a value $H(r) \approx H_1(r_1/r)^2$. The maximum field intensity is determined from the condition that the magnetic pressure be equal to the pressure in the shock wave reflected from the compressed magnetic fields, $H_{max}/8\pi \approx K_{ref}p_1$, which yields a magnetic field intensity $H \geq 10^7$ Oe if $K_{ref} \approx 10$ and $p_1 \approx 10^6$ atm. The velocity of the skin delocalization of the field $v_H \approx c^2/4\pi\sigma r_{min} \leq v_{sh} \leq 10^7$ cm/sec cannot greatly influence the compression of the field. This method of obtaining fields is convenient because it is simple, has small dimensions, and can be readily regulated by choosing the type of gas, the pressure, etc.

The velocity in front of the compressed magnetic field (magnetic mirror) is $v_z = v_\perp/\tan\theta \sim v_\perp/\theta$, where θ is the cone angle. At the attainable $v_\perp \approx 10^7$ cm/sec and $\theta \approx 10^{-2}$, we obtain $v_z \approx 10^9$ cm/sec. Such a moving magnetic mirror can be used to accelerate conductor particles, charged particles, and plasma batches.

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TRACES OF "PHOTON EDDIES"

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According to a hypothesis advanced some time ago [1], in the early universe, during the phase of almost complete homogeneity, there existed local dynamic motions of the photon gas and the plasma dragged by it ("photon eddies") superimposed on the general cosmological expansion. The hydrodynamics of this mixture, in conjunction with the gravitational instability, determines of necessity the subsequent structure of the universe. It will be shown below that the consequences of the hypothesis, which pertain to the velocity and density spectra of metagalactic structures, are confirmed by astronomical observations.

During the course of the cosmological expansion in the primordial eddies, assumed to be initially subsonic, a Kolmogorov velocity spectrum is established:

$$v_k \propto k^{-1/3}. \tag{1}$$

The wave-number interval in which the spectrum (1) takes place is bounded on the side k by dissipative processes (mainly radiant viscosity). The limit on the side of small k, which is of interest to us here, is determined by the requirement that the hydrodynamic time t_g be small compared with the cosmological time t_{exp}. The upper limit of the scales with the spectrum (1) amounts to, when recalculated to the present time, $30\Omega^{-1}$ Mpsec, encompassing a mass up to $2 \times 10^{15}\Omega^{-2}M_\odot$ ($\Omega = \rho/\rho_{crit}$).

The density inhomogeneities resulting from the hydrodynamic instability at the instant of plasma recombination (at a red shift $z_{recomb} \sim 10^3$), differs significantly in amplitude, depending on the relation $t_g \lessgtr t_{exp}$. At large scales (lower sign) they are small, and their Fourier spectrum has a form characteristic of small alternating-sign perturbations in a homogeneous isotropic medium [2]:

$$(\delta\rho/\rho)_k \backsim k^2. \tag{2}$$

When $z < z_{recomb}$, small inhomogeneities increased (like z^{-1} up to $z \sim \Omega^{-1}$) under the influence of the gravitational instability, which, depending on the scale of the inhomogeneities and on the value of Ω, leads at the present time to one of two possibilities.

I. The inhomogeneities remain gravitationall unbounded. In this case: a) The spatial correlation of the velocities remains unchanged ("is frozen") and the initial exponent of the velocity spectrum remains unchanged. b) The velocity of the internal motions does not exceed the differential velocity of the cosmological expansion in the same scale. c) The exponent of the density inhomogeneity spectrum does not change. d) The density contrast between the inhomogeneities and the background remains relatively small.

II. The inhomogeneity have time to become gravitationally bound. We define the condition for separation from the background in a scale $R = 2\pi/k$ by the formal requirement $(\delta\rho/\rho)_k = 1$. Let the spectrum of the density and inhomogeneities at the instant of recombination be $(\delta\rho/\rho)_k = ak^x_{recomb}$ $(x \geq 0)$. Taking into account the relation $k = k_{recomb}$ $(1 + z)/(1 + z_{recomb})$, the instant of the isolation of the system, depending on its scale, is given by the equation $(1 + z_{isol})^{x+1} = ak^x\,(1 + z_{recomb})^{x+1}$. Thus, the formation of agglomerates of galaxies begin simultaneously with the process of the separation of the galaxies themselves, and the larger the mass of the cluster, the later it is completed. The average density of the system, attained at the instant of its isolation from the background, is

$$\rho_{isol} \backsim z^3_{isol} \backsim R^{-3x/(x+1)} \backsim M^{-x}.$$

Similarly, if the spectrum of the turbulent velocities had at the instant of recombination the form $v_k \sim k^y_{recomb}$, then the gravitational isolation has by now transformed it into the spectrum

$$v \backsim R^{-y + x(y + 1/2)/(x+1)}.$$

Consequently, the inhomogeneities making up gravitationally closed systems differ from gravitationally unbound systems in the following essential respects: a) the spectrum of the velocities of the internal motions at the initial spectra (1) and (2) goes over into

$$v \backsim R^{4/9}, \tag{3}$$

b) the mean-square velocity of the internal motions becomes larger than the differential Hubble velocity, c) the resultant spectra of the inhomogeneities, at an initial spectrum (2), is given by

$$(\rho - \rho_0)/\rho_0 \backsim R^{-2}, \tag{4}$$

i.e., it remains the same, d) the density contrast between the inhomogeneities and the background (the average density of which is ρ_0) becomes appreciable.

