above. In addition, such effects as loss of electrons in the orbit and multiple traversals of the target by some electrons may be responsible for some of the disagreement.

When it occurs, the loss of a substantial number of electrons in the orbit is detected by a photomultiplier tube, and it appears as "grass" on the oscilloscope at the control desk. Activation data were taken only when the loss of electrons appeared to be inappreciable, as indicated by a negligible amount of grass.

It is a sincere pleasure to acknowledge the cooperation, during the course of the experiment, of Dr. L. Jackson Laslett who originally suggested the method used to monitor the beam. Appreciation is also extended to Mr. Don Steward and Mr. Philip Phipps for their assistance in preparing the table of photon values.

* Contribution No. 169 from the Institute for Atomic Research and Department of Physics. Work performed in the Ames Laboratory of the AEC.

† Now at Hughes Aircraft Company, Culver City, California.

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The Role of Turbulence in the Evolution of the Universe

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It can be considered now as an unquestionable truth that "*from one to ten thousand million years ago, the matter of the (known) spiral nebulae was compressed into a relatively restricted space, at the time the cosmic processes had their beginning*" and that during that stage "*the density, pressure, and temperature of matter must have reached absolutely enormous proportions*" since "*only under such conditions can we explain the formation of heavy nuclei and their relative frequency in the period system of elements.*"[1]

A detailed study of the conditions obtained during the early stages of the expansion process[2] leads to the conclusion that the temperature and density at the age t (in seconds) were given by the expressions:

$$T = 1.5\times 10^{10}/t^{\frac{1}{2}}\,°\mathrm{K}, \quad \rho = \rho_0/t^{\frac{3}{2}}, \tag{1}$$

where ρ_0 is a constant to be adjusted by considering the nuclear building-up processes and has a numerical value of the order of magnitude 10^{-3} g cm^{-3} sec$^{\frac{3}{2}}$.

It is important to notice that during these early stages of expansion, the mass density of radiation quite considerably exceeded that of matter. Thus, for example, we find from Eq. (1) that at $t=900$ sec (15 min), $\rho_{\mathrm{rad}}\cong 0.5$ g cm^3 and $\rho_{\mathrm{mat}}\cong 10^{-8}$ g cm^3. Under these conditions, when radiation was predominant, matter was deprived of any possibility of condensing under the action of gravitational forces. It is, thus, reasonable to assume that the originally uniform gaseous material could start to break up into individual gas clouds (protogalaxies) only during the era when the density of radiation sank below the density of matter. The observational fact that the present distances between the neighboring galaxies exceed their geometrical dimensions by a factor of about a hundred suggests that the break-up must have taken place at a time of about one hundredth of the present age, and that at that time the mean matter density of the universe was comparable with the present matter density, 10^{-24}, inside of the galaxies. Using $t=3\times 10^7$ years$\cong 10^{15}$ sec in Eq. (1), we find $T\cong 500°$K and $\rho_{\mathrm{rad}}\cong 10^{-25}$. This is indeed comparable with the present intragalactic density as well as with the result given by the density formula in Eq. (1). In order to find the sizes and masses of condensations we must insert the values of T and ρ for $t=10^{15}$ sec into the well-known Jeans' formula for gravitational instability. By doing so we find for the diameters and masses of condensations the values of $\cong 10^4$ light years and $\cong 10^8$ sun masses, which are in agreement with the hypothesis that the original condensations were the gaseous protogalaxies. It cannot be emphasized too strongly that all the numerical values derived above are off by an order of magnitude or even more from the actually observed values. This can easily be due, however, to the highly preliminary nature of the calculations.

An important point in applying the classical Jeans' formula to our case is that it is derived specifically for a nonexpanding gas, whereas our model is rapidly expanding. This point was investigated by the author in collaboration with Drs. S. Ulam and N. Metropolis (unpublished), with the unfortunate result that the expected condensations would never form in the originally homogeneous material, unless there are some additional physical factors favoring large-scale fluctuations of density. The attempts to provide for such an additional factor by considering the effect of radiation pressure (similar to the Spitzer-Whipple theory of stellar origin) have also failed. Thus, it seems at present that the only way of understanding the formation of gaseous protogalaxies lies in the assumption of extensive turbulent motion in the primordial expanding material.[3] Such turbulent motion would result in strong density fluctuations leading to compression eddies of all different sizes in accordance with Kholmogoroff's spectral law of turbulence. If such an assumption is made, we can easily see how gravity forces, which become of importance as soon as the radiation density sinks below the matter level, could grab the condensation eddies of suitable sizes to form the protogalaxies of proper masses and geometrical dimensions.

The existence of such turbulent motion in the primordial material of the universe is, in fact, strongly suggested by the recent studies by H. Shapley and C. D. Shane of the space distribution of galaxies in the observed part of the universe.

Although Reynold's number for the universe is always sufficiently large to expect the presence of turbulent motion, it is, however, difficult to see how such a motion could originate in a uniformly expanding homogeneous material. Thus, it may be well to introduce the primordial turbulence on a postulatory basis along with the original density of matter and the rate of expansion.

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Thermal Conductivity of Carbons and Graphite

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The purpose of this note is to direct attention to some interesting characteristics of materials commonly known under the name of carbons, which make them in a certain sense unique among nonmetallic thermal conductors. In spite of their great practical importance they have not yet been systematically studied. The best available data are those of Powell and Schofield;[1] the two heavy curves in Fig. 1 represent the temperature dependence of the conductivity for polycrystalline graphite (G) and for a baked carbon (B) as roughly obtained from their work. The graphite curve is extended to lower temperatures following the results of Buerschaper.[2] The room temperature conductivity of polycrystalline graphite is definitely smaller than half of that of a single graphite crystal along the graphitic planes. In fact Pirani and Fehse[3] found for carbon filaments with well-aligned crystallites of graphite a conductivity higher than that of copper! Although the anisotropy of a single crystal certainly is not as large as for the electric conductivity ($\rho_{\perp}/\rho_{\parallel}\sim 10^5$), the main heat transfer occurs probably for polycrystalline materials in a zigzag path along the graphitic planes. The curve (G) is of the general type observed for nonmetallic crystals, the conduction being chiefly the result of transfer of elastic vibrations via valence bonds, with a negligible contribution from the conduction by the free