2. Complete vanishing of the complicated structure when sufficiently strong electric fields are applied.

3. Practically complete lack of influence of the electric field on the resonance spectrum in the paramagnetic region (Fig. 3).

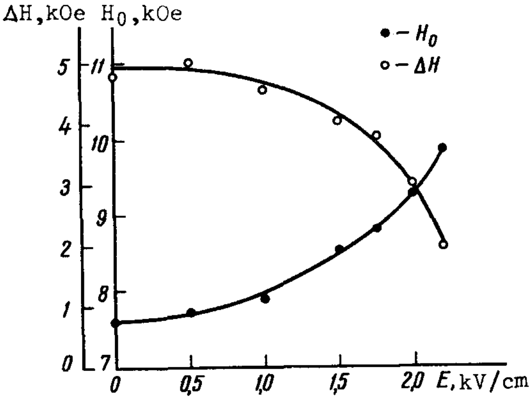

Fig. 2. Position (H_0) and width (ΔH) of the line vs. the intensity of the external electric field (E) at orientation H ∥ E ∥ [001].

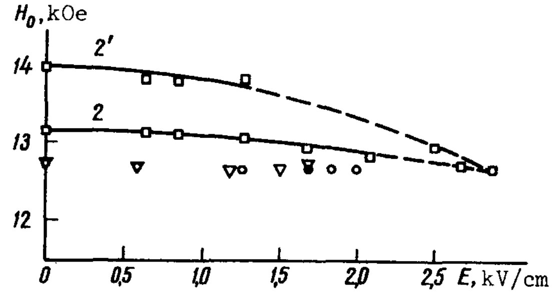

Fig. 3. Dependence of maxima of the line (0-derivative) on the field intensity E at different temperatures for the orientation H ∥ [100], E ∥ [001]. □) T = 298°K, o) T = 315°K, ▽) T = 323°K. Plots 2 and 2' correspond to points 2 and 2' of Fig. 1-I.

To explain the observed phenomena we can consider the following model. Owing to the magnetoelectric interaction, a certain electric polarization is also produced in a magnetically ordered piezoelectric. Then the precession of the magnetic moment is accompanied by a corresponding precession of the electric polarization. The joint motion of the two moments can lead to a change in the ferromagnetic-resonance line shape, or even to a splitting of the line into two (or more lines if electric domains are present). This effect should depend on the orientation of the sample, since χ_{me} (magnetoelectric susceptibility) is a tensor. When a sufficiently strong external electric field is applied, the motion of the electric moment freezes, and the usual ferromagnetic-resonance line is then observed. In the paramagnetic phase the effect should be much weaker owing to the small value of the magnetization in the external field.

Besides the described measurements we investigated also samples of spherical form and at frequencies in the 3 cm band. The results were similar.

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NATURE OF GRAVITATIONAL FIELD

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Measurements of the oblateness of the sun (Dicke, Goldenberg [1]) lead to the estimate $\delta \sim +10\%$ for mercury, where $1 - \delta$ is the velocity of relativistic rotation of the perihelion in units of its Einstein value. The result (the δ-effect) shows that Einstein's equations (for which $\delta = 0$) are inaccurate and raises the question of the correctness of the fundamental metric principle of general relativity theory (identification of the gravitational field with the field of the curvature tensor of 4-space). We shall show that with some refinement the metric principle (as such) admits of direct empirical verification. The refinement consists of assuming that the equations of gravitation (in analogy with [2,3]) correspond to the variational principle and obey rigorously the equivalence principle in the sense [3] that the gravitational interaction is included in the Lagrangian of the matter (a metric interaction is admissible, in which the equivalence principle is satisfied only with a specified degree of accuracy; private remark by E. L. Feinberg, 1965). In such a case, the gravitation equations, regardless of their concrete form, lead to geodetic equations of motion for a particle in a gravitational field, which in turn lead to certain general conclusions.