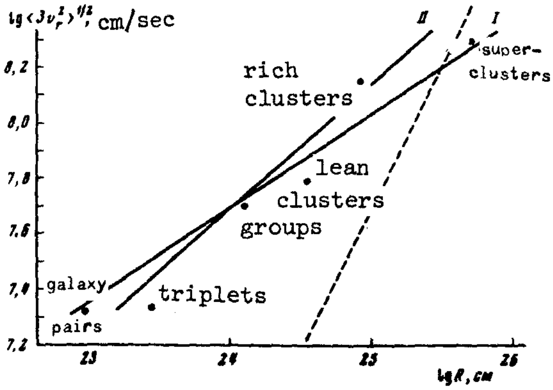

Fig. 1. RMS internal-motion velocities averaged over the sample, vs. effective radius of galaxy system. The solid lines represent the slopes (1) and (2) of the expected spectra in the extreme situations I and II. Dashed line - differential Hubble velocity.

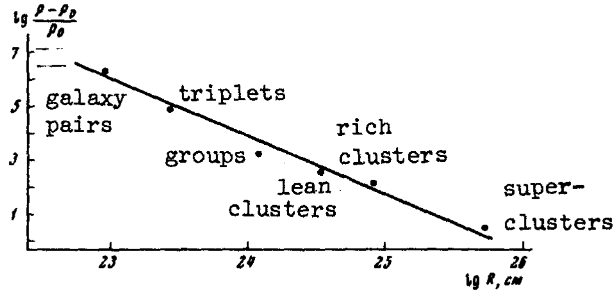

Fig. 2. Density contrast between galaxy systems and background as a function of the mean effective radius of the system. The solid line shows the expected slope (3). The horizontal strip corresponds to a transition to individual galaxies ($\langle\rho\rangle$ = const [4]).

Thus, the existence of primordial vortical motions in the universe leads to the following pricipal consequences: the spectrum of the peculiar velocities of the metagalactic structures should increase with scale and should have a Kolmogorov exponent (0.33) or one close to it (0.44), and the density contrast between the structure and the background should decrease in inverse proportion to the square of the dimensions of the corresponding structure, regardless of the dependence on its gravitational coupling.

We have undertaken searches in galactic clusters of the indicated traces of cosmological turbulence. Figures 1 and 2 show the average dispersions of the radial velocities and densities of visible matter, taken from [3] and averaged over 143 systems of galaxies of different populations (87 pairs, 11 ternary systems, 29 groups, 15 clusters, and supercluster, i.e, a cluster of clusters), as functions of the average effective radii of the systems. The reduction of these data by means of a regression analysis yields

$$\langle v^2 \rangle^{1/2} \sim R^{0,40 \pm 0,08}, \quad (\rho - \rho_0)/\rho_0 \sim R^{-(2,09 \pm 0,22)} \tag{5}$$

with correlation coefficients 0.97 and 0.99, respectively. The confidence interval was calculated at a significance level 0.32, corresponding to the least-square method.

Relations (5) agree, within the limits of accuracy, with the values expected for both indicated possibilities I and II. To choose between them it is sufficient to recognize that situation I, as follows from the data of Figs. 1 and 2, is refuted by the fact that its consequences b) and d) are not satisfied. Situation II, to the contrary, agrees with the observations for all scales, in all the expected consequences, with the exception of the supercluster for which consequence b) is not satisfied in any case. We can therefore conclude that clusters of galaxies, except those with the larger scales, represent, on the average, gravitationally coupled systems, of the supercluster type, for which the differential Hubble velocity is suppressed only partially. In such large scales, both the spectrum and the spatial correlation of the velocities are "frozen" making it possible, in principle, to obtain information concerning the correlation properties of the primordial eddies. In smaller scales, traces of these properties have been probably retained in uncondensed clouds of intergalactic gas, which are in situation I.

A confirmation of the relations discussed above yields weighty arguments in favor of the hypothesis that premordial cosmological turbulence exists. Further clarification of its properties will be made possible by more detailed observational data.

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CERTAIN PROCESSES OF QUANTUM ELECTRODYNAMICS AT HIGH ENERGIES AND SMALL SCATTERING ANGLES

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As is well known, the amplitudes of the γe and $\gamma\gamma$ scattering processes, calculated in the first nonvanishing order of perturbation theory at high energies $\sqrt{s}$ and at fixed momentum transfers $q = \sqrt{t}$, depends little on s, meaning that the cross sections of these processes decrease with increasing energy. In this paper we present results of calculations of the Feynman diagrams shown in the figure. The diagram corresponding to Delbruck scattering can be obtained by replacing the electron line in Fig. a by a line corresponding to a nucleus. In this order of perturbation theory, the elastic γe and $\gamma\gamma$ scattering do not decrease with increasing energy. Further iteration of the block shown in Fig. c leads to a series in terms of the quantity $\alpha^2 \ln s$ ($\alpha = 1/137$). The parameter $\alpha^2 \ln s$ becomes of the order of unity at fantastically high energies, but summation of this series is of interest from the general theoretical point of view of investigating the problem of the vacuum Regge pole in quantum electrodynamics.

The diagrams of the figure were calculated also by Cheng and Wu, whose results were recently published [1]. They actually considered not a photon but a neutral vector meson with mass λ. Their expression for the scattering amplitude at $t = 0$ in the limit as $\lambda \to 0$ contains an infrared divergence, which is not contained in the initial diagrams.

To calculate the asymptotic form of the diagrams, we used the Sudakov method [2], wherein the integration momenta are resolved into components $k_{\parallel}$, which lie in the plane p_1 and p_2, and $k_{\perp}$, which are perpendicular to this plane. In the integrals with respect to the perpendicular components of the photon momenta, which converge at the lower limit, it is