oscillations).

3. There are N types of charged particles as well as N types of neutrinos, but unlike in case (1) the neutrinos are not strictly longitudinal, and in addition there is no exact conservation of the lepton charges. In this case the diagonalization of the states is quite complicated, but one can see immediately the physical consequences of such a scheme.

At sufficiently large distances from the source, the existence of the oscillations leads to dilution of neutrinos of one type, say electronic, by the N possible ones. The low-energy neutrinos (such as those from the sun) can be distinguished by means of one attribute, namely, at sufficiently large distance from the sun most neutrinos, more specifically the fraction (N - 1)/N, will be sterile. Indeed, their energy is less than the mass of any charged lepton other than the electron; thus the only possible process by which they can be registered is $\nu_e + n \to e^- + p$. This gives rise to a fact of importance for neutrino astronomy, namely that the neutrinos from the sun can be registered on earth with very low efficiency. Therefore even if the flux of neutrinos registered from the sun on earth turns out to be extremely small, it will be possible to draw unequivocally revolutionary conclusions, from the point of astrophysics and cosmology, with respect to explaining the neutrino properties discussed in the present article (of course, I do not have in mind here the negative result of the experiment of Davis et al. [18], the interpretation of which, in my opinion, still lies in the framework of the known astrophysics and elementary-particle physics).

Fortunately, the theoretical scheme that can lead to such a sorry state for observational neutrino astronomy, is esthetically unattractive, and one can hope that it is not realized in nature.

I take pleasure in thanking S.M. Bilen'kii, S.S. Gershtein, and M.A. Markov for discussions.

[1] E. Lipmanov, Zh. Eksp. Teor. Fiz. 43, 893 (1962) [Sov. Phys.-JETP 16, 634 (1963)].
[2] E. Lipmanov, ibid. 46, 1917 (1964) [19, 1291 (1964)].
[3] F. Low, Phys. Rev. Lett. 14, 238 (1965).
[4] M. Schwartz, Reports on Progress in Physics 28 (1965).
[5] S. Gershtein and V. Folomeshkin, Yad. Fiz. 8, 768 (1968) [Sov. J. Nuc. Phys. 8, 447 (1969)].
[6] V. Mokeev and V. Folomeshkin, IFVE Preprint, STF, 68-6-K, 1968.
[7] C. Betourne et al., Phys. Lett. 17, 70 (1965).
[8] R. Budmitz et al., Phys. Rev. 141, 1313 (1966).
[9] H. Behrend et al., Phys. Rev. Lett. 15, 900 (1965).
[10] B. Pontecorvo, Paper at Internat. Conf. on High-energy Physics, Kiev, 1970; JINR Preprint E1-5439, 1970.
[11] B. Pontecorvo, Zh. Eksp. Teor. Fiz. 53, 1717 (1967) [Sov. Phys.-JETP 26, 984 (1968)].
[12] B. Gribov and B. Pontecorvo, Phys. Lett. 28B, 493 (1969).
[13] L. Landau, Zh. Eksp. Teor. Fiz. 32, 405 (1957) [Sov. Phys.-JETP 5, 336 (1957)]; A. Salam, Nuovo Cim., 5, 299 (1957); T.D. Lee and C.N.Yang, Phys. Rev. 105, 1671 (1957).
[14] Ya. Zel'dovich, Dokl. Akad. Nauk SSSR 86, 505 (1952); F. Konopinski and H. Mahmoud, Phys. Rev. 92, 1045 (1953).
[15] I. Kowakani, Prog. Theor. Phys. 19, 459 (1958); E. Lipmanov, JETP 37, 1054 (1959); A. Sokolov, Phys. Lett. 3, 22 (1963).
[16] J. Bahcall and S. Frautschi, Phys. Lett. 29B, 623 (1969).
[17] G. Kocharov and B. Ferberg, Preprint, Ioffe Inst., No. 299, October 1970.
[18] R. Davis, D. Harmer, and K. Hoffman, Phys. Rev. Lett. 20, 1205 (1968).

NONLINEAR EFFECTS IN THE PROPAGATION OF HYPERSONIC WAVES IN INDIUM ANTIMONIDE

S.N. Ivanov, I.M. Kotelyanskii, G.D. Mansfel'd, and E.N. Khazanov
Institute of Radio Engineering and Electronics, USSR Academy of Sciences
Submitted 8 February 1971
ZhETF Pis. Red. 13, No. 6, 283 - 285 (20 March 1971)

We report here observation of nonlinear effects in the amplification of hypersonic waves of frequency 1 - 2 GHz in indium-antimonide crystals with $n = 4 \times 10^{14}$ cm^{-3}, $\mu = 6 \times 10^5$ cm^2/V-sec at T = 77°K, under conditions when the parameter $q\ell = 5 - 10$, where q is the wave vector of the sound wave and ℓ is the electron mean free path. As noted in [1 - 4], under these conditions one can expect the appearance of a new type of nonlinear effects, characteristic of the case $q\ell > 1$ and due to distortion of the electron momentum distribution function as a result of the electron interaction with the strong sound wave.

According to estimates, this type of nonlinearity is expected to set in at sound-flux intensities $10^{-2} - 10^{-1}$ W/cm^2.

The excitation and registration of the sound in the InSb crystals were carried out by a well-known pulsed method using a CdS epitaxial electroacoustic converter. The double-conversion losses did not exceed 40 - 50 dB. In the