As applied to the δ-effect, the geodetic principle shows that the real metric of the external field of the sun does not coincide with the Schwarzschild matrix, for which the Ricci tensor is $R_k^\ell = 0$. Consequently, in a real field $R_k^\ell \neq 0$ in vacuo (the density of the solar radiation introduces a contribution of $10^{-6}\%$ in the estimate of δ), and the metric cause of the δ-effect is the nonlocal connection between R_k^ℓ and the material tensor T_k^ℓ. The nonlocality contradicts only the Einstein equations ($R_k^\ell = \kappa(T_k^\ell - \frac{1}{2}\delta_k^\ell T_n^n)$) but not the general metric equations [2,3] (from which it follows), and is in itself no argument against the metric theory. This item, however, admits of verification in principle.

The nonlocality leads to the occurrence of anomalous gravitational waves, in the field of which $R_k^\ell \neq 0$. We shall show in the next communication that the metric structure of the equations of gravitation exclude a finite rest mass μ for the anomalous gravitons if $\delta \neq 0$. Consequently, the experimental value of μ for real gravitational waves (which is unknown at present) is one of the criteria of the metric principle.

As applied to astronomical data, the metric principle leads to phenomenological relations (which are independent of the concrete form of the theory) between the observed non-Einstein quantities. In fact, let us consider the gravitational field of the sun, assuming it to be static and spherically-symmetrical (the quadrupole effect results in negligible corrections, $\sim 10^{-3}\%$, to the coefficients [4]. The metric of the central field contains three radial functions, of which one is determined by the method used to measure the distance, and the second is determined by the gravitational field [4]. By measuring the angular distance r of the object relative to the center of the sun (distance relative to the sun) we have: $ds^2 = c^2 f\, dt^2 - (hf)^{-1} dr^2 - r^2(d\nu^2 + \sin^2\nu\, d\varphi^2)$, where f and h are functions of the field, which are assumed to be empirically unknown. In the Schwarzschild metric ($h = 1$, $f = 1 - r_0 r^{-1}$, $r_0 = 2Gmc^{-2}$, m = sun's gravitational mass [4]) there is only one empirical parameter, r_0. In the non-Einsteinian field $h = 1 + u(r)$ and $f = 1 - r_0 r^{-1} + w(r)$, where u and w are due to the nonlocal coupling between R_k^ℓ and T_k^ℓ, and r_0 has the same meaning as before (i.e., $rw \to 0$ as $r \to \infty$). Consequently, we now have two empirical functions u and w, which can be determined from the equations of motion by means of two (obviously non-Einsteinian) observable quantities, after which the remaining non-Einsteinian observables turn out to be connected with the phenomenological relations, the form of which depends only on the character of the equations of motion; the latter are geodetic for all metric theories of the type of [2,3], making it possible to verify them empirically as a whole. Regardless of the verification of the theory, the phenomenological relations may turn out to be quite useful for a metric analysis of the empirical data.

Let us derive a phenomenological relation for the observables δ, δ_K, and δ_γ, where δ was defined above, δ_K is the relativistic corrector to Keppler's law ($T^2a^{-3} = 4\pi^2(Gm)^{-1}(1 + \delta K)$, a is the major semiaxis relative to the sun, T is relative to the proper time of the planet), and $1 - \delta_\gamma$ is the empirical angle of the gravitational deviation of the light beam on the edge of the sun in units of its Einstein value. Assuming that u and w are small (see above; this is permissible, since $\delta \sim 0.1 \ll 1$), taking them into account in the geodetic equations in first approximation only, and neglecting the eccentricity (error ~10% for Mercury and Pluto and < 1% for the remaining planets), we get

$$\delta(r) = \frac{r}{3r_0}u - \frac{r^2}{3r_0}\frac{dw_1}{dr} + \frac{r}{3r_0}\left(w - 2r\frac{dw}{dr}\right), \tag{1}$$

$$\delta_K(r) = \frac{3r_0}{2r}(1 - 2\delta(r)) + w_1 + \frac{1}{2}w, \tag{2}$$

where $r_0 = 2Gmc^{-2}$, $w_1 = -r^2r_0^{-1}w'(r)$, r - radius of orbit (relative to sun) of the planet to which $\delta(r)$ and $\delta_K(r)$ pertain, and

$$\delta_\gamma = \frac{r_\odot^2}{2r_0}\int_{r_\odot}^{\infty}\frac{dr}{r\sqrt{r^2 - r_\odot^2}}\left(u + w - r\frac{dw}{dr}\right), \tag{3}$$

