tremal if the focusing conditions are fulfilled.

The magnitude of the effect can be estimated from the following simple considerations. We consider initially the value of the sample resistance in the absence of a magnetic field. The electric field differs from zero only in the immediate neighborhood of the contacts. Since the free path length noticeably exceeds the dimensions of this region, the resistance of the sample is determined only by electron acceleration near the contacts and does not depend on the free path just as, for example, in the case of the anomalous skin effect. In the absence of a magnetic field each of the contacts can be considered independently. In order to avoid unimportant complications connected with introducing a contact with a wire made of another metal, we regard the contact as a small area of diameter D in which there is contact between two half-spaces occupied by the single crystal studied and separated by a thin insulating diaphragm with a hole. In this form the problem resembles passage of a dilute gas through a hole. If the potential difference applied to the sample is V, the electrons going through the contact in either direction receive a speed increment equal to $\pm eV/p$ (where p is the Fermi momentum), from which a current $\sim (e^2V/p)D^2N$ arises (N is the electron density in cm^{-3}), i.e., the contact resistance is

$$R = p / e^2 D^2 N. \qquad (2)$$

If the current is led into the sample through two microcontacts, the resistance of the sample in the absence of a magnetic field will equal the sum of the resistances of both contacts. If there is a magnetic field and the focusing condition is also fulfilled, part of the electrons accelerated in one contact already have this speed increment when they fall upon the other contact. As a result, the resistance of the sample decreases by a factor equal to the ratio of the solid angle in which focused electrons move to the whole angle in which electrons move from the contact. The values of these angles are determined by the required precision of focusing, i.e., by the dimensions of the contacts. A simple calculation shows that the relative decrease of the resistance due to focusing is $\sim (D/L)^{2/3}$, where L is the distance between the contacts.

From these estimates we find that for L = 0.05 cm, D = 10^{-4} cm, and a measuring current of order 10 mA, the amplitude of the voltage peaks should be of order 10^{-7} V, which is fully measurable.

One of the basic difficulties of this experiment is the necessity of precise preliminary setting of the field direction. Such a setting could evidently be carried out using at first a field strong enough so that the resistance of the sample depends noticeably on the field direction and assumes a minimum value at the desired field direction.

Investigation of the effect described could give information on the curvature of the Fermi surface, and on the value of the free path and its temperature dependence. With a particular choice of parameters it is possible to impart to the electrons an energy large in comparison with kT and to study the dependence of the free path of the electrons on their energy.

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MAGNETIC MODEL OF THE UNIVERSE

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IN the following we make the assumption that a primordial homogeneous magnetic field existed in the universe and we examine the features of the corresponding cosmological solution. Such a possibility has been cited by Hoyle,[1] but he considered it unsatisfactory and unpalatable, and contrasted it with the self-excited field in a steady-state theory with creation of matter.

The assumption of a primordial magnetic field has been the subject of a whole series of papers in which the difficulties due to the spontaneous origination of the galactic field have been pointed out.[1-3] Other works have considered the formation of the universe by condensation of a conducting gas within a magnetic field, in which case the structure of the galaxies and their radio-emanations are dependent on the orientation of the original inter-galactic field relative to the angular momentum of the gaseous cloud. A magnetic field which is homogeneous within the limits of a galaxy or of a cluster of galaxies has been considered in connection with the problem of quasars[8] and cosmic rays.[9]

In the present paper we take the next step in the direction of considering fields which are homogeneous on ever increasing scales. We assume that the original field was uniform over the entire universe during that hypothetical stage of the evolution of the universe when the distribution of matter was also uniform. Subsequently, when gravitational instability brought about the formation of individual stars, galaxies, and clusters of galaxies, the enhancement of the lines of force of the field by matter led to an enhancement and an entanglement of the field in the galaxies. We will examine the features of the cosmological solution corresponding to the period when homogeneity had not yet been destroyed.

Irrespective of the magnitude of the field and of the ratio of energy density of the field to the density of ordinary matter, the presence of the field changes the general symmetry properties of space. Without a field one can satisfy the conditions of homogeneity (equivalence of all points) and of isotropy (equivalence of all directions at each point), and this was realized in Friedmann's solution. Homogeneity is possible in the presence of a field but isotropy is destroyed by the presence of a preferred direction along the field. Those solutions in which there is a minimal reduction of symmetry are examined below.

The common properties of all the solutions examined below are due to the fact that the magnetic field exists despite the absence of any electric current anywhere. This follows formally from the homogeneity of the field curl $\mathbf{B} = 0$. The fulfillment of the conditions for the entrapment of the field (conservation of the flux of the field through a contour formed from the given particles) follows from the equations of the general theory of relativity independently of the conductivity of matter. In this case $dB/dt = -2H_\perp B$, where $H_\perp$ is the Hubble constant for lateral expansion.

A time dependent magnetic field is accompanied by the appearance of a helical electric field $\mathbf{E} = (H_\perp/c)\,\mathbf{r}\times\mathbf{B}$. However, the entrapment of the field leads to the circumstance that an observer moving along with matter believes the electric field to be zero at the origin of coordinates. This pertains at any point of space, and the homogeneity of the solution is not violated. Charged particles moving relative to matter are deflected by the field but, as before, their energy decreases only in the course of the expansion.

