Meetings and Conferences

SCIENCE SESSION OF DIVISION OF GENERAL PHYSICS AND ASTRONOMY USSR ACADEMY OF SCIENCES

(April 26–27, 1972)

Usp. Fiz. Nauk 108, 595–598 (November, 1972)

A science session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on April 26 and 27, 1972, in the Conference Hall of the P. N. Lebedev Physics Institute. The following papers were presented at the session:

1. E. P. Aksenov, E. A. Grebenikov, V. G. Demin, G. N. Duboshin, and M. D. Kislik. Current Problems and Methods of Celestial Mechanics.
2. V. B. Braginskiĭ, A. B. Manukin, E. I. Popov, V. N. Rudenko, and A. A. Khorev. Search for Gravitational Radiation of Extraterrestrial Origin.
3. V. I. Pustovoĭt. Effects connected with Phonon Production in Semiconductors.
4. L. V. Dubovoĭ, A. G. Smirnov, V. G. Smirnov, and D. I. Stasel'ko. The Use of Holography for Investigating Processes in a Thermonuclear Plasma and in a Moving Arc Discharge.

We publish below summaries of three papers.

V. B. Braginskiĭ, A. B. Manukin, E. I. Popov, V. N. Rudenko, and A. A. Khorev. Search for Gravitational Radiation of Extrateresstrial Origin. 1. This paper presents the results of the first series of measurements on two gravitational antennas for the purpose of detecting against the background of Brownian oscillations spontaneous responses induced by gravitational radiation from extraterrestrial sources. The antennas, whose parameters were close to the parameters of Weber's antennas[1] ($m = 1.3 \times 10^6$ g, $f_{quadr} = 1640$ Hz, $Q = 10^5$, relaxation time $\tau^* = 20$ sec), were placed in vacuum chambers ($p < 1 \times 10^{-4}$ Torr) separated by a distance of 20 km. The anti-seismic insulation of the antennas was the same as in the investigations[1]. In contrast to the investigations[1], we used modulation capacitive displacement transducers to measure the small quadrupole vibrations of the antennas; in[1] piezoelectric gauges recorded the strains. The capacitive transducer converted a vibration amplitude of 4.5×10^{-14} cm (this corresponds to σ_{Brown}, the root-mean-square (rms) amplitude of the Brownian oscillations) into a radio-frequency signal of amplitude $\sim 4 \times 10^{-7}$ V.

The construction of the transducer and the arrangement for the absolute ponderomotive calibration of the antennas are described in detail in[2]. The amplitude of the vibrations was recorded on a photographic plate from an oscillograph (the drawing speed was 0.6 mm/sec and the diameter of the beam spot was less than 0.2 mm), and this allowed us to distinguish on the photoplate, without using an electronic coincidence circuit, vibration-amplitude variations with a time resolution not worse than 0.3 sec. The recording apparatus of each antenna was located near the antenna, in contrast to the investigations[1]. The recordings were synchronized with the aid of precisely-timed radio signals and with chronometers in the intervals between the clock markings of the radio signals.

2. Analysis of the simultaneous recordings of 20 days yielded the following results:

a) The sensitivity of the transducers allowed the measurement of a 2×10^{-14}-cm change that occurred in a time interval $\hat{\tau} = 2$ sec in the amplitude of the quadrupole mode of the antenna vibrations. This amplitude change corresponds to the rms fluctuation drift $\delta x_0 = \sigma_{Brown}\sqrt{2\hat{\tau}/\tau^*} \approx \frac{1}{2}\sigma_{Brown}$ of the amplitude of the Brownian oscillations (for details, see[3]).

We have verified for temporally long (of the order of 300 τ^*) sections of the recordings the validity of two hypotheses: I) does the measured absolute rms value of the amplitude of the vibrations correspond to σ_{Brown} II) is the vibration-amplitude distribution a Rayleigh distribution with the dispersion precomputed from the known m, T, and f_{quadr}? No statistically significant disagreement was detected between the experimental results and the predictions corresponding to these hypotheses (F- and K(λ)-criteria were applied).

b) We detected the occurrence in both antennas of relatively infrequent bursts of vibrations of clearly nonthermal origin (whose frequency exceeded the statistical predictions). The statistics of these bursts is characterized by the following data: 1) a sharp amplitude change δx_0 occurs on the average 100 times a day for $\delta x_0 = 3\sigma_{Brown}$ in a $\hat{\tau} = 2$-sec period and 20 times a day for $\delta x_0 = 5\sigma_{Brown}$ in a $\tau = 2$-sec time interval; 2) the $3\sigma_{Brown}$ level (with a rise time of from 0 to 20 sec) is exceeded on the average 100 times a day, the $5\sigma_{Brown}$ level, 40 times a day; statistically, the $3\sigma_{Brown}$ level is expected to be exceeded 100 times in a day, the $5\sigma_{Brown}$ level, once in 10 days.

c) Using different methods of analyzing photorecordings (including the method used by Weber[1], through collation of the photorecordings, but without the use of an electronic gating device), we were not able to detect coincident bursts to within 0.5 sec.

About 30 "suspicious places" were noted which corresponded to the occurrence of bursts ($\delta x_0 > 2\sigma$) with a time lag of between 0.3 and 10 sec, "coincidence to within 1 sec" being satisfied in several cases. However, the vastly different structure of the bursts (shape, rise time) does not allow us to consider these events as a reaction to the influence of one and the same source.

Note that in the investigations[1], 1–2 coincidences per week were observed in the first series, while in the subsequent series 1–2 coincidences per day were observed; to within 0.2 sec the amplitude of the bursts was equal to or exceeded the $3\sigma_{Brown}$ level. If we assume that the duration of the expected gravitational radiation bursts is roughly 2 sec, then we may detect a density flux of 1×10^7 erg/sec x cm^2; if the bursts last longer: 5–10 sec, then the detectable density flux is correspondingly equal to $(5-2) \times 10^6$ erg/sec $\times$ cm^2. It is not difficult to estimate that the attained level of sensitivity is 1.5 orders of magnitude worse than the potential sensitivity of an antenna with such f, Q, and m (for details, see[3]). This is due, on the one hand, to the relatively high level of nonthermal bursts and, on the other, to the inadequate resolution of small displacements because of electronics noise ($\delta x_0 = 2 \times 10^{-14}$ cm).

The discrepancy between the results obtained in this series of measurements and in the investigations[1] is possibly explained by the nongravitational effects described in the papers[4].

The authors take this opportunity to express their gratitude to Ya. B. Zel'dovich, G. I. Petrov, M. A. Sadovskiĭ, B. T. Vorob'ev, and V. N. Martynov for valuable discussions and help in the work.

[1] J. Weber, Phys. Rev. Lett. **22**, 1320 (1969); **24**, 276; **25**, 180 (1970).

[2] V. B. Braginskiĭ, V. P. Mitrofanov, V. N. Rudenko, and A. A. Khorev, Pribory i Tekh. Eksperim. No. 4, 246 (1971) [Instruments and Experimental Techniques No. 4, 1239 (1972)].

[3] V. B. Braginskiĭ and V. N. Rudenko, Usp. Fiz. Nauk **100**, 395 (1970) [Sov. Phys.-Uspekhi **13**, 165 (1970)]; V. B. Braginskiĭ, Fizicheskie éksperimenty s probnymi telami (Physical Experiments with Test Bodies), Nauka, M., 1970.

[4] M. E. Gertsenshteĭn, ZhETF Pis. Red. **14**, 611 (1971) [JETP Lett. **14**, 427 (1971)]; R. A. Adamyants, A. D. Alekseev, and N. I. Kolosnitsyn, ZhETF Pis. Red. 277 (1972) [JETP Lett. **15**, 194 (1972)]; I. I. Kalinnikov and S. M. Kolesnikov, Astron. Tsirkulyar (Astron. Circular) No. 619 (1971).