where $r_\odot = 7 \times 10^5$ km is the radius of the sun ($r_0 = 3$ km). Estimating the derivative by dividing by r (u and w should be power functions because $\mu = 0$; μ is defined above), we can easily verify that, with an error $\sim r_0r^{-1} \lesssim 10^{-7}$, we can cross out from (1) and (2) all the w-terms except w_1, and retain in (3) only u. As a result we obtain the very simple phenomenological relation

$$\delta_\gamma \approx \frac{3}{2}r_\odot^2\int_{r_\odot}^{\infty}\frac{dr}{r^2\sqrt{r^2 - r_\odot^2}}\left[\delta(r) + \frac{r^2}{3r_0}\frac{d\bar{\delta}_K(r)}{dr}\right], \tag{4}$$

where $\bar{\delta}_K(r) = \delta_K(r) - 1.5r_0r^{-1}(1 - 2\delta/r)$ is the non-Einsteinian part of δ_K; the symbol $\approx$ denotes an error $\lesssim 10\%$ (neglect of eccentricity). The empirical information needed to verify (4) is obvious.

Equation (4) leads to certain predictions. If $\delta > 0$ for all planets (as for Mercury), then probably $\bar{\delta}_K'(r) < 0$ and $r^2r_0^{-1}|\bar{\delta}_K'(r)| \sim \delta(r)$. The result corresponds to a probable sign $\delta_\gamma < 0$ and $|\delta_\gamma| \sim \delta$ (eclipse data $\delta_\gamma = -0.13 \pm 0.07$ (1919), -0.15 ± 0.15 (1947), and $+0.03 \pm 0.06$ (1952)). If it turns out in the future that $\delta_\gamma < 0$, $\delta > 0$, and $r^2r_0^{-1}|\delta_K'| \ll \delta$, then this will be a direct refutation of the geodesic principle.

Before sufficiently exact verification data are obtained, we believe that the doubts concerning the metric nature of the gravitational field are unfounded.

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INTERBAND TRANSITIONS IN SEMICONDUCTORS IN A MAGNETIC FIELD UNDER THE INFLUENCE OF A STRONG ELECTROMAGNETIC WAVE

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It is shown in a number of papers [1-2] that intense laser emission is capable of causing multiquantum transitions of electrons from the valence band of a conductor to the conduction band. In this note we wish to show that application of a constant magnetic field makes it possible to obtain a resonant increase of the absorption coefficient in the presence of a strong electromagnetic wave. The transitions produced thereby are forbidden by the selection rules with respect to the magnetic quantum number and have a probability proportional to certain powers of the intensity of the external radiation.

The potentials of the constant magnetic field parallel to the z axis and of a plane circularly-polarized wave are specified in the form

$$A(H) = (0, xH, 0), \quad A(t) = (b\cos\omega t,\ b\sin\omega t,\ 0).$$

For an electron in vacuo, the solution of the relativistic wave equations in such field is known. To find the wave functions of an electron in a semiconductor, we introduce the creation and annihilation operators a^+ and a:

$$a = \frac{1}{r_0}\left(\frac{cp_x}{eH} - i(x - x_0)\right),\ [a, a^+] = 1,\ x_0 = -\frac{cp_y}{eH},\ r_0 = \left(\frac{2c\hbar}{eH}\right)^{1/2}. \tag{1}$$

We use them to define the operator

$$\Lambda = \exp\left[-\frac{i}{\hbar}\int^t \gamma(t')dt' + \mu a^+ - \mu^* a\right],$$

where $\mu(t)$ and $\gamma(t)$ satisfy the equations

$$\dot{\mu} = -i\omega_c\mu - i\frac{eb}{mcr_0}e^{-i\omega t},$$
$$\gamma = -\frac{im\omega_c r_0^2}{4}(\dot{\mu}\mu^* - \mu\dot{\mu}^*) + \frac{1}{2}mr_0^2|\dot{\mu}|^2,\quad \omega_c = \frac{eH}{mc}. \tag{2}$$

Let us assume that the conduction band and the valence band are parabolic and nondegenerate. The wave functions can be written in such a case as follows: