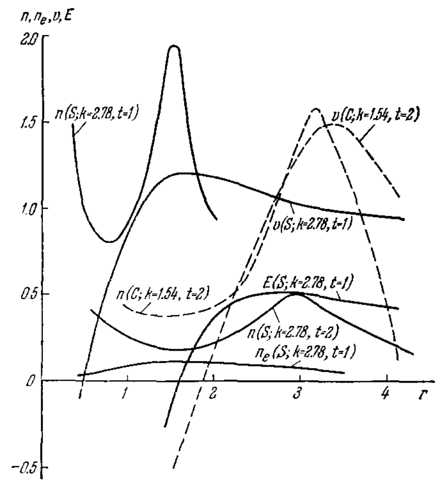

FIG. 1. Structure of pulse.

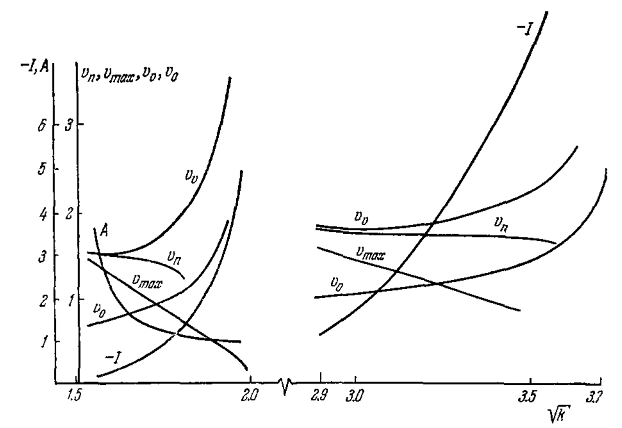

FIG. 2. Parameters of self-similar wave as functions of the initial density $\sqrt{k}$.

sound frequencies and to use them for the investigation of the liquid state. These promise an opportunity of a deeper study of the liquid state of matter by acoustic methods.

M. A. Gintsburg. Nonlinear Waves in Cosmic Plasma

In the first part of the paper the author described his work on acceleration of particles in nonlinear waves with a magnetic field in the vicinity of the earth and on the sun[1].

The second part is devoted to a solution of the problem of the expansion of a strongly inhomogeneous plasma. The initial density varies like C/r^2, where r is the distance from the axis, and the Debye radius can no longer be regarded as a characteristic dimension. If the ion density is $n = C/r^2$, and the electrons did not succeed yet in leaving the ions, $n_e = C_1/r^2$, but at the same time succeeded in acquiring a Boltzmann distribution, $n_e = e^{\varphi}$ ($T_e \gg T_i$), then an electric field $E = 2/r$ is automatically established in the plasma, and this blocks the electrons in a potential well and keeps them attached to the ions.

The time evolution of the plasma and of the field was investigated for three cases: spherical plasmoid (S), cylindrical column (C), and a plane layer (P). The main results are as follows: 1) a pulse of velocity, field, and density is produced, traveling with velocity v_v; $v_v > u_s$, where u_s is the velocity of the ion sound, to which all the velocities in Figs. 1 and 2 are normalized; 2) the effect of velocity inversion, which is now directed towards the center, takes place in the region behind the pulse. The absolute value of the velocity increases (ion-acceleration effects).

Figure 1 shows the structure of the pulse. The spherical pulse (S) is shown for two successive instants of time t = 1 and t = 2; we see how it spreads out. Figure 2 shows the dependence of the velocity of the characteristic points of the pulse on the initial density $\sqrt{k}$ (k—density at a distance of 1 cm from the axis, expressed in units of $\kappa T_e/4\pi e^2$, v_v—velocity of the maximum-velocity point, v_n—velocity of the maximum density, v_{max}—maximum ion velocity, v_0—velocity of the velocity-inversion point, A—pulse amplitude, −I—rate of change of the total number of particles.

The problem of stationary expansion ($\partial/\partial t \equiv 0$) of a plasma jet in a transverse direction, due to runaway of electrons, has also been solved. This runaway leads to a rotation of the velocity vector of the ions until it coincides with the radius vector at the observation point.

A numerical solution of the magnetohydrodynamic equations shows that oscillations of the particle velocities, fields, and density arise also in the expansion of a cold plasma (both in an initial magnetic field and in an initial electric field).

[1] M. A. Gintzburg, Astron. zh. 45, 610 (1960) Soviet Astronomy AJ 12, 484 (1968); Kosm. issledovaniya (Cosmic Research) 4, 296 (1966); J. Geophys. Res. 72, 2749 (1967); Phys. Rev. Lett. 14, 625 (1965) and 16, 327 (1966).

A. Ya. Kipper. Certain Theoretical Questions in the Formation of Magnetic Fields of Stars and Nebulas

Nonstationary processes in outer space constitute the most interesting branch of astrophysics. In the case of nonstationary cosmic rays, a significant role is played by magnetic fields, which change the character of motion of the matter or give rise to various new phenomena.

The main problem of cosmic magnetic fields is their origin. It has been established by now that the initial presence of very weak fields suffices to give rise to strong fields. The motion of matter with high electric conductivity strengthens a weak field to almost any intensity. On the other hand, the initial weak field can arise in the presence of forces of non-electric origin. A number of rather likely hypotheses have been advanced in the literature concerning this question. It seems that the origin of cosmic magnetic fields is by now clear and requires no further consideration.

Nevertheless certain problems connected with the origin of cosmic magnetic fields have not yet been solved, such as the conditions under which a field is expected to appear, especially a strong one, the question whether the magnetic field of a star is an exception or a regular phenomenon, etc.

The author has advanced the idea that each cosmic body with dimensions of a star always has a magnetic field in a rather tangled form. If the star has besides the tangled magnetic field also a regular one, then the latter originates from the tangled field by the rotation of the star.

The problem of the tangled magnetic field gives rise to the problem of the energy spectrum, or the problem of the distribution of the energy among the individual Fourier components of the field in a certain equilibrium state. Since the laws governing the tangled magnetic field correspond almost completely to the laws of turbulent motion of a viscous liquid, it is possible, by using the latter, to obtain the spectral law also for the case of interest to us. In the paper, however, the problem is solved by means of different ideas, which can lead to new aspects.

A high-temperature plasma can be represented as a mixture of ionized gas and a gas consisting of particles of electromagnetic radiation—photons. In the state of thermal equilibrium, there should exist photons of all wave-lengths, from the very shortest to the very longest and superlong ones, on the order of several dozen, hundreds, thousands of kilometers and more. On the other hand, in the case of an electrically conducting medium the superlong-wave electromagnetic radiation can no longer be represented by traveling waves, as can be done in a dielectric medium or in vacuum. From the corresponding analysis of Maxwell's equations it follows that superlong wave radiation in the case considered by us is expressed and represented by a tangled magnetic field which remains practically invariant in time. Thus, in the spectral representation, the magnetic field is a continuation of the spectrum of the ordinary electromagnetic radiation into the long-wave band. In a state of a certain, say thermal, equilibrium the tangled magnetic field is an organic part of the general spectrum of the electromagnetic radiation, and should always be present. We can therefore draw from this a new deduction, namely that the tangled magnetic field is a normal satellite of any star, just as the shorter-wavelength electromagnetic radiation.

The most general mechanism generating the weak primary field consists of the random fluctuations of the charges and electrons in the high-temperature plasma. Of course, these fluctuations are not the only causes of the magnetic field. In calculating the energy density of the superlong-wave part of the electromagnetic-radiation part in thermal equilibrium, it is not necessary to know the mechanism producing the magnetic field. It is only important to assume that the superlong wave radiation appears and that the principle of entropy increase is realized during a conceivable time interval. The spectral energy density is then calculated by the methods of thermodynamics and statistical physics.

If we disregard the motion of the medium, using the well-developed plasma theory, we can calculate the spectral distribution of the energy density of the superlong wave part of the electromagnetic radiation (the medium is assumed to be infinite):

$$E_\lambda \, d\lambda = \frac{1}{8\pi} \overline{H_\lambda^2} \, d\lambda = kT \frac{d\lambda}{\lambda^4}, \qquad (1)$$

where k is Boltzmann's constant, T is the temperature of the medium, λ is the wavelength of the Fourier component of the field (the wavelength of the superlong wave photon), and $\overline{H_\lambda^2}$ is the mean-square value of the field intensity

It should be noted that within the framework of formula (1), i.e., without allowance for the motion of the medium, the energy density E_λ does not depend on the electric conductivity σ. Thus, in the given approximation, the energy density E_λ is the same in an electrically-conducting medium, a dielectric, or vacuum. The role of the electric conductivity becomes significant if the motion of the medium is taken into account.

Allowance for the motion of the medium greatly complicates the problem. However, at a large value of the electric conductivity, $\sigma \gg 1$, and also in the case of turbulent isotropic motion of the plasma, the formulas for the determination of the spectral distribution of the energy or the average strength of the magnetic field can be obtained in the following form:

$$E_\lambda \, d\lambda = \frac{1}{8\pi} \overline{H_\lambda^2} \, d\lambda = kT \exp\left[\frac{\overline{v^2}}{c^2} \frac{\sigma}{\tau} \alpha(\lambda)\right] \frac{d\lambda}{\lambda^4}, \qquad (2a)$$

$$E = \int_{\lambda_0}^{\infty} E_\lambda \, d\lambda = \frac{kT}{3} \exp\left[\frac{\overline{v^2}}{c^2} \frac{\sigma}{\tau} \alpha(\lambda)\right] \frac{1}{\lambda^3} \quad (\infty < \lambda \leqslant \lambda_0), \qquad (2b)$$

where $\overline{v^2}$ is the mean-squared velocity of the medium, τ is a certain quantity with the dimension of time (it characterizes the attenuation of the turbulent motion), $\alpha(\lambda)$ is a certain function on the order of unity and varies slowly with λ, and λ_0 is the wavelength that determines the wavelength interval in which formulas (2) can be employed (the function $\alpha(\lambda)$ is almost constant and is larger than zero).

In order of magnitude, we can write

$$\overline{v^2} = 10^5 - 10^7 \text{ cm/sec}, \quad T = 10^6 - 10^7 \text{ (in star)},$$
$$\sigma = 10^{16} - 10^{18} \text{ sec}^{-1}, \quad \tau = 10^7 - 10^9 \text{ sec},$$
$$\lambda_0 = 10^5 - 10^{10} \text{ cm}, \quad \alpha(\lambda) = 1.$$

Depending on the concrete values of the parameters $\overline{v^2}$, σ, etc., E_λ and E can, in accordance with formulas (2a) and (2b), be quite large. Thus, for example, at quite acceptable values of the indicated parameters we can obtain for $(\overline{H_\lambda^2})^{1/2}$, i.e., for the mean value of the magnetic field intensity, values on the order of several Gauss and more.

However, a more accurate calculation of $\overline{H_\lambda^2}$ calls for a determination of the function $\alpha(\lambda)$. In view of the technical difficulties in solving this problem, it is advantageous to perform the calculations with an electronic computer.

V. A. Akulichev, L. R. Gabrilov, V. G. Grebinnik, V. A. Zhukov, G. Libman (East Germany), A. P. Manych, L. D. Rozenberg (deceased), Yu. I. Rudin, and G. I. Selivanov. Influence of Ultrasound on the Formation of High-energy Particle Tracks in a Liquid-hydrogen Bubble Chamber.

The main shortcoming of the existing bubble chambers is the presence of a structurally-complicated mechanical expansion system[1], which limit the oper-