V. I. Pustovoĭt. Effects Connected with Phonon Production in Semiconductors. We consider effects which arise in semiconductors in a strong electric field and which are connected with phonon production. It turns out that a magnetic moment should appear in a homogeneous semiconductor crystal located in an electric field which is strong enough for phonon generation to occur (the electroacoustomagnetic effect[1]). Physically, the magnetic moment is due to the appearance of a rotational current component generated by the extra force which the phonons produced exert on the electrons. For a rotational current component to appear, it is necessary that the directivity diagram for the phonon radiation inside the Cerenkov cone be nonsymmetric about the direction of the drift velocity vector. The observation of the electroacoustomagnetic effect (it has not as yet been experimentally detected) will be easiest in piezoelectric semiconductor crystals in which a sufficiently strong electron-phonon interaction exists and in which, furthermore, one can always ensure the necessary anisotropy of the directivity diagram of the phonon radiation by the proper choice of the crystal orientation.

To explain the physical essence of the electroacoustomagnetic effect, let us consider the equilibrium conditions for a unit volume of the electron gas under the conditions when phonon production arises:

$$en\mathbf{E} - \nabla nT - m\nu n\mathbf{v} = 0; \tag{1}$$

here e is the charge, m the electron mass, n the electron concentration, ν the effective rate of collision of the electrons with the scattering centers, $\mathbf{v}$ the velocity, T the absolute temperature in energy units, and $\mathbf{E}$ is the electric field (in the low-frequency case being considered here the inertial terms are, naturally, unimportant). In the presence of phonon production the electron concentration $n(\mathbf{r}, t)$ and the electric field $\mathbf{E}(\mathbf{r}, t)$ fluctuate with amplitudes proportional to the amplitude of the generated sound waves, and therefore we must assume that

$$\mathbf{E}(\mathbf{r}, t) = \mathbf{E}_d + \mathbf{E}_\sim(\mathbf{r}, t), \quad n(\mathbf{r}, t) = n_0 + n_\sim(\mathbf{r}, t), \tag{2}$$

n_0 and $\mathbf{E}_d$ being here slowly varying functions of the coordinates and time. Now substituting (2) into Eq. (1) and averaging over time and space, we obtain the equilibrium conditions (1) in the form

$$\mathbf{E}_d - \frac{1}{\sigma_0}\mathbf{j} + \mathbf{F} = 0, \quad \sigma_0 = \frac{en_0}{m\nu}, \tag{3}$$

where $\mathbf{j} = \langle en\mathbf{v}\rangle$ is the average value of the current density and $en_0\mathbf{F} = e\langle n_\sim \mathbf{E}_\sim\rangle$ is the density of the so-called acoustoelectric force exerted by the generated phonons on an element of volume of the electron gas. It is precisely the appearance of this force that changes all the properties of a crystal in an external field. The electric field $\mathbf{E}_d$ is a potential field; therefore, from (3) follows immediately the relation

$$\operatorname{rot}\mathbf{j} = \sigma_0 \operatorname{rot}\mathbf{F}, \tag{4}$$

from which we can see that when $\operatorname{rot}\mathbf{F} \neq 0$, a rotational current component arises in the crystal and, as a result of this, a magnetic moment appears in the sample.

We consider the anomalous Hall effect in a semiconductor located in a strong electric field and show that under the conditions of phonon generation the experimentally measurable Hall constant R, given by the relation $R = E_H/JB$, where E_H is the Hall emf, J is the current in the source circuit, and B is the magnetic field (we have in mind a Hall open sample in the form of a parallelepiped, in which $\mathbf{B}$ is directed along the z axis, $\mathbf{J}$ along the x axis, and the Hall emf is measured along the y direction), sharply decreases, changes sign, and increases in absolute value. As in the case of the electroacoustomagnetic effect, such behavior of the Hall constant is due to the appearance of the extra force exerted on the electrons by the generated phonons[1]. Such anomalous behavior of the Hall constant was recently discovered in p-tellurium (see[2]).

Phonon generation in a strong electric field leads to a sharp change in the scattering of x-rays, γ-rays, and slow neutrons[3]. The random motion of the atoms in a crystal lattice leads to a decrease in the structural-scattering intensity and, furthermore, to the appearance of a diffuse peak in the scattered radiation. In a strong electric field, when the generation of nonequilibrium phonons appears, the random motion of the atoms and nuclei sharply intensifies and the intensity of the structural scattering peak decreases sharply, while the proportion of the diffuse scattering increases. It is significant that the characteristic generation time for the nonequilibrium phonons can be fairly small (this is the