The assumed magnitude of the homogeneous field at the present time is less than 3×10^{-9} G, so that the corresponding energy density $Q < 4\times10^{-19}$ erg/cm^3 is many times smaller than the rest-energy density of ordinary matter,

$$\varepsilon = \rho c^2 > 3\cdot10^{-20}\ \text{erg/cm}^3.$$

The equations for anisotropic, homogeneous motion have been considered in a series of works,[10-14] particularly for the case when an electromagnetic field is present.[15-17] An explanation of entrapment from energy considerations is given in the specially interesting paper of Brill[18].

An important particular case is a plane world:

$$ds^2 = -dt^2 + b^2(t)\,(dx^2+dy^2) + a^2(t)\,dz^2$$
$$= -dt^2 + b^2(t)\,(dr^2 + r^2 d\varphi^2) + a^2(t)\,dz^2,$$

where r and φ are polar coordinates in the x, y plane.

The Hubble "constant" is a tensor[19,20]: $H_{zz} = H_{\|} = \dot{a}/a$, $H_{xx} = H_{yy} = H_\perp = \dot{b}/b$. In this case the solution at the contemporary period can be very close (accurate to Q/ϵ) to Friedmann's plane solution $H_\perp \approx H_{\|} = H$, $a \sim b \sim t^{2/3}$. However, a plane anisotropic solution is possible only at critical matter density:

$$\rho = \rho_c = (2H_{\|}H_\perp + H_\perp^2)/8\pi \approx 3H^2/8\pi = 10^{-29}\ \text{g/cm}^3.$$

When $\rho > \rho_c$ the homogeneous anisotropic solution has the metric

$$ds^2 = -dt^2 + b^2(t)\,(dr^2 + \sin^2 r\,d\varphi^2) + a^2(t)\,dz^2$$

and is qualitatively different from Friedmann's closed model with infinite volume, due to extension along the z axis. When $\rho < \rho_c$ we have

$$ds^2 = -dt^2 + b^2(t)\,(dr^2 + \sinh^2 r\,d\varphi^2) + a^2(t)\,dz^2.$$

In both cases, the bending of the metric in a plane perpendicular to the field must lead to a noticeable anisotropy of the distribution of the remote sources with a red shift $\Delta\lambda/\lambda \sim 1$. Evidently, the assumption of a homogeneous but magnetically anisotropic universe is compatible with observations only in the case $\rho = \rho_c$, which is considerably greater than the density of visible stars.[21] The magnetic model is in complete agreement with the assumption of cold matter and with the presence of neutrinos in the early stages of evolution.[22]

The singularities of the metric in the early stages will be examined separately.

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COHERENT RADIO EMISSION FROM COSMIC SHOWERS IN AIR AND IN DENSE MEDIA

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In a previous paper [1] the author evinced the presence of a moving excess negative charge in electron-photon showers and its associated coherent radio emission. In the present article some calculations are made concerning this coherent radio-emission, from which follow several new possibilities for registering showers by their flashes of radiation. It is shown in particular that at small Cerenkov angles (for example as for showers in air) the conditions for coherence are fulfilled even for wavelengths much smaller than the dimensions of the particle cluster in the shower. The role played by the shower core in bringing energy to the working layer during registration of the radio emission in dense media is also noted.

We consider the coherence conditions for radiation from excess charge in a shower in a medium. This charge,

$$Q \approx e(N_e - N_p) \approx 0.1\, eN_e$$

at maximum shower development is distributed proportionally to the density of particles in the shower [1]. (The shower particle cluster, after traveling a distance L in the medium, has a longitudinal dimension z much smaller than the transverse dimension ρ; indeed

$$\rho \approx L\theta_s;\ z \approx L\Delta v_z/c \approx L(1-\cos\theta_s) \approx L\theta_s^2/2,$$

i.e., $z/\rho \approx \theta_s \ll 1$). Therefore the cluster may be taken as very thin and we consider only the radial distribution of charge density $\sigma(\rho)$. The interference factor Φ, obtained by integrating the retardation over the cross sectional area of the cluster, is (c' is the light velocity in the medium)

$$\Phi = \frac{1}{Q}\int e^{i\omega\rho n/c'}dq, \quad dq \approx \sigma(\rho)\,\rho d\rho d\varphi.$$

It is easily seen that

$$\boldsymbol{\rho}\mathbf{n} = \rho\sin\theta\cos(\varphi-\psi), \quad \frac{1}{2\pi}\int_0^{2\pi} e^{ix\sin\varphi}d\varphi = J_0(x),$$

therefore

$$\Phi = \frac{2\pi}{Q}\int_0^\infty J_0\left(\frac{\omega}{c'}\rho\sin\theta\right)\sigma(\rho)\,\rho\, d\rho.$$

It is already evident from this that for $(\omega/c')\rho_{\text{eff}}\sin\theta < 1$ the charge distribution radiates like a point charge, i.e., the radiation is proportional to the square of the charge. Since Cerenkov radiation power increases with increasing frequency, the maximum frequency of coherent radiation, given by $\omega_{\max} \approx c'/\rho_{\text{eff}}\sin\theta$, i.e., $\lambda'_{\min} \approx \rho_{\text{eff}}\sin\theta$, is of most interest. For the